# Community-scale Geothermal Systems

for

## Energy Planning for Resilient Military Installations

December 6, 2017

Dan Dixon, P.E., Lincoln Electric System

# 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

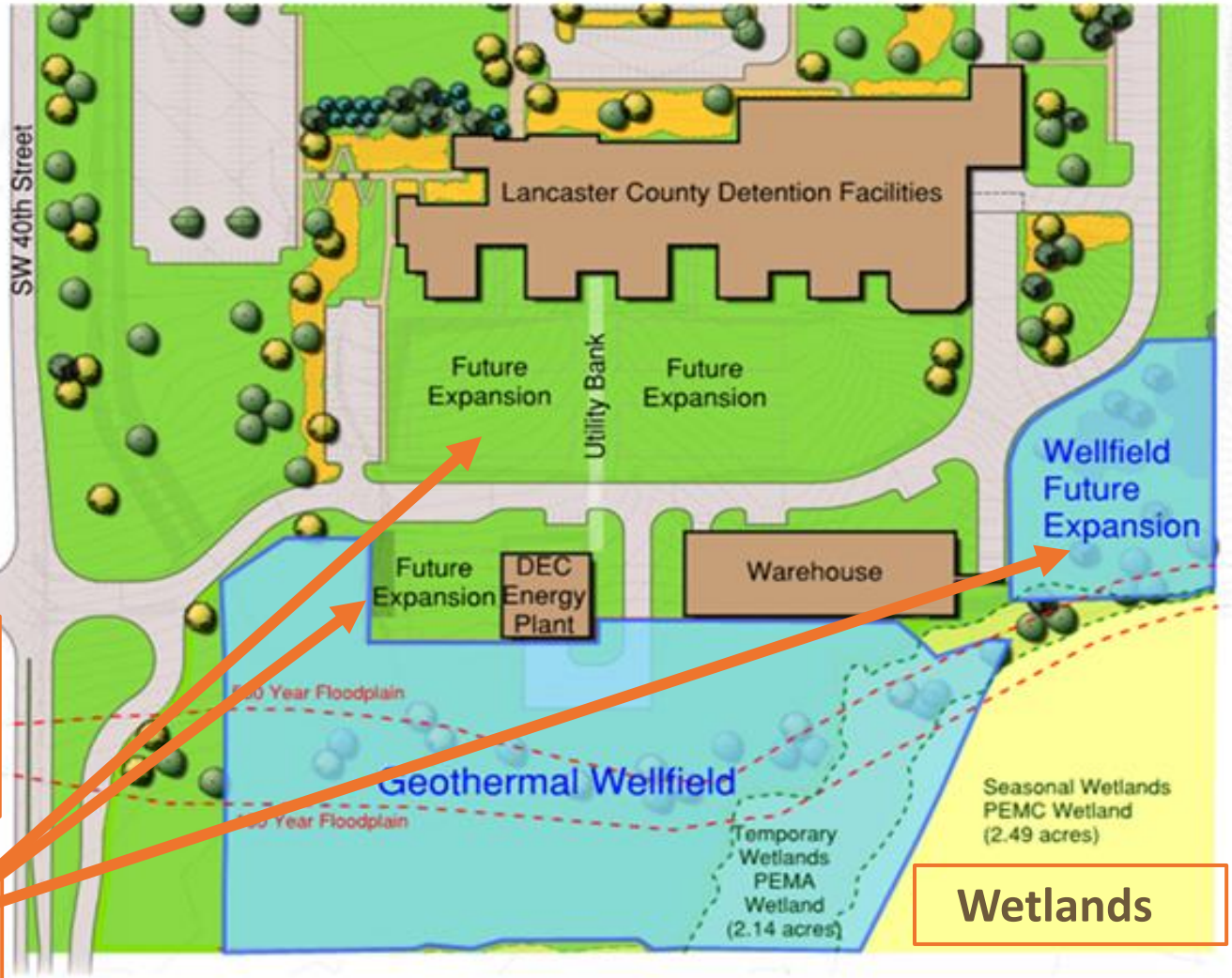
# SW 40th TEF-Compound & Well Field



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

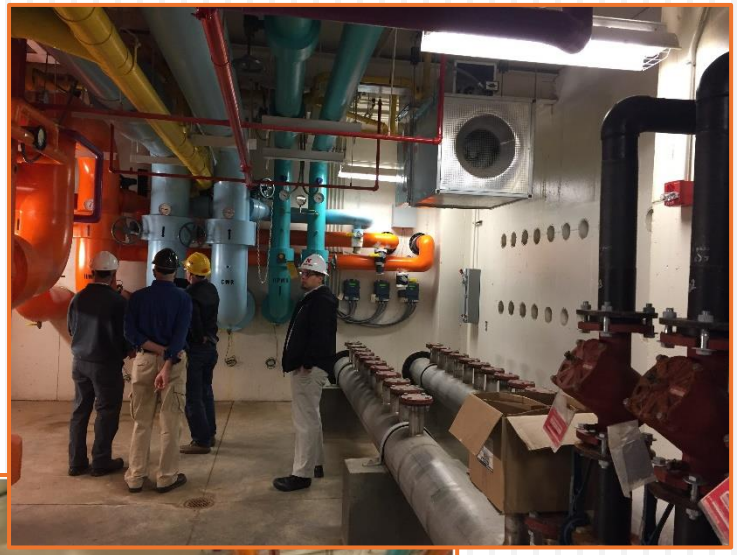
4 fields in 8 acres
667 bore holes, 300 ft. deep, 6" dia.

