



Comparative Analysis of Hospital Energy Use:  
Pacific Northwest and Scandinavian.

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# Final Report

University of Washington's  
Integrated Design Lab

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# INTRODUCTION

## SUMMARY

This study is an outgrowth of previous research evaluating high quality, low energy hospitals that serve as examples for new high performance hospital design, construction, and operation. Through extensive interviews, numerous site visits, development of case studies, and data collection this team has established thorough qualitative and quantitative analyses of several contemporary Scandinavian and Pacific Northwest hospitals. These hospitals serve as significant examples for design teams that seek operational precedents for achieving aggressive energy and interior environmental quality (IEQ) goals. It is clear that a direct side-by-side quantitative energy comparisons of international and national examples are necessary for design teams and decision makers to draw informed conclusions about the viability of implementing energy saving solutions. This report seeks to provide such a comparison and to illustrate examples of qualitative attributes that lead to high indoor environmental quality.

## ENERGY USE IN HEALTHCARE

Today, operational hospitals in the U.S. consume an enormous amount of energy. Buildings as a whole account for 50% of energy consumption; the remainder is consumed by transportation and industry (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. This figure has increased since 2004, when healthcare consumed 4.3% of the total delivered energy within the building sector (EIA, 2012). Looking at healthcare's energy footprint in another way, hospitals are the second most energy intensive building type per square foot, just behind fast food restaurants, and as an industry spend over \$8 billion annually on energy costs (HHI, 2013). These figures speak to the opportunity for hospital energy efficiency to have a real impact – if hospitals reduce their energy footprint, the overall energy picture for the U.S. would be affected, as would the cost to deliver healthcare.

Reducing energy use also has a direct impact on carbon emissions and thus has 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.

Programs such as the Green Guide for Healthcare and its successor LEED for Healthcare have interest in both energy reduction strategies and high interior environmental quality. The 2030 Challenge, which has been adopted by the AIA, the U.S. Conference of Mayors, and numerous architectural firms, is a more aggressive program focused on energy and aims for carbon neutrality by the year 2030. These programs highlight interest in attaining high performance buildings, including hospitals and healthcare facilities. As design teams, owners, and the public look to effectively achieve goals set out by these programs, guidance and evidence for how to attain realistic and effective reductions in energy and implementation of successful design strategies is necessary. Many case studies documenting the positive attributes of new hospital facilities do not include energy as part of the overarching description, and if they do, the systems and strategies are described without quantitative or comparative metrics for energy. This leaves ownership and design teams without a quantitative comparison of real-world examples that would help to build a stronger case for implementing strategies that lead to exceptionally high performance facilities.

## INDOOR ENVIRONMENTAL QUALITY IN HEALTHCARE

The best examples of high performance buildings address both energy efficiency and high interior environmental quality. Aspects such as daylight, access to view, fresh air, and how facilities fit into the greater community are important factors in driving high

quality design. These attributes are especially important in the healthcare setting as they positively impact both human health and performance and contribute to better healing environments for patients and better workplaces for staff. There is increasing emphasis on evidence based design in the U.S., and designing high interior environmental quality in the healing environment has been widely recognized as an important aspect of patient comfort and well-being. Beyond the patient environment, healthcare workers spend a great deal of time in places that lack connections to the exterior environment and have little or no access to daylight, view, or fresh air. For example, the diagnostic and treatment areas of the hospital often lack these high quality attributes that can have a positive effect on satisfaction and productivity.

Many qualitative factors such as daylight, view and fresh air have been shown to be beneficial for both patients and for staff. Inherently, incorporating these elements into building design has a strong implication on building form. Decreasing the distance to available windows and increasing the amount of windowed perimeter brings the building occupant closer to the natural elements that promote human health and greater productivity.

Daylight is directly correlated to human health. In 2002 a non-visual photoreceptor was discovered in the human eye that mediates the body's daily rhythms by sensing light and dark. In settings where we have access to natural light the body synchronizes its internal clock to the changing nature of sunlight. Windowless environments disrupt these cycles; one study of night-shift nurses associated their schedules with an increased risk of cancer. This suggests that disrupting our relationship to the daily cycles of natural light has a negative effect on our health. View of green space has also been proven to be beneficial to human health. People prefer spaces with views, and some studies indicate that patient rooms with views translate into faster healing times, less stress, and a reduction in the use of pain medications. Finally, when operable, windows provide fresh air and a sense of personal control. Simply allowing occupants to have this sense of personal control increases the range of temperatures that they report as comfortable. This means that buildings with operable windows can be designed to permit a wider range of interior temperatures that are considered comfortable, lessening the burden on their mechanical system. All of these factors - the rhythm of daylight, a view outside, and the personal control of fresh air from operable windows increases human appeal. The importance of these factors emphasize that indoor environmental quality is crucial for the success of the hospital as a healing environment, and as a successful, productive work environment (Berson, 2002; Brager, 2004; Dimich-Ward, 2007; Edwards, 2002; Joseph, 2006; Ulrich 2008, 2002, 1984).

## **PRECEDENTS AS EXAMPLES TO ACHIEVE SUCCESS**

Groundbreaking precedents and strong evidence for energy efficient and high quality design are fundamental for making the case for leaders in hospital design, construction and operation industries to embrace change in their practice. There has been a large up-growth in evidence based design – documenting evidence of successful energy efficient design is the next step in providing a framework for leaders to effectively create truly high performance healthcare facilities. Yet high quality and reliable data sources for energy use in operational hospitals is severely lacking. This information is vital in order to provide a foundation for energy goal setting and energy improvement in building design.

The work that the project team has been engaged in over the last seven years addresses achieving high performance hospitals in practice. This includes working with design teams, owners, and other partners to research, examine operational examples, and consult on best practices for specific projects as well as on general strategies for achieving the highest performing hospitals. As part of this work, we have researched the most

energy efficient and highest quality designs that are operational today. These examples provide a framework for practitioners to set goals and attain successful results.

When this team began its high performance healthcare research in 2006, it was clear that there were no built examples of hospitals in the U.S. that reached the level of energy savings that would achieve the 2030 Challenge, or a 50% energy reduction from typical operational hospitals. The best examples of hospitals that operated at these low energy levels were in Scandinavia. Scandinavia is a leader in sustainability and has focused on increasing building energy efficiency for far longer than the U.S. The project team found that these international hospitals can serve as a useful resource to evaluate how to achieve significant energy reductions in U.S. hospitals.

## **SCANDINAVIAN PRECEDENTS**

In 2009, the University of Washington Integrated Design Lab (UW IDL) led a study tour of Scandinavian hospitals with Northwest hospital owners, facility managers, mechanical engineers, and architects that provided the opportunity for these key leaders in health-care to gain first-hand experience and develop a better understanding of a different approach to hospital design and energy efficiency. These Scandinavian examples can serve as road-maps for energy efficient, high quality healthcare design in the Northwest, and also provide indications of successful strategies that can be applied nationwide. The strength of these examples is that they are operational precedents of how to re-evaluate the typical hospital typology to provide daylight, fresh air, and views, thus allowing for better working, healing and visiting experiences for staff, patients, and visitors. They also generally use one-half to one-quarter the amount of energy of typical Pacific Northwest operational hospitals, and therefore also serve as examples of how to achieve aggressive energy reduction goals in practice.

## **ENERGY EVIDENCE FROM SCANDINAVIA**

The low energy profile of these Scandinavian hospitals is highlighted by several reports including a report by the Center For the Analysis and Dissemination of Demonstrated Energy Technologies (CADDET), which shows that the United States is one of the largest energy users for healthcare, second only to Canada (CADDET, 1997). More recent findings by the University of Washington Integrated Design Lab (UW IDL), as reported in a 2009 ASHE paper, compare energy used by hospitals in the Pacific Northwest region of the United States to those in Norway and Sweden. To generalize, United States hospitals use about twice the amount of energy as Norwegian hospitals, and about four times the amount used in Swedish hospitals (Burpee, 2009).

The architectural, building mechanical and central plant systems used at these facilities dramatically reduce the energy necessary for operation. A short list of methods that some of these hospitals employ includes severely limiting re-heat, reducing air change rates, using displacement ventilation in combination with radiant heating and cooling, recovering heat from all internal heat sources, and relying on ground-source heat pumping for the majority of additional heating and cooling needs.

The operational Scandinavian hospitals featured in our research would all meet the 2008 - 2030 Challenge Goals with energy use less than half of typical operational hospitals in the U.S. Some of the newest northern European designs are expected to use one fifth the energy of average existing Northwest hospitals. Where operational Scandinavian hospitals are achieving our stretch goal, Scandinavians are also progressing their designs to utilize even less energy than their current highly efficient buildings. There are clearly lessons for us to learn from these examples. One of the biggest ideas that can be observed from the Scandinavian hospitals, apart from the overall building form, is their efficient use of thermodynamics. Unlike in U.S. hospitals, heating and cooling are maxi-

mized to the fullest potential by only being used where needed and by recovering excess energy before being exhausted.

It became clear to the group of experts that participated in the 2009 study tour that a more in-depth and comparable energy analysis was needed and would provide a stronger foundation for comparing these Scandinavian examples to U.S. examples. This project and report outlines the results of a side-by-side energy comparison of Pacific Northwest and Scandinavian examples using Portfolio Manager as a tool for comparison.

## **QUALITY EVIDENCE FROM SCANDINAVIA**

As early as the 1980s Northern Europe began to re-examine the typical post-war hospital form, which consisted of a deep-span, dark and little-windowed, multi-floor diagnostic and treatment block, topped by a patient room tower. Beginning with Norrköping Hospital in northern Sweden, Scandinavian designers began to turn the typical form on its side, placing care facilities on one side of the hospital and arranging patient rooms on the other, all connected by a long central spine. This model allows for most spaces to connect to the building's exterior, and significantly reduces time spent in elevators. In many respects these "horizontal model" hospitals echo hospital design as it was practiced as early as the 1860's, before equipment like mechanical ventilation and fluorescent lighting was available. Since the first horizontal hospital models, Scandinavian hospitals have developed further and have explored other themes: An "unbundled" model places each center of care into separate thin buildings in a connected community campus. Another model uses a flexible approach to blend the centers of care. (Verderber, 2000, 2010; Dilani, 1999).

