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Hybrid Geothermal: Triple-Tiered HVAC Savings

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Hybrid Geothermal:

Triple-Tiered HVAC Savings

Dedicated-heat-recovery-chiller and geothermal-heater/chiller technologies reduce heating, cooling, geothermal costs

Editor's note: The 40-year-old HVAC system at Kankakee Valley High School (KVHS) in Wheatfield, Ind., was in need of an upgrade. Teachers complained of being hot or cold daily; the boilers were in desperate need of repair or replacement; the chiller was old, inefficient, and undersized; the cooling tower was rusting through; and the pumping and piping system was said to look as if famed cartoonist Rube Goldberg had designed it. Following is the story of the system's overhaul told from the perspectives of key participants.

Getting Started

By GLENN KRUEGER, PHD
Superintendent
Kankakee Valley School Corp.
Wheatfield, Ind.

School-corporation philosophy. We began talking about renovating the system during the fall of 2005, shortly after Hurricane Katrina ravaged gas-drilling platforms in the Gulf of Mexico and the price of natural gas rose to \$1.40 a therm. Kankakee Valley's operating budget was stretched beyond revenues. Energy efficiency was seen as a means of controlling the huge gas-price increase. The school board insisted that energy efficiency be considered in the selection of a design firm and, as much as possible, wanted a plan to protect against future gas-price volatility.

Instrumental to our plans was the involvement of our energy suppliers, including Northern Indiana Public Service Co., which encouraged us to look at geothermal and other high-efficiency electric options, and Jasper County Rural Electric Membership Corp., which encouraged a high-efficiency electric solution for schools and provided a small grant to aid the construction of energy-efficient systems.

Choosing a consultant. A steering committee consisting of myself, the director of business, a local consulting engineer, and the head of maintenance was appointed. The committee wanted a reasonable initial cost, ease of maintenance, reliability, and economy of operation. Following a pre-screening of all credentialed design firms in Northern Indiana, a request for qualifications was issued. Ten firms were invited to participate in an information-gathering day at the schools and given a month to prepare recommendations for KVHS. Each firm then was given an hour-and-a-half to present its ideas. The consensus recommendation was to replace the HVAC sys-



Kankakee Valley High School measures 200,000 sq ft.

tem at KVHS. Estimates ranged from \$20 to \$30 per square foot.

The steering committee chose Durkin & Villalta Partners Engineering (DVPE) of Indianapolis. DVPE presented the most comprehensive solution with the greatest operating-cost savings. Even though the KVHS HVAC system was not a poor performer from an energy standpoint, with a slightly below-average Energy Star score of 41, DVPE saw potential for significant energy savings.

The Design

By TOM DURKIN, PE, LEED AP
Senior Partner

Durkin & Villalta Partners Engineering
Indianapolis, Ind.

A discriminating client. Kankakee Valley School Corp. asked us to assess the condition of existing infrastructure—namely, piping and ducts. First, we looked for signs of piping deterioration, such as patch clamps and leaks from dielectric corrosion. Chilled-water insulation had deteriorated primarily because of vapor-barrier breaches, and this had caused minor exterior corrosion of piping. We found evidence of valve-packing leaks and localized problems, but nothing systemic. After studying the original plans, we asked for pipe samples at a couple of locations where water velocity was believed to be the greatest. Those samples showed that the interior of the lines was in excellent shape and that, where sized to accommodate the new system, the existing piping network could be kept.

Most of the ductwork was in good shape as well, but needed to be cleaned and resealed, with all air inlets and outlets replaced.

Based on the decision to reuse—as appropriate—the heating and cooling distribution network, the decision to retain HVAC terminal systems was made. Unless there was a compelling reason to change (e.g., inadequate size, the addition of cooling, the updating

of ventilation air to current standards), areas of the school served by two-pipe unit ventilators would remain as such, as would areas that were multizone, areas that were variable-air-volume (VAV), and so on. All terminal equipment would be replaced and modernized with direct digital controls. Everything was evaluated to make sure it met the client’s objective of efficiency, meaning an inefficient option would not be perpetuated simply to save money.

ally, a boiler—available, a heat-recovery chiller was selected in keeping with the best-practice model.

