Community-scale Geothermal Systems

for

Energy Planning for Resilient Military Installations

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DEC Overview

- District Energy Corporation (DEC) is a Nebraska nonprofit corporation and a City of Lincoln and Lancaster County inter-local agency
- It was organized in 1989 for the purposes of constructing, financing, furnishing, and operating thermal energy facilities to serve governmental entities
- DEC is governed by a 5 member Board of Directors, representing the City and County
- DEC has no employees
  - Instead the DEC Board of Directors contracts with Lincoln Electric System, the city-owned electric utility, which manages DEC's systems and affairs
  - The Management Contractor (LES) provides financial, operating, and capital updates at each of the quarterly Board of Directors' meetings

DEC Overview

DEC currently owns four thermal energy plants and is in the process of constructing two more

- 9th & K County/City Thermal Plant
  - Serves local government campus
  - Provides chilled and hot water and utilizes ice storage for demand control

- 14th & K State Boiler Plant
  - Serves State Capitol & other state government facilities
  - Provides 125 psig steam

DEC Overview

- **West Haymarket Central Utility Plant**
  - Serves City/University of Nebraska Joint Public Agency, which includes arena surrounding developments
  - Provides chilled and hot water

- **SW 40th Thermal Energy Facility (focus of today's discussion)**
  - Serves Lancaster County Adult Detention Facility
  - Provides chilled and hot water and utilizes geothermal, water to water heat pumps
  - Provides backup utility power (***not*** life-safety), grid dispatchable

DEC Overview

Plants under construction

- 91st & Rokeby Thermal Energy Facility
  - Will serve the new Lincoln Electric System Operations Center and Headquarters
  - Will provide chilled and hot water and will utilize geothermal heat pumps
  - Will provide backup utility power (*not* life-safety), grid dispatchable
- Pioneers & Hwy 2 Central Utility Plant
  - Will serve the Nebraska State Penitentiary
  - Will provide chilled water and steam for both space conditioning and process
  - Will provide backup utility power (*not* life-safety)

SW 40th Thermal Energy Facility (TEF)

Geothermal SW 40th TEF-16,500 SF

Back-up Power

Chilled Water
Hot Water
Electric Power

County Adult Detention Facility
786 Beds; 290,000 SF

4/2009-Began Engineering
10/2009-Energy Services Agreement
5/2010-Began Construction
1/2012-Completed Well Field Install.
3/2012-Completed Plant Construction
6/2012-Completed Commissioning
7/2012-Compercial Operation

9/1/2013 CADF Commercial Operation Date

SW 40th TEF-Design Considerations

Peak Loads	Design	Actual
Heating, mmBtu/h	4.5*	9.4*
Cooling, tons	740	865

*Customer A/E provided peak space conditioning value but did not include in-floor heating or ice-melt loads totaling 5.5 mmBtu/h. Thus, true "peak load" closer to 10 mmBtu/h that caused concern during first year of operation. In addition, customer did not start accepting "full" chilled water service until September 2013, which did not allow for thermal build-up in well field causing Jan leaving water temperature to drop to 38°F

Advantage to Geothermal Heat Pump System for this Facility

- Projected 29% Energy Cost Savings vs. Conventional Plant
  - First year savings of $166,500
- No Boiler Emissions
- No cooling towers with associated water treatment and other O&M costs
- 50-year life cycle cost analysis showed a net present value of $8M savings vs. conventional

Redundancy

- Spare heat pump bank
- Spare circulating pumps
- Two utility power feeds
- Back-up generation with spare engine

SW 40th TEF-Water-to-Water Heat Pumps

-5 Heat Pump Banks = 4 req'd + 1 Spare
-5 Modules per Bank; 2 Compressors/Bank
-1 Bank = 4.2 mmBtu/h Heating Mode
-1 Bank = 312 tons Cooling Mode
-Heating Design Load = 1.1 Banks = 4.5 mmBtu/h
-Cooling Design Load = 2.37 Banks = 740 tons