The changes in Scandinavian hospital form, from the traditional deep and flat diagnostic & treatment base-block with tall patient tower typology to a horizontal and perforated building with increased window area that provides a much greater connection between hospital occupants and the exterior environment, yields the benefits of natural light, views and the personal control of operable windows. Differences in culture and codes require small adaptations to import these technologies to contemporary U.S. buildings. When observed closely, Scandinavian hospitals are inspiring examples for future U.S. hospital development. These hospitals are not only energy efficient but also embody excellent indoor environmental qualities that make them superior places to heal, work and visit.

## **APPLICABILITY OF SCANDINAVIAN PRECEDENTS FOR U.S. DESIGN**

Rethinking energy use and the interior quality of hospitals to the degree that we have shown may seem unimaginable for new hospital design, but international models strongly support our findings and provide a roadmap to successful transformation for hospital designs into the future. Recently constructed hospitals in Scandinavia, specifically exhibit a broad range of the strategies that can be incorporated into healthcare design nationally. It is clear, however, that we cannot take these hospitals as a "rubber stamp," exactly duplicating the buildings or systems implemented in these Scandinavian hospitals. Instead, the building and systems strategies that lead to deep energy savings and high indoor environmental quality in these Scandinavian examples created the framework for this team's Targeting 100! research, in which quantitative energy and cost modeling show that there is a cost-effective path for meeting deep energy goals, such as the 2030 Challenge, in the U.S. today, while still abiding by health, safety, and energy codes and standards (Burpee 2013). The quantitative energy comparison from this project will deepen the understanding of how these Scandinavian hospitals use energy in comparison to U.S. examples in the Pacific Northwest. These comparisons also provide evidence that the systems and strategies used by these international precedents offer a valid framework for reducing operational energy use in the U.S.

# METHODS

## THIS STUDY

The hypothesis of this study is that Scandinavian hospitals located in similar climates to the Pacific Northwest consume significantly less energy than their Pacific Northwest counterparts due to differences in architectural, building mechanical, and plant systems. This hypothesis is based on previous research on these groundbreaking examples as well as in-depth consultation and collaboration with U.S. hospital projects seeking to improve their energy footprint. This research allows a direct comparison between eight hospitals to evaluate the similarities and differences in their energy profiles and design attributes.

*Key research questions being addressed include:*

- How do international and national energy footprints compare?
- What sources of energy are used?
- What is the energy split by fuel type and end use?
- How does the energy use compare when it is weather normalized?
- What are the Energy Star scores of comparable national and international hospitals?
- What are attributable differences between high and low Energy Star performers?
- What are key design strategies that differ between national and international hospitals?

## RESEARCH DESCRIPTION

For this analysis, four Scandinavian hospitals were evaluated and compared to four Pacific Northwest hospitals. The Pacific Northwest and Scandinavian hospitals were chosen for their energy performance, age, size, and indication of relevance in current hospital design. The Pacific Northwest was chosen as a specific study area since its climate most closely matches that of Scandinavia's climate. The Scandinavian cities are higher in latitude (Copenhagen 55°N, Oslo 59.9°N, Trondheim 62.5°N, compared to Portland 45.5°N, Seattle 47.6°N), and have more heating and cooling degree days. Portland and Seattle are both in ASHRAE Climate Zone 4, Copenhagen is in Climate Zone 5, and Oslo and Trondheim are in Climate Zone 6. While these Scandinavian cities have relatively more extreme climates than the temperate climate of the western Pacific Northwest, they provide a valid comparison since an increase in both heating degree days and cooling degrees means that those examples require more energy to accommodate climate related loads than their Pacific Northwest counterparts.

figure 1. Comparison of number of heating degree days and cooling degree days in each study city, determining the ASHRAE Climate Zone.

	Heating DD	Cooling DD	ASHRAE Climate Zone
Portland	4816	468	4
Seattle	4934	271	4
Copenhagen	6329	1682	5
Oslo	9121	1093	6
Trondheim	8523	943	6

The eight hospitals are compared based on energy performance, as determined by Portfolio Manager. The U.S. Environmental Protection Agency's Portfolio Manager is the tool most widely used by building owners and operators to track building energy performance. This product tracks energy based on source energy use (the amount of energy that must be produced to serve the building) and accounts for the impact of weather as well as key physical and operational attributes of the building. It collects relevant information about a building including square footage, occupancy, electrical energy use, gas energy use, and water consumption, and through a series of regression analyses provides an ENERGY STAR Rating. The ENERGY STAR Rating ranks the building's performance in comparison to other similar buildings to create a percentile based "score," where 100 means that it is the top performing building of its type and size. Since this

is a widely used tool and regression analyses are performed to normalize the data, it provides a platform for comparing calibrated data between buildings.

Unique attributes of systems, strategies, and architectural configurations are also documented and analyzed in this report. In-depth case studies have been developed and presented to illustrate these comparisons. The results are compiled as a complement to online tools that the team is simultaneously developing, aimed at guiding practice for achieving radical energy reductions in hospitals. These online tools can be viewed at [idlseattle.com/t100](http://idlseattle.com/t100).

## RESEARCH METHODS

Data for this report was gathered through new and existing relationships with the hospitals studied, and was collected through interviews, site visits, and e-mail correspondence. The empirical data for the Scandinavian examples was gathered in an effort to match the information needed for imputing the data into Portfolio Manager. Due to differences in units, post-processing of the data was necessary in order to enter U.S. equivalent values for area, energy, etc. For the Pacific Northwest examples, the hospitals shared their Portfolio Manager accounts, enabling access to data that had been previously imputed by the organizations. For all hospitals, the data analyzed is for 2011, except as noted for Rikshospitalet, where data from 2011 was unavailable, thus data from 2010 is reported.

An interesting aspect of gathering the necessary data to input into Portfolio Manager is that it comes from various resources across the hospital. For example, energy data, hospital attributes such as the number of MRI machines, and the number of full time employees all come from separate groups. Even in U.S. hospitals this information must be gathered across the organization, requiring a coordination of data and communication. It was necessary for the team to consolidate these data and develop consistency and accuracy, as well as enter it correctly into Portfolio Manager.

In order to better understand the Portfolio Manager tool, the research team attended a half-day training workshop. The team is also in close contact with Clark Reed at the Energy Protection Agency's ENERGY STAR Program, in order to ensure that the discussion and conclusions in the report are sound. One of the questions that emerged was which city to use as the location of the international hospitals: international cities with U.S. embassies are already in Portfolio Manager, but cities without embassies must be best matched either by geographic or climatic proximity to cities that are in Portfolio Manager. The assumptions for each hospital are noted in both the "Results" and "Case Studies" sections below.

The four Scandinavian hospitals chosen for analysis are: Rikshospitalet in Oslo Norway, Akershus Hospital in Oslo Norway, St. Olav's Hospital in Trondheim Norway, and Rigshospitalet in Copenhagen Denmark. At the time of the initial publication of this report, the Pacific Northwest hospitals have chosen to remain anonymous. It is at their discretion whether they will chose to be named in the future. These hospitals represent a broad range of ages and sizes, and were chosen to best match the Scandinavian examples.



# RESULTS & DISCUSSION

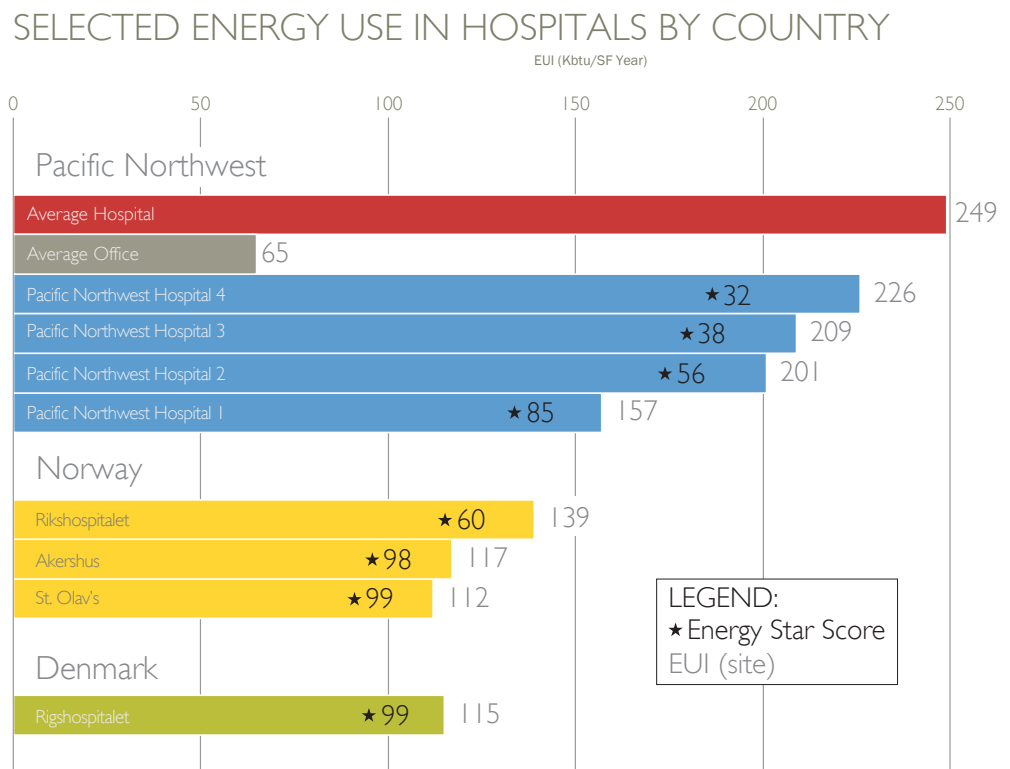
## ENERGY USE COMPARISONS - SITE ENERGY USE

The graph below compares energy intensity of the Pacific Northwest and Scandinavian hospitals evaluated in this study. The data is reported in site EUI, or Energy Use Intensity. EUI is normally reported in units of kBtu/SF Year in the U.S. and in KWh/SM Year in Europe. This measure is similar to using a miles per gallon rating for cars and it enables a side-by-side comparison of buildings' energy use footprints. Site EUI encompasses all of the energy, electricity, natural gas, steam, oil, etc., used at the building divided by the building's size in square feet, on an annual basis. The data below represents the total site energy used by each hospital in 2011, as measured by utility meters for all energy sources and uses, and calculated by Portfolio Manager.

