Energy Intensive Buildings
Trends and Solutions
Data Centers

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Critical Facilities Round Table
Energy Committee
7-21-06

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Agenda

- Overview of energy use in technology facilities
- New and existing facility energy cost saving strategies
  - Data centers
  - Clean rooms
  - Laboratories
- Implications of utility rate structures
- Conclusions
- How to get Started

Energy Reduction Strategies
Data Centers, CleanRooms & Laboratories

- Technology Buildings
  - Data Center Heat Loads – Air cooling
  - Clean Room Environments – Filtered air changes
  - Biotech Process Confinement – Pressurized air
  - R&D Labs – Bio-chemical Exhaust
- Technology Priorities
  - Fast track design-build
  - Systems reliability and performance
  - Operator and process efficiencies
- Technology Operating Costs
  - Electricity is highest operating cost in CA facilities
  - HVAC accounts for 50% of power consumption

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Energy Reduction Strategies
Data Centers, CleanRooms & Laboratories

- Realistic Strategies
  - Proven techniques
  - Easy to implement
  - Minimal risk
  - Low cost
  - Flexible operations
  - ROI of 2 years or better
  - Facility type specific solutions

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Energy Reduction Strategies
Data Centers

Where are the losses?

- Mechanical systems
  - The ratio between mechanical load and the power delivered to the servers varies between 0.7 and 1.5
- Electrical systems
  - System efficiency varies between 75% and 92%
- Computer and process equipment
  - Power supply efficiency varies between 55% and 75%

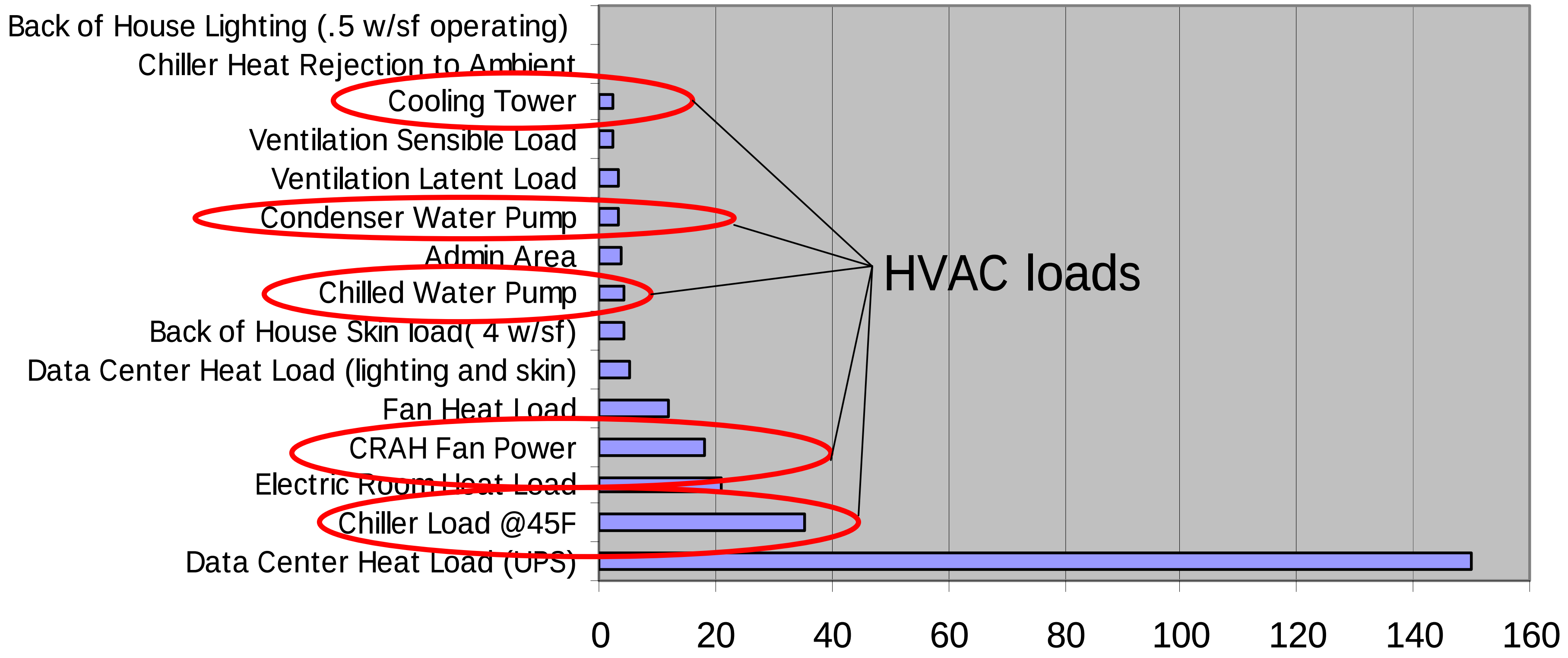
Energy Use in Data Centers

Components of Energy Use (150 w/sf => 267 watts/sf)

Energy Use Component	**Watts/SF**	**Percent**
Data Center Heat Load (UPS)	150	56%
Chiller Load @45F	35	13%
Electric Room Heat Load	21	8%
CRAH Fan Power	18	7%
Fan Heat Load	12	5%
Data Center Heat Load (lighting and skin)	5	2%
Back of House Skin load(4 w/sf)	4	2%
Chilled Water Pump	4	2%
Heat Load	4	1%
Condenser Water Pump	3	1%
Ventilation Latent Load	3	1%
Ventilation Sensible Load	2	1%
Cooling Tower	2	1%
Chiller Heat Rejection to Ambient	1	0%
Back of House Lighting (.5 w/sf operating)	1	0%
Total	**267**	**100%**