Proposed solution. DVPE has installed numerous dedicated-heat-recovery-chiller (DHRC) systems in school buildings. A DHRC can be earth-coupled, creating a new generation of geothermal system called geothermal heater/chiller (Geo-H/C).² The relative efficiencies of various heating options are given in Table 1. Although efficiency differences also exist on the

Heating option	Cost per therm
Electric resistance heat	\$2.43
Gas-fired steam boilers	\$2.79
Gas-fired 180°F hot-water boilers	\$1.86
Gas-fired low-temperature (130°F maximum) boilers	\$1.24 ^{1*}
Recovered heat via DHRC	57 cents ^{**}
Geothermal heat via Geo-H/C	53 to 65 cents [*]

Based on delivered-gas price of \$1.12 per therm and electricity at blended rate of 8.3 cents per kilowatt-hour
^{*}Varies based on entering-water temperature
^{**}DHRC operating cost, no credit for the cost of chilled water

TABLE 1. Heating costs.

Elements of efficiency. With the document “HVAC Best Practices for K-12 Schools” from the U.S. Department of Energy’s now-defunct Rebuild America program as a guide, we:

- Designed everything around low-temperature (130°F maximum) heating water.¹
- Used heat-recovery chillers to address any concurrent heating and cooling loads.
- Optimized/minimized auxiliary power, such as that for fans and pumps.
- Made sure the mechanical system could handle summertime high humidity. While that generally means having a summer source of heat—usu-

ally, they are not nearly as dramatic as those on the heating side. Heating costs are more important at this site, where the average winter exceeds 6,000 heating degree-days.

Despite their obvious efficiency advantage, geothermal systems have a significant downside: the first-cost premium associated with connecting to the earth, which for a closed-loop system for a school means numerous vertical wells, or bore holes. In Indiana, one well for every 20 MBH of heat required is reasonable. (Note: The performance of geothermal wells can be highly variable. Design should not commence until a thermal-conductiv-

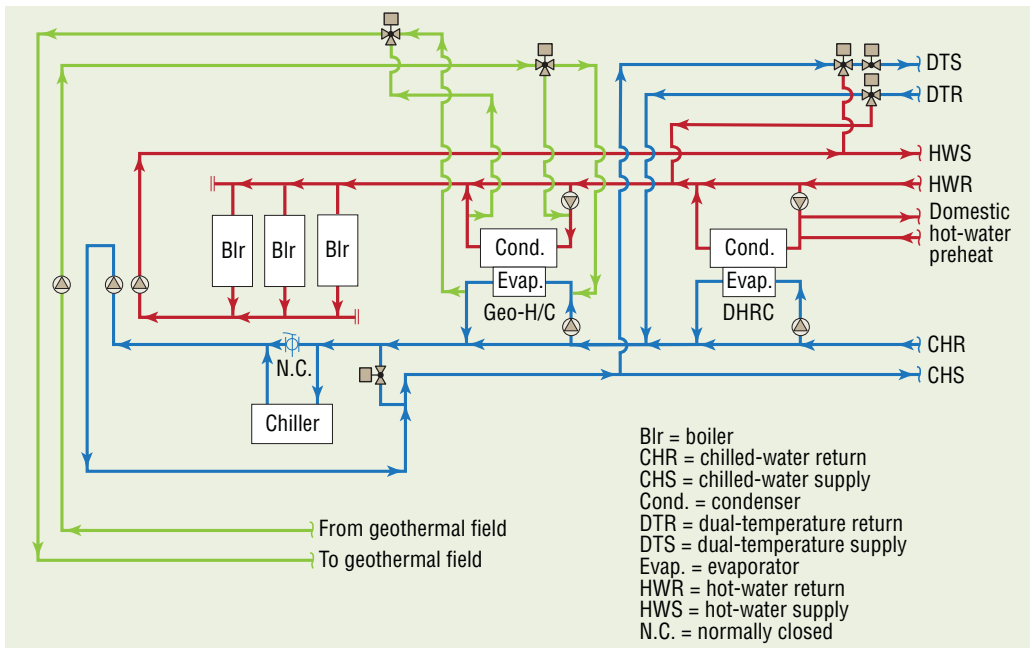


FIGURE 1. Hybrid-geothermal-4-by-2-with-DHRC system.

ity test has been performed.) Ensuring that the most extreme heating demands can be met typically requires additional wells. A smarter solution, however, is a hybrid geothermal system.

