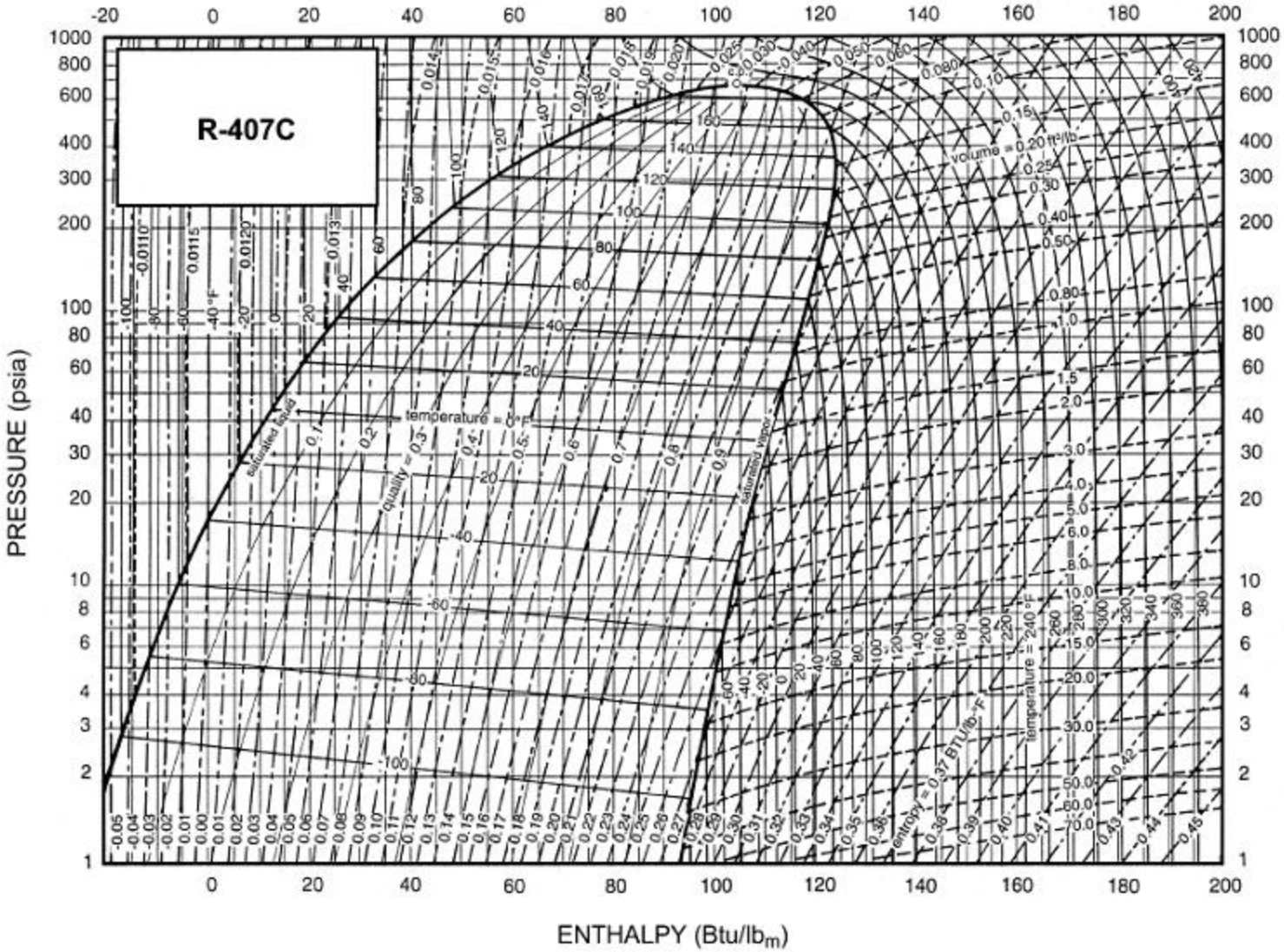
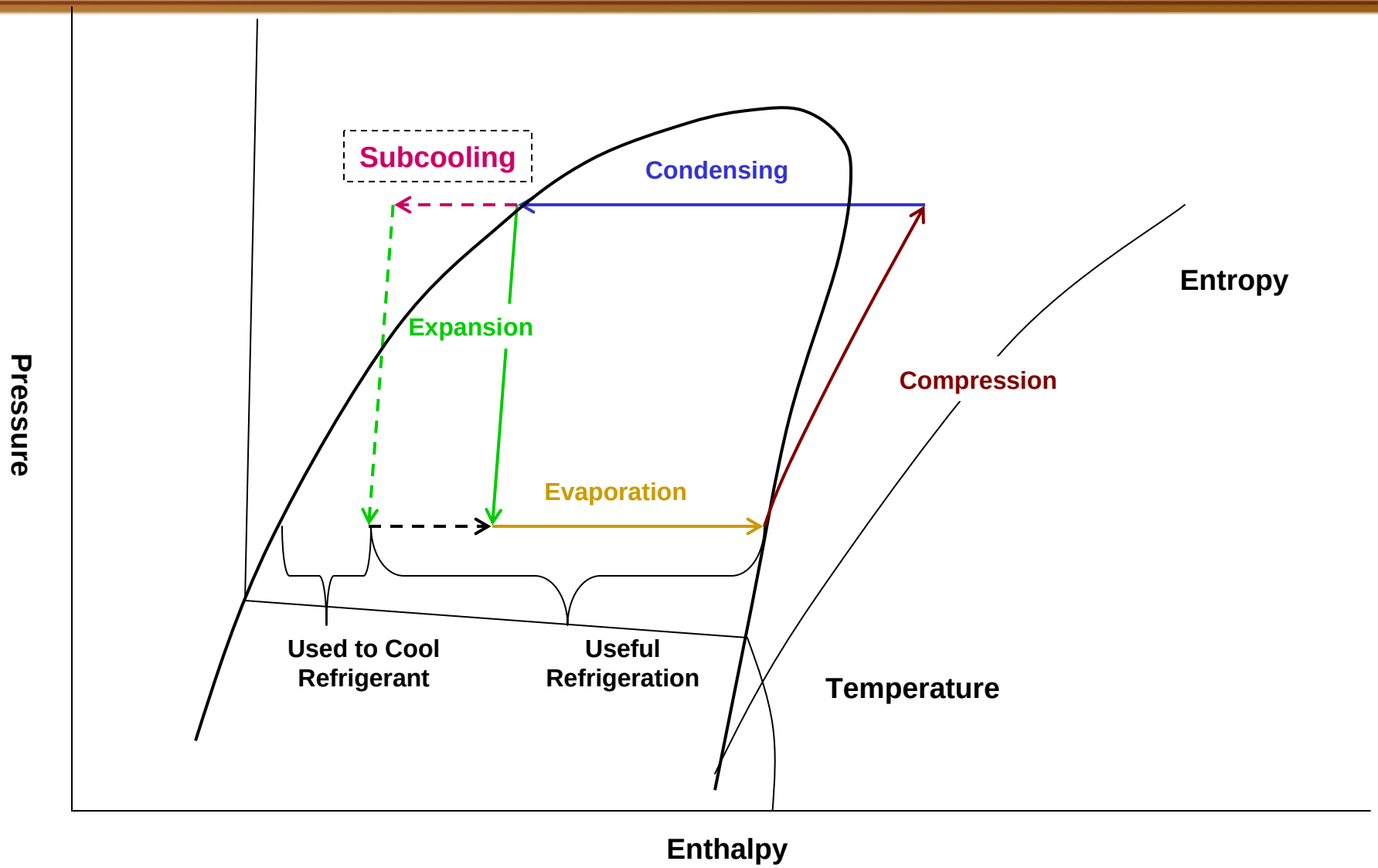
Supermarkets & Subcooling

No place for the faint of heart!

Why Subcooling?