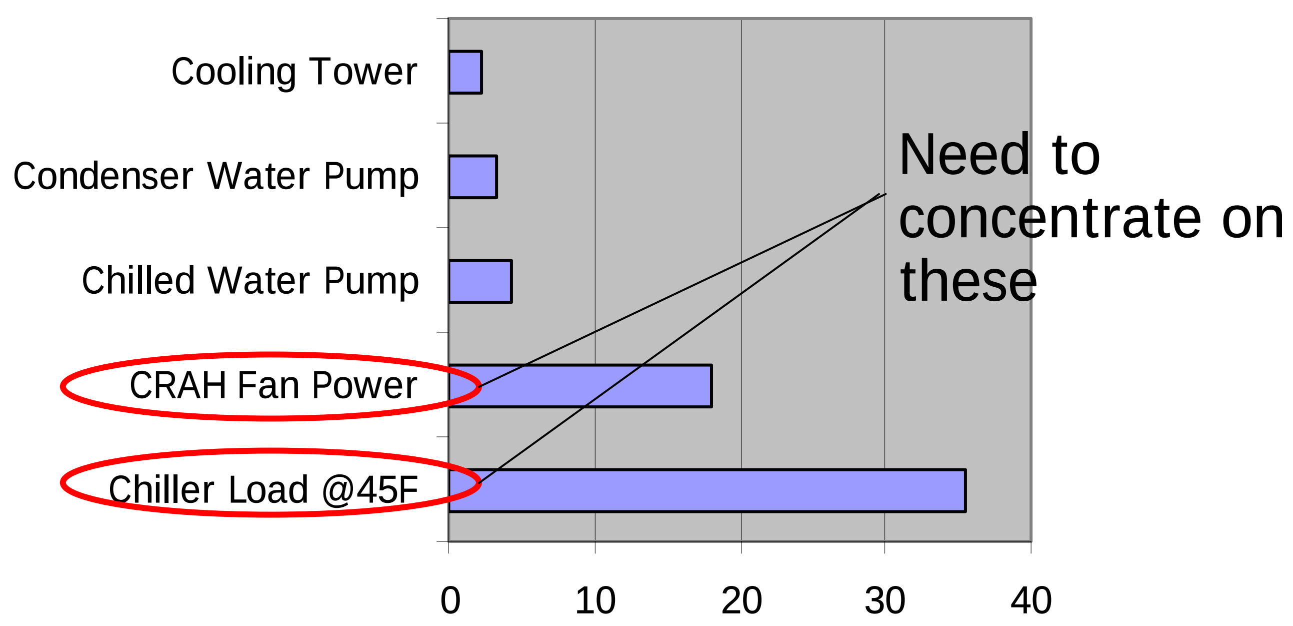
Energy Use in Data Centers
Mechanical Loads

Components of Energy Use



Energy Use in Data Centers
Highest Demand

Energy Use of HVAC Components



Data Center
Energy Reduction Strategies

- Alternate 1 – Increasing chilled water supply temperature (thus air supply temperature)
- Alternate 2 – Using water-side economizer with Alternate 1
- Alternate 3a – Using chilled water cabinets with Alternates 1 and 2
- Alternate 3b – Using air-side economizer with Alternates 1 and 2

Energy Use in Data Centers

Alternate 1 - Chilled Water Supply Temperature

- Traditional approach is to supply 45˚F water to yield 55˚F air
- Why? Mostly to overcome hot spots and combat against recirculation of air
- ASHRAE recommends 72˚F at the inlet to the server
- Air coming out of floor could be 65˚F, meaning higher chilled water supply temperature
- Need to analyze energy savings based on varying supply water temperatures

Energy Use in Data Centers

Case Study

- Used 1000-ton water-cooled centrifugal chiller
- Rated at 0.565 kW/ton at 45˚F chilled water supply and 85˚F condenser water as base case
- Looked at varying chilled water supply from 45˚F to 55˚F
- Also used bin data to determine number of hours at wet bulb temperatures (which determine what condenser water temperature is available)
- Used Los Angeles as a location

Energy Use in Data Centers

Case Study (based on performance data from chiller manufacturer)

