# University Medical Center Heat Recovery Chiller Optimization

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## ABSTRACT

Facilities departments at university medical centers are constantly trying to upgrade infrastructure with competing demands for capital improvements. High profile medical technology improvements compete for that same capital, and usually win, creating additional load on that infrastructure. Promoting heat recovery and system optimization as a means of improving infrastructure capacity and reliability without large capital expense can create a win-win scenario for everyone.

## INTRODUCTION

The facilities department at the hospital was proposing upgrades and optimization of their chilled water (CW) system to provide both comfort (seasonal) cooling and equipment (process) cooling. Equipment cooling varies with procedures and serves some steady loads. The hospital chilled water system consisted of three major mechanical systems from three different construction periods which had some interconnection for back-up. Chiller capacity was around 2,500 tons, but many operating scenarios involved running at least four chillers partly loaded. One chilled water system (two chillers) had heat recovery capability out of an exhaust air stream. The system was decreasing in effectiveness due to age and continued plugging of heat exchange surfaces. Recovered heat was used in building ventilation reheat, but the heat recovery (HR) chiller operated between 2 and 3 kW/ton over most of its range. When heating loads are not met by the HR chiller, steam is purchased from the main campus heating plant.

Hospital administration, like all hospitals, must be focused on patient care. Building infrastructure is there to support the rapidly changing demands—facilities are seldom viewed as "profit centers." Buildings last for 40 years, while mechanical equipment lasts for 20 and medical technology changes from 2 to 10 years; for example, the recent conversion to digital record keeping and the advancement of computers in medicine.

University hospitals are a focal point for change, and thus the attention of management is directed to breakthrough medical developments and more glamorous profit centers. How does the chiller in the basement get the attention of the hospital administrator when the chief of cardiology wants the latest in diagnostic equipment? It's difficult to draw attention to energy savings of $10,000 per year when medical procedures are costing $10,000 an hour. The answer may lie in finding an opportunity to minimize risks, improve reliability, and please the doctors by improving "patient comfort" and "public image." Improving comfort and control by installing variable speed systems and improved heat recovery does save energy, but it is sometimes easier to promote efficiency by selling other project benefits.

**Phase I: Chiller Variable Speed Drives**

The owner began improvements about three years ago with the installation of variable speed drives on a 600-ton and a 700-ton chiller because the utility offered a large incentive, significantly reducing the capital investment by the owner. It was relatively easy to get approval for this project, which saved about 335,000 kWh per year (largely comfort cooling load).

The facilities department proposed the upgrade of two 20-year-old HR chillers. Those chillers reclaimed heat from exhaust air streams, but were losing effectiveness due to lint accumulation, contained hazardous banned refrigerants, and were operating in the 2-3 kW/ton range. This project would provide savings to pay for itself in about 12-15 years, but administration had many demands for capital with much better returns on investment, so our project was not a high priority. The Cardiology department in the hospital needed increased cooling capacity for a scanner, and the hospital needed more CW capacity, which was very expensive. The facilities department quickly proposed that upgrading the HR chillers could provide added CW capacity and reliability. The project was quickly approved because it served the higher profile cooling need, as well as the aging and less efficient equipment need.

**Phase 2: HR Chiller Replacement**

Two existing heat recovery chillers in the hospital were replaced with state-of-the-art variable speed chillers. One larger HR chiller (recovering heat from chilled water return) and one process chiller, variable speed pumping, and a cooling tower were installed to provide heat recovery and increased capacity for comfort cooling and process cooling loads. Benefits were lower electrical use and increased reliability.

Other CW improvement measures were part of the project, such as interconnection of various small CW loops so that other loops are now available to the HR chiller, or when HR was not needed, the most efficient combination of chillers could be used. Energy savings from phases one and two come from several sources:

- Improved existing chiller performance through variable speed operation.
- Reduced pumping costs through variable speed drives.
- Reduced exhaust fan energy because of removal of old heat recovery coils from airstreams.
- Heat recovery efficiency is greatly improved (below 1 kW/ton) and the amount of recoverable heat still increased.
- Process chilled water efficiency greatly improved through new chiller (below 0.4 kW/ton).

Total energy savings from phases 1 and 2 are 2,350,000 kWh and 2,800 thousand lbs of steam purchases.

The HR chiller is set up to be the lead chiller. Its capacity is equivalent to the two chillers that were removed. Heat is rejected first to a 130-degree building heating loop, heating water then goes through a domestic water pre-heater (plate and frame heat exchanger with air gap between fluids). If there is little building heating load and no domestic water use, the heat gets rejected to an exhaust air stream. During periods of heavy heating requirements or not enough available recovered heat, heating is still purchased from the main campus steam system.

The energy savings were sufficient to allow the use of energy performance contracting as the method of construction, solving two issues facing the owner: Time for design and construction, and method for financing.

Normally, state-owned institutions go through a two-year state budget cycle on large capital projects before they can even begin design. Washington State law (RCW 39.35) allows the use of energy performance contracting in public facilities when the energy savings pay for the project and the net present value of the project proves to have the "best value" for the state of any of the alternatives. This law also allows a performance contract to be negotiated on the terms of "best value," not lowest competitive bid. Thus the owner was able to greatly reduce the construction time and substantially complete the installation within nine months.

