

Field Study: Performance of Commercial GSHPs

- Goal: Identify characteristics that tend to provide economic value and long-term dependability
- Goal: Provide recommendations to improve future installations, identify and optimize component costs
- Sponsors: Electric Power Research Institute, Southern Company and Tennessee Valley Authority
- Series of articles on the project appeared in the *ASHRAE Journal* from June 2012 through February 2013
- For non-ASHRAE members pdf files can be found at www.geokiss.com

An Energy Star Rating of 84 Indicates That Energy Use is Less Than 84% of Buildings of a Similar Type (Offices are compared to other offices, schools are compared to other schools, etc. and results are normalized for climate, occupancy, schedules, and internal loads)

84

Energy Star
Rating



Statement of Energy Performance FACILITY SUMMARY REPORT Oakdale Elementary School

For 12-month Period Ending: July 31, 2007
Date Generated: December 12, 2007

This document was generated using EPA's Portfolio Manager system. All information shown is based on data provided by the Portfolio Manager account holder. Depending on the use of the SEP Facility Summary, building owners or managers may want to have a professional engineer (PE) verify that the underlying data is accurate. Blank space has been left intentionally on the SEP Facility Summary for a PE stamp.

601 South Adelaide
Normal, IL 61761

Year Built: 1954
Gross Floor Area: (ft²) 43,212

Facility Space Use Summary

K-2 School

| Space Name | Gross Floor Area (ft²) | Number of Students | Number of PCs | Operating Hours/Week | Cooking Facility | % Air-Conditioned | % Heated | Months | Ventilated |
|---------------|------------------------|--------------------|---------------|----------------------|------------------|-------------------|----------|--------|------------|
| Entire School | 43,212 | 472 | 118 | 40 | Y | 100 | 100 | 10 | Y |

Energy Performance Comparison

| Results | Current | Baseline | Delta | Target | Industry Average | ENERGY STAR |
|---------------------------------------|---------|----------|-------|--------|------------------|-------------|
| Energy Performance Rating | 84 | 84 | 0 | | 50 | 75 |
| Energy Intensity (kBtu/ft²) | | | | | | |
| Site | 31.76 | 31.76 | 0.00 | | 45.74 | 36.97 |
| Source | 101.23 | 101.23 | 0.00 | | 145.79 | 117.84 |
| Energy Cost | | | | | | |
| \$/year | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 |
| \$/ft²/year | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 |
| CO ₂ Emissions (tons/year) | 352.00 | 352.00 | 0.00 | | 506.04 | 406.74 |

Minimum Required to
Achieve Energy Star

75

Building Occupant Comfort and Satisfaction Survey

???😊 😊 😞???

☒ Check the box that reflects your level of satisfaction with the summer indoor temperature and humidity

☐ **Very Dissatisfied** ☐ **Dissatisfied** ☐ **Acceptable** ☐ **Satisfied** ☐ **Very Satisfied**

☒ Check the box that reflects your level of satisfaction with the winter indoor temperature

☐ **Very Dissatisfied** ☐ **Dissatisfied** ☐ **Acceptable** ☐ **Satisfied** ☐ **Very Satisfied**

☒ Check the box that reflects your level of satisfaction with the air quality (odors, stuffiness, air “freshness”)

☐ **Very Dissatisfied** ☐ **Dissatisfied** ☐ **Acceptable** ☐ **Satisfied** ☐ **Very Satisfied**

☒ Check the box that reflects your level of satisfaction with the acoustics (noise levels related to heating and cooling equipment)

☐ **Very Dissatisfied** ☐ **Dissatisfied** ☐ **Acceptable** ☐ **Satisfied** ☐ **Very Satisfied**

☒ Check the box that reflects your level of satisfaction with the lighting level

☐ **Very Dissatisfied** ☐ **Dissatisfied** ☐ **Acceptable** ☐ **Satisfied** ☐ **Very Satisfied**

If are Dissatisfied or very dissatisfied, was the lighting level ☐ **Too Low** or ☐ **Too High**

☒ Check the box that reflects your level of satisfaction with the responsiveness and ease of reporting building maintenance problems

☐ **Very Dissatisfied** ☐ **Dissatisfied** ☐ **Acceptable** ☐ **Satisfied** ☐ **Very Satisfied**

☒ Check the box that reflects your ability to adjust the thermostat settings in your space

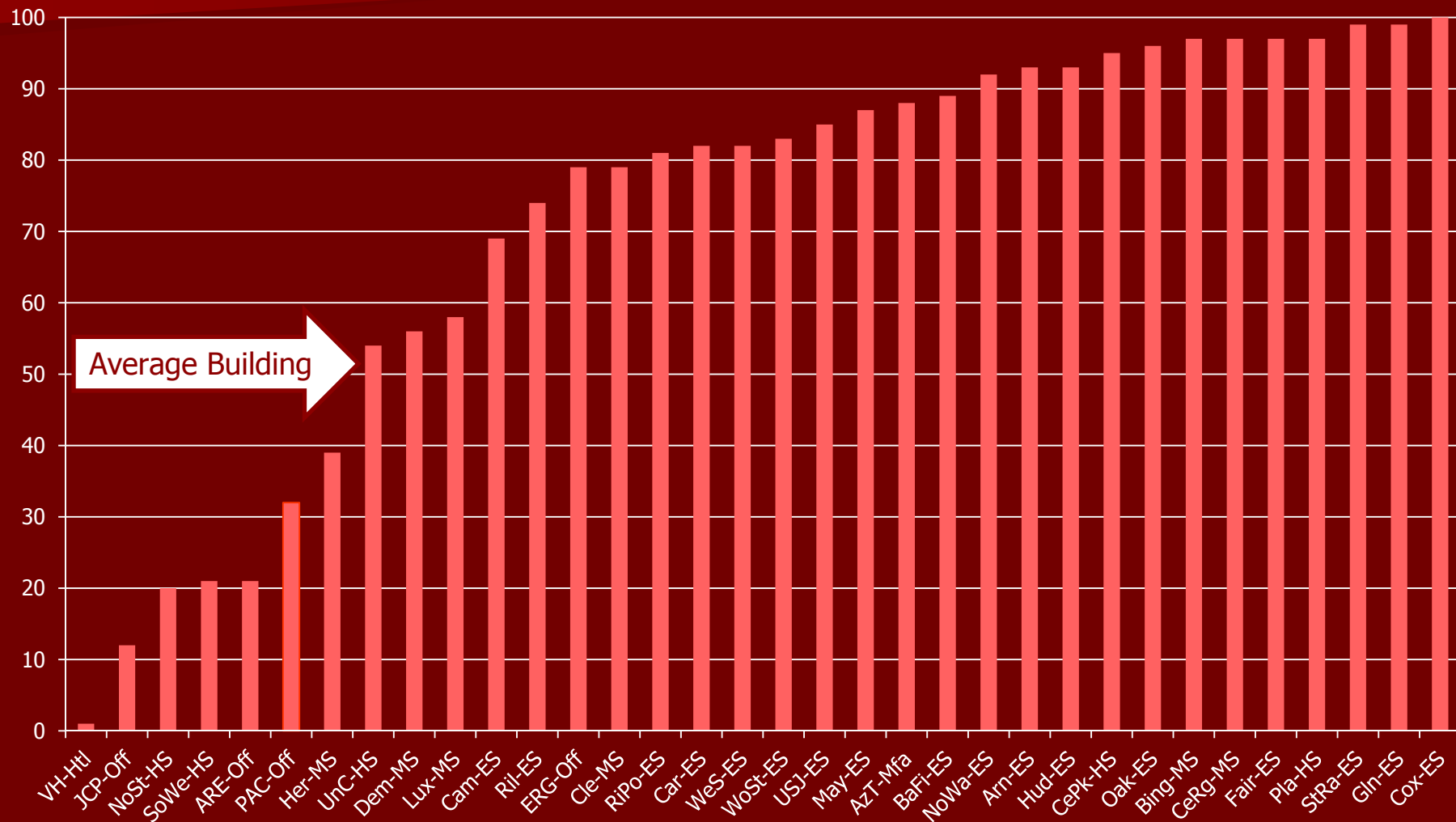
☐ **Very Dissatisfied** ☐ **Dissatisfied** ☐ **Acceptable** ☐ **Satisfied** ☐ **Very Satisfied**