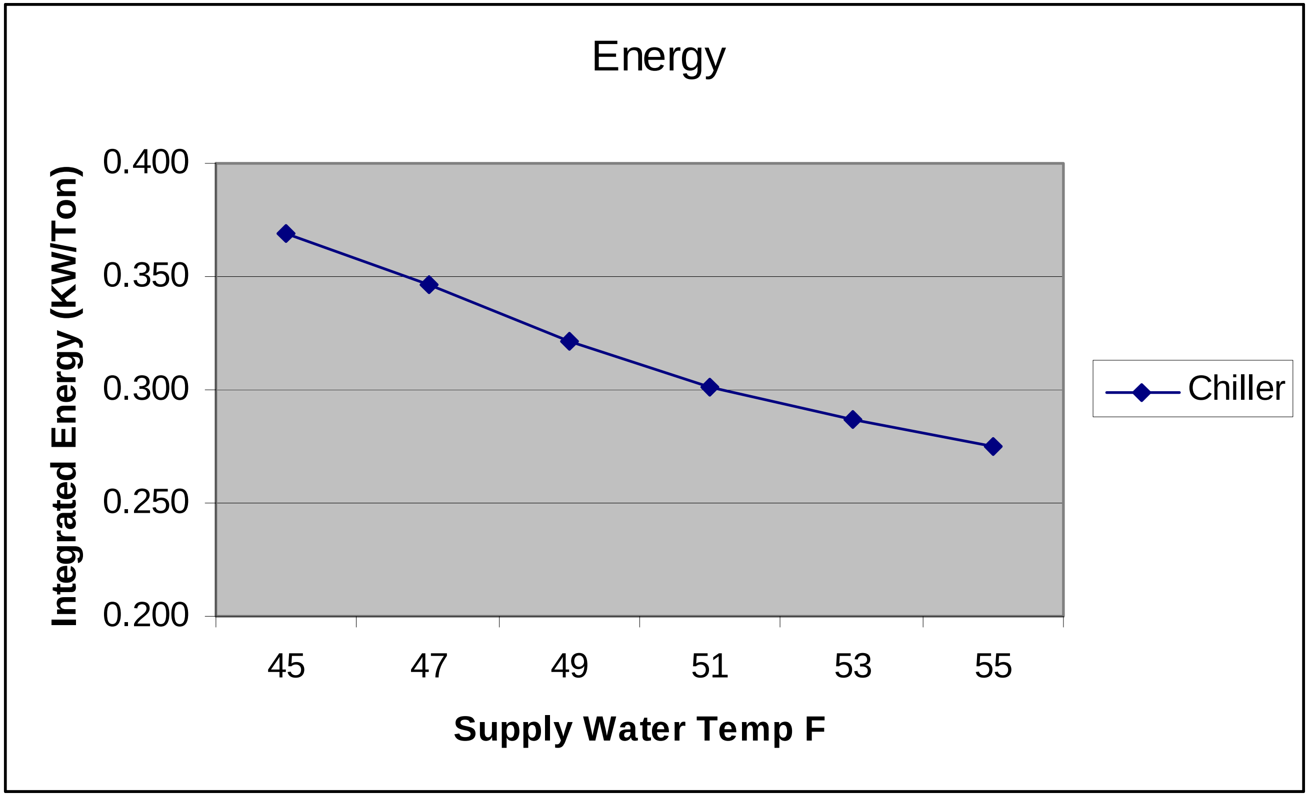
Energy (KW/Ton)					
Chilled Water Temperature (F)	Entering Condenser Water Temperature (F)				
	85	75	65	60	Integrated
45	0.565	0.463	0.376	0.338	0.369
47	0.535	0.439	0.353	0.315	0.346
49	0.509	0.414	0.332	0.289	0.321
51	0.483	0.387	0.309	0.271	0.301
53	0.459	0.367	0.288	0.262	0.287
55	0.432	0.346	0.267	0.256	0.275

Energy Reduction

Standard ARI formula for determining rated kW/ton (optimizing condenser water temperature)