Nominal 62 ton Scroll Heat Pumps

- Ea. Bank dedicated to either htg or clg
- Summer scheme
  - 3 banks dedicated to cooling
    - 936 tons capacity
  - 1 bank dedicated to heating
  - 1 spare "swing" bank
- Winter scheme
  - 2 banks dedicated to heating
    - 8.4 mmBtu/h capacity
  - 2 banks dedicated to cooling
  - 1 spare "swing" bank
- Upside-Modularity of heat pumps a benefit relative to larger, traditional packaged chillers for redundancy
- Downside-"Commercial" as opposed to "Industrial" quality & robustness

SW 40th TEF-Domestic Hot Water

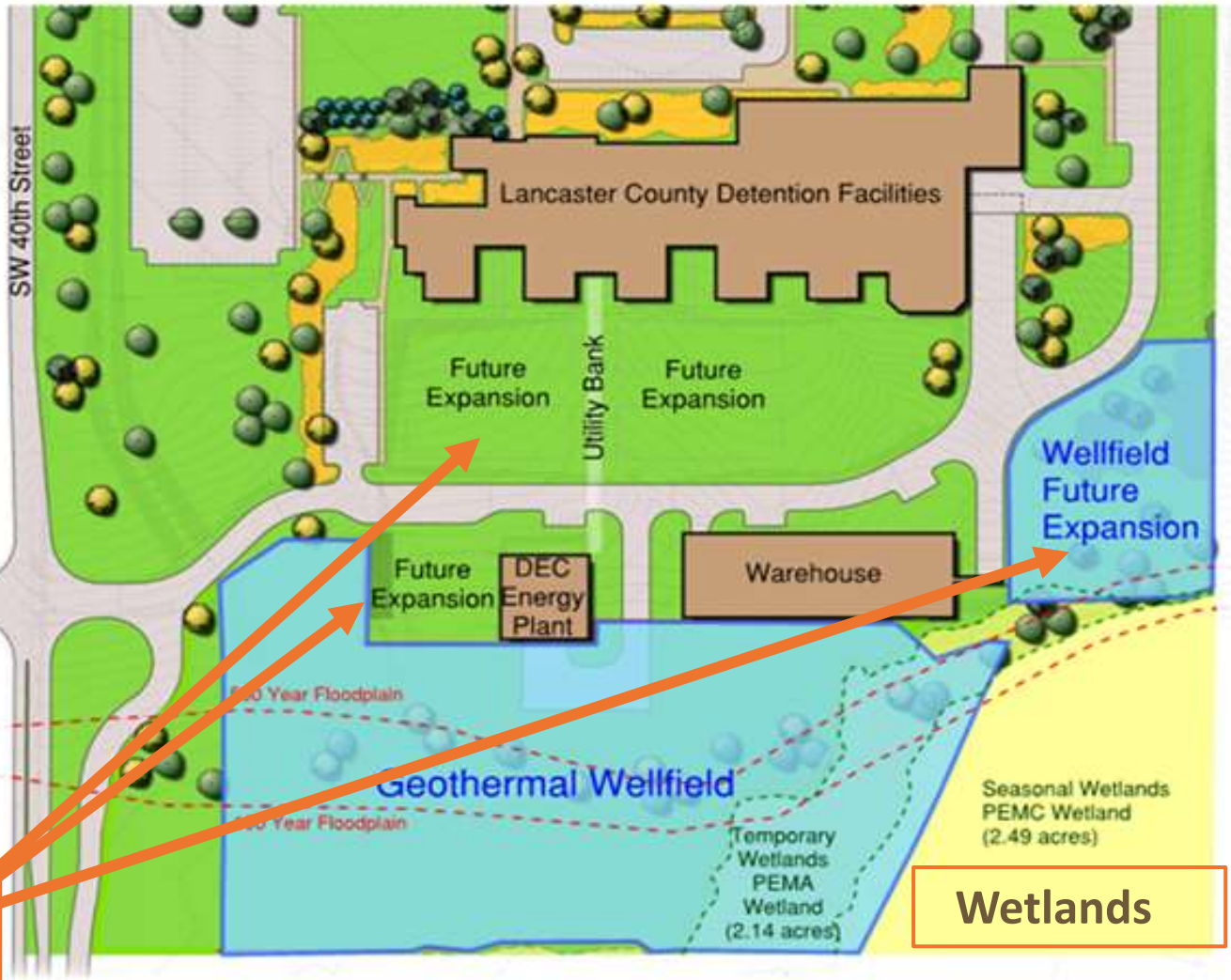
- 1st Stage: Piping/Heat Exchanger arrangement allows heat transfer with DEC distribution lines, either:
  - Hot Water Return, Hot Water Supply, or Chilled Water Return
  - Temperature Rise from 55°F to 115°F
- 2nd Stage: Customer's W-t-W Heat Pump located in Detention Facility and connected to DEC Wellfield
  - During peak cooling periods, operated for simultaneous cooling and domestic hot water heating
  - Temperature Rise to 140 °F
- Advantages
  - Balances load (Detention Facility is cooling dominated)
  - Projected Energy Cost Savings of at least 35% for DHW Production
- Currently not operable due to evaporator leaks
- Customer does use natural gas for kitchen, laundry & redundancy