Other Comments:

Energy Star Rating of All GSHP Buildings

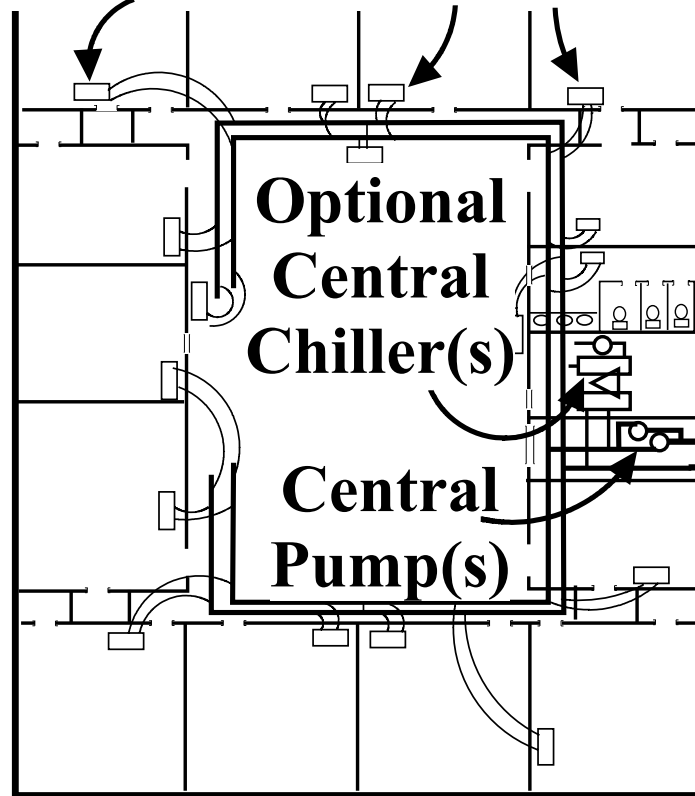
ES-Elem School, MS-Mid School, HS-High School, Off-Office, Htl-Hotel, MFa-Multi Family