Note areas for future expansion



# SW 40th TEF-Well Field



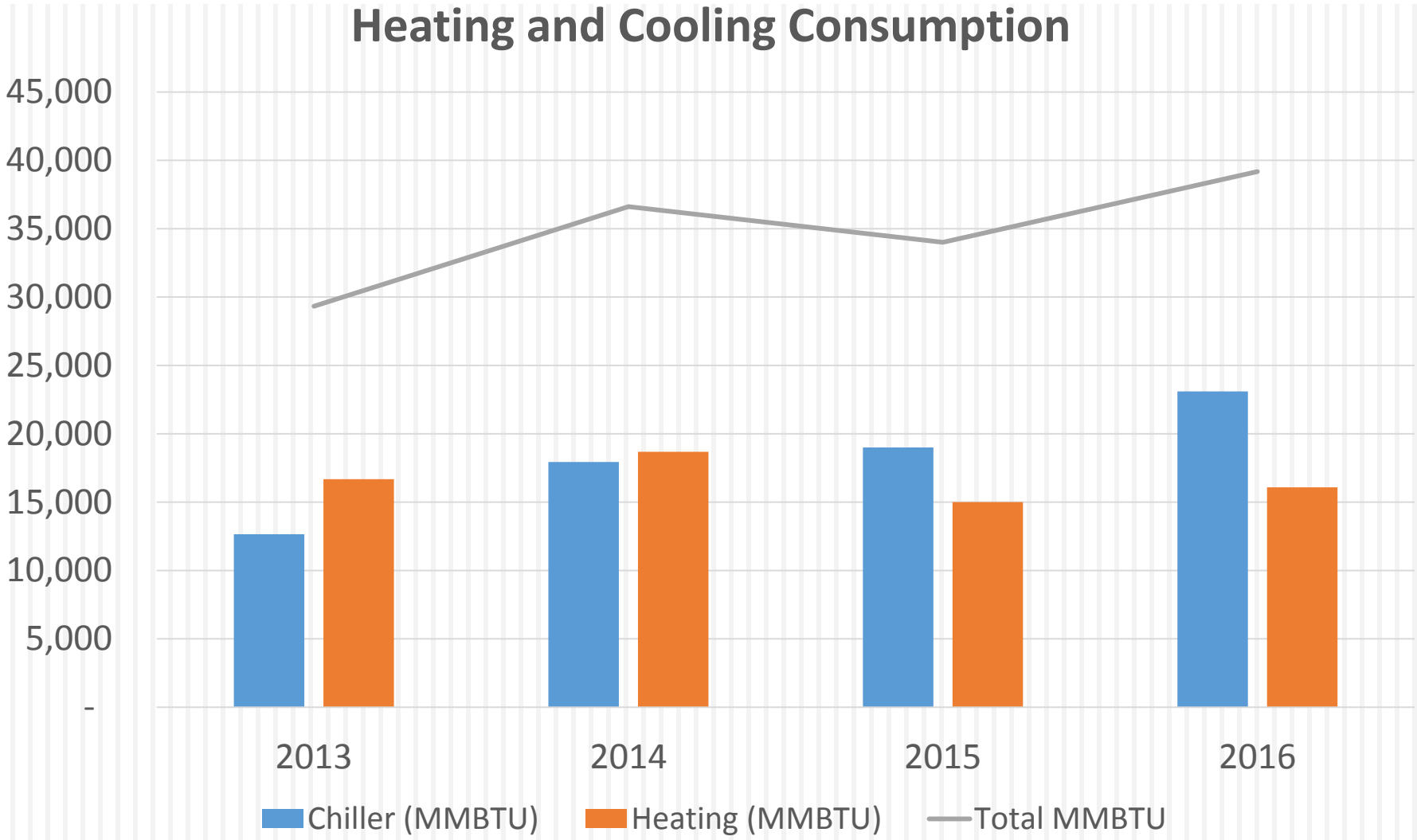


Well Field Headers entering basement of plant; note spare risers for future well headers. Basement allows for easy access.