The top bar, in red, depicts the median EUI for a Pacific Northwest hospital, calculated as 249 kBtu/SF Year. This is determined using the EPA's Target Finder Tool and imputing a 477,000 SF hospital with 226 beds, 1238 employees, and 2 MRIs with a target ranking of 50. The grey bar depicts an average office building's energy footprint as a point of comparison, to show how energy intensive hospitals are per square foot compared to typical commercial office buildings. The value for the average office building was determined by referencing the 2003 Commercial Building Energy Consumption Survey (CBECS), which shows the average energy use for various building types on a national and regional basis. This average, 65 kBtu/SF Year, is the average for offices in the "Pacific" region. The blue bars represent actual energy used in 2011 for the four Pacific Northwest hospitals chosen for evaluation in this study. The yellow and green bars represent actual energy consumed by the Scandinavian examples.

These results show that the Pacific Northwest hospitals use more energy on site, on a square foot basis, than their Scandinavian counterparts using between 157-226 kBtu/SF Year with an average of 198 kBtu/SF Year. These Pacific Northwest examples represent well operated facilities that are relatively efficient compared to their counterparts, highlighted by the fact that each hospital is below the median EUI for the Pacific

figure 2. Selected site energy use for Pacific Northwest and Scandinavian hospitals. This graph shows site EUI and Energy Star ratings.



Northwest hospital determined with Target Finder. The Scandinavian hospitals use, on average, 120 kBtu/SF Year, a 40% reduction from their Pacific Northwest counterparts. As compared to the median Pacific Northwest benchmark (249 kBtu/SF Year), the highest performing Scandinavian example (St. Olav's) shows a 55% reduction from typical operational hospitals in the Northwest.

## ENERGY USE COMPARISONS - SOURCE ENERGY & ENERGY STAR

While site energy use intensity is used as a common metric for comparing buildings, the EPA uses a different metric, source energy use intensity, to calculate ENERGY STAR rankings. Source energy intensity includes the energy that a building consumes, in addition to the energy impacts of transmitting, delivering, and producing the fuels that are used by the building. The EPA uses source energy intensity in an effort to evaluate the complete energy performance of a building including the impacts of building performance at the site level as well as the embodied energy of the fuels that are used. The energy used by a building can come in one of two forms, either primary energy or secondary energy. Primary energy is the raw fuel that is burned directly at the building to create heat or electricity. Examples include natural gas or fuel oil. Secondary energy is the energy product created from raw fuel and delivered to the building. Examples include electricity purchased from the grid but produced at an electrical plant, or heat from a district steam system. Since secondary energy sources are produced off-site, they embody additional energy due to their production, transmission, and delivery. As an illustration, electrical source energy intensity takes into account the energy required to produce the electricity at the power plant, the energy lost through transmission, as well as the energy used at the building level.

The embodied energy of various fuel types are expressed in a source to site ratio. Electricity has the highest embodied energy of the various secondary fuel types, calculated as 3.34 by the EPA. This ratio means that for every unit of electrical energy used in the building, it takes 3.34 times more energy to produce, distribute and transmit that same unit of electricity. The EPA uses one national conversion rate to determine the site vs. source impacts of various fuels even though the efficiency of secondary energy sources vary by region and production methods. For example, most of the electricity generated in the Pacific Northwest is produced by hydroelectric dams, thus that electricity does not embody as much energy as electricity produced by coal or natural gas fired electricity plants in other regions. Other secondary fuels include district heating, steam, and cooling have much lower source to site ratios, from 1.28 to 1.05 as calculated by the EPA.

In order to characterize a building's ENERGY STAR Rating, Portfolio Manager uses a database of existing, operational buildings and performs a regression analysis that includes rankings for building type, location (climate), size, and other building operational and physical characteristics. For hospitals, the data set that Portfolio Manager accesses was updated in 2011 by the EPA in collaboration with the American Society for Healthcare Engineering (ASHE) and the American Hospital Association (AHA). The data set includes 191 operational hospitals nationally. From this data set, it was determined that size, number of patient beds, number of full time employees, number of MRIs, and number of cooling degree days were significant in determining the energy intensity of hospitals. These attributes do not determine the energy intensity of hospitals, but they are indicative of a hospital's relative energy intensity.

ENERGY STAR score is based on a percentile ranking. That is, a building with an ENERGY STAR score of 50 means that statistically 50% of buildings of that type, size, locale perform better and 50% perform worse. To qualify for an ENERGY STAR Certification, a building must have an ENERGY STAR score of 75 or higher, that is, it must perform better than

75% of buildings with a similar composition of typology, size, and location as determined by Portfolio Manager's regression analysis.

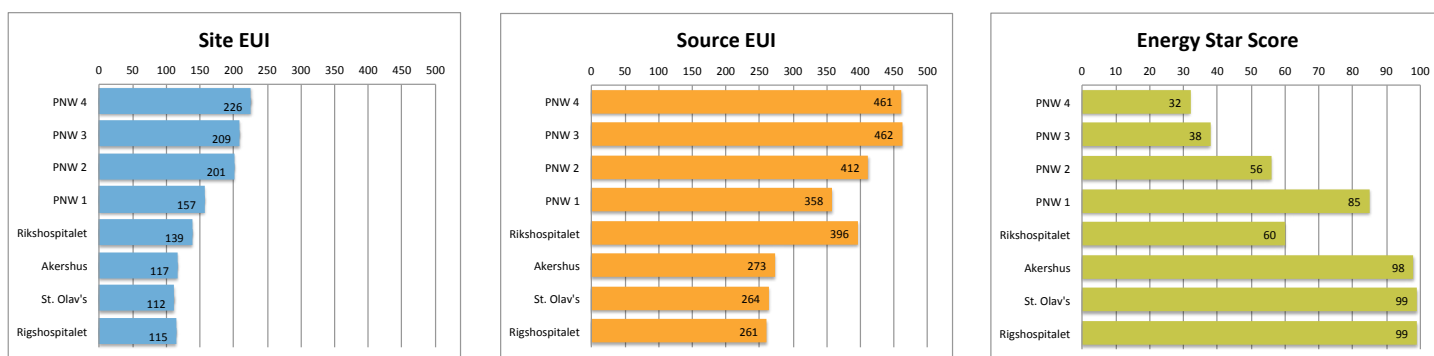
The graphs in Figure 3 show a comparison between site EUI, source EUI and ENERGY STAR Score. Figure 4 shows the hospitals' site EUI in combination with the fuels that are used to operate the facilities. From this graph, it can be seen that the Pacific Northwest examples primarily use a split between electricity and natural gas. The Scandinavian examples primarily receive heat from district systems, either district heat or steam. Direct comparison between site EUI and ENERGY STAR score is problematic since ENERGY STAR scores are based on source energy intensity, which varies by fuel type. In this study, the inequity between site EUI and ENERGY STAR score is illustrated by comparing Rikshospitalet and Pacific Northwest Hospital 1 (PNW 1). The overall site EUI for Rikshospitalet is 139 and its ENERGY STAR Score is 60 where the overall EUI for PNW 1 is 157 and it has a higher ENERGY STAR Score of 85. Rikshospitalet generates its heat primarily with on-site electric boilers, translating the site EUI of 139 kBtu/SF Year (site) to 396 kBtu/SF Year (source). Even though the electricity used to power the boilers at Rikshospitalet comes from hydroelectric sources, Portfolio Manager uses one source to site conversion ratio for any electricity use. PNW 1 uses district steam as its heat source, which has a much lower source to site ratio, and translates to a source EUI of 358 kBtu/SF Year, and therefore a better ENERGY STAR score even though its site EUI is significantly higher than Rikshospitalet's site EUI.

ENERGY STAR'S use of source vs. site energy has implications to design, construction and operations professionals that plan and track building energy use. If all other attributes were equal, two buildings using the same amount of energy at a building or site level may score differently in ENERGY STAR because of the fuel type that the building uses. For example, an all electric building would score much lower than a building that utilizes a district hot water system for heating since electricity has a higher source to site energy ratio than district hot water. If attaining an ENERGY STAR Certification is a primary objective, reducing the site EUI is one step. Understanding and planning for the type of fuel that is utilized on-site may be a secondary beneficial consideration for achieving the goal of ENERGY STAR Certification.

## SOURCE ENERGY CALCULATION AND BASELINE ESTIMATING

The source vs. site calculation methodology for ENERGY STAR Ranking has implications for the design phase of a project. For the 2030 Challenge, for example, it is recommended that design teams use the EPA's Target Finder tool to establish an average operational baseline for goal setting purposes. Typically that is done using the default assumptions for fuel mix. That is the amount of electricity and natural gas by percentage that the building will use. This default is established on a regional level. In the Pacific Northwest, a fuel split of 36% electricity and 64% natural gas is assumed.

figure 3. These graphs depict eight hospitals, 4 Pacific Northwest and 4 Scandinavian showing site Energy Use Intensity or EUI (in kBtu/SF Year), Source EUI (also in kBtu/SF Year), and Energy Star score. The site and source EUI graphs are graphed with the same horizontal scale to show the relative scales of site EUI and source calculation methods.





