Hybrid ground-source heat pumps

SAVING ENERGY *AND* COST

ENERGY CENTER OF WISCONSIN

www.ecw.org

REPORT BRIEF

Hybrid ground source heat pump systems have the potential to make ground source heat pump systems (GSHP) more cost effective. Though GSHP systems can significantly reduce energy consumption in commercial buildings, the high first cost of installing the ground heat exchanger (GHX) can be a barrier. A hybrid system uses conventional technology such as a cooling tower or boiler (Figure 1) to meet a portion of the peak heating or cooling load. This innovation allows you to install a smaller, less expensive GHX.

Comparing hybrids, GSHPs and conventional HVAC

In a study sponsored by the U.S. Department of Energy, the Energy Center analyzed performance and economic data from three hybrid installations to:

- disseminate lessons learned,
- validate models for others to use in analyzing hybrid systems, and
- assess the economic and environmental effectiveness of hybrids in comparison to GSHPs and conventional HVAC.

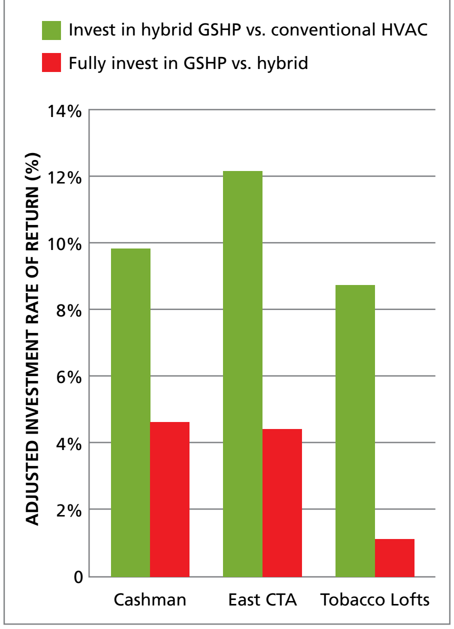
Our analysis found that all three installations were economically cost effective. The average rate of return for investing in hybrids in these three cases was 10%. If they had invested in additional GHX to go to a full GSHP system, the rate of return on the *additional* investment would have averaged just 3% (Figure 2).

Additionally, choosing a hybrid does not sacrifice environmental benefits (including carbon savings) because, in general, the supplemental equipment operates very infrequently due to the typical part-load operation of these commercial buildings.

Lessons learned

By monitoring and analyzing installed hybrid ground source heat pump systems, the Energy Center was able to add to the body of knowledge on the design of these systems. Some of the lessons learned from study of these buildings include:

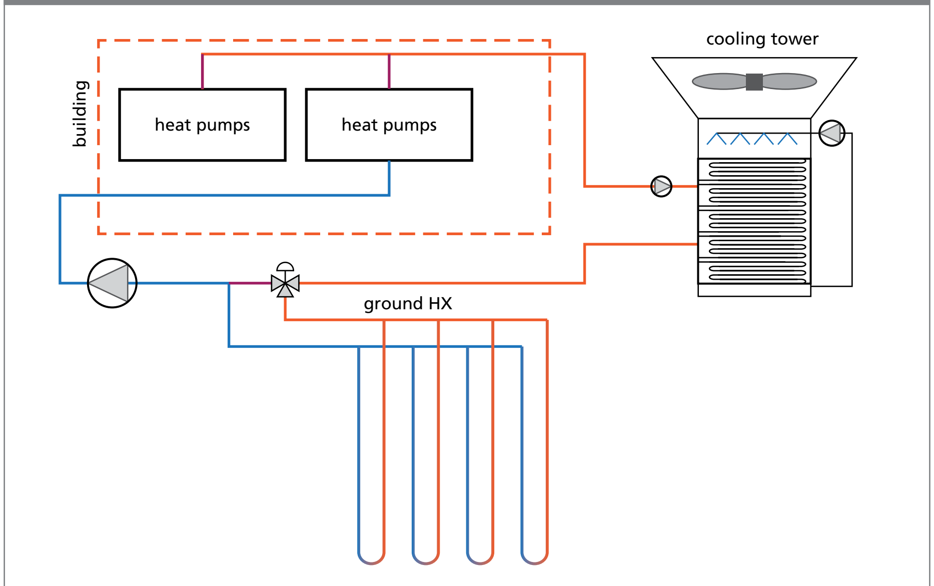
Figure 2—THE ECONOMICS OF HYBRID SYSTEMS



Component sizing in a hybrid system is extremely important—do not oversize the load that drives the GHX size. Use a sizing algorithm that optimizes the tower or boiler (see references and software options below; use hourly—8760—loads as inputs if at all possible).