***Three Engineering Firms Did 92% of the
90+ Rated Buildings**

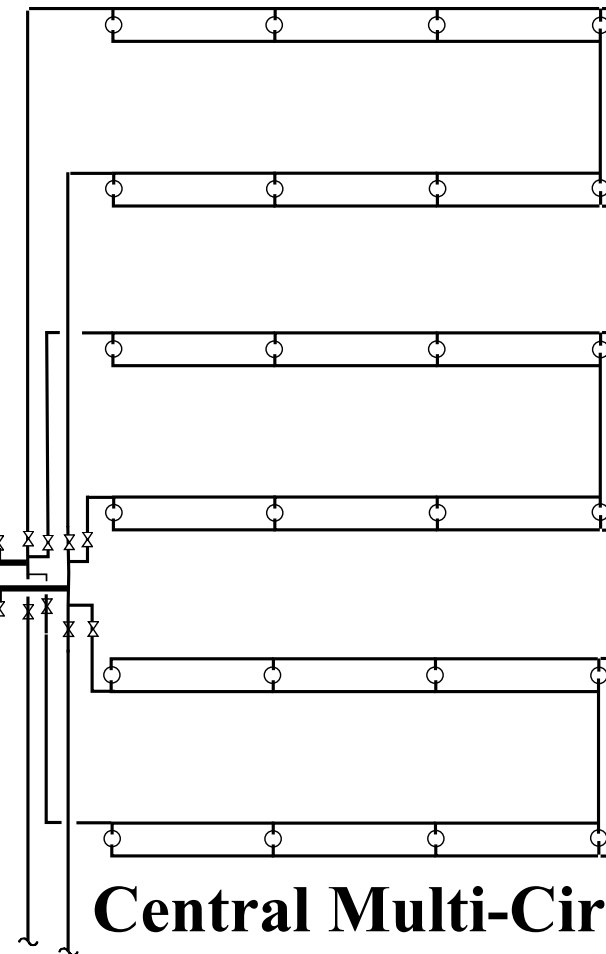


Central Ground-Coupled Heat Pump Loop

**Heat Pumps, Fan Coils, or
VAV Terminals in Zones**



Multi-Story Building



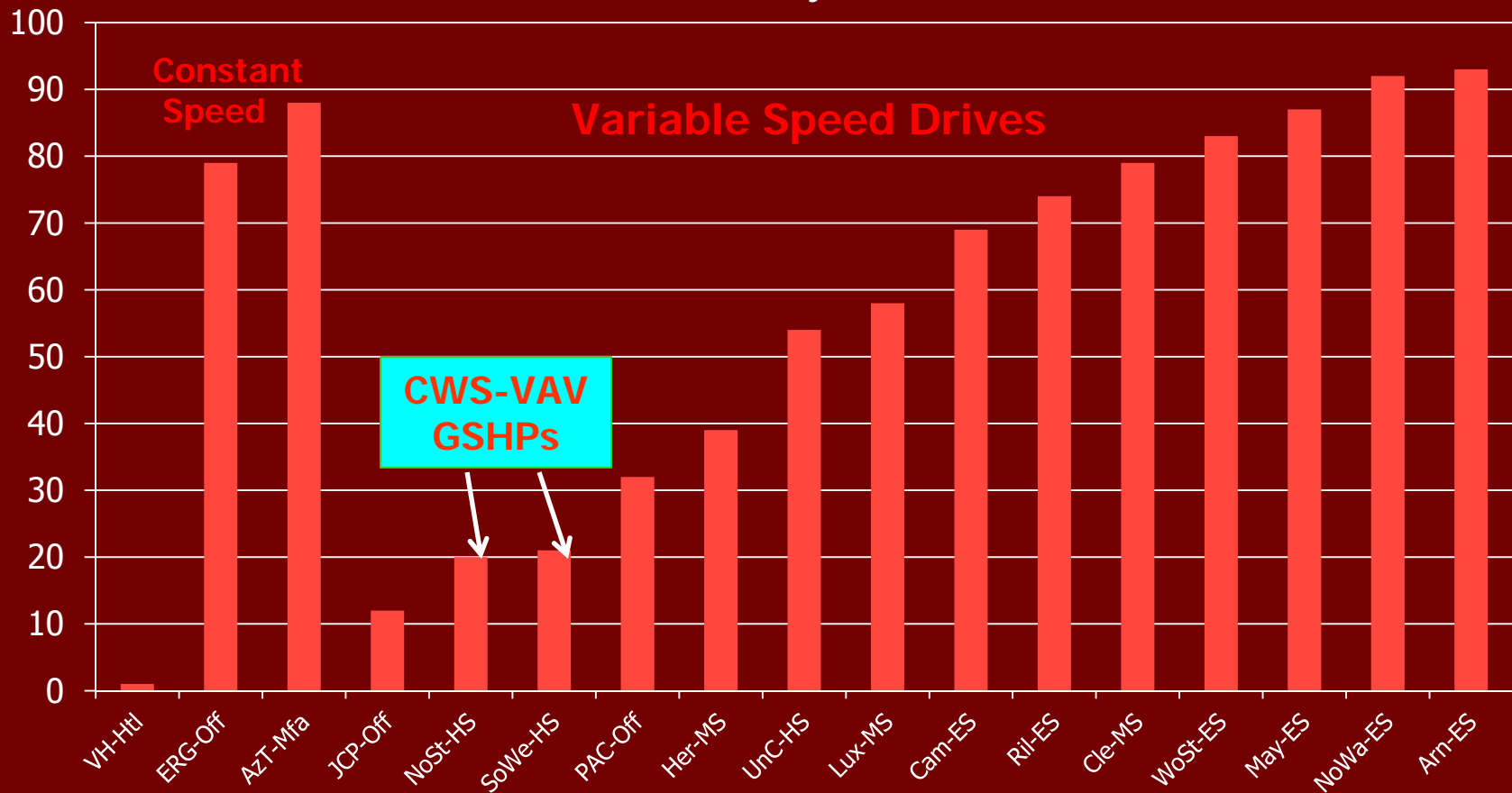
**Central Multi-Circuit
Ground Loop**

Central Loop, Central Pump

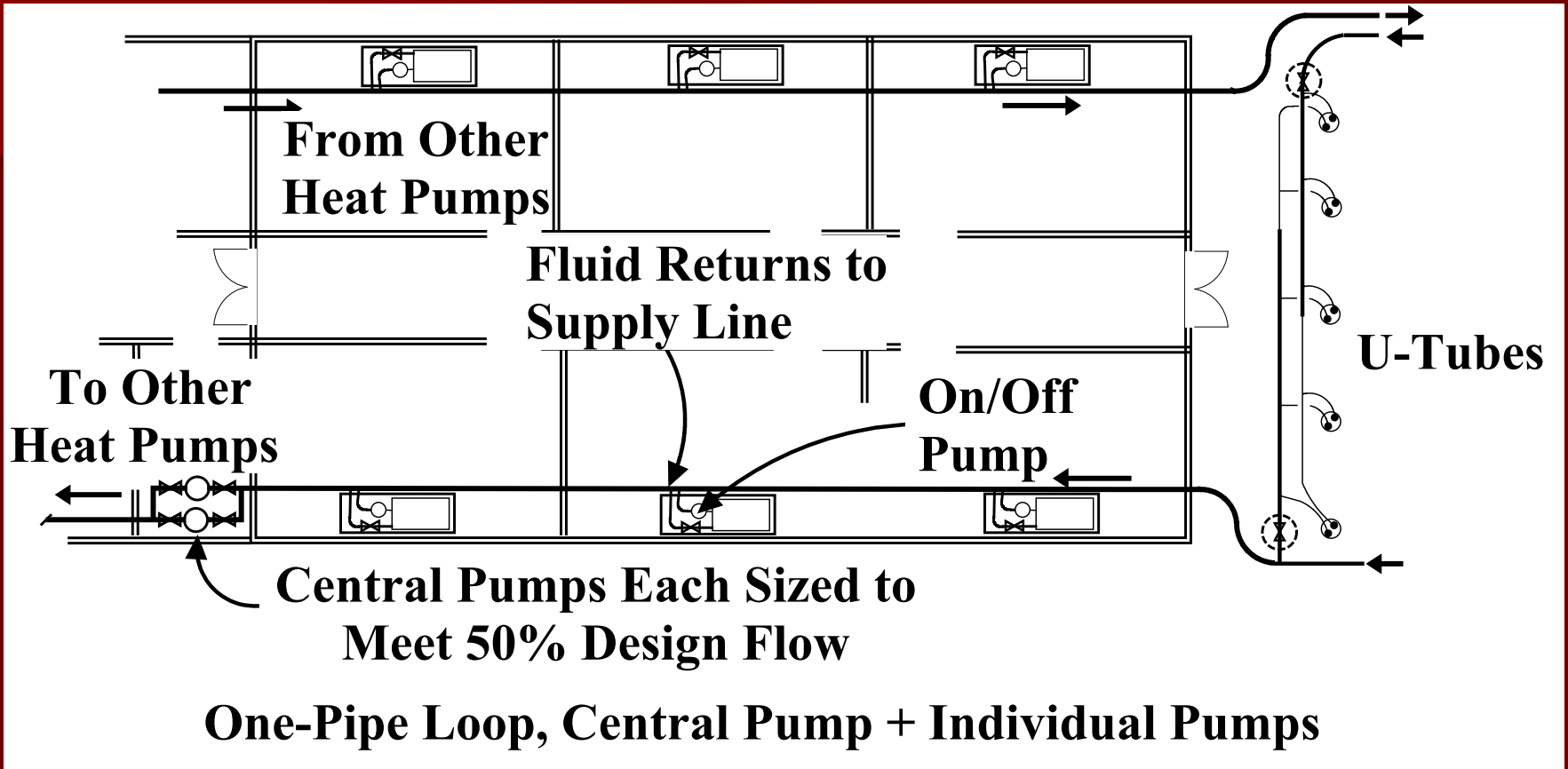
Energy Star Ratings of Central Loop GSHP Buildings with Central Pump