SW 40th TEF-Compound & Well Field

Construction Permits: Air, Army Corp Nationwide, 404 Wetlands, Construction Storm-water, Well drilling. Soil had to be restored to original topography

4 fields in 8 acres
667 bore holes, 300 ft. deep, 6” dia.

Note areas for future expansion

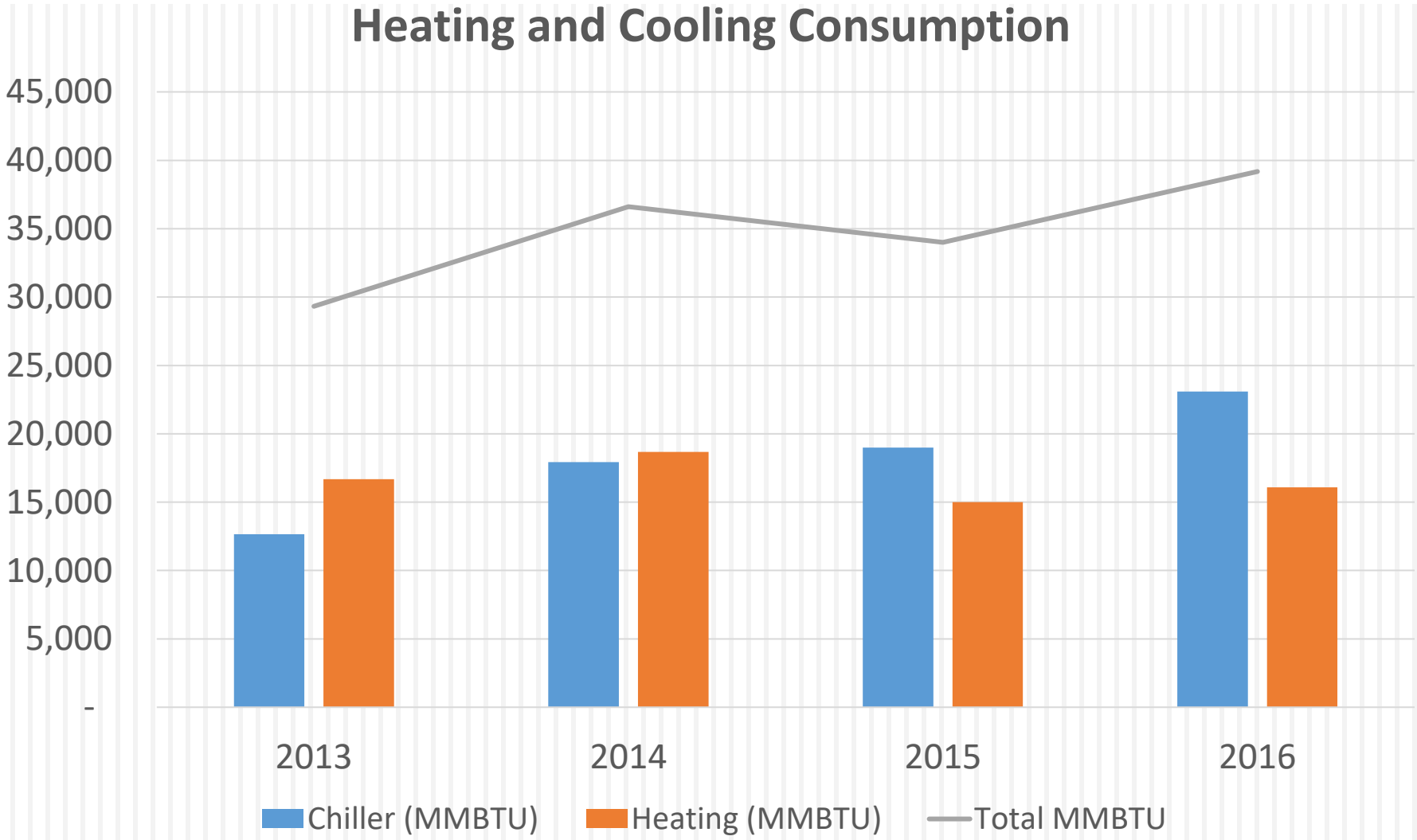


SW 40th TEF-Well Field

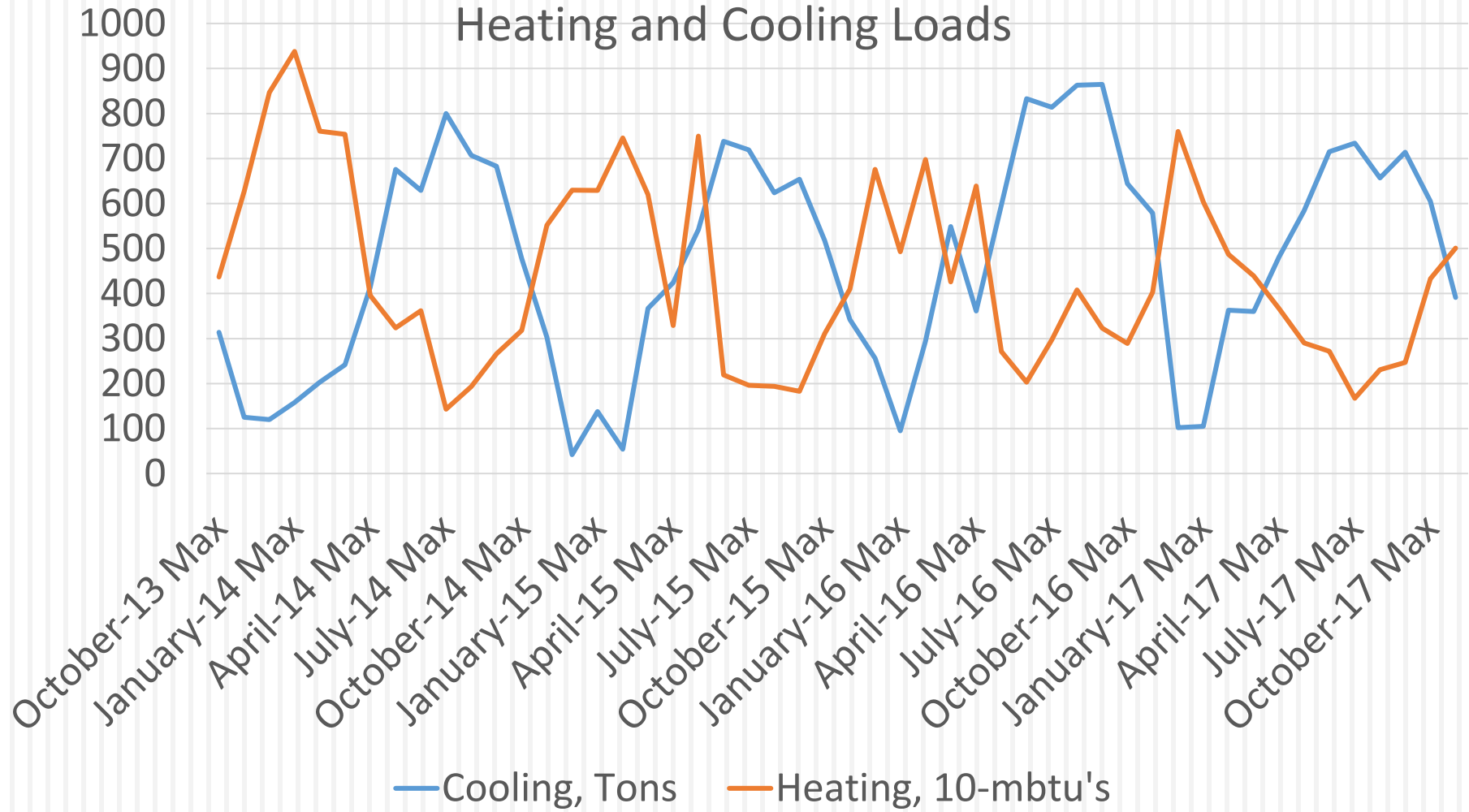
Well Field Headers entering basement of plant; note spare risers for future well headers. Basement allows for easy access.