**Phase 3: CW Optimization and Data Center Consolidation**

Phase 3 remained with the final interconnections required to upgrade the chilled water looping and the control modifications necessary to integrate chiller and cooling tower operation. Parts of older CW loops remained undersized to return all the available return chilled water to the HR chiller under all scenarios, and the controls programming for optimizing all chillers remained. This work was expected to proceed more slowly because, even though there were associated energy savings, there was a lot of piping cost and programming cost involved. Paybacks were in excess of 15 years and there was not an immediate demand for the project to be implemented.

During the construction of phase two, the hospital realized the need for expansion of a department in the hospital that housed a central data server room in the middle of patient areas. That data center had to move, and the only place available was another data room which was served by its own undersized air cooled chiller. The facilities department offered to absorb this data center load into its CW system where it could use the heat through the HR chiller. The IT department could then relocate all the data equipment into the new data center, freeing up valuable patient care floor space inside the hospital. This also gave a good base load to the HR chiller under all outside temperature conditions—a win-win situation. This did require expanding the CW system to cover that new data center, but heat recovered and UPS efficiency improvements greatly improved the project savings. The following discussion outlines many of the benefits.

In the audit for this data center consolidation project, it was found that 164 1-2kW uninterruptible power supply (UPS) systems were spread among several data rooms to provide clean, redundant power to the mission critical data servers in those rooms. Data rooms use a considerable amount of energy through lighting, IT loads, and cooling. UPS systems are often overlooked as high energy users. These UPS systems were lightly loaded, possibly due to a common perception that lightly loaded UPS systems provide better reliability.

It is important to note that there are several types of UPS systems on the market. They are characterized by the way they provide power to IT critical loads. In general, UPS systems that are lightly loaded do not perform up to manufacturer specifications of efficiency. Therefore, having many small UPS systems that are lightly loaded wastes a significant amount of energy. It is also important to note that this energy lost, in the form of heat, must be removed by the air conditioning. So by operating UPS systems at light load, there is in effect a double penalty: once in the original losses and again by having to remove that heat from the building.

At the hospital, the 164 small UPS systems were found operating at an average of 18 percent load (operating at 74 percent efficiency). After consolidating onto one large UPS operating at 75 percent load (and therefore 92 percent efficiency), the result in electricity savings amounted to 222,069 kWh/year from the UPS losses alone, and an additional 259,431 kWh/year from the cooling load reduction. The consolidated data center in this case provides a consistent heat recovery load to the HR chiller, expected to top out at 60 tons, which will be recoverable year around.

Aside from energy savings, it should also be noted that there are operational savings. In the instance of the hospital, approximately $16,000 per year in service maintenance costs will be saved by centralizing the IT infrastructure, $10,000 of which is attributed to the contracted labor required to monitor and repair the 164 UPS systems throughout the facility, with the other $6,000 resulting in the cost of battery replacements and maintenance of IT critical infrastructure in multiple data closets.

There are other qualitative improvements to the operations of IT services for the hospital in the realm of faster response of personnel to IT specific issues, less travel time between multiple data closets, and improved security with a single data center. Given that confidential records and other sensitive data are present, there is a need to provide secure access to authorized personnel only. By reducing the number of data rooms, the owner will only need to retrofit one center with the necessary security technology. Although these benefits were not considered as part of the project savings, they did factor into the decision-making process.

The energy savings from the data center consolidation plus the optimization savings were a clear justification for continuing the work under energy performance contracting. The construction time was less than six months from audit to substantial completion. Construction included some loop interconnections and the energy management system reprogramming to optimize chiller operation. As mentioned earlier, the HR chiller is now the lead chiller as long as there is heating load, and the other chillers are staged depending on most efficient, to match the load. Total energy saved due to all three phases of the optimization project are projected at 2,750,000 kWh per year and 4,240,000 lbs of steam per year. Overall annual operating cost savings are about $225,000 for the hospital.

## CONCLUSION

Even though the energy savings supported the projects, they probably would have proceeded slowly. The main reason for rapid approvals and construction was quick response to meeting patient, doctor, and owner needs. Energy efficiency improvements can get greater recognition by management when increased capacity satisfies other growth needs. Energy performance contracting can provide better collaboration between the owner and the contractor, plus a means of financing the chilled water system improvements quickly. Heat recovery provides increased CW system capacity and savings to help pay for it. Optimization helps with improved efficiency, reliability, and redundancy.

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## ABOUT THE AUTHOR

**Bob Johnson** has worked for the last 19 years in the public sector. For the past five years, he has been working for WA State Department of General Administration, Engineering, and Architectural Services, managing energy service company projects for public agencies, school districts, colleges, and universities. Before that, with WA State University's Cooperative Extension Energy Program, he provided technical assistance to clearinghouses for questions on industrial energy use as

well as commercial and institutional building energy use. He managed numerous design and capital construction projects at maximum and minimum security prisons, including energy system components while working for WA State Department of Corrections, and prior to that as energy systems engineer for the WA State Energy Office he was lead engineer for the pool of engineers working on commercial, institutional, municipal and industrial programs. Duties included providing technical assistance and energy information to energy professionals through clearinghouse services, performing energy auditing, and teaching courses on refrigeration, pumping, lighting, energy accounting, compressed air, and boiler and steam systems for building operator certification training. Prior to his experience in public facilities, he worked over 25 years in the private sector as mechanical engineer and project manager for several consulting firms.