The geothermal component of a hybrid system handles 90 to 95 percent of the work, with low-temperature condensing boilers taking care of the rest. The same logic holds true on the cooling side. A hybrid design may increase or decrease the total cost of a project, depending on how many bore holes can be eliminated, but more important is the assurance that ample capacity is available to meet all conditions.

For KVHS, a hybrid-geothermal-4-by-2-with-DHRC system was designed. Hybrid geothermal 4-by-2 with DHRC is a three-tiered-heating and three-tiered-cooling system. Heating and cooling return lines (right side of Figure 1) and a portion of heating and cooling water are pumped through a DHRC. The DHRC transfers British thermal units (Btu) from cooling loops to heating loops. The DHRC runs during summer and winter, anytime an air-handling unit is in occupied mode. (See the “Coordinating the Economiz-

ers” subsection later in this article.) After all Btu that can be swapped are moved to heating loops, water goes to the Geo-H/C. The Geo-H/C runs in cooling mode anytime outside air is above 65°F and in heating mode all other times. If additional cooling is required, an air-cooled unit is available. If, during winter, heating capacity in the geothermal field is insufficient, boilers carry the school.

The least expensive Btu are the ones already in the building, from students and lights. While the placement of the DHRC ahead of the Geo-H/C may seem contradictory to Table 1, consider:

- The initial purpose of the DHRC is to provide summer reheat without a boiler running. The Btu from the building need to be moved from the chilled-water return line to the heating system before they get rejected to the ground by the Geo-H/C.
- If the operation cost of the DHRC is charged against the heating cost, then cooling is free, and the overall cost for a concurrent heating/cooling load will be less.
- The heating efficiency of the Geo-

H/C decreases proportionally as the well field cools. Thus, during parts of the year, return water from the well field is cooler than return chilled water from the building, making the DHRC the more efficient machine.

Also of note in Figure 1:

- The domestic-water tie-in, because water heating is a constant requirement in a school and another good place to reject Btu.
- The location of the dual-temperature return. If it were connected on the building side, the two-pipe units (all have face/bypass control, and load

diversity shows up as low delta-T) would negatively impact the efficiency of the DHRC.

The equipment is sized as follows:

- DHRC, 100 tons.
- Geo-H/C, 150 tons.
- Boilers, 6.0-MMBH input.
- Air-cooled chiller, 200 tons.

Everything was sized for a significant addition to the mechanical system.

As we were preparing our bid documents, Superintendent Krueger reminded us that efficiency, though important, had to be justified economically. A design consisting of conventional boilers and chillers was submitted as a base bid, with a hybrid-geothermal design submitted as an alternate. The base bid was \$4,615,300. The premium cost of the hybrid system was \$1,180,000 (20 percent of the total project), with a calculated payback of 11.3 years.

Controls

By BEN KINCAID

Hydronic Application Specialist
Fluid & Thermal Systems
Indianapolis, Ind.

My first thought was, “What is Durkin smoking?” My second thought was, “He talked somebody into letting

us build this thing?” Then, I looked at the numbers. The efficiency and the logic were there, although maybe not very apparent at first blush.

Prior to the KVHS project, my company had done five earth-coupled central systems and 20 or so heat-recovery-chiller jobs with DVPE. One of our collaborations won an American Society of Heating, Refrigerating and Air-Conditioning Engineers Technology Award. Although KVHS would be our first project to combine DHRC and Geo-H/C technologies, we were no less confident.

With 25 hydronic lines leaving the boiler room and numerous terminal units, the specifications called for a “cross-connection verification test” to ensure coils were piped correctly. Thanks largely to Scott Perez, field superintendent for D.A. Dodd Inc. of Rolling Prairie, Ind., none was piped incorrectly.

Start-up and Shakedown

By KURT STEVENS,

Commissioning Agent,

KB Solutions,

Greenwood, Ind.,

and JOHNNY MAN,

Start-up Technician,

Fluid & Thermal Systems,

Indianapolis, Ind.

A good design contributes greatly to commissioning. On this project, we felt we had reachable performance targets, even though the scope of our involvement did not include participation prior to construction.

A mechanical system is only as good as its operators, and its operators are only as good as their understanding of the system. On the KVHS project, the key people on the school side, Superintendent Krueger and Director of Operations and Maintenance Jim Bachman, were involved every step of the way.