The tables in Figures 5 and 6 show the numerical data used to generate the previous graphs, as well as the inputs assumed in Portfolio Manager building area, number of full time employees, number of beds and number of MRIs. Here, annual energy consumption is shown as a total. More detailed monthly energy use for the Scandinavian hospitals can be found later in the report in each hospital’s case study. The monthly profiles for the Pacific Northwest hospitals has not been shown.

This table also shows baselines that are estimated by Target Finder using each building’s specific attributes of size, location, number of beds, full time employees, and MRIs. Target Finder does not allow the input of international locations, so Seattle was used as the location for the Scandinavian hospitals. Of note here is the difference between the baseline estimates when these attributes are entered without assuming a fuel split (labeled “Blind Energy Mix” in the table) and the estimates when the actual fuel mix of the hospital is entered (labeled “Actual Energy Mix” in the table). The percent energy reduction of the actual energy consumed by the hospital compared to those baselines is shown in the following two columns.

Using fuel mix as a determinant of baseline energy consumption has implications for early energy goal setting for new facilities. Energy goals are best set at the earliest stages of the design process, well before the technologies that serve the hospital have been chosen. Specific technologies or methods for operating the facility ultimately establish the amount of each fuel that will be consumed by the facility. However, consequential energy reduction strategies may rely on re-thinking the traditional configuration of heating, ventilation, and air-conditioning systems, which result in changes to a “typical” split between electricity, natural gas, and other fuel sources such as district energy.

Using a fuel blind baseline early in design can lead to a deeply energy efficient hospital that achieves a significant building energy performance goal, but does not reach the expected ENERGY STAR ranking. An example that highlights this clearly is Rikshospitalet, which achieves a 38% energy reduction from its Target Finder baseline using default fuel

ENERGY BY END USE FOR EIGHT HOSPITALS

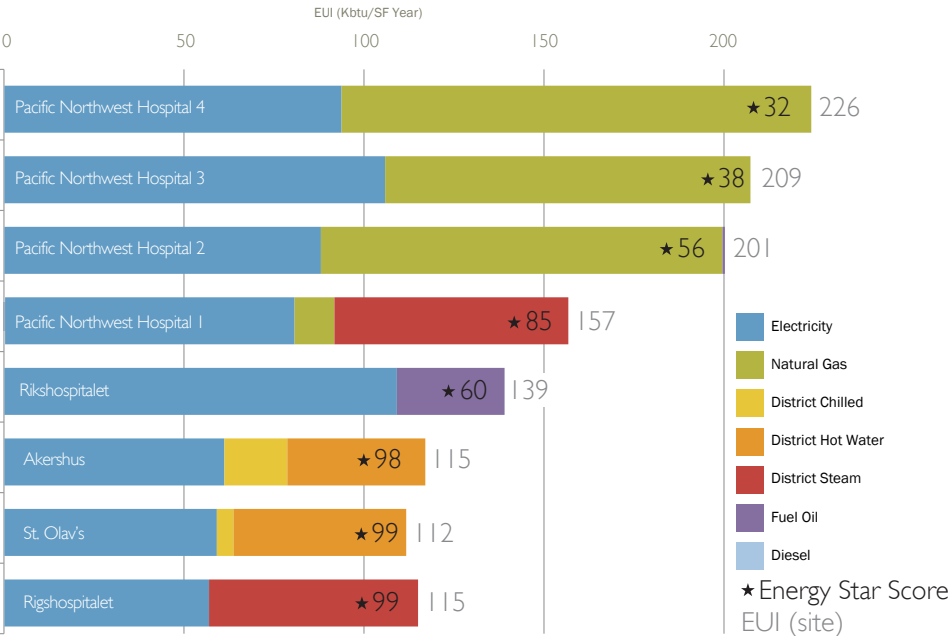


figure 4. This graph shows site EUI with fuel types and the Energy Star score overlaid.

Hospital	Portfolio Manager Results			Target Finder Baselines		2030 Challenge Goals		Energy Mix		Total Energy
	Energy Star Score	Site EUI	Source EUI	Blind Energy Mix	Actual Energy Mix	% reduction from blind fuel mix	% reduction from actual fuel mix	Type	%	kBtu
PNW 4	32	226	461	209	194	-8%	-16%	Electricity	42%	216,024,868
								Natural Gas	58%	
PNW 3	38	209	462	220	185	5%	-13%	Electricity	51%	132,085,832
								Natural Gas	49%	
PNW 2	56	201	412	236	214	15%	6%	Electricity	44%	146,429,603
								Natural Gas	56%	
								Fuel Oil	0.2%	
PNW 1	85	157	358	238	193	34%	19%	Electricity	51%	142,563,323
								Natural Gas	7%	
								District Steam	41%	
								Diesel	0.1%	
Rikshospitalet	60	139	396	226	148	38%	6%	Electricity	78%	301,628,547
								Fuel Oil	22%	
Akershus	98	117	273	226	182	48%	36%	Electricity	52%	149,672,484
								District Chilled	15%	
								District Hot	33%	
St. Olav's	99	112	264	242	191	54%	41%	Electricity	53%	241,536,728
								District Chilled	4%	
								District Hot	43%	
Rigshospitalet	99	115	261	231	191	50%	40%	Electricity	49%	356,968,089
								District Steam	51%	

figure 5. Data table depicting Energy Star Score with site and source EUI, Target Finder baselines both fuel blind and with the actual energy mix, percent energy reduction if using those Target Finder baselines and a description of fuel mix and total energy expended at each hospital.

mix assumptions, the baseline that would most commonly be used during the design phase of a project. Based on the hospital's actual fuel split, however, it only achieves a 6% reduction from the modified Target Finder baseline that is calculated based on actual fuel splits. This actual fuel split significantly affects its ENERGY STAR score, ranking 60, since the hospital's source EUI is much higher than anticipated in a fuel blind analysis. As a point of comparison, a similarly sized Pacific Northwest Hospital (PNW 1) achieves slightly lower reduction from the fuel blind Target Finder baseline, 35%, and a 19% reduction using the actual fuel split, ranking 85 with ENERGY STAR. Since ENERGY STAR uses source energy consumption compared to a calculated source baseline to help determine a hospital's ranking, the calculation depends directly on the fuels that are used. This leaves questions about the relationship between using Target Finder to establish baseline site EUI assessments early in the design process, and ultimate ENERGY STAR rankings.

## ENERGY STAR'S SCORING SYSTEM

Between 2010 and 2011, the EPA changed the data set and regression analysis that it uses to determine the ENERGY STAR ranking. Many Pacific Northwest hospitals' ENERGY STAR scores were affected by the switch, including some of those studied in this research. Some scores were reduced enough that hospitals went from being ENERGY STAR certified in the old system, yet were unable to renew that certification the following year even though their energy use remained unchanged. This has caused questions about the validity of the new ENERGY STAR data set and regression analysis that is used for hospitals. There is concern that ENERGY STAR score may not be the best metric for comparing buildings to one another. While the ENERGY STAR ranking system does not create an effective comparison between buildings at a site level, Portfolio Manager remains a high quality tool that building owners can derive value from by comparing relative differences year to year and building to building within their own organization. Similarly, for this study, the Portfolio Manager tool provided a direct comparison of the hospitals highlighted in this report.

Hospital	Ft <sup>2</sup>	FTE	Beds	MRI	Energy/FTE (kBtu/yr)	Energy/Bed (kBtu/yr)	Ft <sup>2</sup> /Bed
PNW 4	1,000,500	1,361	249	2	158,725	867,570	4,018
PNW 3	635,146	970	194	2	136,171	680,855	3,274
PNW 2	729,769	2,045	324	1	71,604	451,943	2,252
PNW 1	1,010,135	3,738	294	1	38,139	484,909	3,436
Rikshospitalet	2,163,514	5,000	712	5	60,326	423,636	3,039
Akershus	1,275,753	1,250	640	5	119,738	233,863	1,993
St. Olav's	2,156,607	6,602	710	7	36,585	340,193	3,037
Rigshospitalet	3,096,095	8,000	1,100	7	44,621	324,516	2,815

figure 6. Continuation of data table on Page 10, depicting Portfolio Manager inputs for each hospital.

There is similar concern, however, with solely using site EUI for evaluating hospitals, due to clear differences in hospital acuity, program compositions, climate, etc. These concerns with comparative metrics indicate a clear need for developing alternative energy ranking metrics.

This team evaluated the data from the hospitals in this report to assess if there was an alternative methodology for comparing energy to metrics other than building area such as: energy per bed, energy per employee, energy per MRI. These benchmarks are presented in the table in Figure 5 and are represented graphically in Figure 7. These data show a slightly different curve than the site EUI statistics, and the team did not feel that a clear correlation could be made between these data.

One proposed method for equalizing rankings is to use a clinical indicator as it relates to energy use, such as adjusted patient day, discharge rate, or another healthcare related metric that measures acuity or throughput at the hospital. These clinical data were not collected through this study so that metric has not been evaluated, but such a comparison would be valuable to further the conversation about how to best evaluate the energy intensity of healthcare institutions in a way that allows for a clearer comparison between facilities.

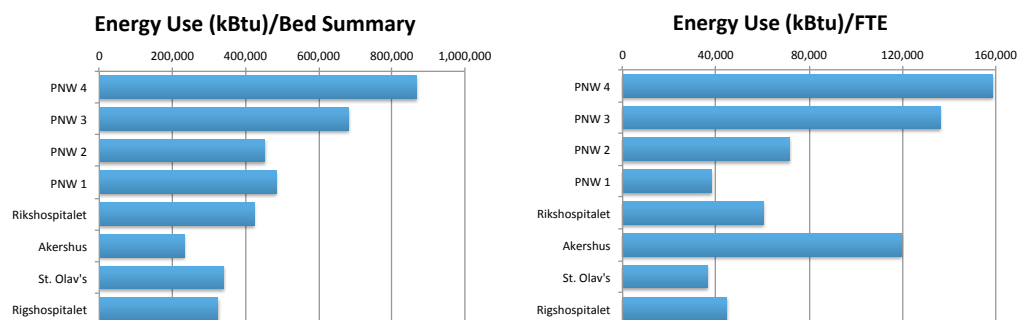


figure 7. These graphs present an alternative method for evaluating energy use intensity, energy on a per bed basis or energy on a per full time equivalent worker basis. It is not clear to the team that either of these methods present a better comparison than site or source EUI (energy per SF), however are presented here for others' analysis of alternative methodologies.