Energy Use in Data Centers

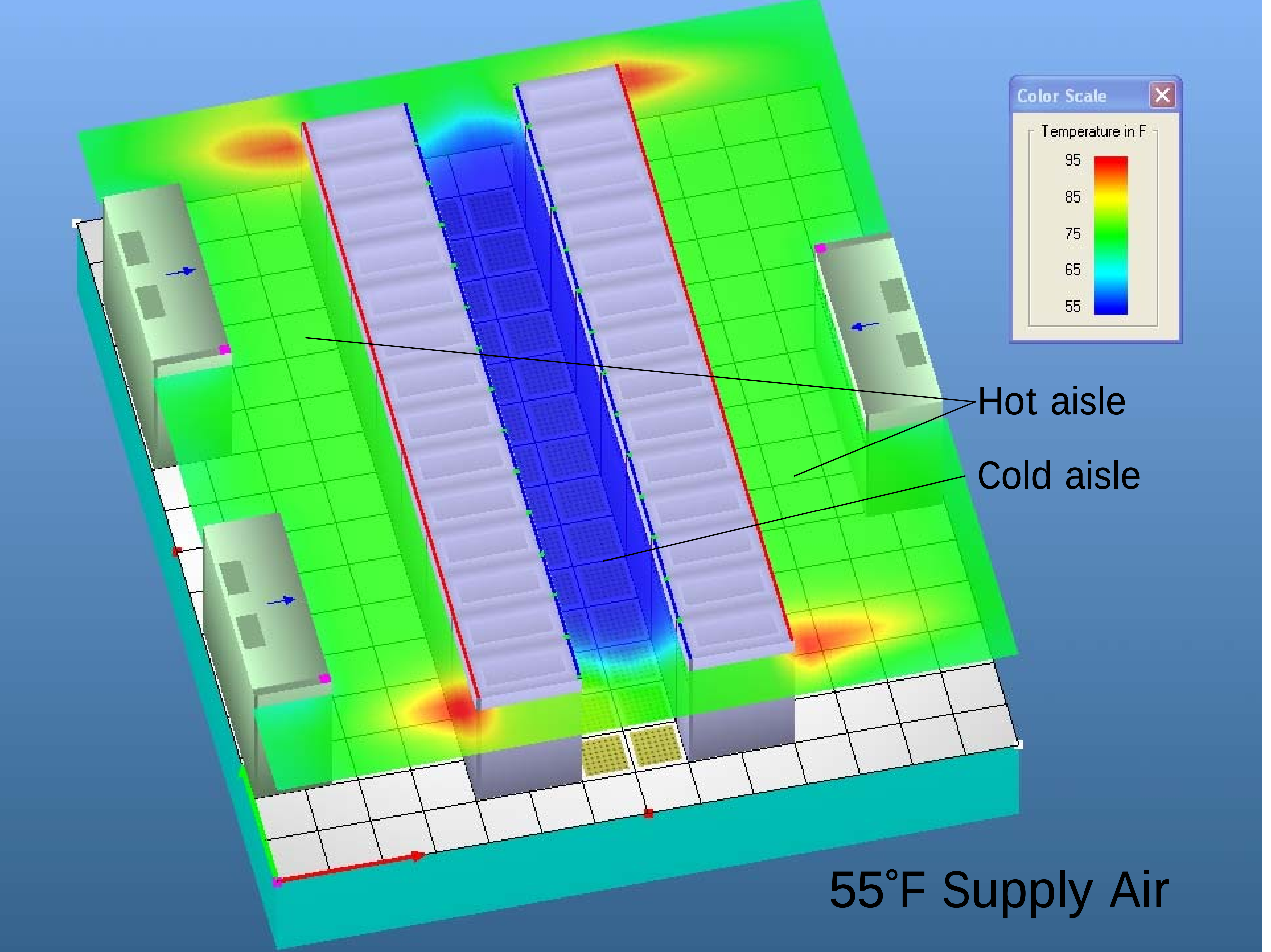
Case Study

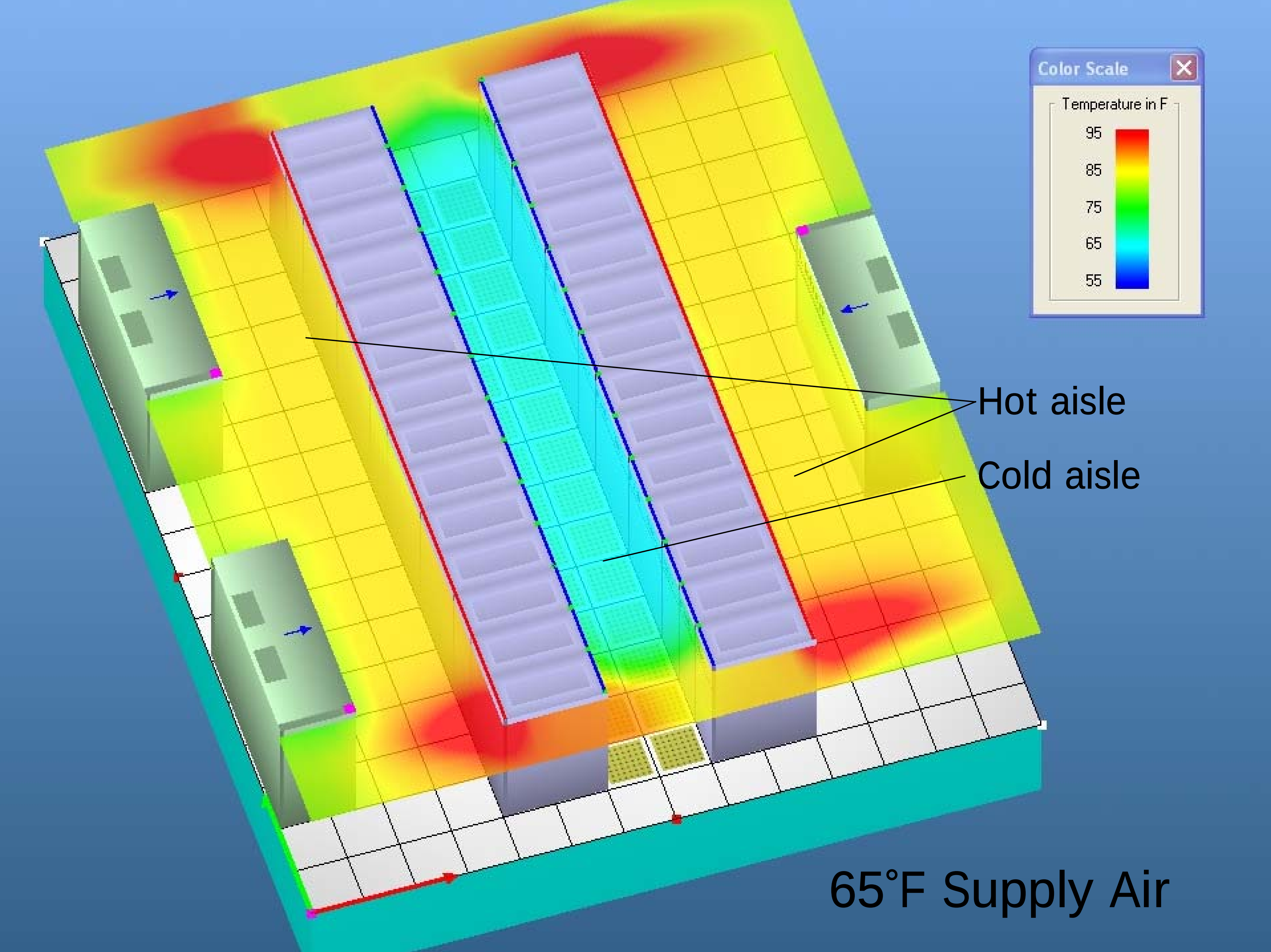


Energy Use in Data Centers

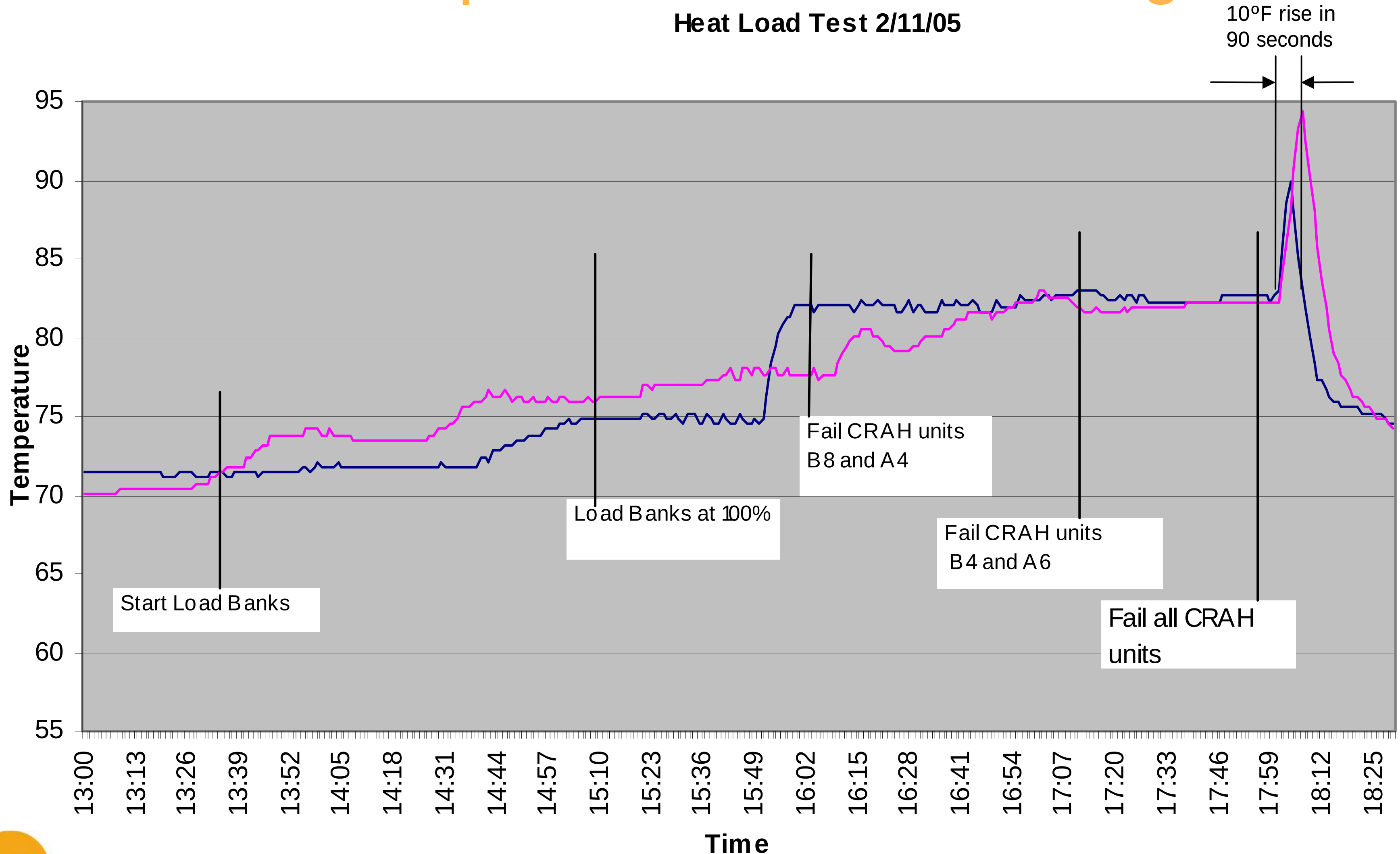
Results

- Going from 45˚F to 55˚F chilled water supply temperature (approximately 55˚F to 65˚F supply air temperature) yields approximately 25% reduction in kW/ton
- Assuming 50,000 SF data center at 150 W/SF, annual chiller energy usage would be approximately 3,800,000 kWH
- Based on average rate of $0.10/kWH, savings over base case = $380,000


Color Scale
Temperature in F
95
85
75
65
55
Hot aisle
Cold aisle
55˚F Supply Air


Color Scale
Temperature in F
95
85
75
65
55
Hot aisle
Cold aisle
65˚F Supply Air

Impacts of Loss of Cooling



100 w/sf — Room B — Room A 150 w/sf

Energy Use in Data Centers

Considerations

- Higher supply temperatures requires better airflow management
- Discourage mixing of cold aisle supply air from hot aisle exhaust air
- Compartmentalization of cold aisle/hot aisle to eliminate recirculation/convective forces
- Higher hot aisle temperatures increases chance of thermal runaway
- May require chilled water storage/UPS power for some HVAC equipment

Energy Use in Data Centers

Alternate 2 - Water-side economizer

- Use of condenser water as chilled water
- Only need to run cooling tower fan and pumps
- Higher design chilled water temperature (55˚F) extends use of economizer
- Energy savings dependent on wet-bulb (moisture content of air) temperature
- Regions with lower wet-bulb temperatures are favorable
- Need approximately 7 to 10˚F "approach" (wet bulb must be 7 to 10˚F less than design chilled water temperature)
- 45˚F to 48˚F ambient wet-bulb