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

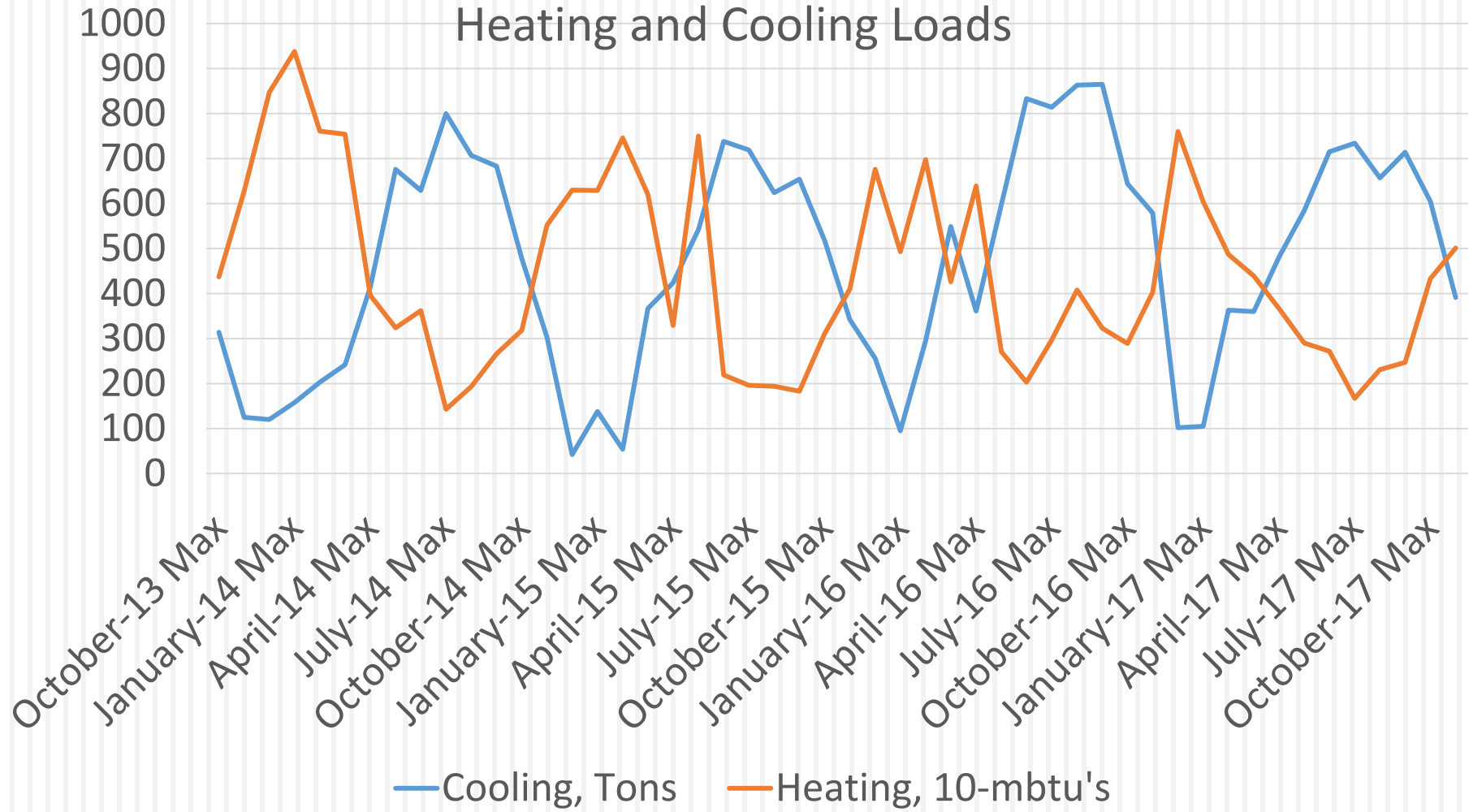
# SW 40th TEF-Annual Energy