## ENERGY RELATED STRATEGIES LEADING TO HIGH PERFORMANCE

Based on the data collected and analyzed in this report, the hypothesis that Scandinavian hospitals consume significantly less energy than Pacific Northwest hospitals stands true. Specific energy related strategies are articulated in the following case studies section. Here, a brief synopsis of those strategies helps summarize some of the major moves that lead these hospitals to be examples of how to achieve high performance in practice. Specific architectural, building mechanical, and plant systems make these hospitals efficient, but more importantly the integration of strategies lead to synergistic savings that enable the level of energy use that we see exemplified in these hospitals.

### ARCHITECTURAL STRATEGIES

- Shading, reducing solar heat gain  
*In order to reduce the total load on spaces so that the cooling load can be accommodated with water-based systems, the Scandinavian examples use a combination of exterior shading devices, most commonly exterior dynamic shading that automatically deploys with the movement of the sun.*
- Improved thermal envelope
- Operable windows with some natural ventilation
- Reformulation of the building massing to create greater exterior connection
- Daylighting throughout with electric lighting reductions

### BUILDING MECHANICAL STRATEGIES

- De-coupled ventilation and thermal tempering, virtually eliminating re-heat  
*One of the biggest departures from traditional U.S. hospital design that has the biggest energy impact is the virtual elimination of re-heat. Re-heat represents at least 40% of a typical U.S. hospitals energy use. In the Scandinavian examples, the systems for delivering fresh air and thermal tempering are commonly separated, where fresh air is delivered with a modest amount of conditioning and supplemental heating and cooling are provided through water-based systems. Typically, heating is delivered through radiators under the window and cooling is delivered (when supplemental cooling is even needed) in radiant cooling panels, or fan coil units in spaces that have greater cooling requirements. This approach of de-coupling heating and cooling from ventilation dramatically reduces re-heat. Air delivery systems also vary and include ceiling diffusers, conventional sidewall grilles, and displacement ventilation through supply grilles low in the volume of the space (including in patient rooms).*
- Control strategies that turn spaces “off” when not in use, including operating rooms
- Heat recovery at every opportunity possible

### CENTRAL PLANT STRATEGIES

- Efficient, centralized energy production with district heating and cooling
- Cooling from direct sources such as lakes and rivers
- Ground source heat pump plants  
*If district energy is not available, most hospitals use heat pumping in some form for heating and/or cooling, including the extensive use of large closed-loop, ground coupled heat pump plants.*

# CONCLUSIONS

This report shows a side-by-side comparison of Scandinavian and Pacific Northwest hospitals evaluating site EUI, source EUI, and ENERGY STAR scores. As hypothesized, Scandinavian hospitals use less energy at a site level compared to their Pacific Northwest counterparts, and they generally rank much higher in ENERGY STAR score, due to both total site energy consumption and source energy type. It is clear that a hospital's site energy utilization, as well as the fuels used to supply that energy, significantly impact the ENERGY STAR ranking.

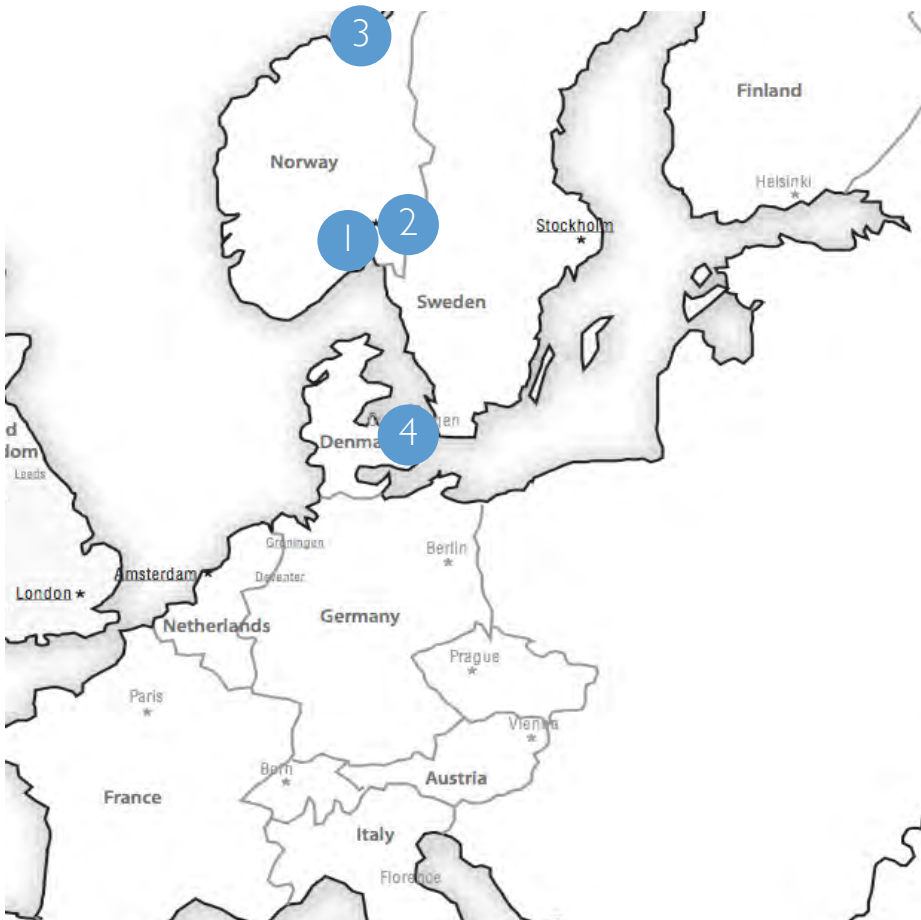
As institutions whose missions are to “first do no harm,” reducing the environmental and health burden of energy consumption and providing high quality healthcare environments should be fundamental priorities for healthcare organizations. These Scandinavian hospitals provide evidence for professionals in design, construction, and operation of U.S. hospitals showing that it is possible to achieve significantly reduced energy footprints and increased indoor environmental quality in healthcare facilities.





# CASE STUDIES

The following section highlights case studies of four Scandinavian hospitals. They begin with architectural context, including attributes that lead to high indoor environmental quality, then follow with summaries of energy related strategies and energy data from this study. The photos, information, and data were gathered through a series of site visits to the hospitals, including the 2009 study tour, interviews, and e-mail correspondence. We have made our best effort to correctly translate information that we have received and convert all units to U.S. equivalents for ease of comparison for a U.S. audience.



- 1 Rikshospitalet
- 2 Akershus
- 3 St. Olav's
- 4 Rigshospitalet

### *Location*

Oslo, Norway

### *Architect*

Medplan AS

### *Mechanical Engineer*

COWI

### *Opened*

2001

### *Beds*

712

### *Energy Consumption*

139 kBtu/SF-year

## RIKSHOSPITALET



## CONTEXT

Rikshospitalet showcases the shift in typology from a predominantly vertical program distribution to a horizontal distribution. Built in 2001, it is the first Scandinavian hospital to depart from the typical Post-War era configuration with a deep plan diagnostic and treatment base with stacked patient tower. This contemporary pavilion hospital draws its inspiration from Victorian hospital models, adapted to today's contemporary practice. This is the large National University research hospital that serves specialized patients from all over Norway. The philosophy that permeates the design is an environment that is for people. Its functional areas are organized as if the building were a town, the departments villages, and the smaller areas homes. These areas are all connected via an "interior street" that runs the length of the hospital. The patient wings and diagnostic and treatment areas are on either side of this street with connecting horizontal circulation bridges.

This shift in form creates the opportunity for plan-enclosed courtyards in the diagnostic and treatment area of the hospital, allowing daylight and views into spaces such as surgery and imaging.

This form creates a variation in the floor-to-floor heights between the treatment building and patient wings. To accommodate this, the treat-



*Image courtesy of Rikshospitalet*





# ENERGY RELATED STRATEGIES



ment floors are layered with interstitial floors so that they match the patient wing floors. These interstitial floors benefit the hospital operations by allowing for easy maintenance of systems, fast reconstruction, and they limit the disruption that occurs on the clinical floors during construction (see the second photograph to the left).

## ARCHITECTURAL STRATEGIES

Windows are operable throughout the hospital. There are also opportunities throughout the hospital to go outside on balconies, and many patient rooms on the ground floor have doors that open directly onto grassy courtyard patios. The highly perforated plan allows daylight in most spaces including diagnostic and treatment rooms, which are organized around interior courtyards (second picture from top on prior page). While there is plenty of daylight, even in operating rooms, the windows are well shaded with both interior and exterior shading systems. This helps with both glare and light control, and limits the amount of radiant solar energy that can enter the envelope thus minimizing solar and cooling loads. The atrium uses a radiant floor and is naturally ventilated through mechanically operated louvers at the top of the tall space. The conditioning of this space is treated as a thermal transition zone where it can be cooler than normal in the winter and warmer than usual in the summer.