Master Weather Data

Edit

Country: United States | State/Province: California | City: Los Angeles

Temp Bin(°F)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg. WB(°F)	Total Hours
100=>104	0	0	0	0	0	0	0	0	1	1	0	0	70.0	2
95=>99	0	0	0	0	0	0	0	0	2	1	0	0	67.0	3
90=>94	0	0	0	0	0	0	0	0	1	3	1	0	64.0	5
85=>89	0	1	1	1	1	1	3	1	6	4	4	0	64.0	23
80=>84	3	2	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10	5	64.0	96
75=>79	7	6	6	8	7	23	71	[illegible]	63	26	20	10	63.0	325
70=>74	17	16	17	25	38	81	179	187	144	84	35	21	60.0	844
65=>69	34	40	50	[illegible]	[illegible]	[illegible]	[illegible]	288	[illegible]	198	88	48	57.0	1629
60=>64	89	107	131	183	263	317	[illegible]	165	221	264	192	128	53.0	2244
55=>59	204	214	248	295	251	102	22	[illegible]	[illegible]	127	215	226	48.0	1941
50=>54	210	181	206	119	50	5	0	0	0	22	115	190	43.0	1098
45=>49	124	84	70	18	2	0	0	0	0	0	37	91	39.0	426
40=>44	48	20	11	0	0	0	0	0	0	0	4	21	33.0	104
35=>39	9	1	1	0	0	0	0	0	0	0	0	2	28.0	13
30=>34	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0
25=>29	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0
20=>24	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0
15=>19	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0
10=>14	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0
5=>9	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0
Total	745	672	744	719	742	721	743	742	719	743	721	742		8753

Approximately 3500 hours per year under 48°F wet bulb

Help | Load Custom | Save Custom | Clear Grid | Peak Temp Bin (°F): 100-104 | Computer Weather | Custom Weather | OK

Energy Use in Data Centers

Alternate 2 - Water-side economizer

- Means that 3500 hours per year, only require cooling tower fans and pumps
- Based on average rate of $0.10/kWH, savings in addition to Alternate 1 = base case = $465,000; over base case = $850,000

Energy Use in Data Centers

Considerations

- More complicated controls
- Chiller plant sequencing (risk of restart problems when chillers are off line) – or stand-by operations
- Additional equipment (heat exchangers)
- Savings will vary greatly depending on location

Energy Use in Data Centers

Alternate 3a - Water-cooled cabinets

- Cabinets use higher chilled water temperature (55˚F)
- Still air-cooled solution, but with controlled, engineered enclosure
- Currently available cabinets range from 15 to 30 kW
- Each cabinet requires 700 watts for fan power
- On average, water-cooled cabinet fans will require 7 to 10 watts/SF of power, compared to 15 watts/SF for CRAH fans
- Still need approximately 10 to 20% CRAH when cabinets are open or emergency

Energy Use in Data Centers

Alternate 3a - Water-cooled cabinets

- Using water-cooled cabinets and 20% CRAHs, annual savings in addition to alternate 2 = $193,000; over base case = $1.1MM

Energy Use in Data Centers

Considerations

- Since contained enclosure, thermal runaway risk increases
- Larger cabinets 91” tall x 31” wide x 47” deep
- Approximately $15K to $30K per cabinet installed ($3500/ton), compared to $30K for 30-ton CRAH ($1000 per ton)
- Only cost-effective when using high density (>15 kW per cabinet) or when factoring in potential reduction in rentable square footage

Energy Use in Data Centers

Alternate 3b - Air-side economizer

- Use of outside air to cool data center
- Higher supply air temperature (65˚F) extends use of economizer
- Energy savings dependent on dry-bulb (thermometer temperature) and wet-bulb (moisture content of air) temperature – enthalpy control
- Regions with lower average dry- and wet-bulb temperatures are favorable
- Need to control supply air temperature to produce optimal dry-bulb and moisture content – don't want air too dry

Energy Use in Data Centers

Air-side economizer

- Design will require central-station air handling units, with return/exhaust fan
- During full economizer, need only to run fans (no chiller, pumps or cooling tower)
- Need to discuss with server manufacturers to understand humidity tolerances

Master Weather Data

Edit

Country: United States | State/Province: California | City: Los Angeles

Approximately 3500 hours per year under 59°F wet bulb

Temp Bin(°F)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg. WB(°F)	Total Hours
100=>104	0	0	0	0	0	0	0	0	1	1	0	0	70.0	2
95=>99	0	0	0	0	0	0	0	0	2	1	0	0	67.0	3
90=>94	0	0	0	0	0	0	0	0	1	3	1	0	64.0	5
85=>89	0	1	1	1	1	1	3	1	6	4	4	0	64.0	23
80=>84	3	2	3	4	2	[illegible]	15	16	21	13	10	5	64.0	96
75=>79	7	6	6	8	7	23	71	78	63	26	20	10	63.0	325
70=>74	17	16	17	25	[illegible]	81	[illegible]	[illegible]	144	84	35	21	60.0	844
65=>69	34	40	50	66	128	191	268	288	230	198	88	48	57.0	1629
60=>64	89	107	131	183	263	317	184	165	221	264	192	128	53.0	2244
55=>59	204	214	248	295	251	102	22	7	30	127	215	226	48.0	1941
50=>54	210	181	206	119	50	5	0	0	0	22	115	190	43.0	1098
45=>49	124	84	70	18	2	0	0	0	0	0	37	91	39.0	426
40=>44	48	20	11	0	0	0	0	0	0	0	4	21	33.0	104
35=>39	9	1	1	0	0	0	0	0	0	0	0	2	28.0	13
30=>34	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0
25=>29	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0
20=>24	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0
15=>19	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0
10=>14	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0
5=>9	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0
Total	745	672	744	719	742	721	743	742	719	743	721	742		8753