- Thermal conductivity of 1.56 Btu/h-ft-^{o}F
- Thermal diffusivity of 1.34 ft^{2}/day

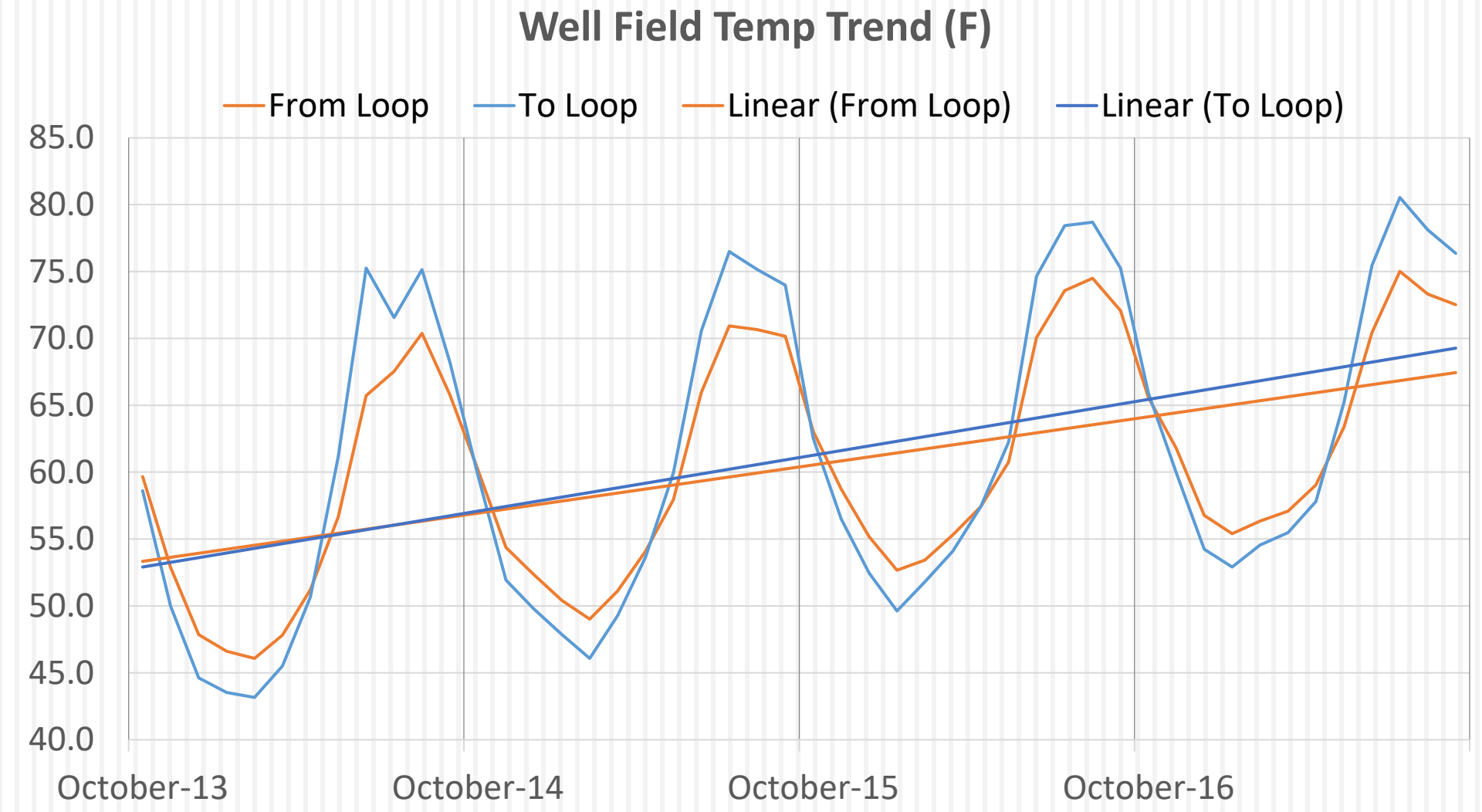
SW 40th TEF-Annual Energy



SW 40th TEF-Annual Load



SW 40th TEF-Well Field Temps



SW 40th TEF-Well Field Temps

Possible Heat Pump Issues with Thermal Build-up

- Decreasing efficiency in cooling mode
- Potential of tripping heat pumps due to high condensing temperature
- Decreasing heat pump capacity in cooling mode

Considerations to address Thermal Build-up

- Have Customer repair domestic heating hot water heat pump
- Increased operation of customer in-floor heating in sally ports
- Increased operation of ice melt system in customer driveways
- Installation of a fluid cooler

SW 40th TEF-Backup Generation

Two-story filter house

Lower Supply Fans

3, 1.86 MW, No. 2 fuel oil generators with room for 4th. 61 seconds from outage to full utility backup for both detention facility & plant.

Description	Cost (2010 $'s)
Preliminary Design	52,645
Backup Power System Design	551,516
Geothermal System Design	144,413
Procurement & Installation of Backup Power System	5,220,855
Procurement of Heat Pumps	1,224,121
Construction of Geothermal Plant	6,252,667
Construction of Geothermal Well Field	1,800,900
External Consultant Geothermal System	1,018,007
Construction Management Geothermal System	569,313
Project Finance-Geothermal	23,299
Project Finance-Backup Power	22,740
Total	$16,880,476

SW 40th TEF-ARRA Grant

- Project Funded in Part by a $5 million ARRA Grant received from the Department of Energy in 2009
  - Required quarterly and annual progress reports
  - Close-out report
  - Buy America Act compliance
  - Davis-Bacon compliance
  - Financial Audit
- Results of Final DOE report performed by Oak Ridge National Labs (ORNL/TM-2016/461)
  - Achieved 27.3% source energy savings vs. conventional system saving $68,000 per year (feasibility study indicated 29%)
  - Reduction of carbon dioxide by 25.5%
  - Saves 3.1M gallons of water per year by eliminating cooling tower resulting in nearly $10,000 of savings
  - Additional energy savings could be achieved by optimizing circulating flow rate during low load conditions