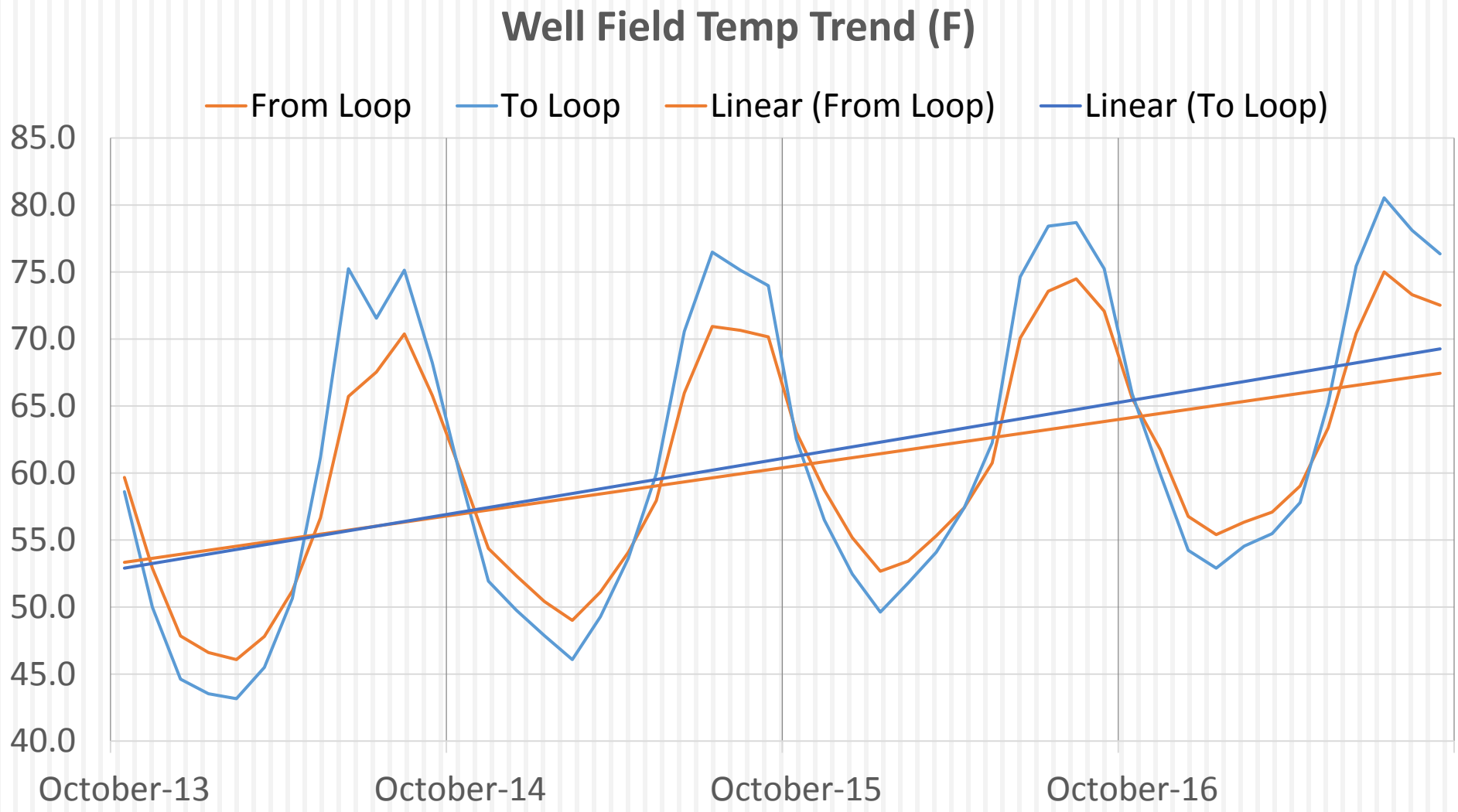
# SW 40th TEF-Annual Load





# 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