Help | Load Custom | Save Custom | Clear Grid | Peak Temp Bin (°F): 100-104

Computer Weather | Custom Weather | OK

Energy Use in Data Centers

Alternate 3b - Air-side economizer

- Means that 3500 hours per year, only supply and exhaust fans
- Using air-side economizer will result in approximate annual savings in addition to alternate 2 = $151,000; over base case = $1.0MM
- Hourly simulation required to determine more accurate energy reduction due to variable moisture content

Energy Use in Data Centers

Considerations

- More complicated controls
- Must balance chiller compressor energy reduction and humidification
- Chiller plant sequencing (risk of restart problems when chillers are off line) or stand-by operations
- Different air-handling system approach
- Savings will vary greatly depending on location

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Energy Use in Data Centers

Summary – Theoretical Savings Based on Strategies

Alternate	Cooling Plant Description	Cooling Plant Annual Energy Cost	Savings	Percentage
Base Case	45^{o}F Water	$ 2,768,748	Base	Base
Alternate 1	55^{o}F Water	$ 2,380,095	$ 388,653	14%
Alternate 2	Water-side Economizer	$ 1,914,244	$ 854,504	31%
Alternate 3a	Water-Cooled Racks	$ 1,721,524	$ 1,047,224	38%
Alternate 3b	Air-side Economizer	$ 1,763,455	$ 1,005,293	36%

Note: data based on $0.10/kWH

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Energy Use in Data Centers

Other energy savings strategies

- Humidification versus outdoor air economizer
- Battery room heat recovery; payback usually less than 3 years
- Ice storage (not really energy savings, but utility cost savings)
- Control/monitoring for better airflow control

Optimizing Existing Data Center Facilities

- Air test and balance on air conditioning units
- Widen dead band of temperature/humidity to prevent fighting
- Seal floor openings
- Blank-off unused spaces in racks/cabinets
- Install supplemental units in high-density areas (to prevent overcooling)
- Take air flow/temperature readings to sync air delivery to actual load

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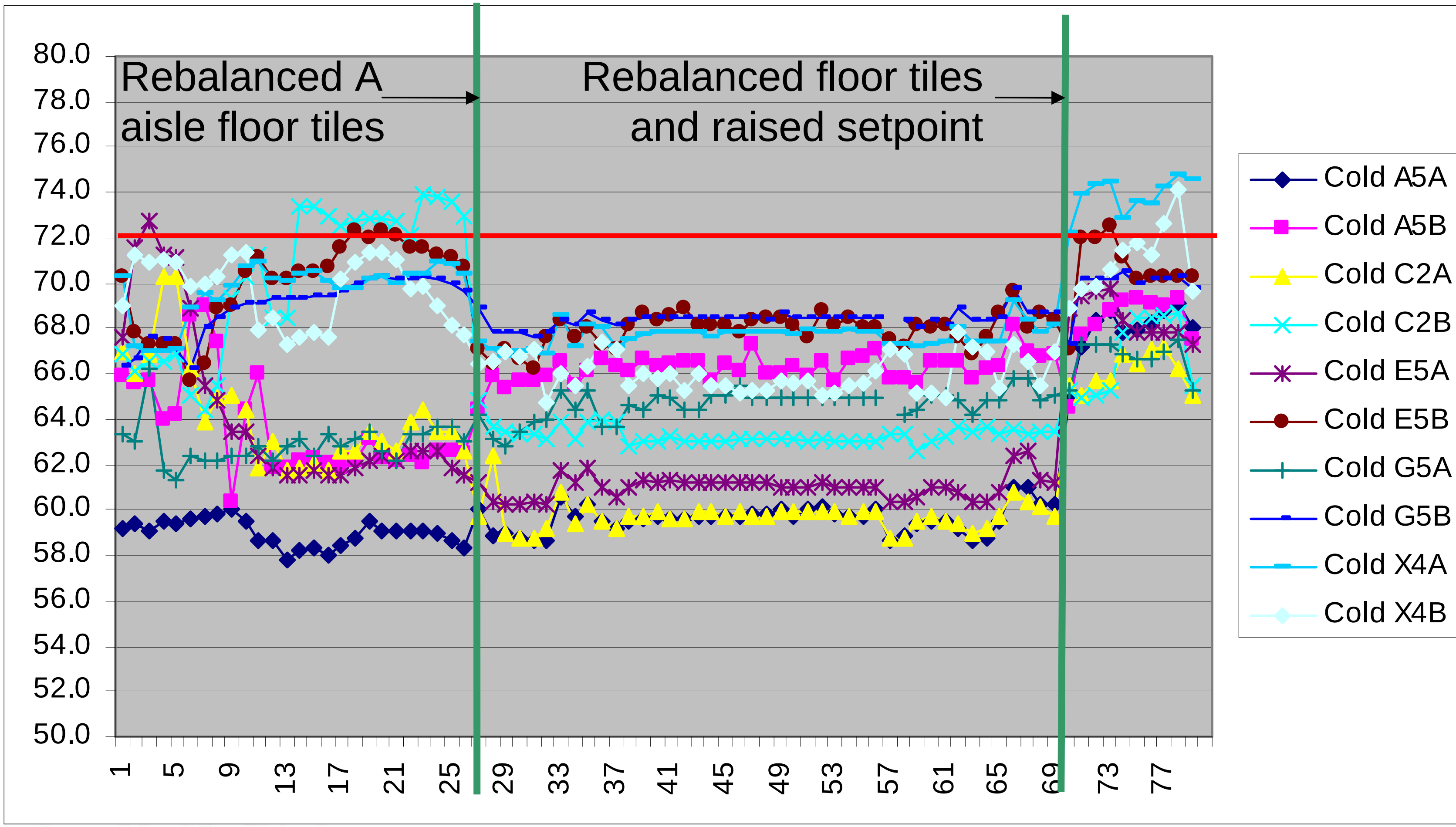
Optimizing Existing Facilities