Energy Star Ratings of GSHP Buildings Central Loop and Central Pump

ES-Elementary School, MS-Middle School, HS-High School, Off-Office, Htl-Hotel, MFa-Multi Family



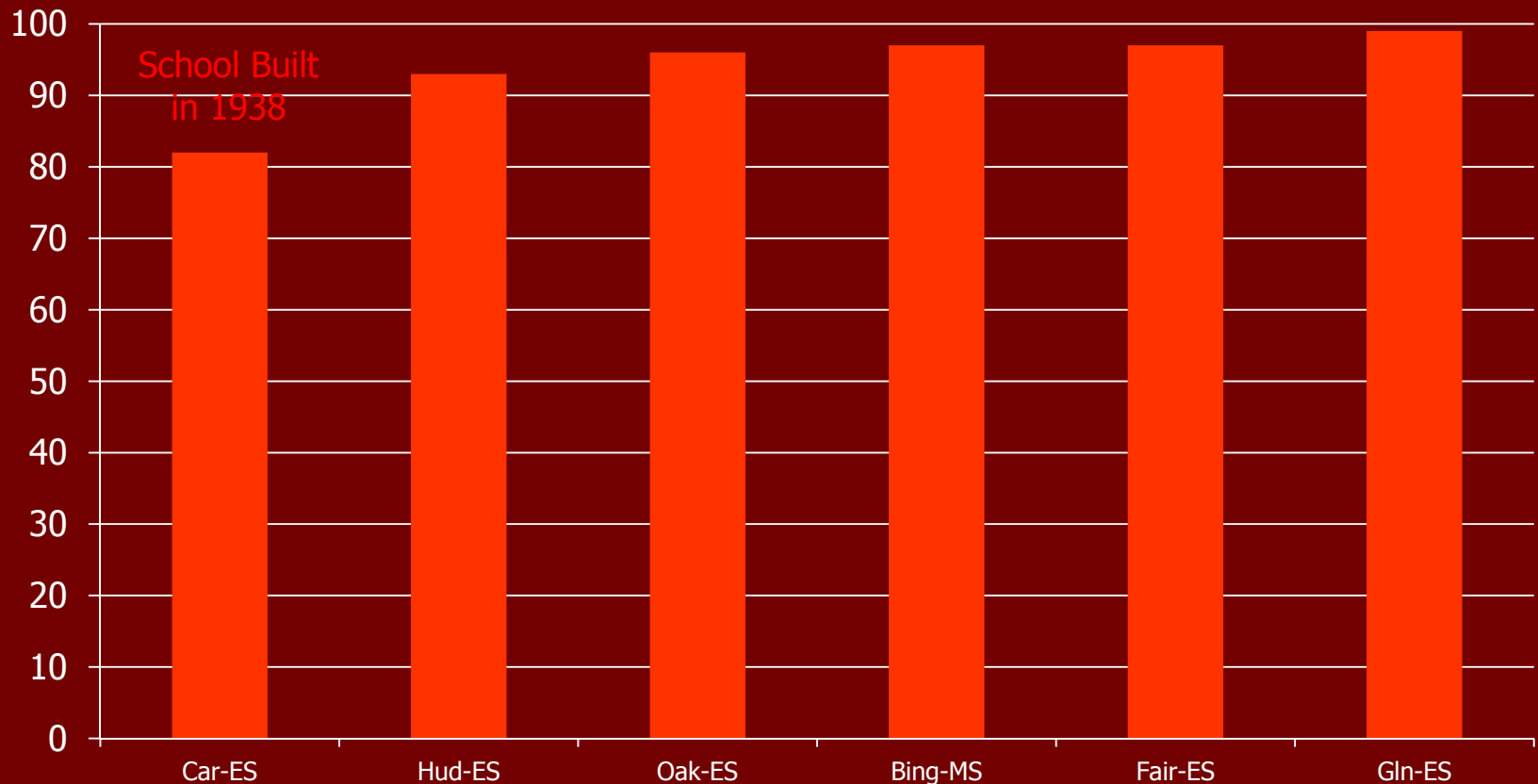
One-Pipe GSHP



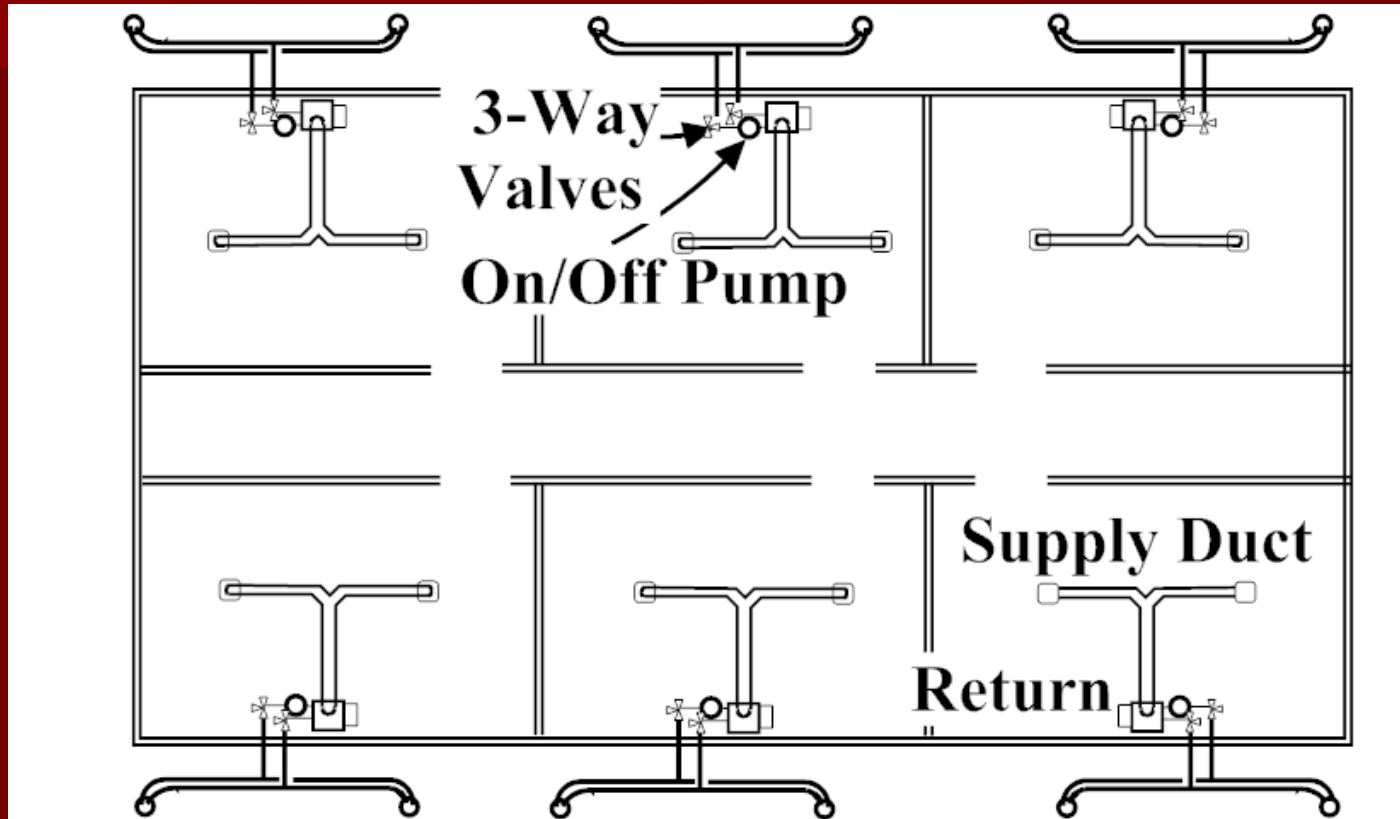
HVAC Cost at \$16 to \$22/ft² in Central Illinois School retrofits

