Using the AEDG in large hospitals

To achieve energy efficiency in a hospital, engineers should fully understand the Advanced Energy Design Guide.

BY PETE SABEFF, PE, LEED AP, *Engineering Economics Inc., Golden, Colo.*

Learning objectives

- Understand the goals and objectives of the Advanced Energy Design Guide (AEDG) for Large Hospitals.
- Learn how experience gained during commissioning can impact building energy efficiency.
- Identify and apply cost-effective energy conservation concepts.

To achieve optimal performance levels in a health care facility, the Advanced Energy Design Guide (AEDG) for Large Hospitals is a useful tool. The process is well laid out, has specific methodologies established per climatic zone, and has energy performance expectations quantified in terms of Btu/sq ft. Energy use is projected to vary from 106,000 to 125,000 Btu/sq ft in geographic zones 1 through 7 (continental United States) for HVAC, lighting, and receptacle/process loads. Slightly more than 50% of expected energy use in a hospital is related to HVAC systems and equipment and is therefore the focus of this article, followed by the relatively less significant impact of lighting and plumbing, beyond current code.

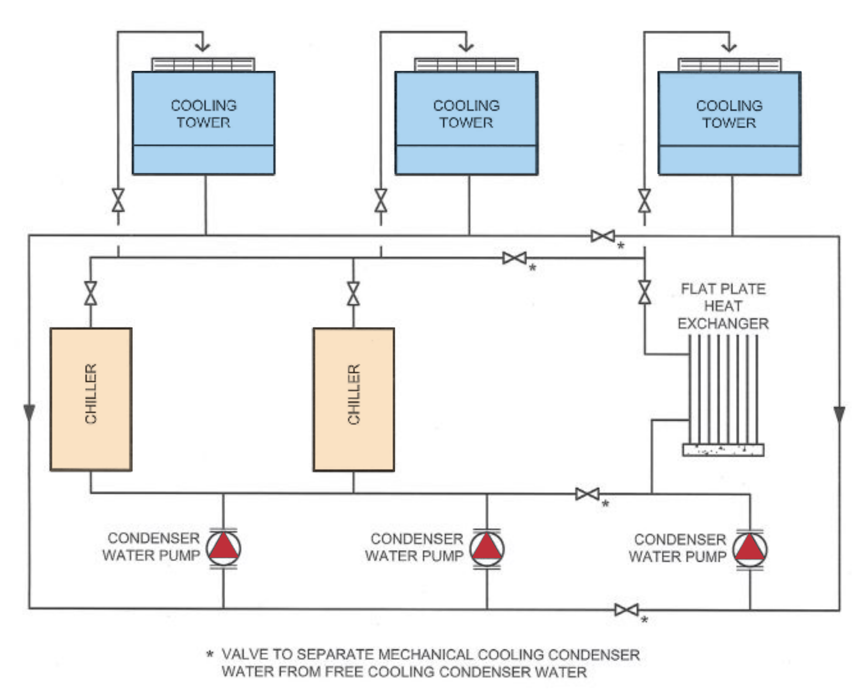
Figure 1: At St. Anthony Hospital in Lakewood, Colo., actual energy usage has been tabulated and graphed, with the AEDG 50% energy use target entered to calculate projected annual energy cost savings. All graphics courtesy: Engineering Economics Inc.

Other guides for hospitals and health care facilities include U.S. Green Building Council LEED for Healthcare, ASHRAE 90.1: Energy Standard for Buildings Except Low-Rise Residential Buildings, and the International Energy Conservation Code (IECC). States may also have various codes; check with the local authority having jurisdiction.

A 50% AEDG energy consumption target is less than half that of conventional hospital consumption—a lofty goal and one that most will say is unattainable. Obtaining usage this low will require pulling out all the stops, and as the AEDG states, employing integrated design practices and applying scrutiny to everything that either directly consumes energy or has an impact on energy use. It will require new practices that all designers and equipment planners will have to take to heart, working collaboratively to reduce loads and, in turn, consumption.