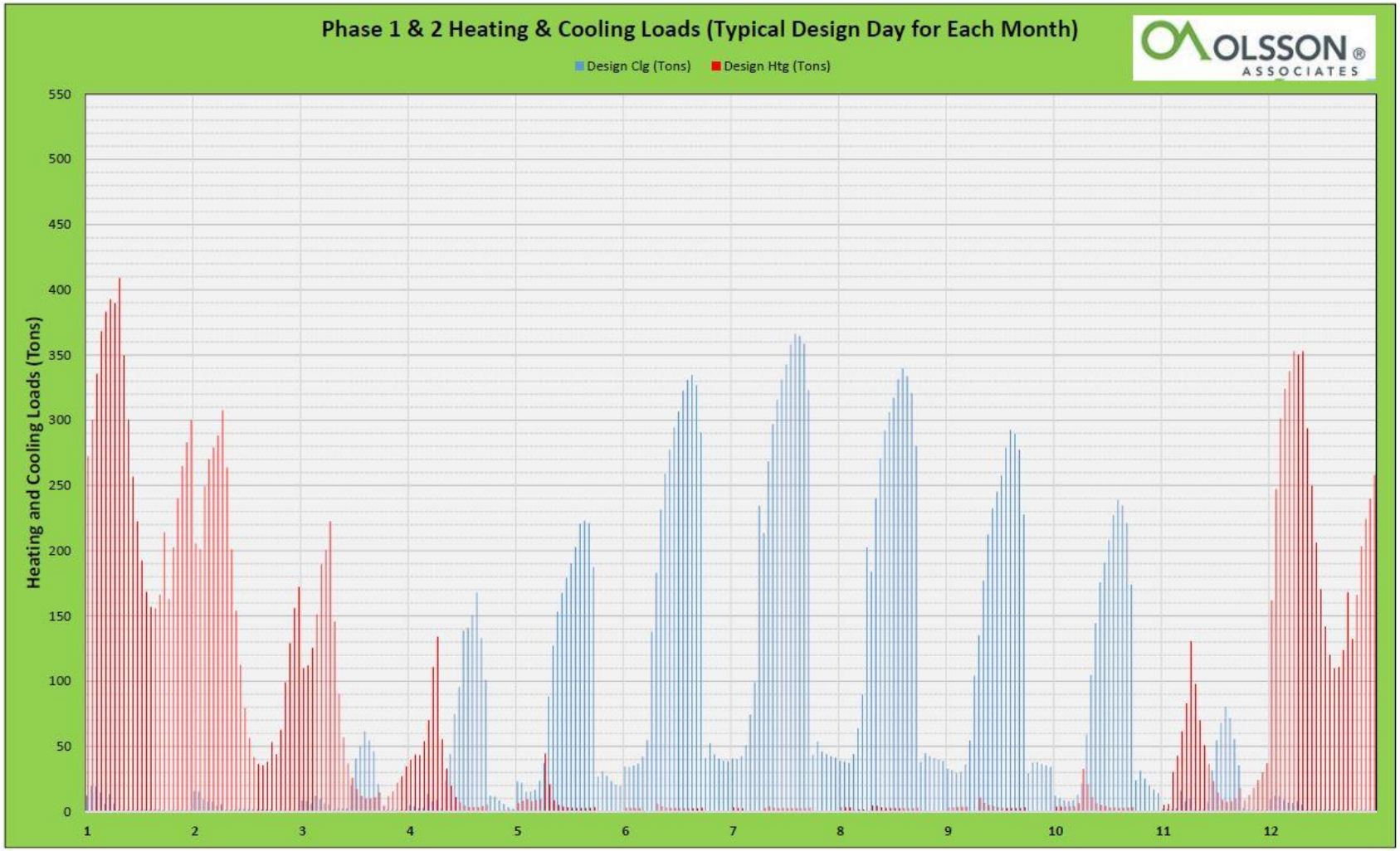
# LES Operations Center Thermal Facility



**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