## BUILDING MECHANICAL STRATEGIES

The major departure from U.S. hospital design at Rikshospitalet is in the de-coupling of heating and cooling from ventilation air, and in the method for delivering fresh air. Patient rooms use displacement ventilation rather than a traditional overhead mixing system to deliver fresh air to the room (see lower supply grills in top photograph on left). Radiant panels provide most of the heat, and there is little cooling in patient rooms. Thus, room tempering has been separated from the ventilation system. Typical overhead mixing systems rely on dilution of the air necessitating more air changes per hour. Displacement ventilation supplies cool fresh air low in the space which rises as it heats up, ideally in a laminar piston effect. The goal of displacement ventilation is to condition the space at a lower air change rate and to carry contaminants directly up and away from occupants, exhausting the air as quickly as possible. It has been shown that displacement ventilation is equal to or better than overhead mixing systems for comfort, ventilation effectiveness, and airborne particle control. Substantial research efforts by Mazzetti and Stantec have been undertaken in the US to determine the validity of these hypotheses and the viability of displacement ventilation systems for hospitals. Displacement ventilation can provide substantial energy savings since ventilation is largely separated from room tempering and fewer air changes per hour are required, at AIA Guidelines comparable levels.



## CENTRAL PLANT STRATEGIES

Hydroelectric power and oil prevalent in Norway, and Rikshospitalet capitalizes on the abundance and availability of those resources, using electric resistance boilers (third picture from top) with a very large supply of back up oil (bottom picture). This strategy leads to a much higher source energy footprint since the electricity that is used for heating purposes embodies transmission loss. When calculated in Portfolio Manager the source electricity also incurs an energy factor for generation, since the calculation is based on a U.S. national standard factor that does not favor hydroelectric generation over electricity produced by combustion of natural gas or coal.





# ENERGY DATA

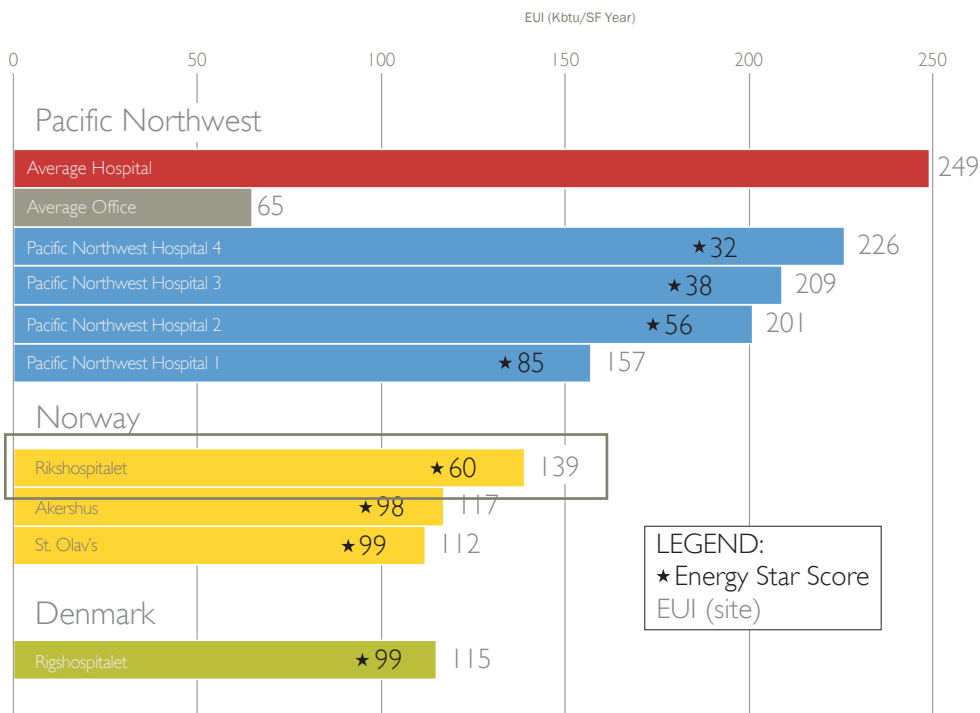
## ENERGY SUMMARY

In 2010, Rikshospitalet used 139 kBtu/SF Year total site energy. This is approximately 45% less than the average Pacific NW energy use for similar acute care facilities. It achieves an Energy Star score of 60, much lower than expected for that site energy intensity. However, this lower score is explained by the source energy calculation used by Portfolio Manager, and the hospital's high proportion of electricity used to produce heat.

Completed **2001** | Location **Oslo Norway**  
 Square Feet **2,163,514** | Beds **592** | Full Time Equivalent Staff **5,000** | MRIs **5**

Month	Electric Boiler (kBtu)	Oil Boiler (kBtu)	Electricity, Grid Purchase (kBtu)	Total
January	19,847,254	9,428,858	12,295,652	41,571,765
February	16,021,065	7,534,693	11,113,131	34,668,890
March	15,370,497	2,751,278	12,036,104	30,157,879
April	6,775,793	270,106	9,872,901	16,918,799
May	6,933,960	759,452	11,084,306	18,777,718
June	4,091,661	22,267	11,067,126	15,181,053
July	3,272,784	0	11,178,961	14,451,745
August	2,557,342	1,292,965	11,228,917	15,079,224
September	3,961,260	1,864,435	11,013,075	16,838,770
October	7,215,872	2,994,529	11,422,131	21,632,531
November	7,514,420	9,978,061	11,307,976	28,800,457
December	7,819,223	28,079,659	11,680,833	47,579,715
<b>Total</b>	<b>101,381,131</b>	<b>64,976,301</b>	<b>135,301,114</b>	<b>236,682,244</b>

## SELECTED ENERGY USE IN HOSPITALS BY COUNTRY



# AKERSHUS

## Location

Oslo, Norway

## Architect

CF Møller

## Mechanical Engineer

AF Statkraft Grøner Theorells

## Opened

2008

## Beds

640

## Energy Consumption

117 kBtu/SF-year



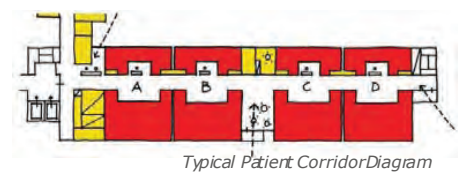
figure 8. exterior



## CONTEXT

Akershus hospital is located just outside Oslo, Norway. It was completed in the fall of 2008 and is a recent example of the contemporary pavilion style hospital. It was designed by CF Møller and displays their Danish design roots in its clean, straight lines, as compared to the more organic form of Rikshospitalet. This hospital demonstrates that this form, with horizontal adjacency between treatment block and patient wings, is still relevant for the Norwegian hospital system.

Patient corridors are organized in clusters where each group has seven patient rooms, three singles and two doubles. Each cluster has a workstation for staff that has borrowed light, captured from above the bathrooms in the patient rooms (bottom picture and section drawing on right). Between the clusters in the corridor are lounge spaces for patients, family, and staff, with an accessible outdoor deck (second picture from top).





# ENERGY RELATED STRATEGIES

## ARCHITECTURAL STRATEGIES

Daylighting is prevalent throughout the hospital. The top photograph on this page depicts a typical scene: where there is abundant daylight, electric lighting is turned off. This is common at Akershus, as well as in many other hospitals and buildings throughout Scandinavia. This has an obvious energy benefit in the electricity that it takes to operate the lights, but also has implications for reducing cooling loads that result from the heat load of lighting.

Solar loads and glare are controlled with an interstitial to the glass blind system, and thermal performance of the envelope is enhanced with triple glazing systems.

The patient bathrooms in this hospital were constructed modularly off-site, dropped into place, and connected with on-site plumbing, saving construction cost and time, and ultimately creating a more efficient construction process.

## BUILDING MECHANICAL STRATEGIES

Each section of the building has its own independently functioning technical tower (with HVAC, electrical and controls) that connects the central plant, building, and technical supply to the individual departments. These centrally located yet distributed technical towers provide short routing paths to functional areas. They contain air treatment, heating and cooling distribution, and automation systems for each floor. The main routing is horizontal with well-planned zones for each line and the ability for flexibility and customization for programming changes.

Heating is provided mainly through hot water radiant systems (seen in the second and third photo on this page). As in Rikshospitalet the atrium space uses displacement ventilation, with the seating serving as the air supply, (bottom photograph). In patient rooms, radiators are placed under the window areas along the outer walls and the temperature in the room is governed using static thermal radiator valves. For rooms with cooling needs, additional spot cooling is provided through radiant systems.

## CENTRAL PLANT STRATEGIES

The building form of Akershus is similar to Rikshospitalet, but the systems approach is more contemporary. Nearly 50% of the heating and cooling for the hospital is provided through district cool and hot water systems, which are generated at a central plant that uses a combination of ground source heat pumping and seasonal energy storage.

The state-of-the art systems include a closed loop ground source heat pump with 350, 200 meter bore holes. The project also re-captures waste heat from systems equipment, medical equipment, lighting, people, and other heat generators. In this sense, this project has solved the thermodynamic equation, thus saving a substantial amount of energy.

# ENERGY DATA

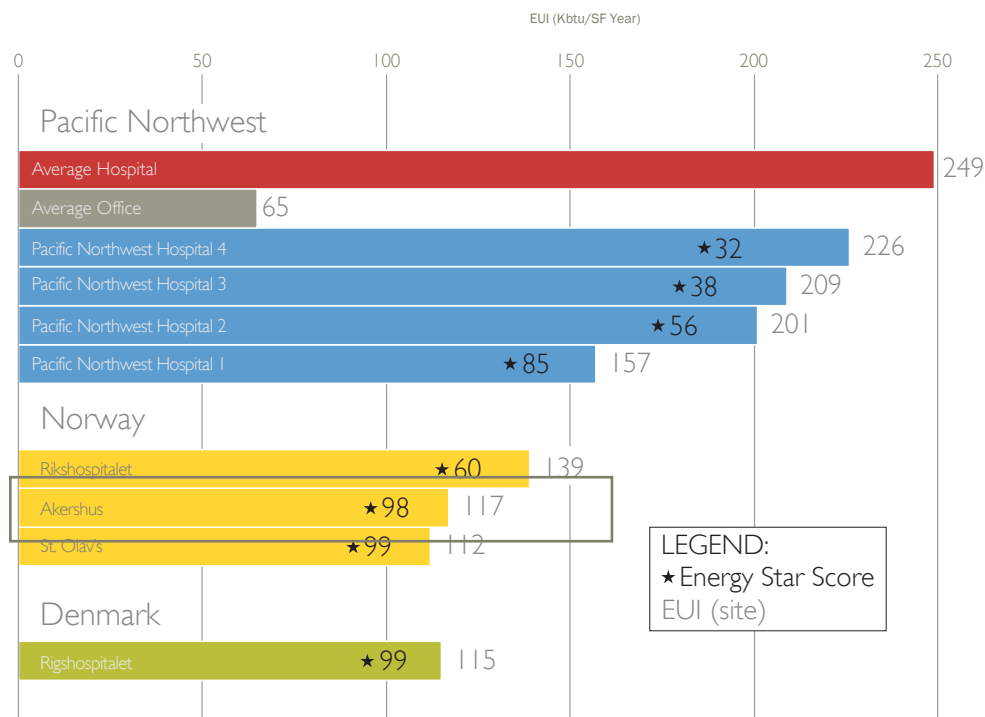
## ENERGY SUMMARY

In 2011, Akershus used 117 kBtu/SF Year total site energy. This is more than a 53% reduction from the average Pacific NW energy use for similar acute care facilities. It achieves an Energy Star score of 98, showcasing its superior energy performance at both the site and source level.