The following is a summary of lower cost/no additional cost design features, but the list should not be considered exhaustive. The AEDG includes additional information, which can be applied in pursuit of the 50% reduction goal. Some items included in the AEDG will require additional funding, and all will take an integrated design approach.

The commissioning process includes the publication of a systems manual. A systems manual is a composite of drawings, technical literature, sequences of operation, and explanation of system operating nuances for operator reference and training. It is not an operations and maintenance manual, nor is it meant as a replacement. The better systems manuals have one-line diagrams, floor plans with equipment locations, and Web links to items listed on the floor plans. If provided in electronic format, the information can be presented with a multimedia format to depict what you have, how it works (generically and as applied), troubleshooting features, and where to get support, parts, or service.



* VALVE TO SEPARATE MECHANICAL COOLING CONDENSER WATER FROM FREE COOLING CONDENSER WATER

Figure 2: **This shows a schematic of mechanical/free cooling condenser water piping.**

Once the design and construction are complete, the final product will be tested and performance will be validated, but the systems may not perform exactly as planned. Over the years, seasonal testing, revisions to set points, and revisions to operating practices based on system actions, reactions, and interactions may be required. The intent is to obtain the best possible results, short of capital intensive modifications.

The process defined by AEDG starts with project conception, followed by team selection, conceptual design, construction documents, construction, and operation. The following addresses these from an owner's representative/commissioning perspective:

- Project conception will be based on owner education, buy-in, and commitment. This should start with owner understanding of health care project design. Site and space planning is first, followed by design narratives provided by each design discipline. The owner's project requirements (OPR) is assumed by the design team, based on their health care design experience, and is not typically published at the outset. These assumptions may be indicative of the actual project requirements, and must be clarified either prior to or during the earliest stages of project design.
- The provisions of AEDG may not be known to the project designers. In recent years, health care construction been heavily based on applying the recommendations of the Health care Facility Guideline Institute (FGI), a well-known publication of health care design. While these guidelines define a higher standard for health care design, they do not address energy efficiency. That has to come from elsewhere, and the AEDG for Large Hospitals is a good start.
- Team selection is similar to interviewing job applicants. On the first go, one will say all the right things. Further investigation and understanding of team dynamics is necessary. Does the design team believe in and practice energy conservation? Do they know the methodologies and apply them in practice? Will the team work interactively and collaboratively? For the team to function collaboratively, they must have the correct chemistry.
- Mechanical, electrical, and plumbing (MEP) system over-sizing is the most frequent malady of new hospital design. One must understand, from a design perspective, there are no claims for over sizing, as there might be for under sizing. The practice will continue, and with few exceptions, equipment over-sizing will be counterproductive to energy-efficient design.
- Energy-efficient conceptual designs should be documented in a checklist and the OPR. The implications for how one will achieve a 50% reduction per AEDG must be identified and documented. The checklist, similar to a U.S. Green Building Council LEED rating checklist, should be used for planning and design. The owner and the design team should create the checklist with assistance of a third party that is knowledgeable in hospital design, energy-efficiency concepts, cost estimating, and technical feasibility.
- A thorough review and assessment of project requirements, and AEDG or Energy Star goals, should be completed by the owner and the design team before the design process begins. The next step is the OPR, which must reflect what the owner expects the project to be, reveal the depth and breadth of the planning, and establish the guiding design principles for the project. While the OPR may have some elements of a design narrative, it should clearly state project requirements, to include the form of the project, performance objectives, and in the case of AEDG, energy-efficiency expectations.
- In addition to checklists and the OPR, the expected Energy Star ranking, or maximum Btu/sq ft, must be identified. Both are tangible and quantifiable, and including them in the OPR is more effective than simply stating a desire for energy efficiency. Ultimately, utility usage will determine both, which can be metered

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with quantifiable results. Unfortunately, verification will not be possible until one year after occupancy, not while the design is under way.