Our approach to commissioning is weighted heavily toward long-term performance and operational efficiency,

so start-up commissioning is only the beginning of the process. Our preference is to monitor systems remotely for at least one year. This allows us to track systems through all four seasons and tweak programming and scheduling.

Our window to the system. The Web portal to the central system features excellent graphics and point control with easy Internet access. We have the ability to fine-tune the system on a daily basis. A separate control system, which also is available online, gives us access to the classroom units and air handlers. We perform the same level of scheduling, monitoring, and optimizing we do on the central system. Also, in conjunction with the building-management system, an ongoing program of carbon-dioxide and humidity testing enables us to ensure excellent indoor-air quality (IAQ).

We not only can monitor the system remotely, we can change system operating parameters as though we were in the school’s energy center. We also can see changes made to the screens or system controls.

Coordinating the economizers.

In conventional HVAC designs, the cheapest source of cooling is outside air, provided the temperature and dew point are not too high. In a system with a DHRC, the cheapest source of cooling is the DHRC—if there is a concurrent need for heat (Table 1). The need for heat could be building heating, domestic water heating, or natatorium water heating. In buildings with variable-air-volume (VAV) and multizone air handlers and spaces with high internal heat loads, such as KVHS, operating dollars can be saved by making the first call for cooling the chilled-water valve, rather than the economizer damper. That means the chilled-water system is available throughout the year, and when air-handling equipment starts, so does the DHRC. The DHRC runs to make 44°F evaporator water and 130°F condenser water. The VAV units operate during winter, just as

they do during summer, with outside-air dampers at minimum setting.

“Coordinating the economizers” means creating opportunities for the DHRC to run. It means heating the building with Btu from the lights and occupants. During the course of a normal school day, once KVHS comes off night setback, the DHRC carries the full heating load at all outside-air temperatures above 35°F.

Through commissioning, we learned there were times when the DHRC was fully loaded transferring heat from the chilled-water return to the heating-water return, and yet additional heat was required. The chilled-water return downstream of the DHRC was 52°F. With the Geo-H/C operating at partial capacity to add heat, but extracting heat from the well field, providing a water temperature of 45°F, the control algorithms were modified so that heat was extracted from the building chilled-water return. Along with normal commissioning debugging, the ability to observe system operation at any time led to system-setup improvements tailored to “actual” operation, as opposed to “predicted” operation. We expect the savings of the second year of operation to improve over those of the first.

Schedule, schedule, schedule. Scheduling is one of the most important aspects of the commissioning process. At KVHS, operating schedules took months to refine.

Recommendations for Phase 2. One of our first observations was that the geothermal field was running cooler than expected. An unanticipated benefit of the hybrid-geothermal design is that we are able to adjust operational strategy and still maintain a high level of efficiency.

Phase 2 of the project—renovation of the middle school that shares the campus—will include the addition of two control valves to the system:

- A valve across the two well-field

lines that will allow water returning from the field to be tempered.

- A valve allowing well water to be pumped directly through the building. This will enable cooling without any compressors running, as the water in all three systems (heating, cooling, and geothermal) is common.

Energy Savings

By **BILL ORSBURN**

Director of Business

Kankakee Valley School Corp.

Wheatfield, Ind.

The General Fund is the main operating fund for Indiana public schools. At Kankakee Valley, staff salaries and benefits account for approximately 90 percent of General Fund expenditures, with utilities constituting a major portion of the remaining 10 percent. The bottom line is that any money saved on utilities can be redirected to the classroom. Conversely, if utility costs are not kept under control, it is conceivable that teachers and/or classroom programs could have to be cut.

At the start of the project, I was pleased to hear our consultant say he thought the new systems would reduce utility costs by \$104,000 a year, even though we were doing several things that might otherwise increase energy use, such as adding cooling to the main gymnasium and auditorium, addressing summer humidity issues, and increasing fresh air into the building.

I have my own way of tracking utility bills and adjusting for the severity of winters and the cost of energy: I look at a running three-year average for all of our buildings. If I adjust high-school consumption by the same increase or decrease the other buildings experienced, I have an accurate picture of

what the high school would have used had it not been renovated (Table 2).

The hybrid-geothermal system shifted building heating from gas-fired boilers to heat recovery and geothermal, so I was anticipating a substantial decrease in gas consumption and an increase in electricity consumption. The analysis is somewhat complicated by the fact that our middle school is fed from the same gas meter as the high school.