Energy Star Ratings of One-Pipe Central Loop GSHP Buildings with On-Off Pumps

Energy Star Ratings of GSHP Buildings
One-Pipe Central Loop, On-Off Pumps
ES-Elem School, MS-Mid School



Loop Field Headers and Building Piping Unitary HDPE Loops

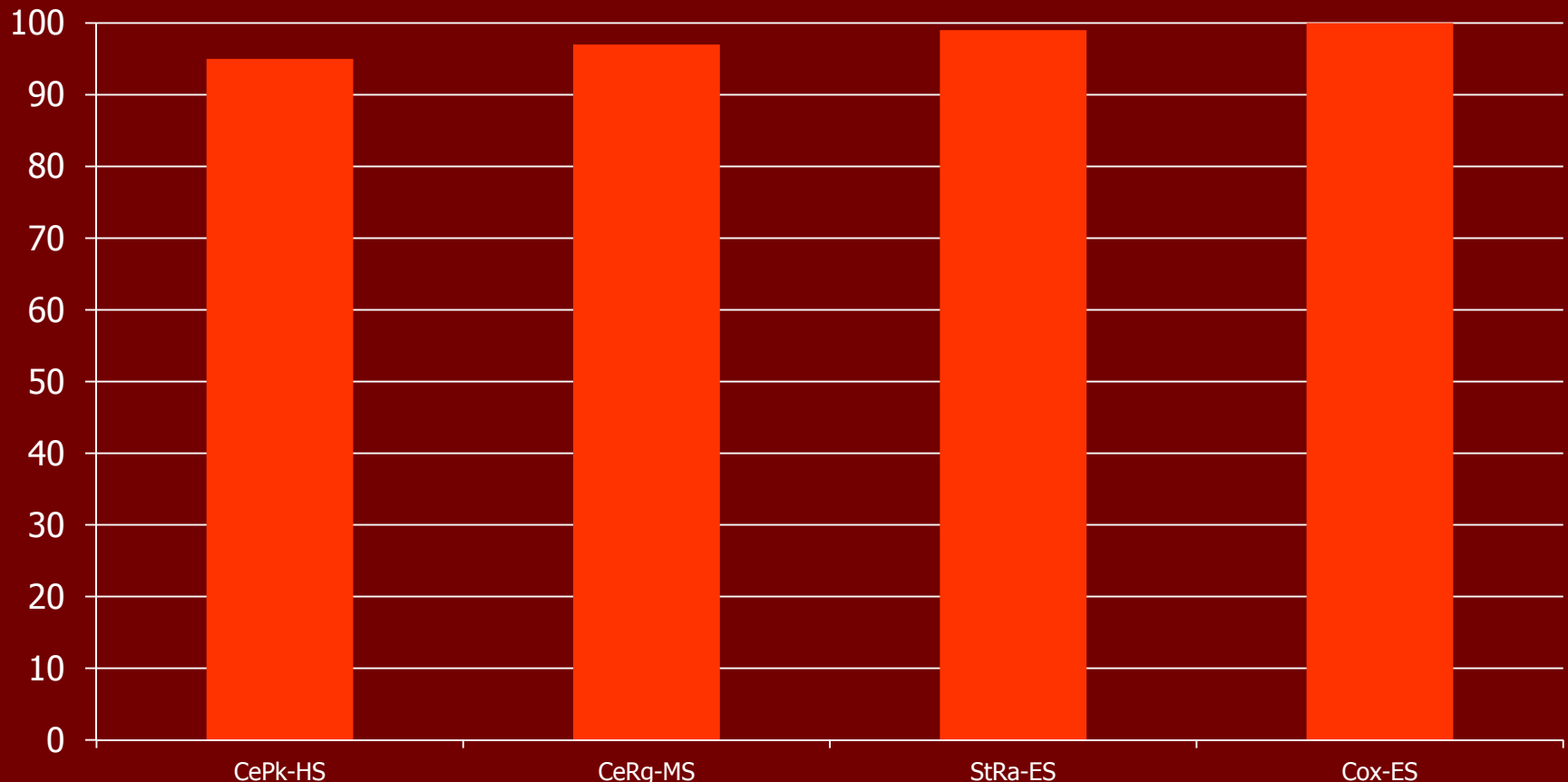


Unitary Loop, Individual Pumps for Each Unit

Energy Star Ratings of Unitary – Single Loop for Each Heat Pump, On-Off Pump

Energy Star Ratings of GSHP Buildings Unitary - Single Loop for Each Heat Pump, On-Off Pump