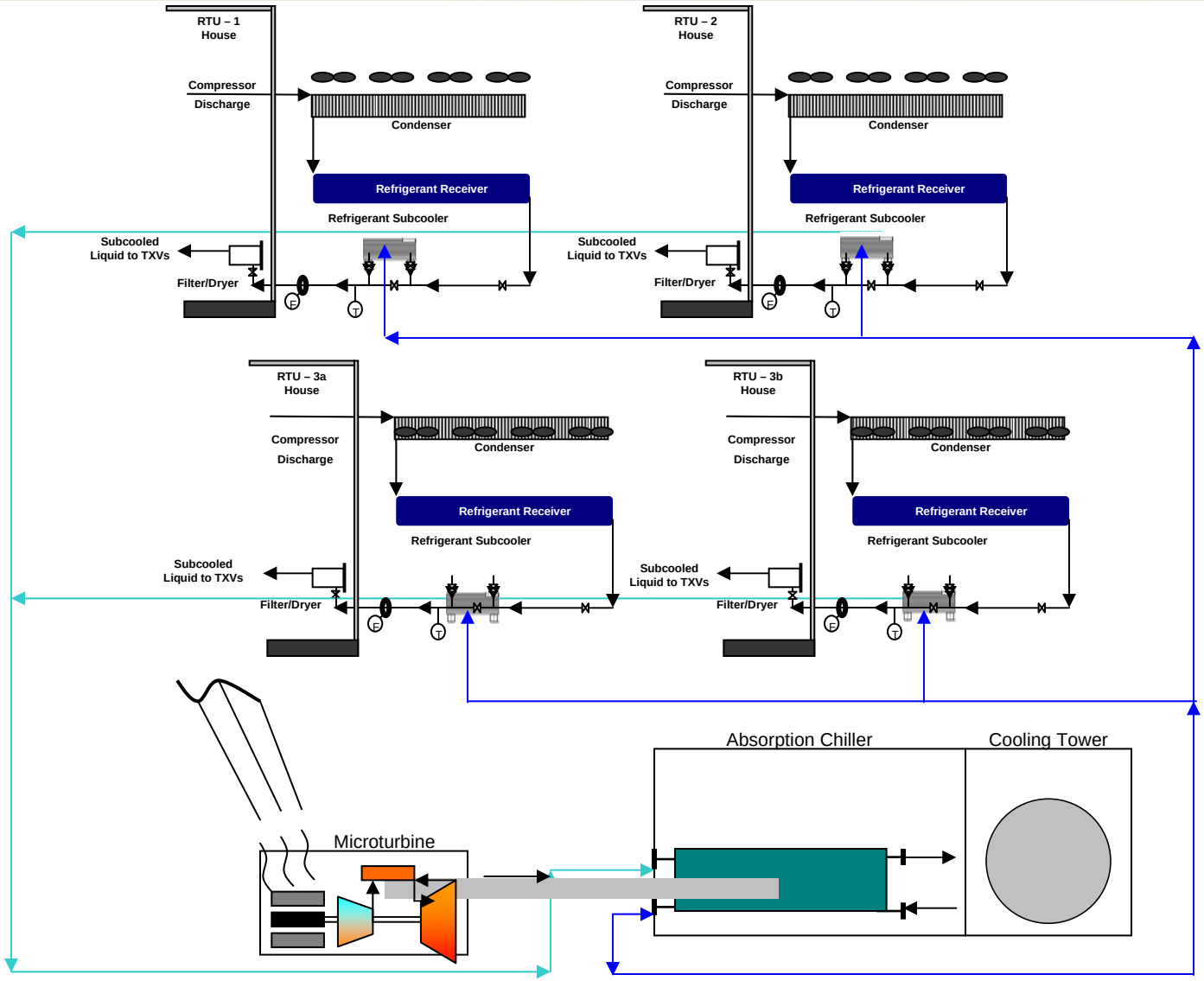


Why Subcooling?



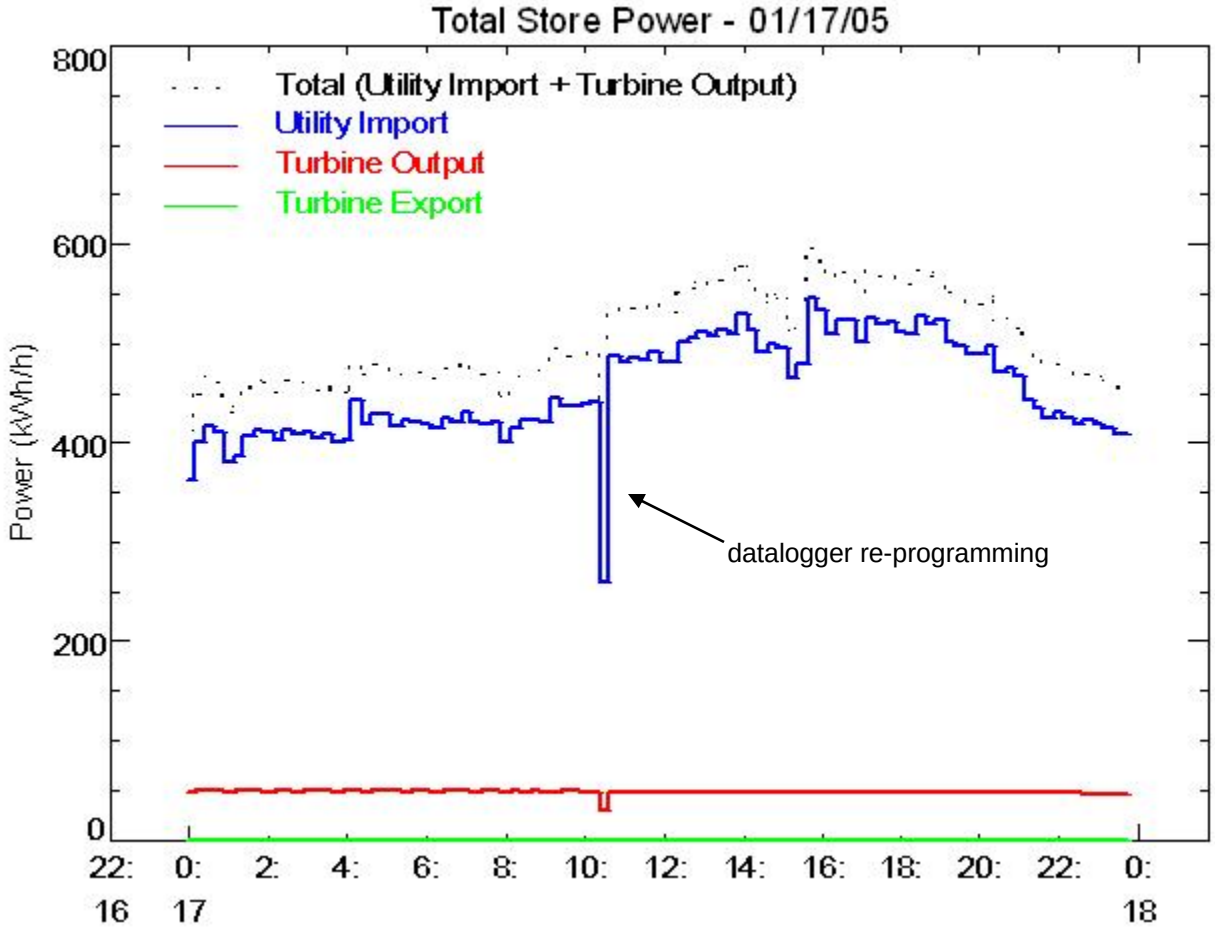
HEB

HEB Design


RTU – 1
House
Compressor
Discharge
Condenser
Refrigerant Receiver
Refrigerant Subcooler
Subcooled
Liquid to TXVs
Filter/Dryer
RTU – 2
House
Compressor
Discharge
Condenser
Refrigerant Receiver
Refrigerant Subcooler
Subcooled
Liquid to TXVs
Filter/Dryer
RTU – 3a
House
Compressor
Discharge
Condenser
Refrigerant Receiver
Refrigerant Subcooler
Subcooled
Liquid to TXVs
Filter/Dryer
RTU – 3b
House
Compressor
Discharge
Condenser
Refrigerant Receiver
Refrigerant Subcooler
Subcooled
Liquid to TXVs
Filter/Dryer
Absorption Chiller
Cooling Tower
Microturbine

The Installation

HEB Store Daily Power Use



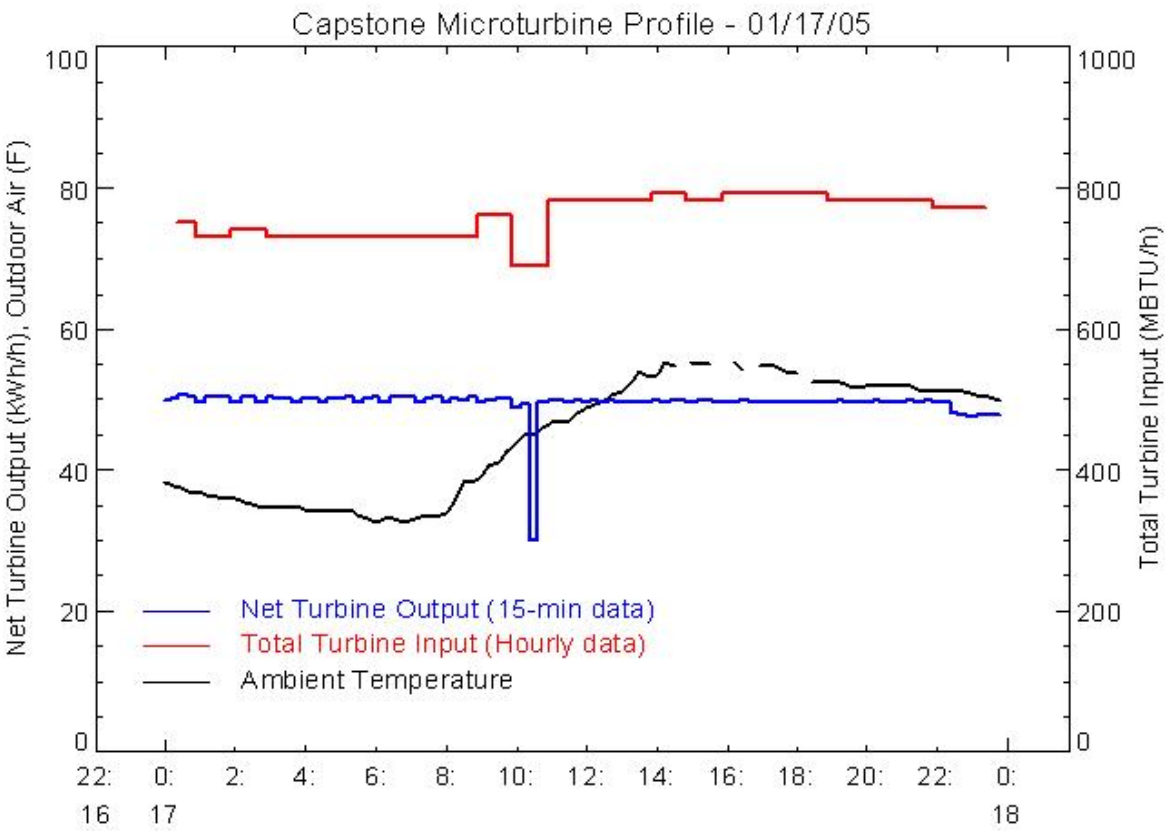
Peak Total Demand: 596.4 kW @ 03:45 PM
Peak Utility Import Demand: 546.7 kW @ 03:45 PM

Total Load: 12084.2 kWh
Utility Energy Purchased: 10895.6 kWh
Energy Generated: 1188.6 kWh
Energy Exported: 0.0 kWh

Capstone Turbine Performance

Net Turbine Output (kWh) : 1188.6
Total Turbine Input (MBTU) : 18261
Net Turbine Generation Efficency : 22.2%
Average Ambient Temperature : 44.5 F