It is interesting to note that the cost of natural gas has leveled off and even decreased slightly. Last year, we bought at \$1.06 a therm, compared with \$1.12 the previous year and \$1.20 the year before that. The “Katrina effect” was relatively short-lived. On the other hand, the cost of electricity went up 21 percent, which we did not anticipate. Still, we are ahead on our scheduled savings.

Even more important than saving taxpayer dollars has been improving the learning environment for students and teachers at KVHS. Since the renovation, hot/cold complaints have been reduced to almost zero, and there has been a palpable improvement in IAQ.

This was a very successful project.



The Geo-H/C at KVHS has three 50-ton modules, with the piping and base sized for the addition of two more modules.

REFERENCES

- 1) Durkin, T.H. (2006, July). Boiler system efficiency. *ASHRAE Journal*, pp. 51-57.
- 2) Durkin, T.H., & Cecil, K.E. (2007, August). Geothermal central system. *ASHRAE Journal*, pp. 42-43, 47-48.

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Gas	Therms	Dollars
Control group, current year	50,953.7	
Control group, three-year average	47,077.5	
Percent change	+8.23	
High-school predicted usage	251,337.7	
High-school actual usage	141,177.4	
Decreased usage	110,160.3	\$123,871.61
Electricity	Kilowatt-hours	
Control group, current year	1,267,936	
Control group, three-year average	1,246,709	
Percent change	+1.70	
High-school predicted usage	2,296,689	
High-school actual usage	2,460,000	
Added usage	163,311.1	\$11,409
Net impact, savings		\$112,462.61

TABLE 2. Utility savings at Kankakee Valley High School (January 2008 through December 2008).

Applications for a Multistack DHRC

- Laundry Water Heating
- Swimming Pool Heating
- Process Heating and Cooling
- Domestic Hot Water
- Building Heat
- Reheat Coils
- Ice Hockey Rink
- VAV Reheat

Typical Buildings for DHRC Applications

- Hotels and Motels
- Resorts
- Recreational Facilities
- Schools
- Hospitals
- Nursing Homes
- Process Cooling and Heating
- Data Centers
- Call Centers
- Campus Cooling and Heating Plants

Benefits

- Reduced CO2 emissions
- Easy retrofit for any mechanical room
- Double Wall Vented Heat Exchanger allows for potable water (optional)
- Payback in less than three years typically
- More efficient than a gas boiler
 - COP can exceed 7.0
- Low load efficiency
- Apply for Leed points
- ASHRAE 15 / B-52 compliant without monitoring or ventilation equipment.

Features

- Independent refrigerant circuits
- No reversing valves
- Auto mode controls
- Control the mode dynamically without input from the BAS

Highly Dependable

- Multiple independent systems for redundancy
- Comprehensive computer monitoring of operations (optional)
- Automatic diagnostic recording of fault conditions
- Rotates lead compressor every 24 hours

Simple To Operate

- Large LCD screen displays information in plain English
- Simple keypad provides control of unit operations

Easy To Install

- Compact modules fit through standard doorways and into elevators
- Modules interconnect easily and quickly
- All refrigeration systems are factory charged and run tested
- Single point power up to 500 MCA