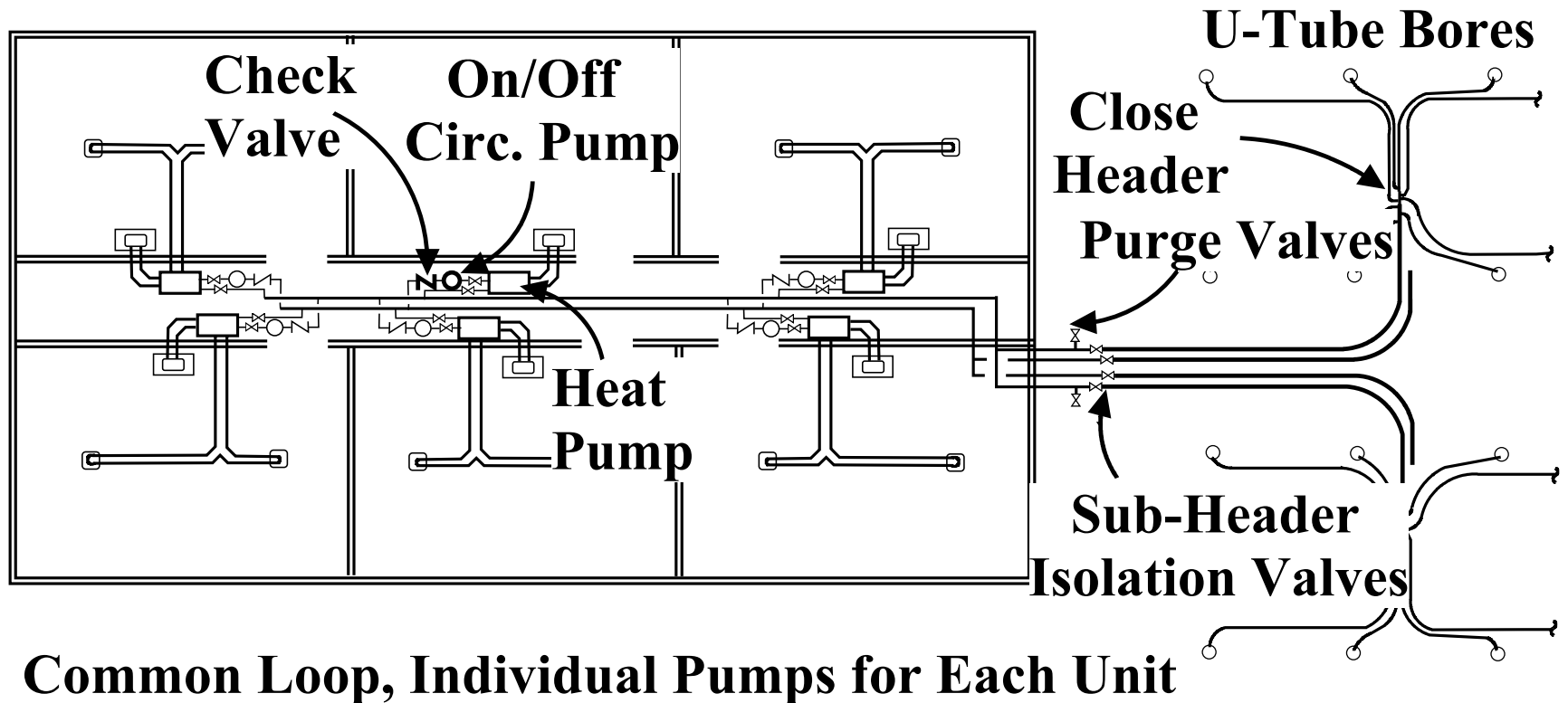
ES-Elem School, MS-Mid School HS-High School,



School district has 31 Energy Star rated schools, four rating 100 in 2011.

Loop Field Headers and Building Piping

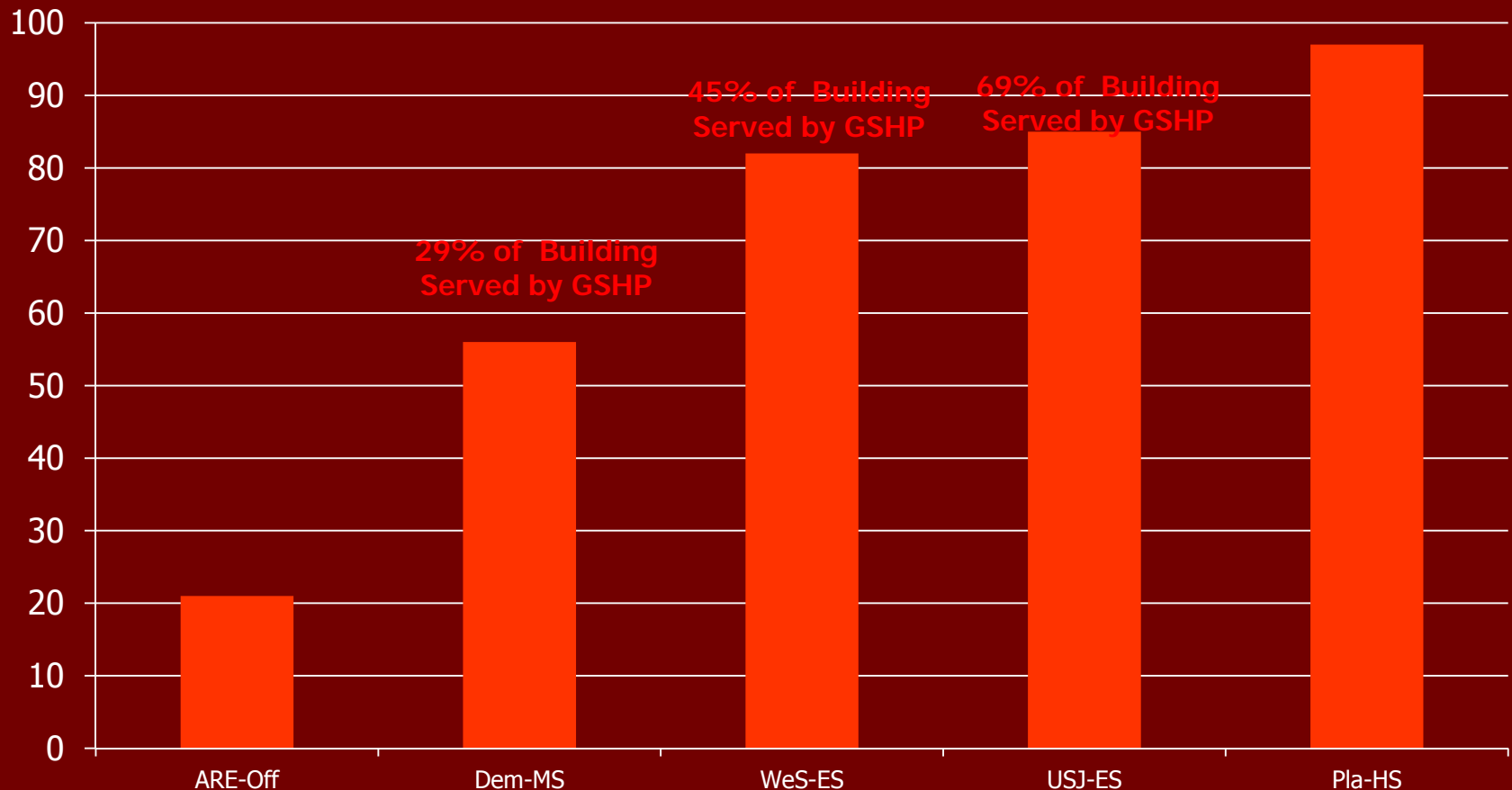
Common HDPE Loops



Energy Star Ratings of One-Pipe Central Loop GSHP Buildings with On-Off Pumps

Energy Star Ratings of GSHP Buildings Central Loop, On-Off Pump on Each Heat Pump