Completed **2008** | Location **Oslo Norway**  
 Square Feet **1,275,753** | Beds **640** | Full Time Equivalent Staff **1,250** | MRIs **5**

Month	District Hot Water (kBtu)	District Chilled Water (kBtu)	Electricity, Grid Purchase (kBtu)	Total
January	9,928,417	1,600,697	6,691,487	18,220,601
February	9,566,639	1,457,351	6,160,281	17,184,271
March	3,744,061	1,628,001	6,789,105	12,161,167
April	2,952,245	1,686,022	6,343,020	10,981,287
May	2,242,000	1,903,768	6,511,188	10,656,956
June	1,220,926	2,346,431	6,235,019	9,802,375
July	1,021,153	2,881,582	6,240,565	10,143,299
August	1,171,625	2,283,969	6,463,898	9,919,492
September	1,683,483	1,531,410	6,443,048	9,657,940
October	3,354,979	1,675,783	6,730,712	11,761,474
November	4,944,072	1,675,783	6,693,613	13,313,468
December	7,234,570	1,689,435	6,946,148	15,870,153
<b>Total</b>	<b>49,064,169</b>	<b>22,360,232</b>	<b>78,248,083</b>	<b>127,312,252</b>

## SELECTED ENERGY USE IN HOSPITALS BY COUNTRY





# ST. OLAV'S

## Location

Trondheim, Norway

## Architect

Medplan AS, Frisk Arkitekter AS  
(Phase I) and Narud Stokke  
Wiig (Phase II)

## Mechanical Engineer

COWI, Gunnar Karlsen

## Opened

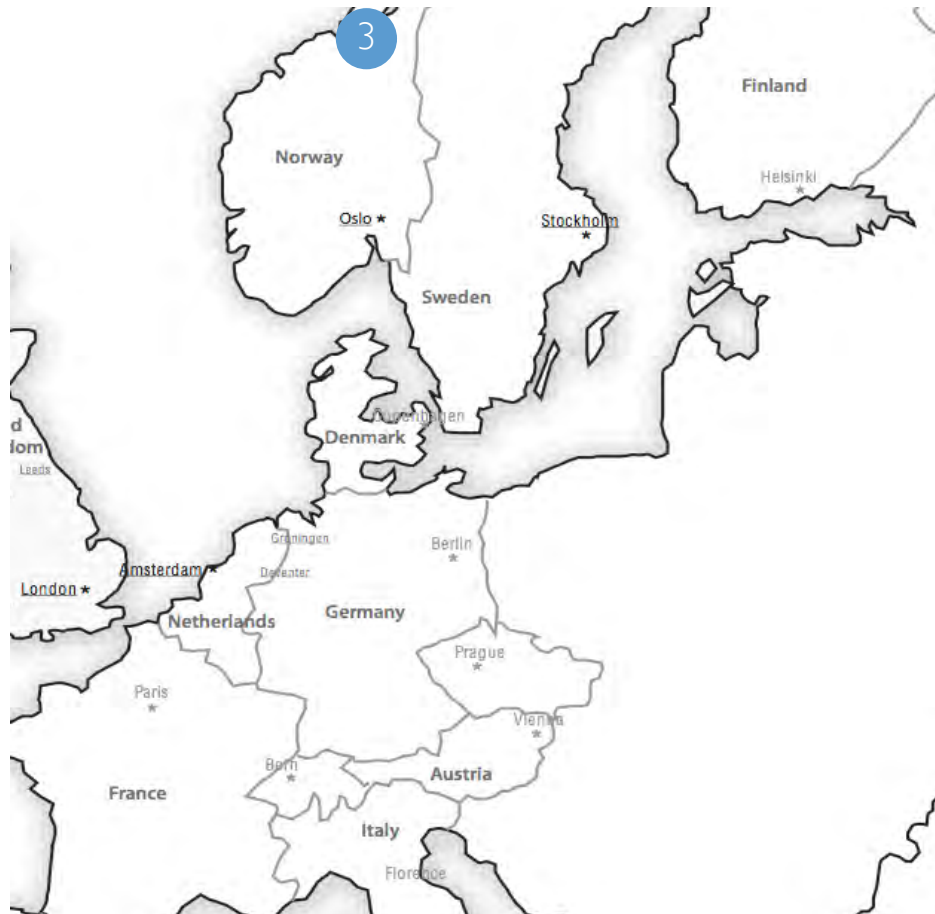
Phase I, 2004-6, Phase II, 2009-15

## Beds

710

## Energy Consumption

112 kBtu/SF-year



## CONTEXT

The original hospital (#1 in top image), is a Post-War Era hospital with deep diagnostic and treatment areas and a patient tower stacked atop. In the development of the new hospital, the designers and team decided to move away from this formulation for a more contemporary configuration that enables greater connections to daylight, views, and the exterior environment.

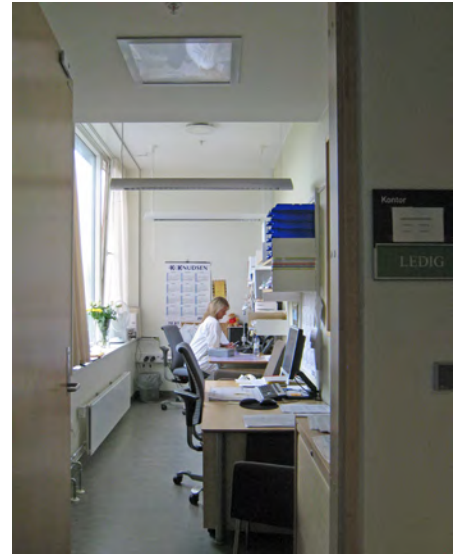
St. Olav's Hospital in Trondheim Norway is an example of a contemporary hospital designed with "community placemaking" in mind. Here the horizontal concept is pushed even further, with buildings spread apart into distinct centers of care that act as individual hospitals. Connectivity between the campus is maintained at the second level via sky bridges, and underground through service functions. Each of the buildings preserves its own unique architectural character allowing the buildings to be recognized and distinguished from one another while softening the potential overwhelming institutional rhythm that might otherwise be created in such a large facility. This unbundling of the hospital into separate centers of care allows each building to be built at the standard that is appropriate for the building type. For example, the laboratory is different than the Women and Children's Hospital, which is in turn much different than the on-site hotel. This helps create a campus-like atmosphere rather than one homogeneous institutional building. The centers of care include women and children's, neurology, cardiology, orthopedic, emergency & cardiology, gastroenterology, laboratory, and supply.

## ARCHITECTURAL STRATEGIES

The Women and Children's Centre is a great example of providing outdoor space and views within an urban setting. The hospital is a thin plan building that wraps around a large central courtyard. Patient rooms have doors that step directly onto upper terraces on the courtyard side, and the terraces are planted and have play equipment. Rooms on the street side of the corridor have small one-person balconies. There are also rooftop terraces adjacent to staff areas and throughout the rest of the hospital. Generous windows daylight the patient rooms and provide light in the surgery suites (bottom photograph on following page). Daylight is controlled on all of the façades (except the north façade) with automated exterior louver blinds that move with the movement of the sun. Micro-adjustments of the shading system can be varied so that occupants can have control over their en-



Image courtesy of St. Olav's







# ENERGY RELATED STRATEGIES

vironment. In the facade shown in the top two photographs, one can see where several rooms/individuals have chosen to override the automated system and keep the blinds open or closed.

## BUILDING MECHANICAL STRATEGIES

St. Olav's uses a de-coupled system using 100% outside air with heat recovery and supplemental heating and cooling provided by water based systems. Cooling, where necessary beyond the fresh air system, is provided through passive chilled beams or fan coil units (depending on the location). Heating is provided through wall-mounted radiant panels. Controls are through a DDC system, and in non-clinical spaces carbon dioxide based occupancy sensing controls airflow. Temperature and lighting are also controlled by occupancy sensors in non-critical spaces.

There are approximately 43 operating rooms at this hospital. Their airflow rate is similar to the code minimums in the U.S. as outlined by the AIA Guidelines. The operating room mechanical systems are designed to be turned down when not in use, to about 30% of full air flow. This is a common operations theme at this hospital, where mechanical systems are programmed to turn down during off-peak conditions. As one of the most energy intensive spaces in a hospital, this airflow turndown in the operating rooms has a significant impact on overall energy intensity at St. Olav's. The bottom two photos show an operating room at St. Olav's, highlighting windows that provide daylight and a sophisticated control panel that controls HVAC overrides, lighting, and other functions in the suite.