Programmable Logic Controller (PLC) System

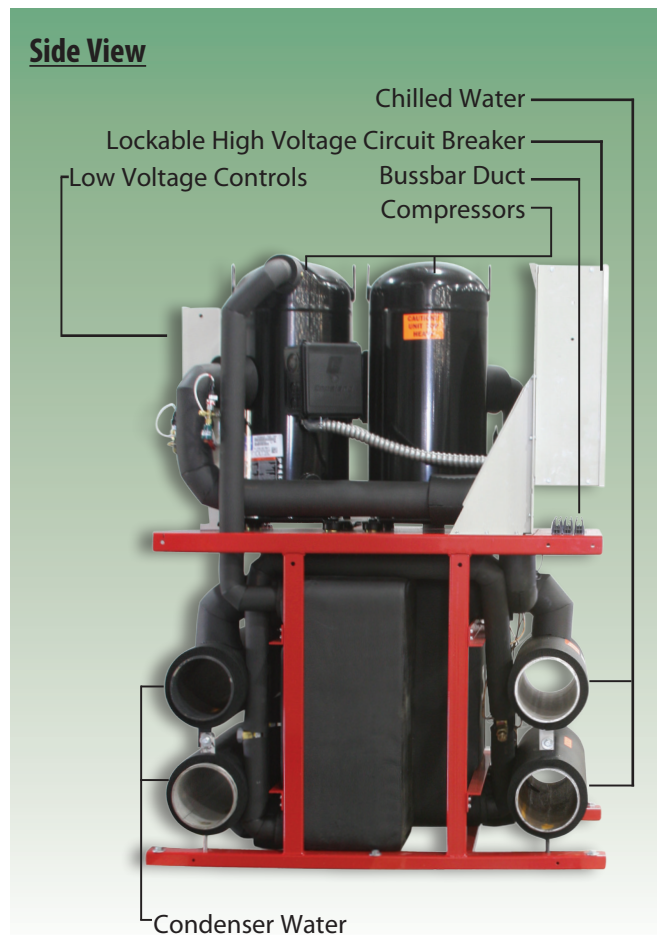
- Manual switch allows redundancy control as each module has a processor allowing it to run even if master controller fails
- Optional Fail-To-Run software
- Display at each module
- Remote display option
- Automatic controls for both chilled and hot water
- Optional BAS Interface

Design Flexibility

- Wide array of module combinations
- Install only the capacity required at the time
- Variable or constant flow options

Simple To Service

- Service can often be performed on a convenient, non-emergency basis
- Most components are standard, off the shelf design
- Able to service one module while system is in operation



Multistack® is the recognized world leader in the design and implementation of modular chillers. Through 20-plus years of product development we have learned how to best capture and control the heat that is typically rejected by the chiller. With that in mind we set out to build the industry's best, most efficient, Dedicated Heat Recovery Chiller™ (DHRC).

During the process of cooling, heat is generated, and, more often than not, discarded to the atmosphere. This process has been around for as long as there have been heating and cooling systems. There are many negative effects with the disposal of heat as waste. Buildings can use two times more energy to do the cooling and dispose of the heat, as if they just took possession of the heat and using that heat where it is needed. Even in the middle of summer, most buildings require a certain amount of heat to be made for proper humidity control, potable hot water, and many other hot water applications. Heat recovery addresses this waste and turns it into a way to lower energy bills, reduce the carbon footprint of a building and will provide tremendous improvement for overall building efficiency. Currently, the requirement for LEED is to improve upon ASHRAE 90.1 by up to 30%. A DHRC can help you get there.

Heat recovery is not a new concept, it has been around since the early 1970s, however it was not easy to implement based on the size of chillers then — and the very limited hot water temperatures achievable. The Multistack DHRC, by the very nature of a modular chiller, changes the application from difficult to simple because it gives you control of hot and cold water simultaneously, and most buildings have a constant heating and cooling requirement. By identifying the maximum and minimum loads of both, it becomes fairly easy to size a DHRC from 10 – 900-tons per array. This allows the DHRC to be a part of the buildings chiller and boiler system —especially since it can produce water up to 180°F.

When a DHRC is applied as a supplement to a building system, it can contribute to the cooling process during the spring, summer and fall, while supplying the hot water for the building for free. During the winter, by directing the DHRC to focus on the constant cooling demands of the building core, a data center or phone room, it will continue to supply hot water—still for basically free and eliminating the use of natural gas for creating the heat.

Anytime a building has a concurrent demand identified, it makes sense to look to the DHRC for a first stage economizer, rather than bringing in cold outside air and exhausting building heat. This application makes even more sense when you have an array of Multistack chillers that are the primary source of cooling for the building, allowing all the heat generated during that first stage to be used—for free!

To associate some dollars saved to this concept, the 45-ton DHRC installed upstream of the condensing boilers at Evansville State Hospital in Evansville, Indiana. Designed to satisfy all the VAV reheating and the domestic hot water—while supplementing the cooling load-- the DHRC is having a significant impact on the utility costs at the hospital by saving \$36,000 - \$54,000 per year, depending on the costs of natural gas. See this case study, and others, at www.multistack.com

These are just some of the reasons a DHRC can be a great addition to almost any building.



Use your smartphone to scan/photograph graphic (left) and download the Multistack DHRC catalog.