Pumping uses a lot of energy in a hybrid system. Minimize pump sizes and focus on part-load performance. For central pumping include a part-load pump of a smaller size (~50%). Consider using smaller individual pumps for “rogue” zones. Choose variable speed wherever applicable with a well-positioned dP sensor that is adjusted downward (post–occupancy) to allow for the lowest speed possible.

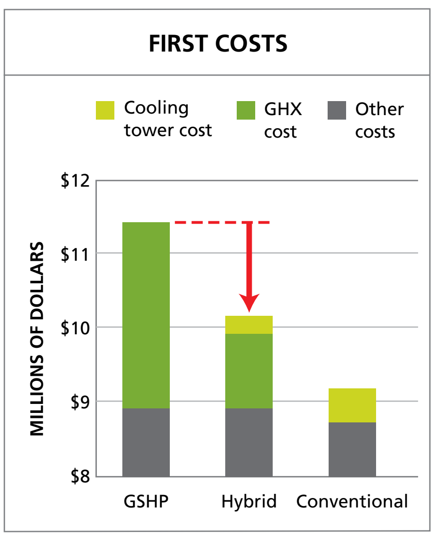
Figure 1—A TYPICAL HYBRID SYSTEM



CASE STUDY: EAST CTA

Courtesy of SH Architecture

East Career and Technical Academy is a vocational high school in Las Vegas, Nevada. Individual, closet-installed heat pumps serve each space and are tied back to the mechanical room via one large variable flow secondary loop. These secondary building loops are connected to a primary loop, which has a 168,000 ft GHX and two, multi-speed cooling towers (167 tons each) attached. East CTA is a heavily cooling-dominated building and investing in a full ground-source system would have been cost-prohibitive. By investing in the hybrid system, the district is saving approximately $0.50/ft² in operating costs annually—only a few cents less than a full ground-source system. And the district realized first cost savings of $1 million by going hybrid.



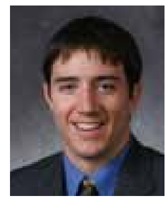
Cooling towers or fluid coolers should be variable speed (if multiple towers, ramp up/down together, not staged), and ramp down quickly enough to shut off shortly after substantial cooling. Tweaking the control setpoints after occupancy can ensure efficient operation.

If using **nighttime precooling** with a cooling tower, operate it for a short period of time (a few hours), right before morning startup, and at a lower fan speed. Precooling does not have to be used to balance load on the ground.

The loop should be able to bypass the GHX. Set a reasonably wide deadband (20–30°F) in which the GHX is not used; with GHX in cooling-dominated systems coming on only ~10°F below the setpoint of the cooling tower.

Boilers should be placed downstream of GHXs and controlled to a setpoint 5–10°F below the GHX. Condensing boilers work very well in these systems.

Heat pump operation—use optimal or staged startup to avoid large peaks. Ensure proper return air paths and maintenance accessibility to the units, and partially economize using outdoor air if possible.



FOR MORE INFORMATION

Contact Scott Hackel at 608.238.8276 x129 or shackel@ecw.org

To read the full study, see: **www.ecw.org/hybrid**

Resources

Software tools

HyGCHP—free version of the model from this study, allows for comparison of a variety of hybrid and conventional design approaches.

EnergyPlus—free software from the U.S. Department of Energy for full building modeling, including hybrid capability.

TRNSYS—full building thermal modeling, with the capability of studying any hybrid system imaginable.

Sizing tools—ground-source sizing tools like GLD 2010, GCHPCalc and GLHEPro have some very basic hybrid sizing capability.

Design references

Basic design information: *A Design Method for Hybrid Ground-Source Heat Pumps* by Kavanaugh (ASHRAE Transactions 1998); other work by Kavanaugh and Rafferty.

Simulation and Optimal Control of Hybrid Ground Source Heat Pump Systems by Xu (Ph.D. Thesis, 2007); **www.hvac.okstate.edu/theses.html**

Optimal hybrid sizing; some sample control sequences: **http://sel.me.wisc.edu/publications-theses.shtml** (thesis by Hackel)