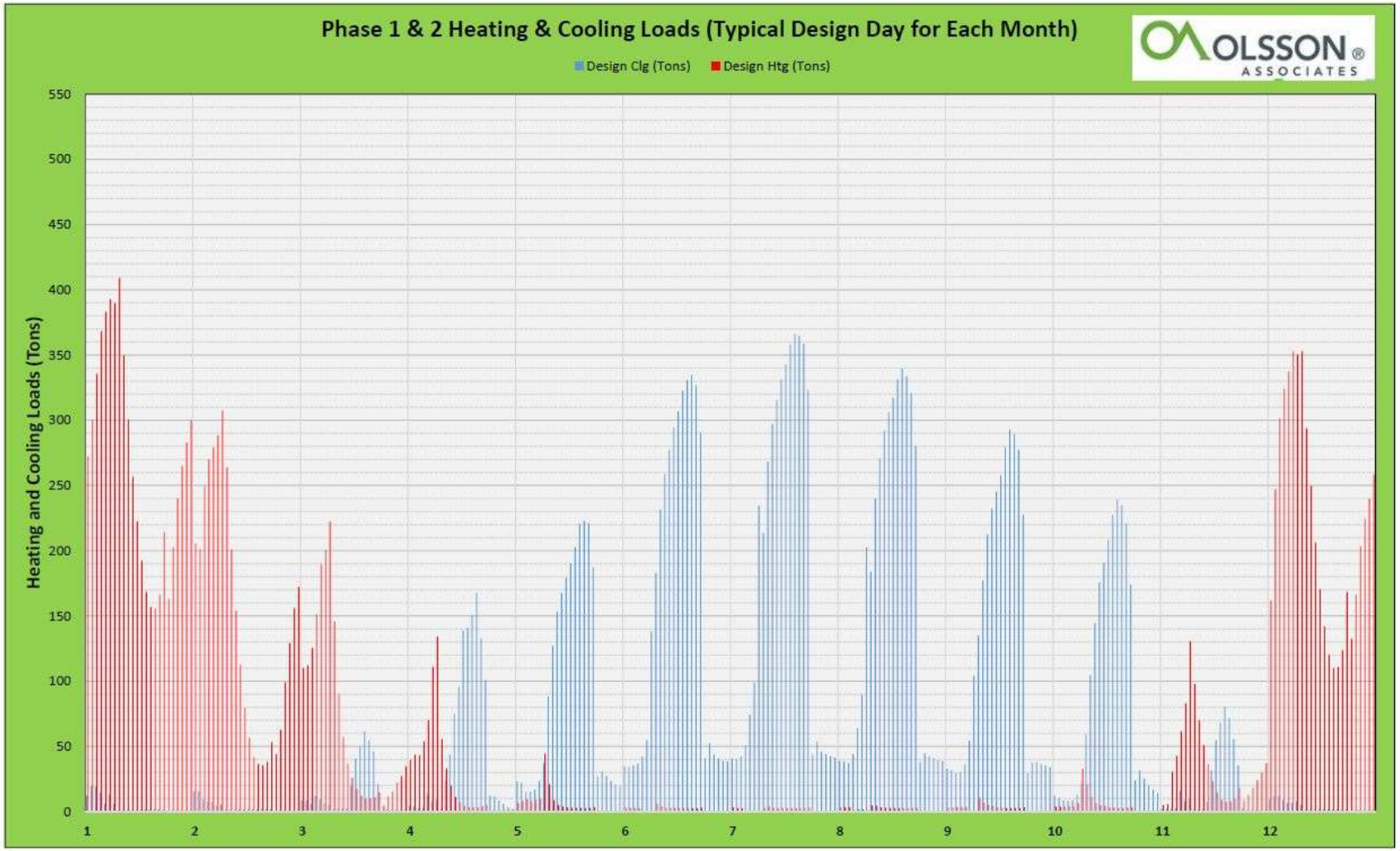
SW 40th TEF-Lessons Learned

- Locate plant “outside” perimeter of compound (depending)
- Plan for initial timing of providing full service heating/cooling relative to customer’s commercial operation date to avoid well field temperature extremes
- Develop a flush plan for the well field early on in the process
- GPS the borehole locations
- Install tracer wire for the HDPE header pipes from well field
- Perform an evaluation to determine best type of water treatment and whether glycol is necessary
- Have an expansion plan for well field, mechanical equipment, and distribution piping outside the building, particularly for well field
- Ensure contractors have proper training for fusing HDPE joints
- Ensure customer understands backup power vs. life safety
- Consider cybersecurity for controls & remote monitoring

LES Operations Center Thermal Facility

Geothermal Heat Pump system very similar to SW 40th TEF
Currently under construction with a May 2018 completion

LES Operations Center Thermal Facility



LES Operations Center Thermal Facility

Installation of the Geothermal Well Field: 320 wells at 365 feet deep, 6” dia.

COMMENTS/QUESTIONS

Thank You