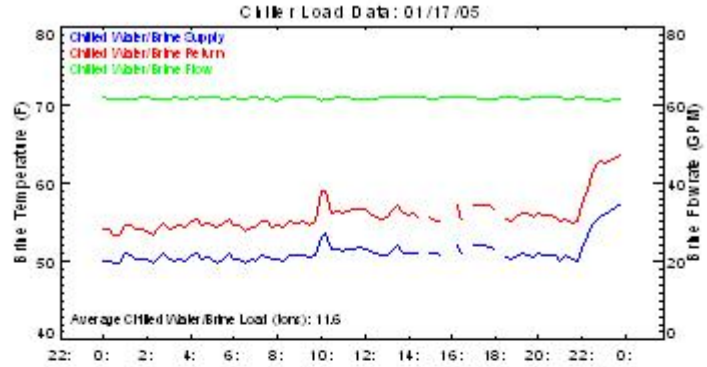
Net Power & Efficiency reflects gas compressor & chiller parasitics

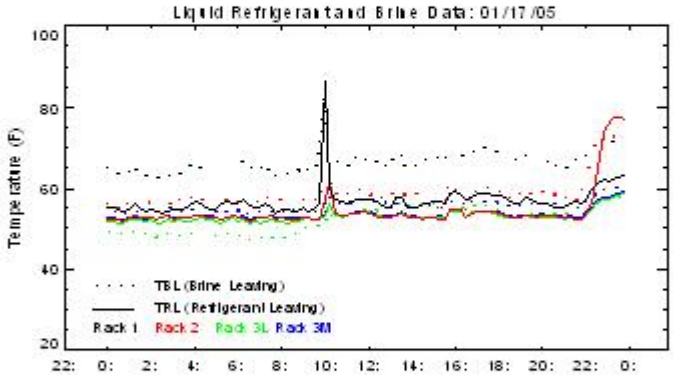


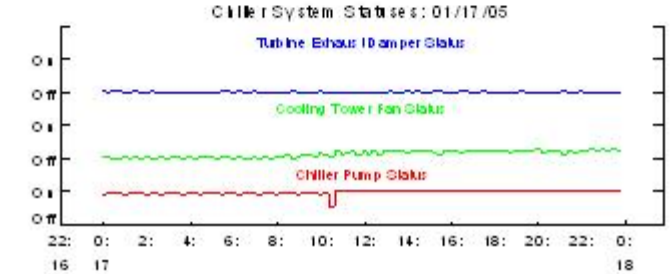
Broad Chiller Performance

Chiller Output: ~12 tons
(at 500-520F Exhaust & 52F CHW setpoint)

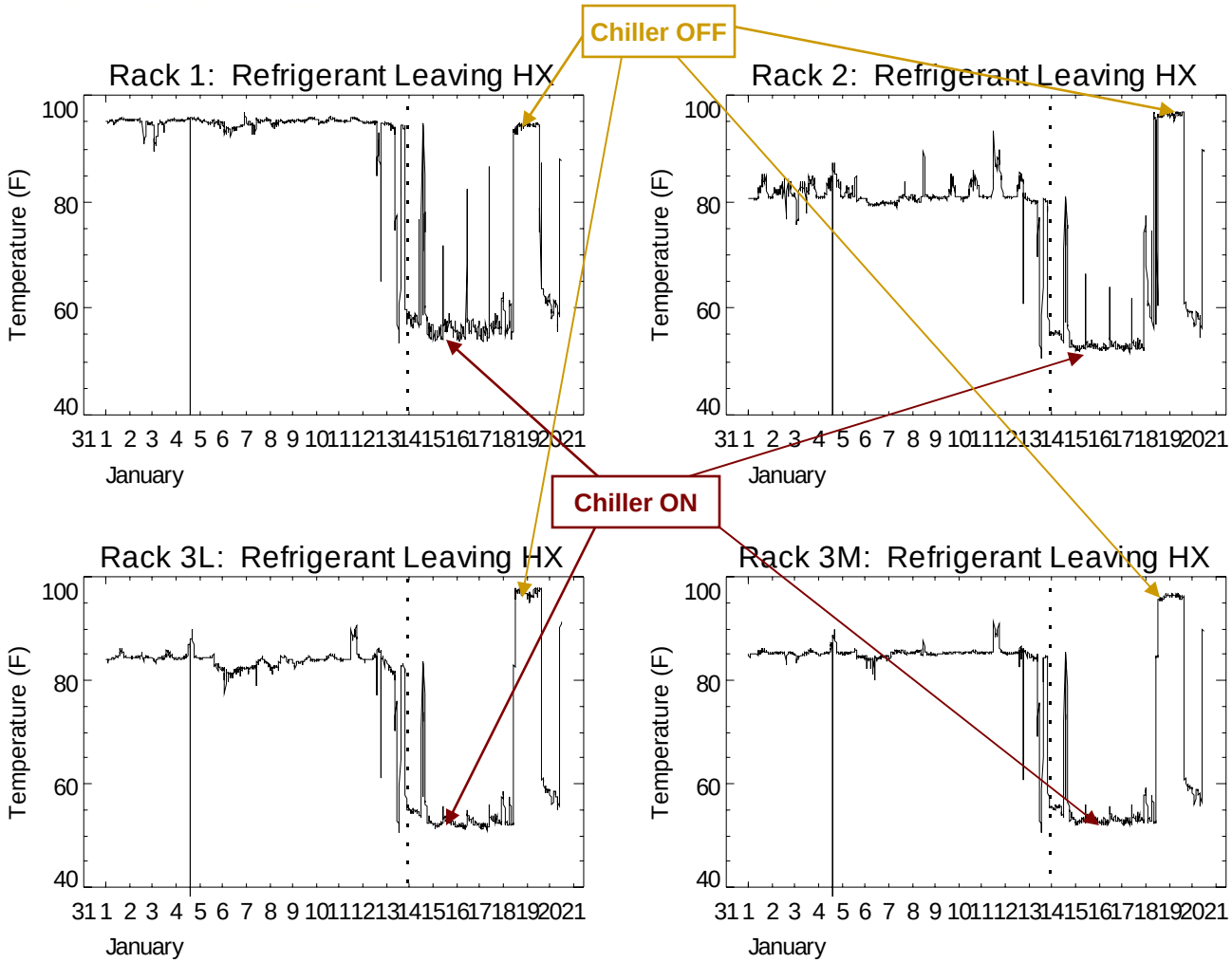
Higher exhaust and liquid refrigerant temperatures in spring/summer will increase load