ES-Elementary School, MS-Mid School, HS-High School, Off-Office

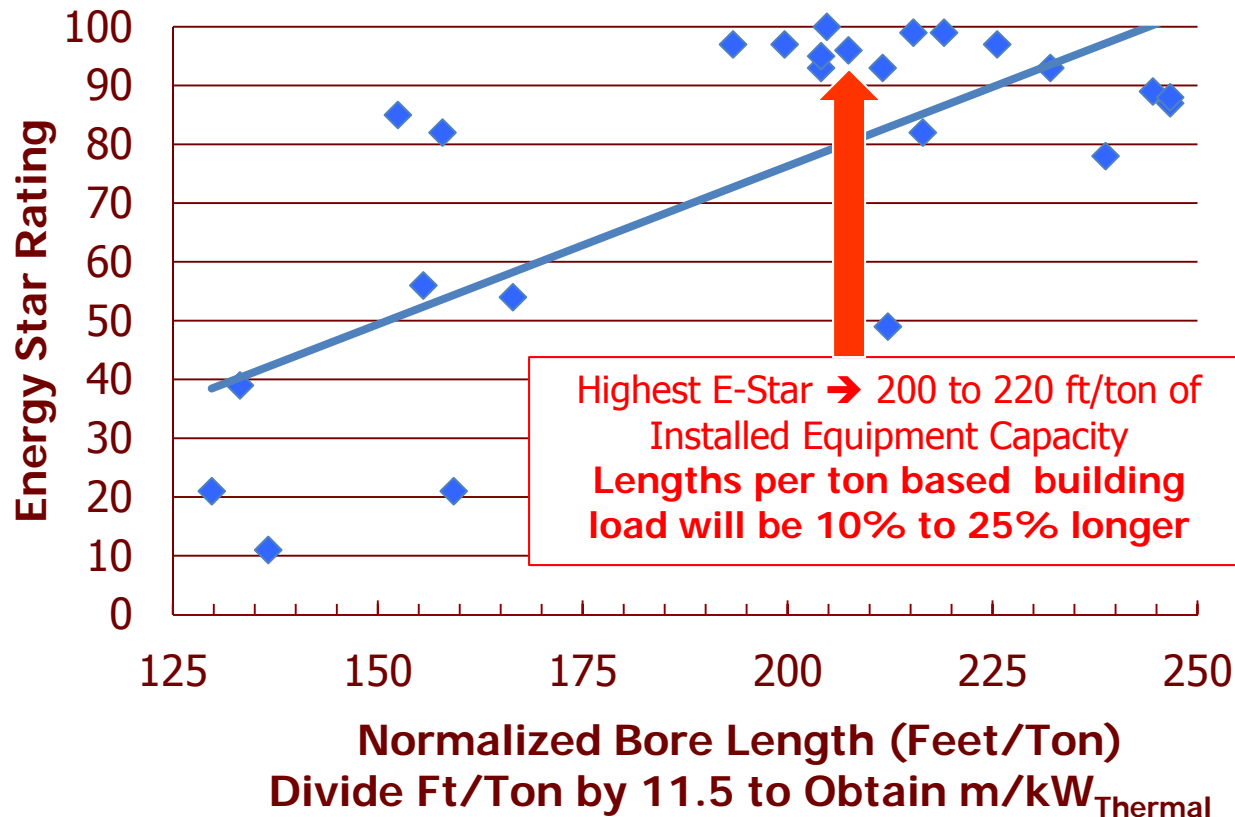


Impact of Ground Heat Exchanger Length

Energy Star vs. Normalized Bore Length per Ton

$$L_b/\text{ton (Nor)} = L_b/\text{ton} * [(90-t_g)/(90-t_{gavg})]$$

* t_{gavg} for all sites = 63°F (17°C)



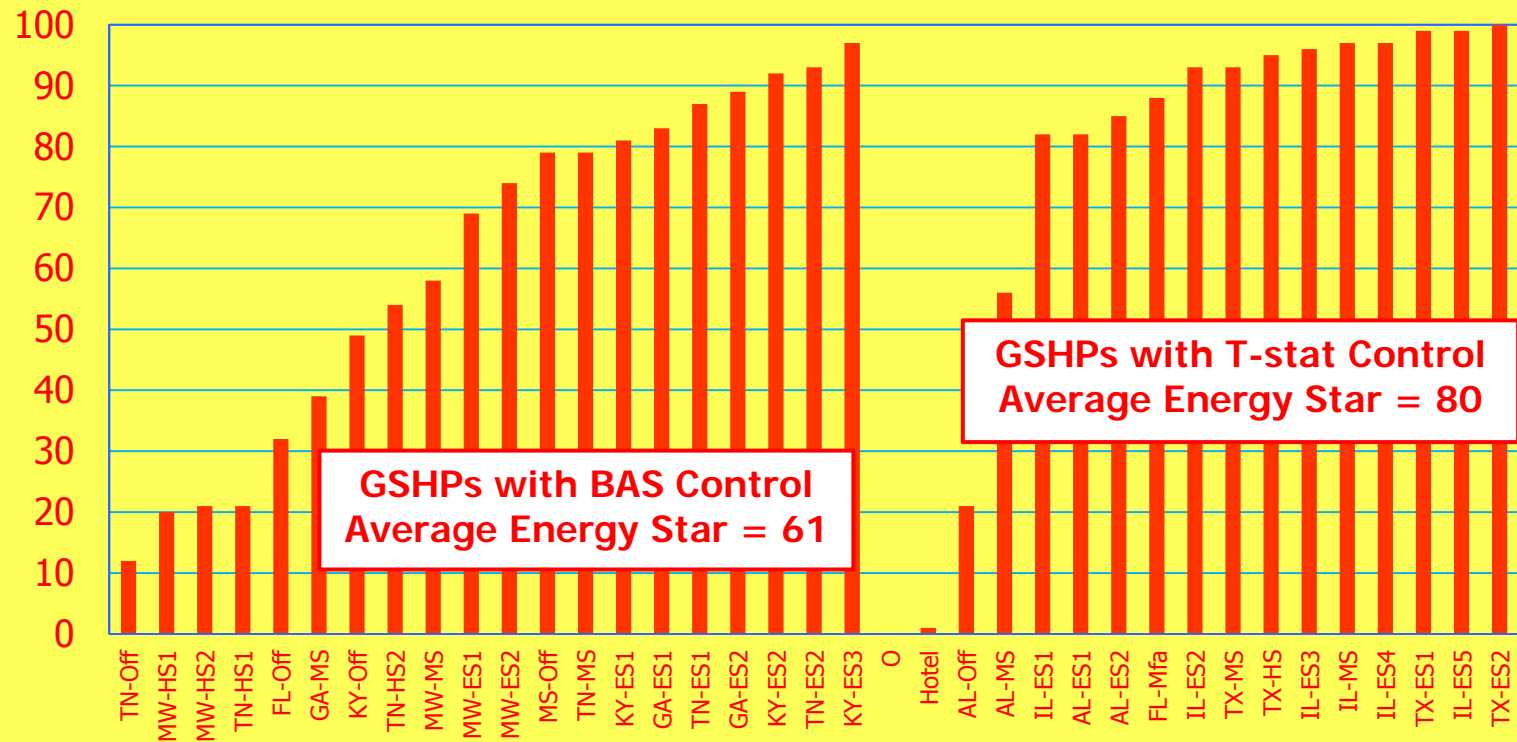
Rearrange Eqn. to find $L_b/\text{ton} = L_b/\text{ton (Nor)} * (90-t_{gavg})/(90-t_g)$