■ The owner, the third party, and the designers must serve as advocates for the process, and remain active throughout the design with regular discussion and debate. While the designer is usually in charge of the effort, either the owner and/or the third party must have technical expertise to challenge and debate to establish the comprehensive truth of the concept and application. Owner advocacy is not an easy or simple task. It requires knowledge, intuition, communication, and commitment beyond opting for low first cost.

■ Every project has a budget, and all too often it is less than what is needed. Most concepts impact all disciplines, not just MEP systems, and understanding budget limitations during conceptual design may be the most important factor moving forward. How to do more with less is required, requiring knowledge and hard work to get there.

■ Cost implications must be addressed and regularly reviewed as the design progresses. Cost estimating will delineate all the variations, requires thorough knowledge of all the disciplines, and must establish the additions and deductions on a conceptual basis. The cost estimator is usually tasked to estimate based on experience, with only limited design documents upon which to base the estimate.

■ Unfortunately, the construction manager (cost consultant) is usually not familiar with the detail of mechanical and electrical costs, often relying on subcontractors to provide input. During the early stages, the subcontractors are in the queue for the job, with emphasis on having adequate budget for their portion of the contract, absent concern for economy and lower cost alternatives.

■ Computer models are used to predict loads and energy consumption, with the intent to define potential payback prior to or in conjunction with the design. However, computers are unable to conceptualize, and the model is only as good as the experience of the input engineer. The computer will give relative performance data but is unable to predict actual performance.

■ One must acknowledge that HVAC energy efficiency is more than selecting energy-efficient equipment, motors, etc. It requires a systematic approach to HVAC design and integrated design concepts and application. Lower loads and the use of natural or more cost-effective energy sources will be required. Lastly, operating equipment efficiently, once installed, will yield the energy savings that will last for the life of the systems.

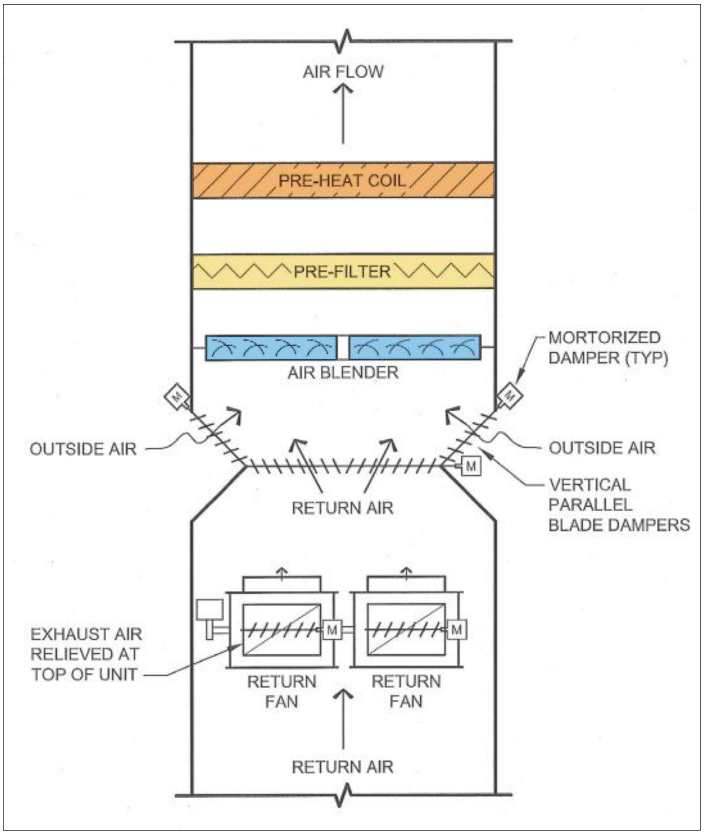


Figure 3: In this mixed-air section configuration, use of dual (opposing) outside air entrances with air blenders (in cold climates) to eliminate stratification and minimize the use of preheat coils.