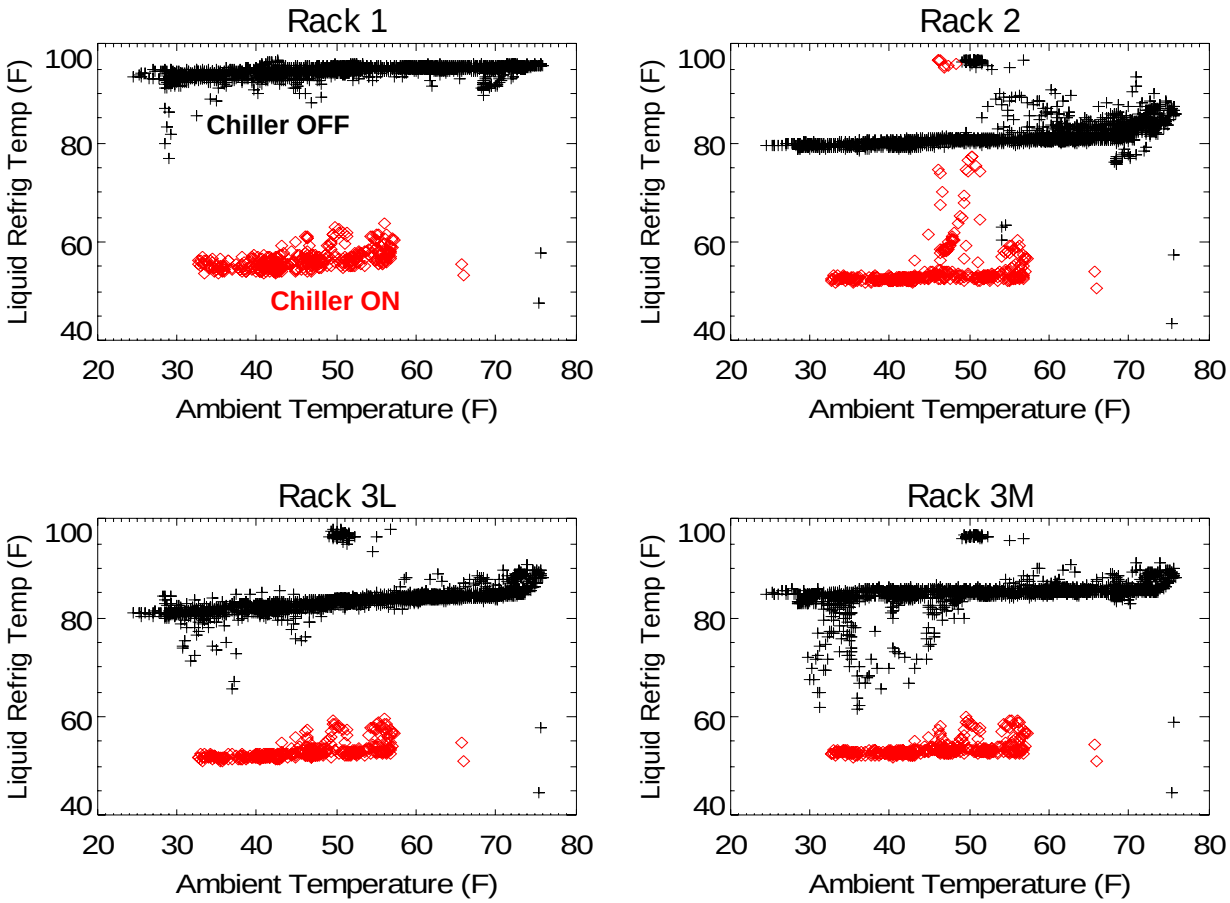


Refrigerant Liquid Temperatures

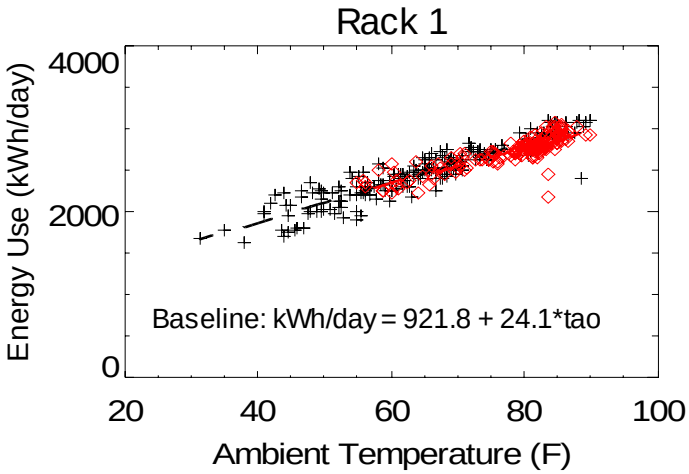


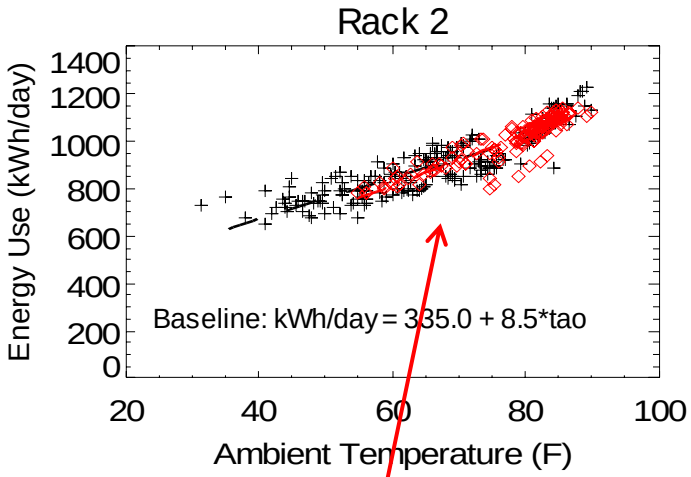
Note: Hussmann expansion valve tune-up started on Jan 14. Now all liquid temperatures are 90-95°F with chiller OFF

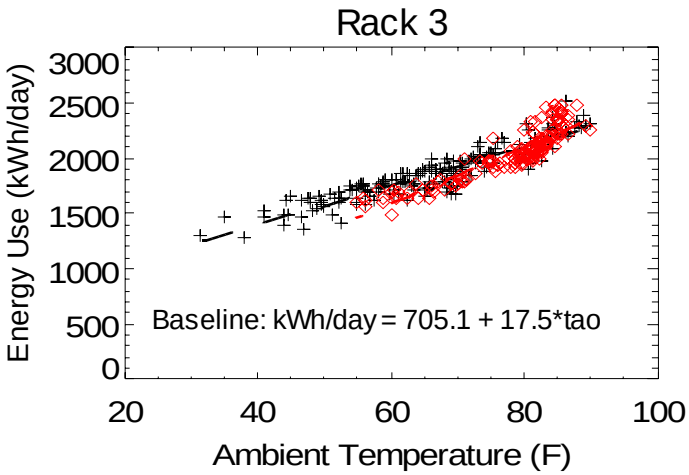
Rack Liquid Refrigerant Temperatures



Variation of Daily Rack Energy Use with Ambient Temperature

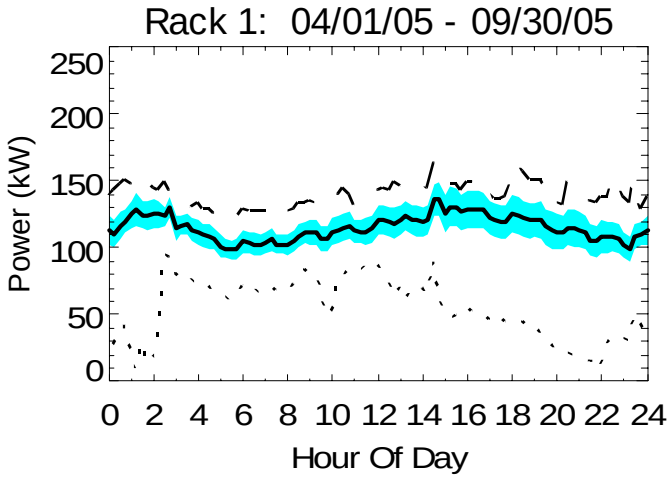


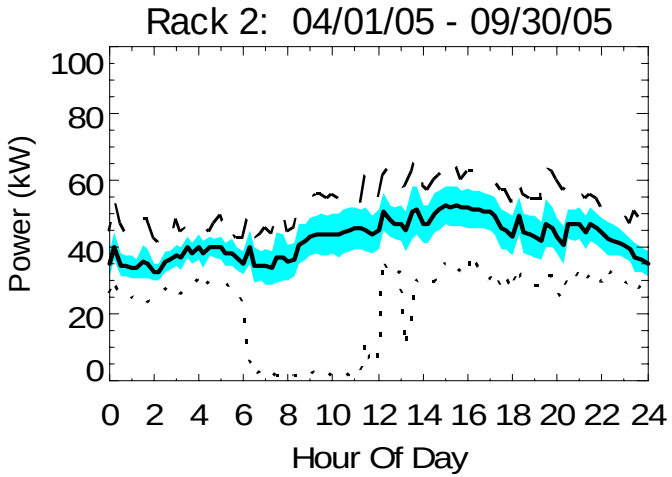


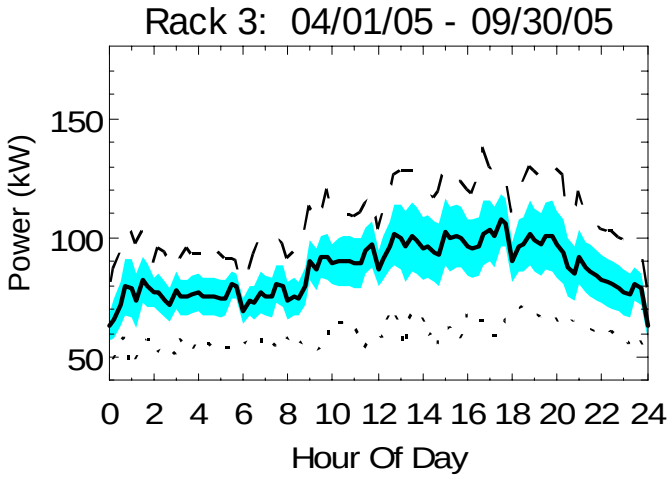


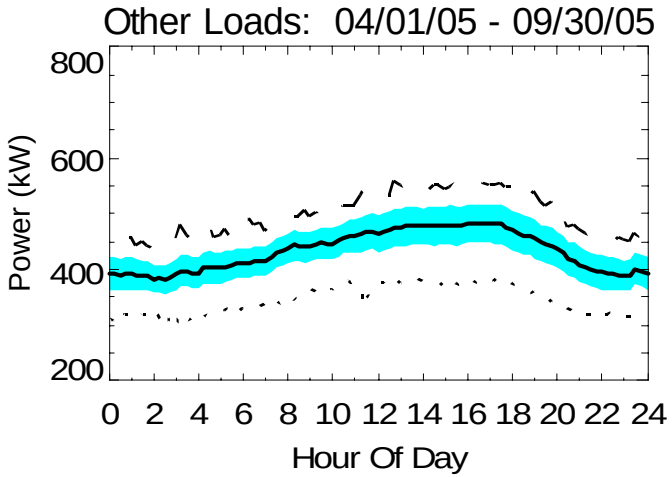
Liquid Refrigerant Subcooling/Chiller ON