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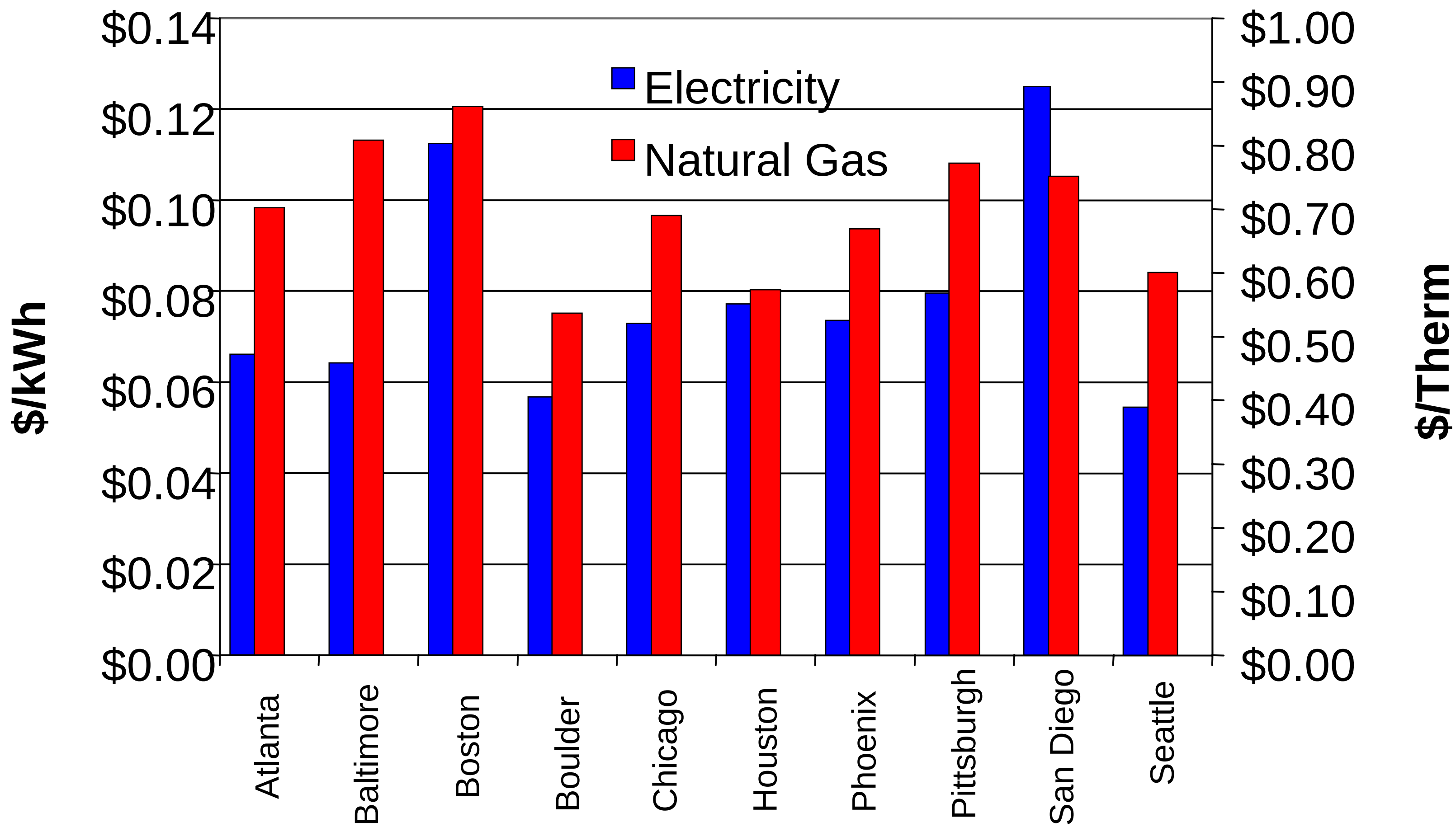
Summary

- Technology building energy reduction strategy is **NOT** "one size fits all"
- "Non-exotic" HVAC strategies – 15% to 30%+ energy reduction
- Must explore and implement various strategies in existing facilities
- Utility rate structure will influence strategy

Utility Cost and Rate Structure Considerations



How to get Started

- Pacific Gas & Electric Customer Energy Efficiency Programs
- Utility financed consulting services
- Utility implementation incentive programs