Concepts to employ

Commissioning large hospitals has led to confirmation of many successful energy conservation concepts. The following are conceptually sound, simple, and proven to produce better environments, lower energy use, and sustainable results. The following is low-hanging fruit—applications of equipment and systematic design that do not add cost and may even reduce cost. Savings obtained by applying the following can be used to fund other energy-reduction features as recommended by the AEDG, which may add cost.

Low-cost HVAC concepts that work, and not likely to be subjected to value engineering cuts by category, include:

Primary equipment sizing/pumping

■ Selecting equipment with better part-load performance. This is a combination of equipment sizing and better turndown, considering that most equipment operates well below full load the majority of the time.

■ Variable flows and variable speed drives (for everything). Variable flow system design is the first step; applying drives is the next step.

■ Variable primary, not primary-secondary pumping for cooling systems. Less pump, and better flow control options.

- Manifolded/paralleled variable speed drive chilled water and condenser water pumps. True redundancy and better flow control options.

Heating

- Hot water in lieu of steam boilers—no centralized steam or condensate systems, no blow down, and lower losses. Steam for sterilization and humidification by unitary equipment that operates only as needed for the load, and only when needed.
- Low-temperature heating hot water—less heat loss and better heat coil modulation. This will require larger coils and/or low-temperature supplemental underfloor heat, and will rule out supplemental higher temperature radiant or fin tube heat.

Cooling

- Use outside air free cooling, whenever free cooling is available. Feasible for most, if not all, space conditioning but may not provide the process cooling needed in specialized rooms (MRI, data center, etc.). This is already required by ASHRAE or IECC codes in many climates (see Figure 1).
- If air side cooling is not possible, install hydronic free cooling. Hydronic free cooling may be the answer if air side free cooling cannot be used for process loads. If hydronic free cooling is required, design with higher chilled water temperatures to permit longer periods of free cooling use, and design the plant with independent mechanical and free cooling condenser water systems. Switching back and forth with colder condenser water reduces the number of hours when free cooling is used, based on operator objection to starting chillers with cold condenser water temperatures. And finally, size free cooling heat exchangers for maximum flow needs (not just tonnage or delta T).
- Do not use, or minimize supplementary direct expansion (DX) cooling, computer room air conditioning units, etc. However, supplemental DX cooling for surgery sub-cooling is recommended. It is more energy-intensive, but will permit running the much larger plant with warmer chilled water, and may permit a later start of chillers as outside air temperatures rise.
- For high-heat equipment cooling, provide supply air near or under the floor, and take exhaust/return air out at the ceiling.

Cooling towers

- Open cooling towers: lower horsepower and with variable speed drive fans.
- The larger the cooling towers, the better (not true for the other equipment).
- Use of indoor condenser water sumps—no tower heaters, drain down, or equalization lines.

Use outside air free cooling, whenever free cooling is available.

Air handling units (AHUs)

- Use of dual (opposing) outside air entrances with air blenders (in cold climates) to eliminate stratification and minimize the use of preheat coils (see Figure 2).
- Lower air velocities through filters, coils, ducts, and fittings. Filter and coil velocities should not exceed 400 fpm. Damper velocities should not exceed 1500 fpm. Supply air should not exceed 1800 fpm, and return or exhaust air velocities should not exceed 1300 fpm.

Instrumentation and controls

Instrumentation and controls are the most important aspects of controlling and refining operations. Most equipment will operate at part load the majority of the year, and minimizing operation of equipment is the most important part of the process.