Average Demand Profile for Refrigeration Racks 1-3 and Other Loads

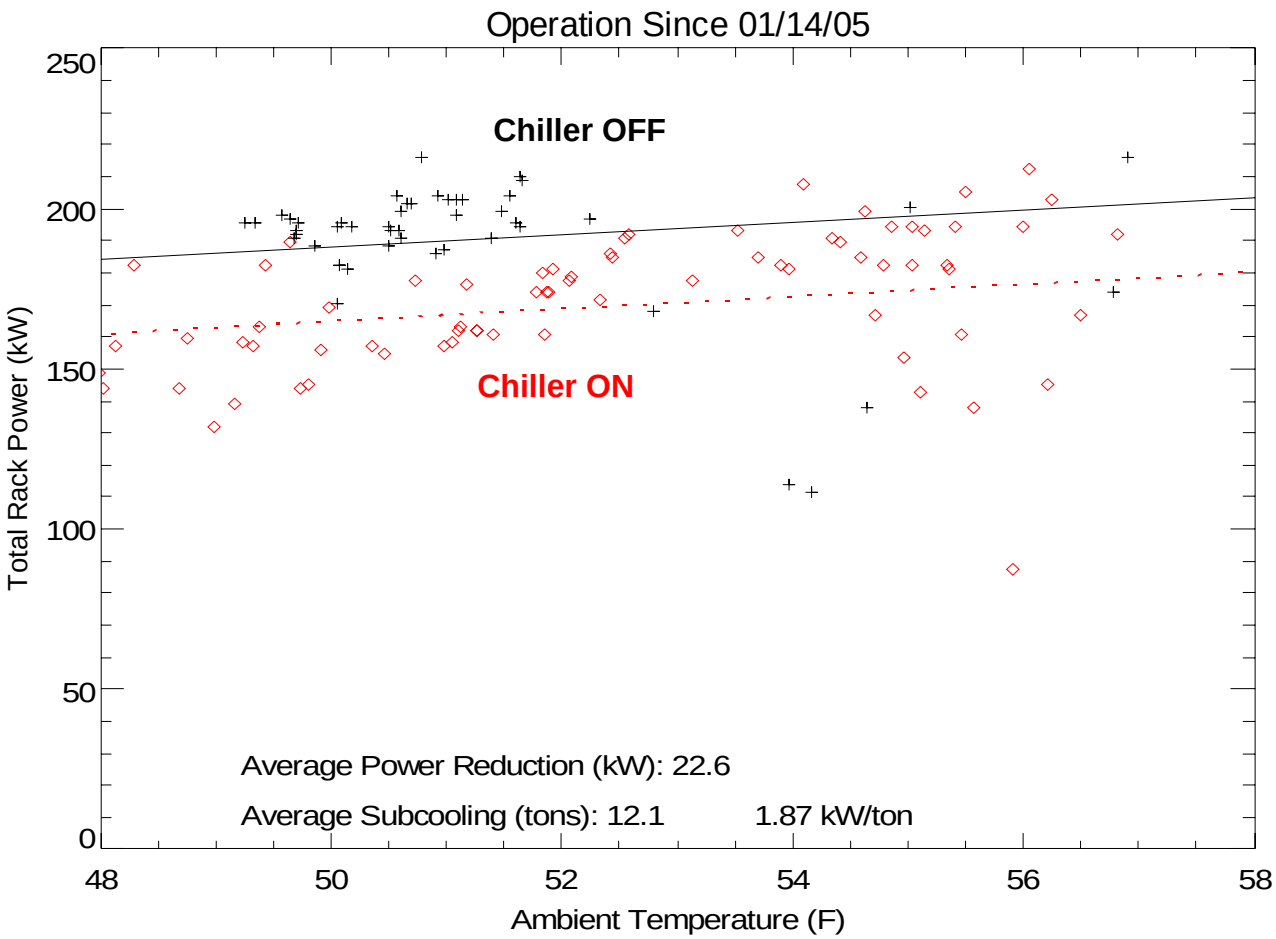








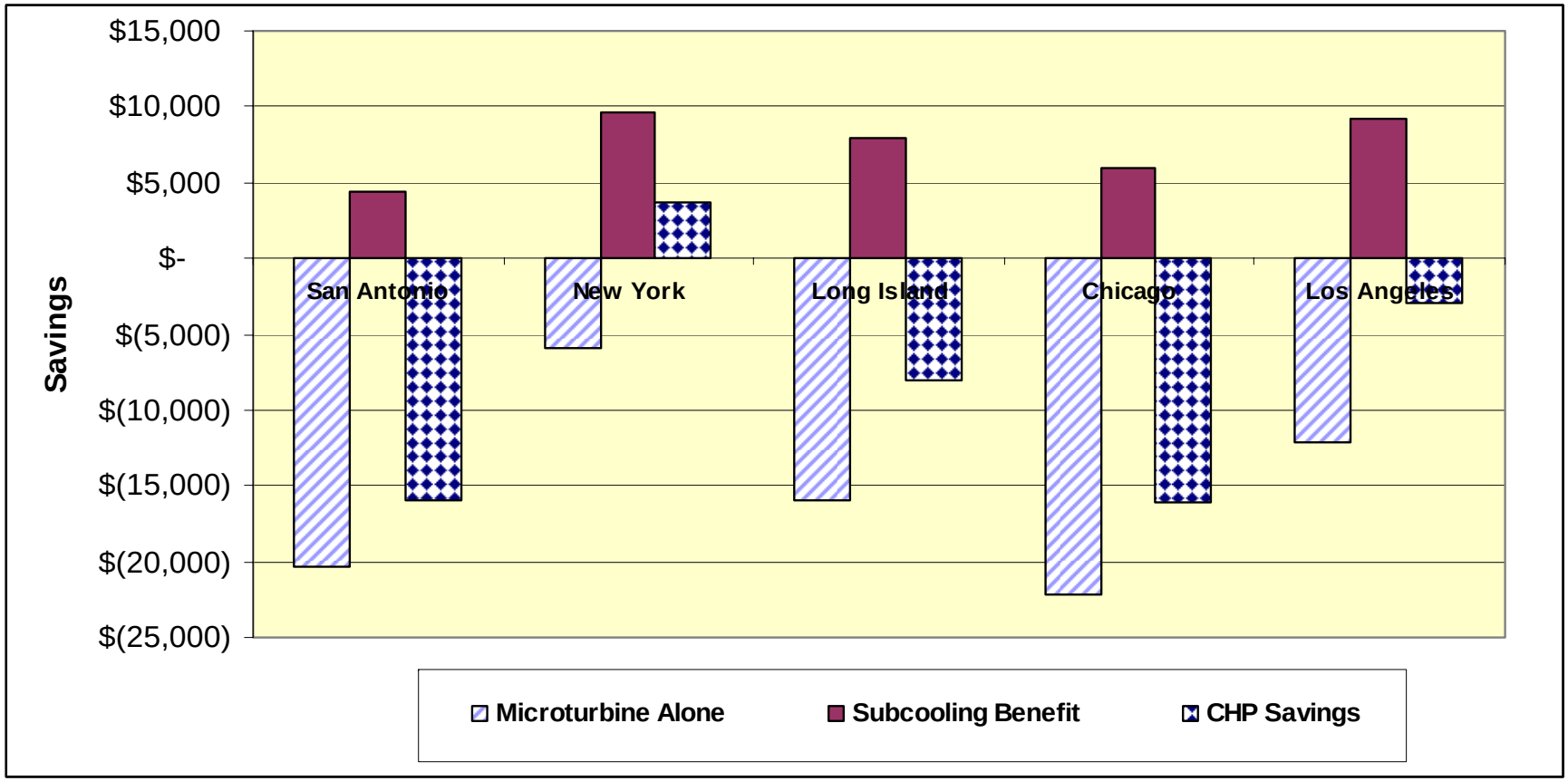
Impact of Subcooling on Rack Power



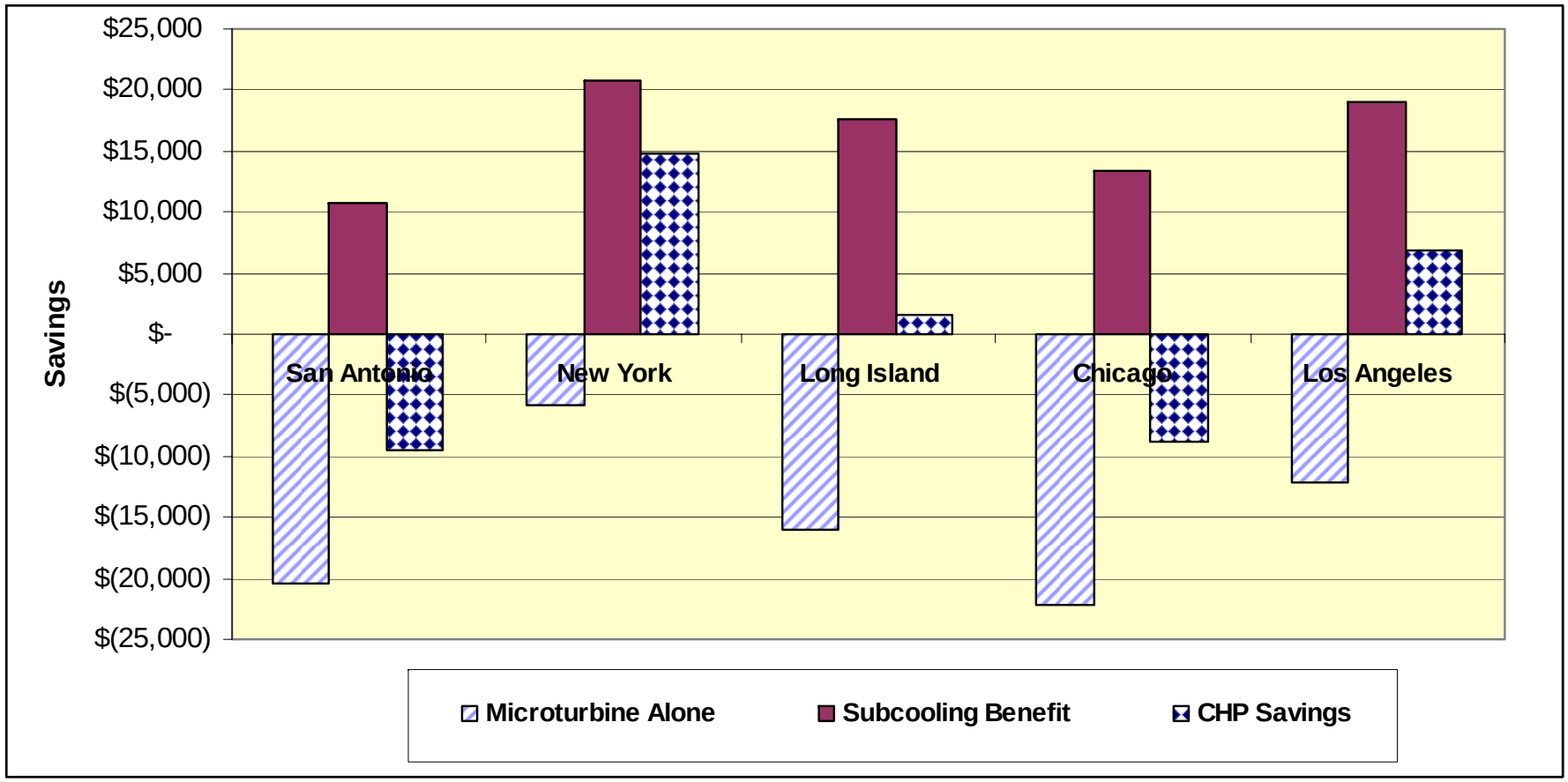
Show me the money

Item	Unit Cost	Size	Cost
Microturbine (C60, gas compressor, etc)	$1,100/kW	60 kW	$66,000
Packaged Chiller		18 tons	$48,000
Field Electrical			$7,000
Field Plumbing, Rigging, Coordination, etc.			$30,000
Total Cost			$151,000