## CENTRAL PLANT STRATEGIES

Heating and cooling is provided by a district source, Statkraft Varme. The incoming temperature of the district heat is 212 degrees Fahrenheit. Statkraft provides district heating to a large part of Trondheim, and they produce heat energy through a combination of burning waste, oil, and natural gas with a small proportion of electricity. District cooling is also delivered from this utility, and is delivered with an incoming temperature of 45 - 48 degrees Fahrenheit. In the winter, the city's river provides free cooling, and in the summer an absorption chiller produces cool water. For this analysis, the "free" cooling in the winter months was not counted in the total energy consumption, since no fuel was used to produce the district cool water. The energy used in the summer months for district cooling was used in the overall energy calculation, shown with an outline in the data table to the right.

# ENERGY DATA

## ENERGY SUMMARY

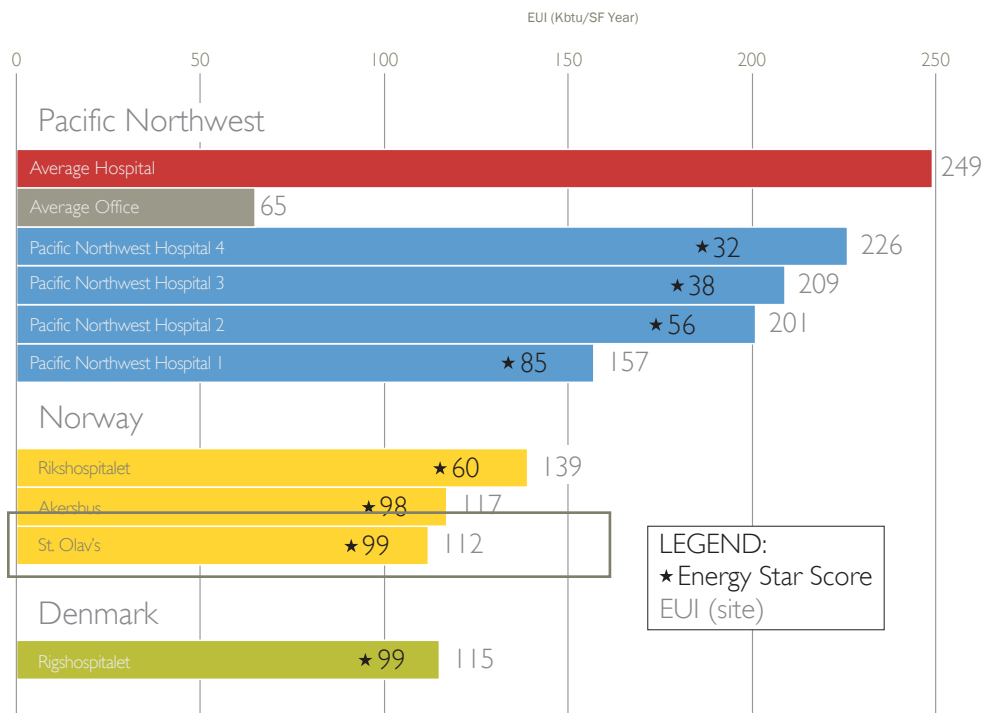
In 2011, St. Olav's used 112 kBtu/SF Year total site energy. This energy use accounts for all of the centers of care, which are metered separately but combined for this analysis. As a whole, this is more than a 55% reduction from the average Pacific NW energy use for similar acute care facilities. It achieves an Energy Star score of 99, showcasing its superior energy performance at both the site and source level. For this analysis, Oslo was used as the location of this hospital in Portfolio Manager. This is the closest city that has a U.S. Embassy and is thus available for Portfolio Manager analysis. The team performed a sensitivity analysis, changing the locale in Portfolio Manager between Oslo, Seattle, and Fairbanks Alaska, which made very little difference (1-2 points) to the overall score.

Completed **2006** | Location **Oslo (Trondheim) Norway**  
 Square Feet **2,156,607** | Beds **710** | Full Time Equivalent Staff **6,602** | MRIs **7**

Month	District Hot Water (kBtu)	District Chilled Water (kBtu)*	Electricity, Grid Purchase (kBtu)	Total
January	16,345,489	2,751,025	11,731,454	28,076,943
February	16,125,629	2,481,379	10,694,223	26,819,851
March	13,766,982	2,803,573	11,794,990	25,561,972
April	8,095,639	2,762,268	10,844,531	18,940,170
May	5,364,323	2,929,896	11,109,011	16,473,335
June	3,218,937	<b>3,256,237</b>	10,476,347	16,951,521
July	2,229,240	<b>3,382,399</b>	9,620,541	15,232,180
August	2,537,239	<b>3,370,082</b>	9,999,366	15,906,687
September	4,082,207	2,723,260	10,015,233	14,097,440
October	9,004,703	2,645,224	10,456,138	19,460,842
November	10,417,483	2,544,935	10,294,799	20,712,282
December	12,632,305	2,572,092	10,708,629	23,340,934
<b>Total</b>	<b>103,820,177</b>	<b>10,008,718</b>	<b>127,745,262</b>	<b>231,565,439</b>

\*Bold indicates purchased cooling in summer

## SELECTED ENERGY USE IN HOSPITALS BY COUNTRY



# RIGSHOSPITALET

## Location

Copenhagen, Denmark

## Architect

Kay Boeck-Hansen & Jørgen  
Stærnøse

## Opened

1970

## Beds

1100

## Energy Consumption

115 kBtu/SF-year



figure 9. aerial perspective

Image courtesy of Rigshospitalet



## CONTEXT

Rigshospitalet serves as an example of an existing facility with a multitude of buildings of varying ages, from those built in the 1800's to the majority of the complex, which was built in 1970. Architecturally this example is more similar to U.S. Post-War era hospitals, with some buildings pre-dating that era that serve support functions at the hospital. An aerial view shows the large campus configuration and the buildings constructed in various scales and eras.

## ENERGY DATA

### ENERGY SUMMARY

In 2011, Rigshospitalet used 115 kBtu/SF Year total site energy, which represents a 54% reduction from the average Pacific NW energy use for similar acute care facilities. It achieves an Energy Star score of 99, showcasing its superior energy performance at both the site and source level.

Completed **1970** | Location **Copenhagen Denmark**  
 Square Feet **3,096,095** | Beds **1,100**  
 Full Time Equivalent Staff **8,000** | MRIs **7**

Month	Steam Heat (kBtu)	Electricity, Grid Purchase (kBtu)	Total
January	29,226,283	4,356,996	33,583,279
February	25,592,077	3,935,191	29,527,268
March	22,210,501	4,371,088	26,581,589
April	12,144,723	4,079,874	16,224,597
May	10,828,935	4,325,632	15,154,567
June	7,578,939	4,302,418	11,881,357
July	5,860,520	4,361,443	10,221,963
August	5,715,783	4,477,172	10,192,955
September	8,492,096	4,313,961	12,806,057
October	13,778,932	4,423,809	18,202,741
November	18,178,927	4,387,392	22,566,319
December	20,797,345	4,411,173	25,208,518
<b>Total</b>	<b>180,405,061</b>	<b>51,746,147</b>	<b>232,151,208</b>



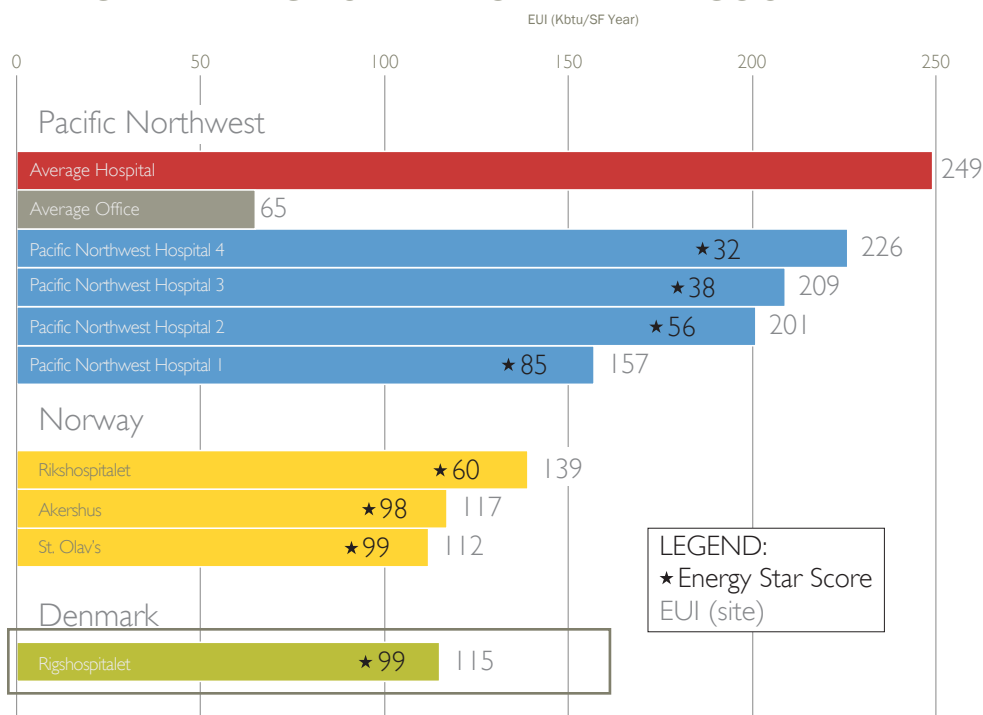
## ENERGY STRATEGIES

Electricity consumption at the hospital has risen less than 10% since 1979, and the hospital has taken many measures to reduce energy consumption in heating and cooling applications, reducing energy consumed by heating by over 40%.

One strategy for reducing this heating energy was to reduce internal steam piping losses through a combination of pressure reduction and piping insulation. Other strategies include dramatic operating room ventilation turn-down during unoccupied periods (from 20 ACH to 1 ACH).

Rigshospitalet uses a district steam system and electricity. Most cooling is provided by direct cooling from nearby lake water, utilizing only pumps to move the water. Some cooling occurs at the electric central cooling plant.

## SELECTED ENERGY USE IN HOSPITALS BY COUNTRY



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