AHUs

- Economizer cycles with proper setup of minimum outside air and supply/return fan tracking. Consideration for indoor and outdoor humidity levels is required. Enthalpy high limit control is not recommended due to the inaccuracy of measuring humidity and calculating enthalpy.
- AHU discharge air temperature control of all AHU functions, in sequence, and with high and low limits as needed to properly control component performance.
- Separate (from mixed air) control of exhaust air dampers. Hospitals reject a substantial amount of air via fixed exhaust air streams. Ejecting even more from the major AHU is not needed or desired, except during full airside economizer cooling periods.
- Supply air temperature and static pressure reset.
- Higher AHU supply air temperatures, with less reheat. Zoning by exposure will permit greater uniformity of loads, but it is difficult to do in a hospital and not likely to be implemented without significant extra cost.
- Larger amounts of warmer discharge air to provide the needed cooling—less air side cooling, and less reheat. This may require larger interior zone airflows to provide equivalent interior cooling with warmer, but more, airflow.

Plant cooling

- Adding stages of cooling is easy. Dropping stages of cooling is far more difficult.
- Measure and totalize cooling equipment power. Based on experimental combinations of equipment operation, select operating routines that yield lower total energy consumption for any given load.

Occupied/unoccupied control

- Occupied/unoccupied control of spaces that are not continually occupied by patients, or continually used by administrative staff. If pressure relationships for infection control are required, maintain the pressure relationships, but with lower amounts of airflow when unoccupied.
- The most significant example is operating rooms (and other high-airflow rooms), where there are very high occupied airflow requirements but much lower requirements when unoccupied.

Note this is airflow setback only when the space is not in use, not temperature or humidity setbacks. The resistance to this simple and effective energy-conservation practice is based on perception, not actual infection control risks.

- Control by individual zones, which is easy to do with variable air volume boxes. For example, efforts by the operating staff of a newer and larger hospital in Colorado reduced night and weekend airflows by more than 20,000 cfm compared to the previous same period, saving fan, heating, and cooling energy for many hours each day, and significantly improving air distribution system diversity.

Power monitoring

- By totaling energy used by plant cooling equipment and experimenting with combinations of pumps, chillers, and cooling towers as well as water temperature resets, operators can determine actual energy performance variations, and can operate equipment at the lowest total energy use. When using variable speed drive equipment, more equipment at part-load performance may be surprisingly more energy efficient.
- Utility meter monitoring via the building automation system (BAS). Utility meters continually measure usage and demand, but that information is not available to the operators other than via the monthly utility bills, or by special request for other than monthly histories. Continual monitoring, in conjunction with time of day, outside air temperatures, and so on, permits the operators to gain greater understanding of when and how peaks are set. Also, of even greater interest is observing how usage does not drop when conventional wisdom says it should.

Graphics packages

- Graphics are required for operator use and understanding of system performance. The adage “a picture is worth a thousand words” could never be more applicable in this case
- Consolidating related system performance information on graphic screens enhance operator understanding of where energy is used, and what is setting the requirement for increasing the output of plant equipment.

Exhaust air

- Less exhaust air can be achieved through better kitchen layouts with smaller kitchen hoods, no isolation exhaust when isolation rooms are not in use, and separate AHU exhaust air damper control.

> **When using variable speed drive equipment, more equipment at part-load performance may be surprisingly more energy efficient.**

- Less exhaust requires less minimum outside air, less heating, and less cooling, with the more significant benefits to be obtained in high humidity areas where dehumidification requirements are prevalent.
- Closer compliance with actual requirements, in lieu of adding a little extra to make sure. To this end, we highly recommend larger variable speed drive exhaust fans with static pressure control, in lieu of fixed speed, constant volume exhaust fans. Exhaust air requirements can be more accurately balanced, and quantities are ensured by varying fan speeds to exactly what is needed at the inlet grills, not just a proportional balance of fixed exhaust air quantities.

Piping

- Less fittings, less devices
- Wyes in lieu of tees
- Full port ball or butterfly valves
- Two-way valves, more diversity.

Humidification

- Less humidification—this is often overdone, and not required or desired. Refer to local codes to determine the amount of relative humidity required in the winter.
- Smaller zones versus entire AHU applications.
- Better control, and shutoff when not required.