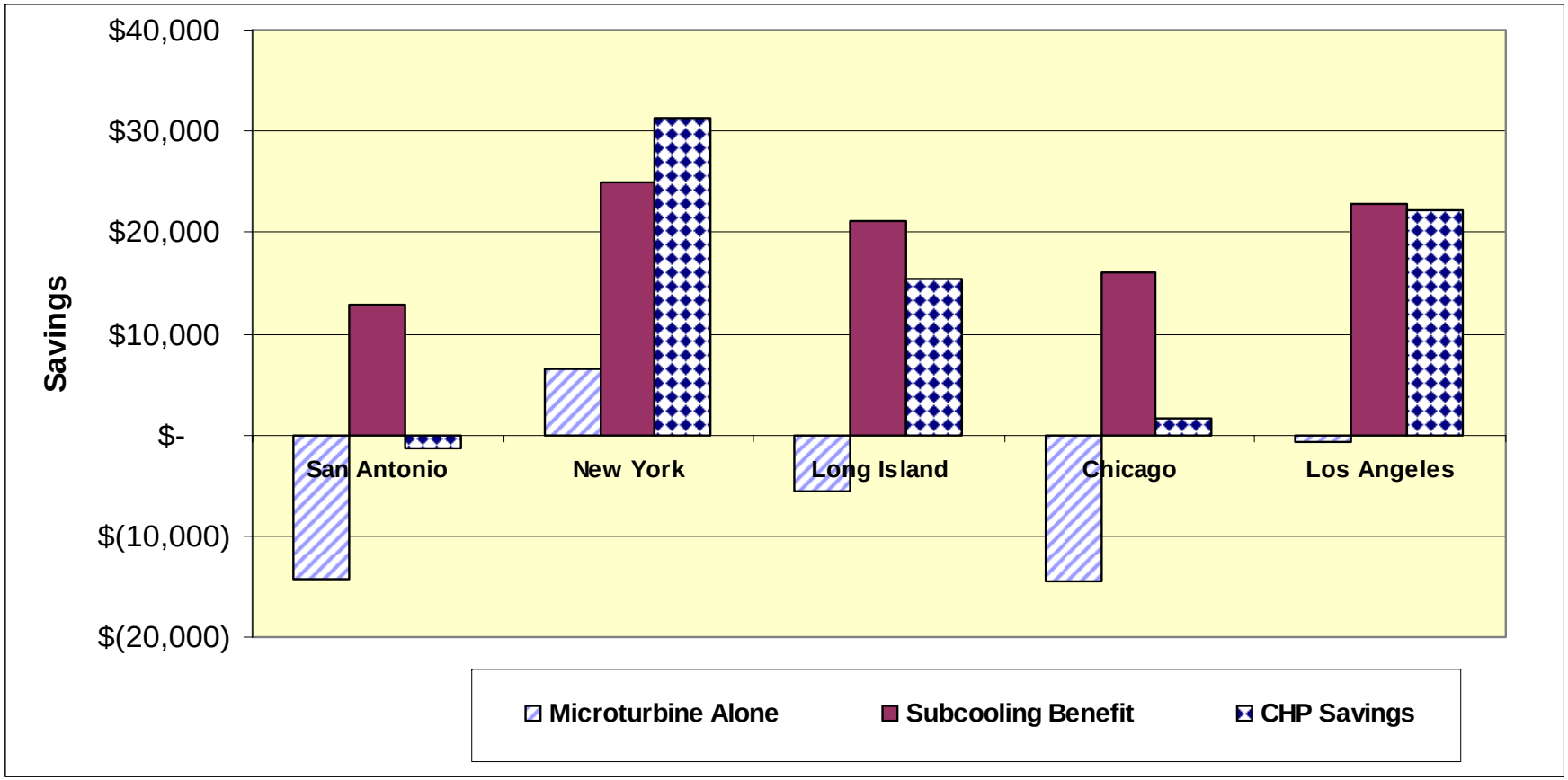
The system as tested at HEB is not cost effective anywhere in the US, in part because of the poor system performance.



If the chiller had performed as expected, the economics of the system improve.



What emerges by projecting a 20% price increase is that the payback in New York reaches 5 years, approaching 7 years for LA



HEB Lessons Learned

- Liquid refrigerant subcooling is indeed a constant requirement of a supermarket.
- Liquid subcooling alone is not enough value to justify applying a CHP system to a supermarket under today's energy economics.
- The temperature which one can subcool to is limited by display case performance. The HEB site was limited to a minimum of 52 ºF chilled water temperature versus our original design of 41 ºF which did impact the system performance.
- Packaged thermally activated chillers must be designed specifically for exhaust gas duty and all subsystems (pumps, fans and controls) must be designed for the CHP application.

HEB Lessons Learned

- Small CHP installations are highly dependent on very low parasitic power requirements (HEB CHP parasitic power was equal to half of the subcooling savings)
- Absorption chiller control system logic needs to be reconciled to the desired performance. In this case the chiller control logic was unable to provide increased capacity as chilled water temperature was allowed to rise (based upon incoming chilled water – a function of ambient). Proper operation would have seen an increase in chiller capacity.
- Displacing electricity (directly with the microturbine and indirectly with subcooling) during time of high gas price and “not-so-high” electric prices is not economically successful.

A&P

The Equipment Concept

Three Operational Modes:

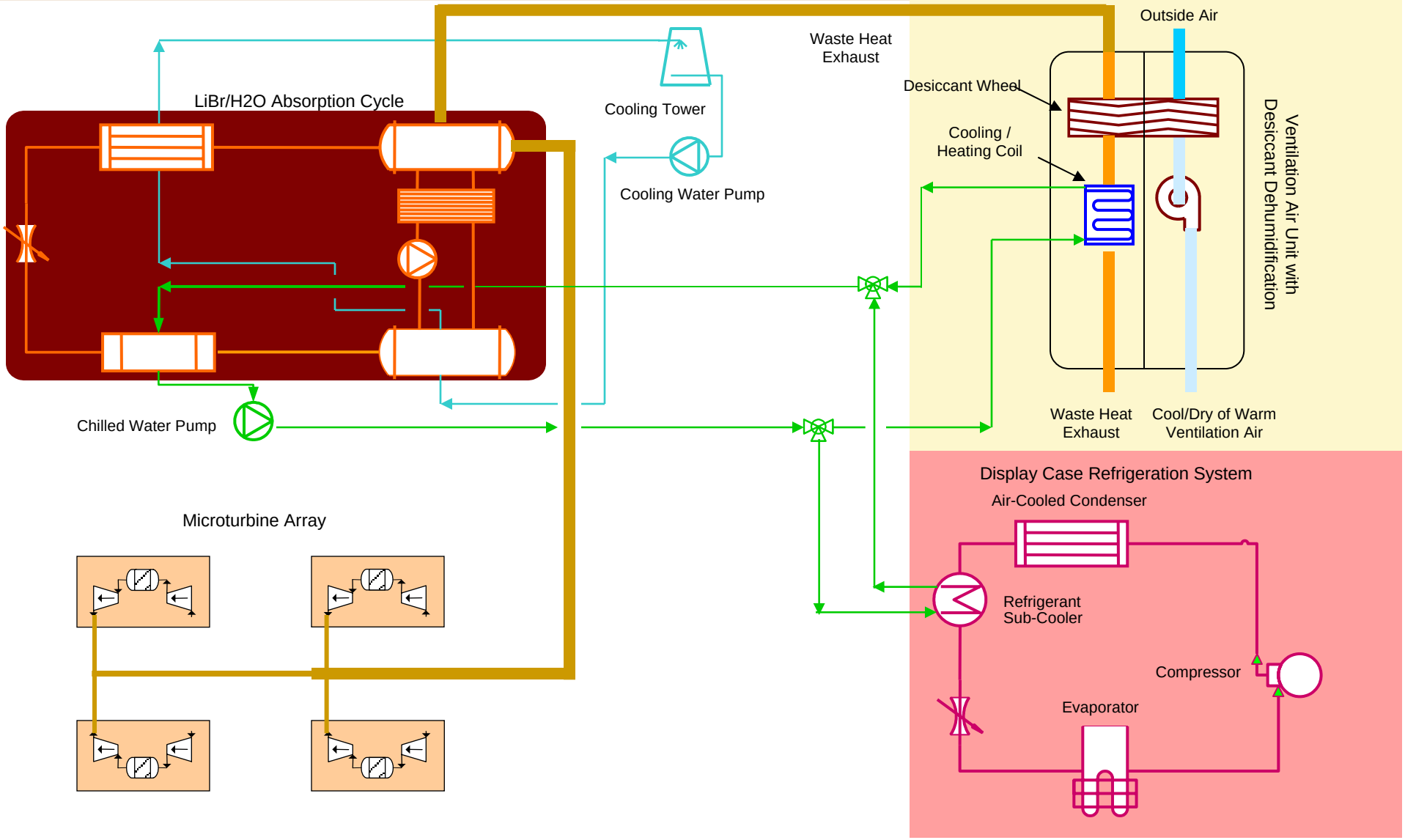
- Power Only
- Power and Cooling
- Power and Heating

First Generation:

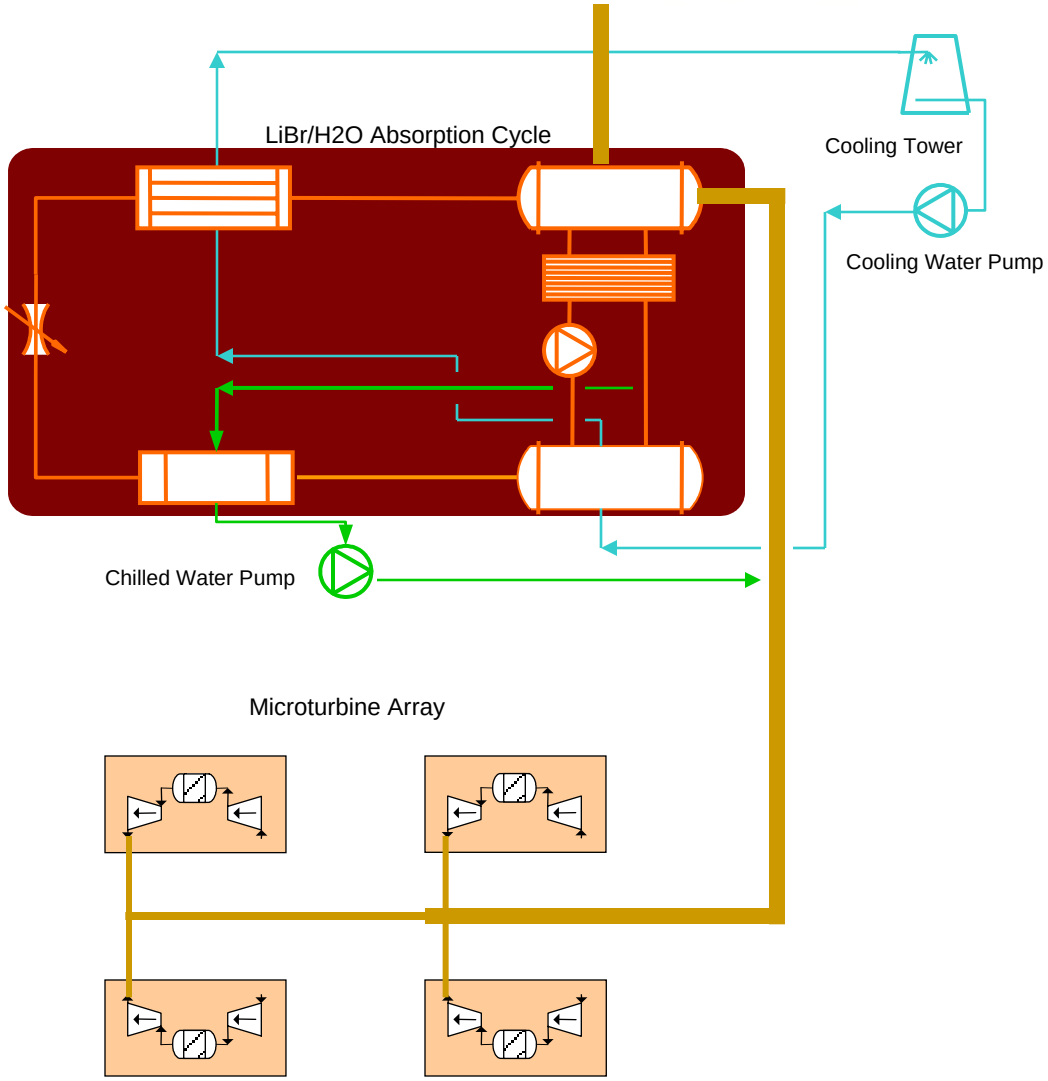
- 240 kW
- 110 RT Cooling
- 900 MBh Heating