For SE TN: $L_b/\text{ton} \approx 210 \text{ ft/ton} * (90-63)/(90-60) \approx 190 \text{ ft/ton of capacity}$

$L_b/\text{ton} \approx 210 \text{ ft/ton to } 240 \text{ ft/ton of cooling load}$

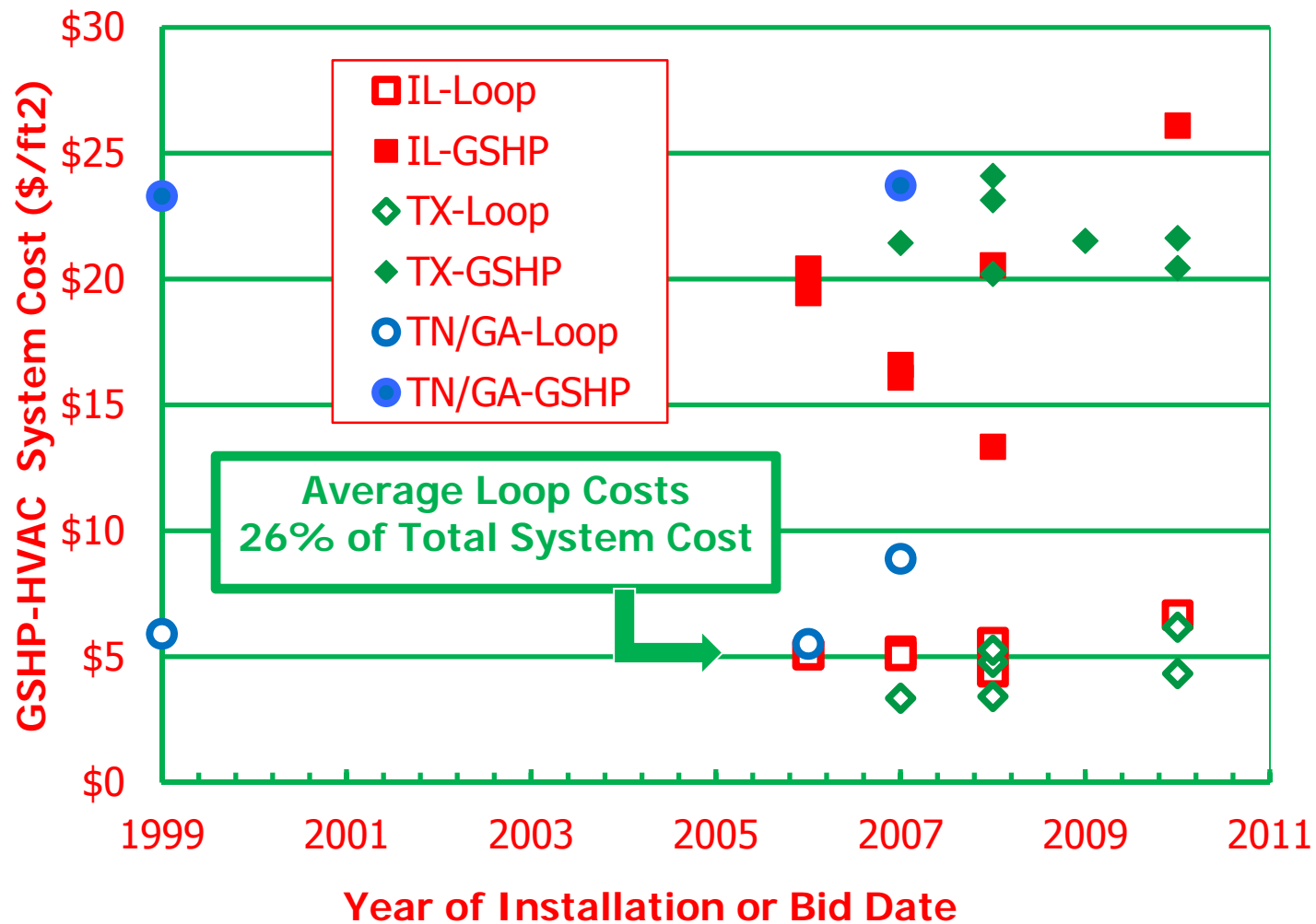
Impact of Control Type

GSHP Energy Star Rating Building Automation System vs. Thermostat Control



GSHP Loop and System Cost – 2010 (\$/ft²)

Few Owners and Engineers Willing to Share Information



Summary

- Most GSHP systems did well (61% E-Star, 33% E-Star > 90)
- Unitary & one-pipe loop GSHPs had average E-Star=95
- Central loop GSHPs had average E-Star=61
- A few GSHPs don't work very well (19% E-Star < 50%)
- The average cost for the inside the building HVAC was 74% of the total GSHP system cost **and has increased by 175% since 1995 survey.**
- The average cost for the ground loop was 26% of the total GSHP system cost **and has increased by 52% since 1995 survey.**
- IMHO the largest factor for success was:

QUALITY OF ENGINEERING DESIGN