De-humidification

- Less intake of humid outside air
- Desiccant wheels in lieu of sub-cooling
- Heat recovery.

Heat recovery

- Heat recovery is usually disappointing—extra air side static pressure losses, contamination of heat transfer surfaces, performance short of expectations, and/or no demand for recovered heat (hospitals really need more cooling or cooling enhancement in very hot or humid climates).
- If exhaust air streams are minimized (the first step), the impact is either too small or too contaminated to justify heat recovery. The goal is to minimize exhaust air and then apply heat recovery, if at all.
- Heat recovery can only be justified in very cold or very hot climates. Mild weather locations, or where the total number of hours when heat recovery will actually pay, may be limited in comparison to the total number of operating hours.

Plumbing

- Right-sizing of domestic hot water heating—the requirements are much less than the number of fixtures in a hospital would lead one to believe. A hospital has many fixtures, but few are used.
- No booster pumps. Excessive use of booster pumps has been a major issue for lower multi-story buildings.
- Centralized domestic hot water recirculation and balancing of recirculation loops. Better flow, less waste at the faucet.
- Mixing valves with good check valves. Integral check valves have been less than satisfactory more often than not, with excessive hot and cold domestic water use to compensate.

Building envelope

- The building envelope and orientation of the building have significant impact on HVAC design, comfort, and operating practices. The orientation of large hospitals on the site is more often limited by the available site, parking, and other factors. However, the building envelope can be optimized by:

- Eliminating thermal bridging. Continuous wall insulation between the structure and the exterior skin, and window frames, and more specifically, window sills must be thermally broken.
- Providing a complete vapor barrier, with emphasis on the integrity of window and door openings, and the junctions of the wall assemblies with the floors and roof assemblies.
- Less glass and better shading.
- Exterior doors that limit infiltration.

Lighting

- Less lighting, better located. General, overhead lighting versus task lighting has been a continual battle.
- More efficient fixtures and lamps. Fewer watts, more lumens per watt, and better light quality to enhance medical diagnostic procedures.
- Lighting controls, so lights are off when not needed. This has been challenging, with the lack of light when needed. Occupancy sensors do not always sense occupancy, particularly if there is little motion in the room. The approach may be some combination of daylighting, motion sensors, time of day control, or local switching in smaller zones.

In conclusion, energy efficiency must be long lasting and sustainable. If planning is followed by simplicity of design, quality construction, validation, loop tuning, and operator education, it will be real and sustainable. It will last longer, and not only be energy efficient initially but also remain energy efficient as modifications to improve or expand are implemented.

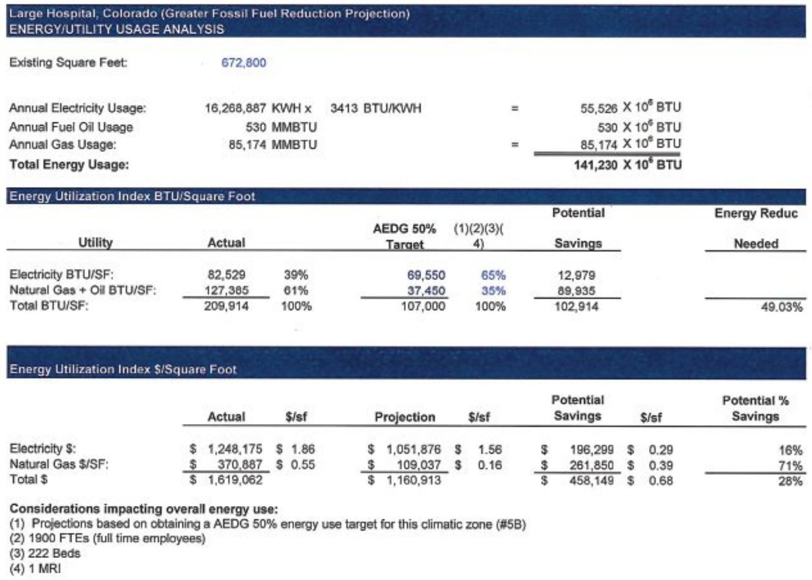
Lastly, we stress the importance of tracking and documenting energy usage. Once a full season of performance has been completed, final proof will be actual energy usage. It may not meet or beat the 50% AEDG energy target for performance, but we will be able to confirm the actual Btu/sq ft. Hopefully, we will have reached the goal, but if not, the intent of energy efficiency will have been at least partially fulfilled—there will simply be more work to be done, with real loads, real equipment, and real weather. **cse**