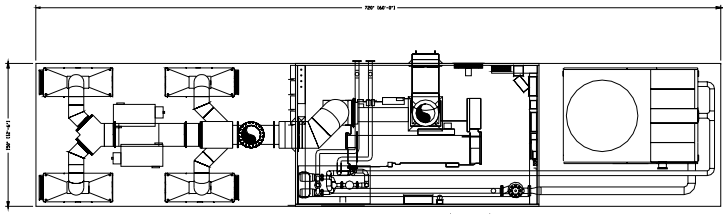
Getting it There was Half the Fun

System Integration at A&P

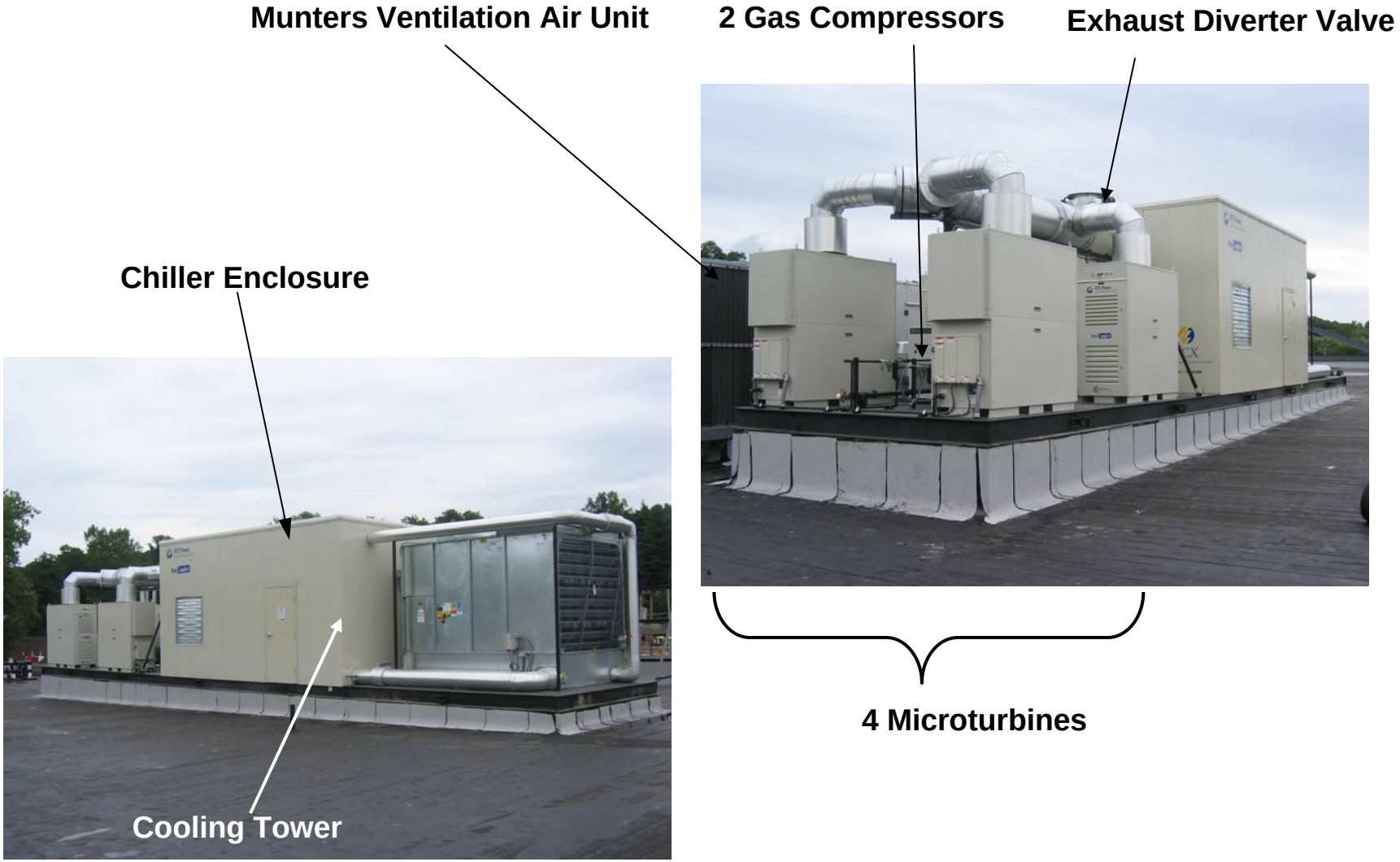


CHP Module at A&P

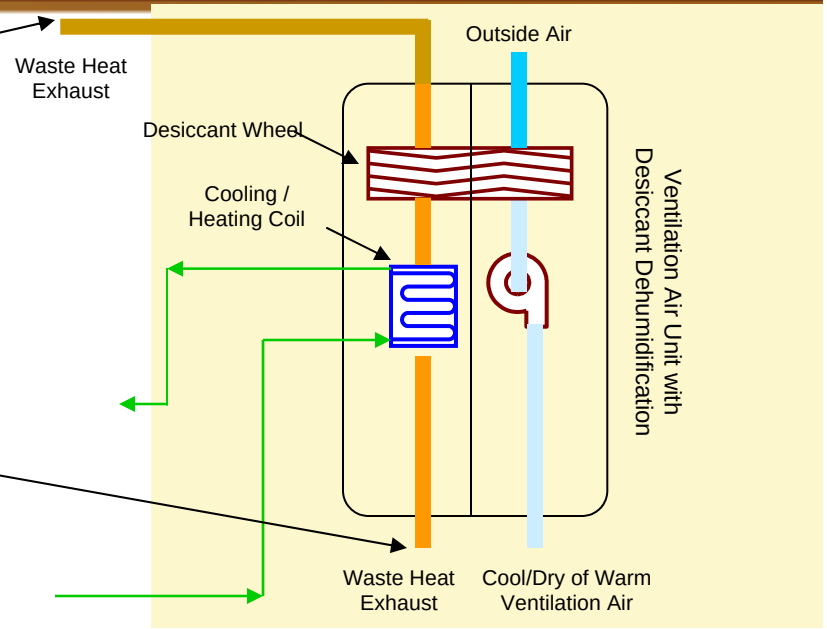




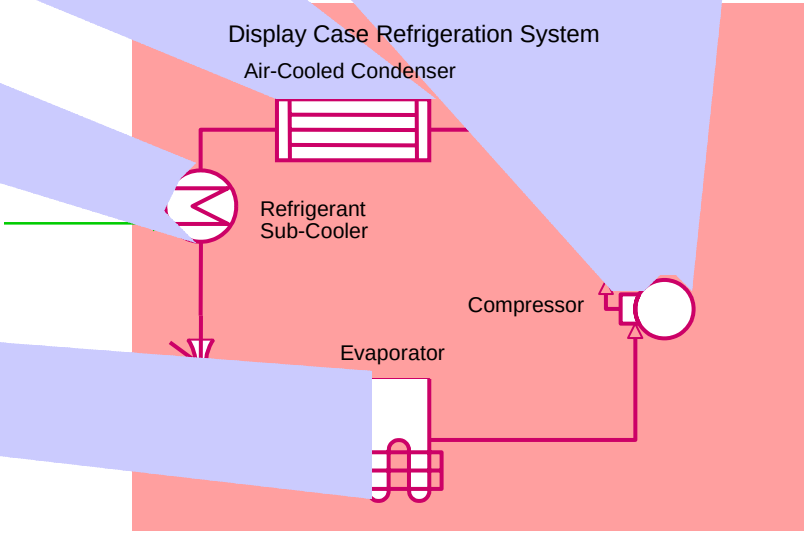
PureComfort 240 @ A&P



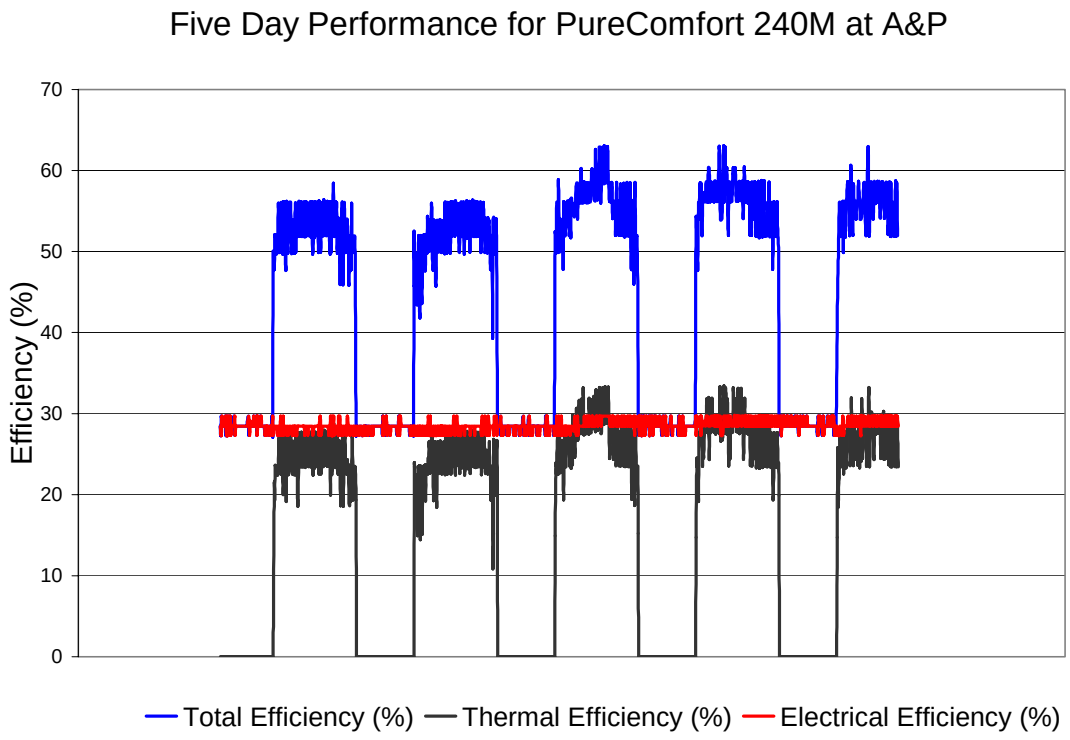
System Integration at A&P



Refrigeration Subcooling at A&P



Performance

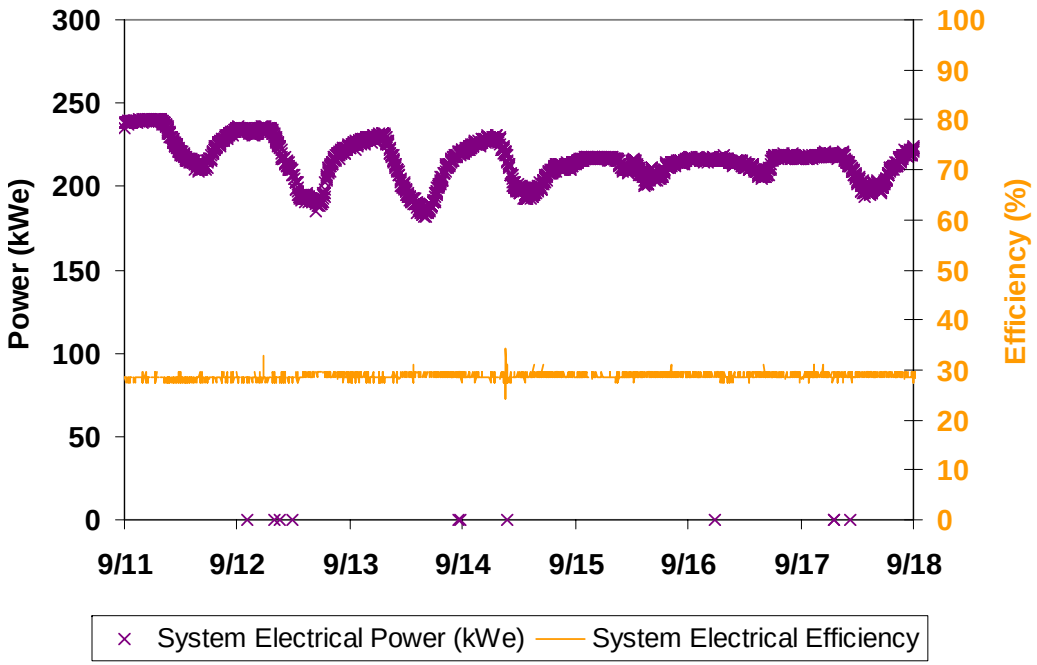


Electrical Efficiency$_{net}$ (%) = [P$_{elect,net}$ (kW) / E$_{input\ fuel,\ LHV}$ (kW)] X 100

Thermal Efficiency$_{net}$ (%) = [(P$_{chiller\ output}$ (kW) + E$_{displaced\ desiccant\ fuel}$ (kW)) / E$_{input\ fuel,\ LHV}$ (kW)] X 100

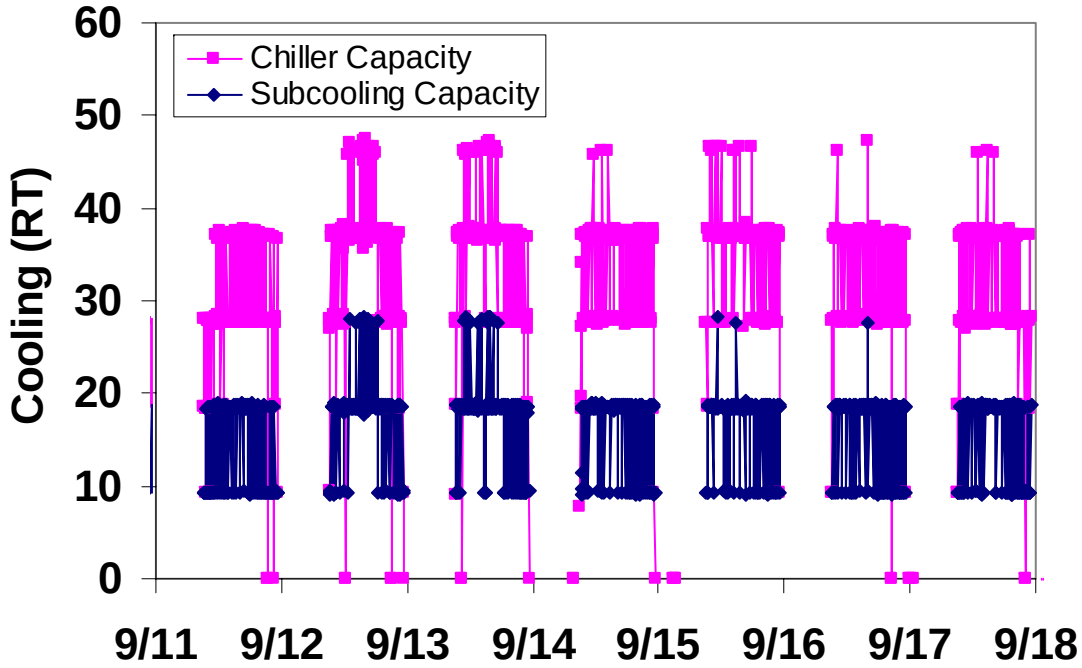
Total Efficiency$_{net}$ (%) = [(P$_{elect,\ net}$ (kW) + P$_{chiller\ output}$ (kW) + E$_{displaced\ desiccant\ fuel}$ (kW)) / E$_{input\ fuel,\ LHV}$ (kW)] X 100

Capstone Turbine Performance



Net Turbine Output (Sept ’05)	154 MWH
Net turbine efficiency	28.5%
Average ambient temperature	68 F
Average maximum temperature	79 F

Carrier Chiller Performance



Chiller Output: ~40 tons (low demand)
Net Chiller Output in Sept 2005 ~ 92 MMBTU
Subcooling: 10-20 tons
Net Subcooling in Sept 2005 ~ 45 MMBTU

September 2005
Avoided Energy Loads & Cost

Quantity	Sept 2005 Raw Cost Savings [$]	Estimated Annual Cost Savings [$]
Grid Electricity	$7,000	$42,000*
Refrigeration Compression	$850	$5,500 †
Space Cooling Compression	$700	$4,000 †
Desiccant Regeneration	$750	$9,000
Space Heating	N/A	$21,000
Total	$9,300 / month	$81,500 / year

*10 year life → Includes regular microturbine maintenance ($17,000/year) & 5 yr. Overhaul ($140,000)
†Includes absorption chiller maintenance ($9000/year, divided between refrigeration and cooling savings)

Gas = $0.69/therm
Electricity = $0.13/kWh

Payback

Gas Cost [$/therm – HHV]	Five Year Lifetime	Ten Year Lifetime (5 yr. Overhaul)
0.50	**2.1**	**2.4**
0.60	**2.5**	**2.9**
0.69	**3.1**	**3.6**

- Assumptions
  - Grid electricity = 13 ¢/kWhr
  - Average net microturbine efficiency = 25%
  - Average net microturbine power = 220 kW
  - System availability = 90%
  - Net installed price = $485,000 - $200,000 (DOE) = $285,000

A&P Lessons Learned

- Getting the right data is critical
- Packaging economics need to match installation economics
- Need better thermal load matching
- Must have “dual mode” capability
- Subcooling is indeed 8,760 load ~ 15 RT at this site

Conclusions

- Subcooling is a small but good load
- 60 kW is too small
- 240 kW maybe too large
- Economics need standby capability for resistive and inductive load
- May work in LA, New York / New England on spark spread, but reliability during crisis may grow in importance

Supermarkets & Subcooling

Questions