Pete Sabeff is president of Engineering Economics Inc., where he has been troubleshooting and commissioning hospital HVAC systems for most of his 40 years in the business. He began as a controls applications specialist, became an energy consultant, and for the past 28 years has been an owner's representative and commissioning agent.

Saving energy at a Denver hospital

As an example of the impact of achieving the target energy savings, information and projections for a new, large, energy-efficient hospital in the Denver area are shown. Actual energy usage has been tabulated and graphed, with the AEDG 50% energy use target entered to calculate projected annual energy cost savings. This facility currently is consuming 210,000 Btu of energy per year, well below what we typically find for new hospitals. Annual utility cost is slightly more than $1.6 million. If the AEDG 50% reduction goal of 107,000 Btu/sq ft for climatic zone 5B is obtained, with the same proportion of electrical and gas use, savings would be more than $800,000 per year.

In this example, 61% of energy used by Btu is fossil fuel energy, and 39% is electrical energy; it is not likely that electrical energy use can be cut in half. This implies that to obtain the goal, the greater portion of reduction will have to come from fossil fuel use for heating and humidification (see Figure 4). Proportionately, electrical savings would be less, and fossil fuel more, with annual cost savings closer to $450,000 than $800,000. In any case, it will take more than adjusting lighting and HVAC settings to obtain the energy use reduction goal. Plug loads from items like medical equipment will have to be addressed.



Large Hospital, Colorado (Greater Fossil Fuel Reduction Projection)
ENERGY/UTILITY USAGE ANALYSIS

Existing Square Feet:	672,800			
Annual Electricity Usage:	16,268,887 KWH x	3413 BTU/KWH	=	55,526 X 10^6 BTU
Annual Fuel Oil Usage	530 MMBTU			530 X 10^6 BTU
Annual Gas Usage:	85,174 MMBTU		=	85,174 X 10^6 BTU
Total Energy Usage:				**141,230 X 10^6 BTU**

Energy Utilization Index BTU/Square Foot

Utility	Actual		AEDG 50% Target	(1)(2)(3)(4)	Potential Savings	Energy Reduc Needed
Electricity BTU/SF:	82,529	39%	69,550	65%	12,979	
Natural Gas + Oil BTU/SF:	127,385	61%	37,450	35%	89,935	
Total BTU/SF:	209,914	100%	107,000	100%	102,914	49.03%

Energy Utilization Index $/Square Foot

	Actual	$/sf	Projection	$/sf	Potential Savings	$/sf	Potential % Savings
Electricity $:	$ 1,248,175	$ 1.86	$ 1,051,876	$ 1.56	$ 196,299	$ 0.29	16%
Natural Gas $/SF:	$ 370,887	$ 0.55	$ 109,037	$ 0.16	$ 261,850	$ 0.39	71%
Total $	$ 1,619,062		$ 1,160,913		$ 458,149	$ 0.68	28%

Considerations impacting overall energy use:
(1) Projections based on obtaining a AEDG 50% energy use target for this climatic zone (#5B)
(2) 1900 FTEs (full time employees)
(3) 222 Beds
(4) 1 MRI

Figure 4: For St. Anthony Hospital in Lakewood, Colo., to obtain its goal, the greater portion of reduction will have to come from fossil fuel use for heating and humidification. This shows 50% energy use projection, assuming fossil fuel reduction is more likely.