

City of Hope Amini Medical Center




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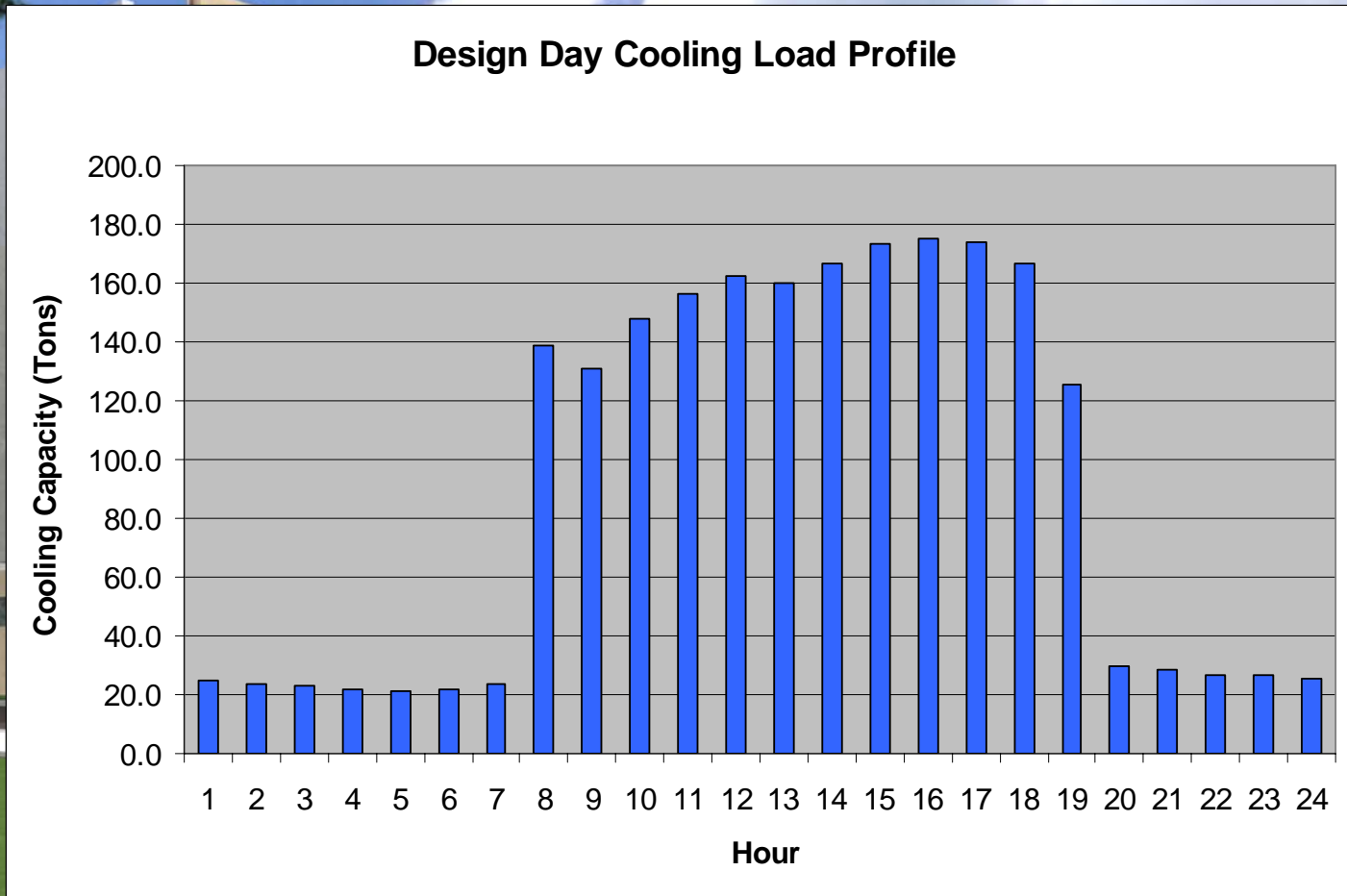
Disclaimer

- Due to limited information regarding the central plant, the Amini Center was removed from the central cooling plant and provided its own independent primary chilled water loop. This redesigned system serves as the baseline of comparison for my thesis depth redesign. For the remainder of this presentation, the “Existing System” refers to the Amini Center’s independent cooling plant.

Building Information

- Location: Durante, California (L.A. Suburb)
 - Size: 3-Stories, 59,800 sf New Construction
 - Occupancy: Clinic, Lab, Office, Moderate Hazard Storage
 - Design-Bid-Build
 - Construction Dates: 06.11.07 – 01.22.09
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Building Load Profile

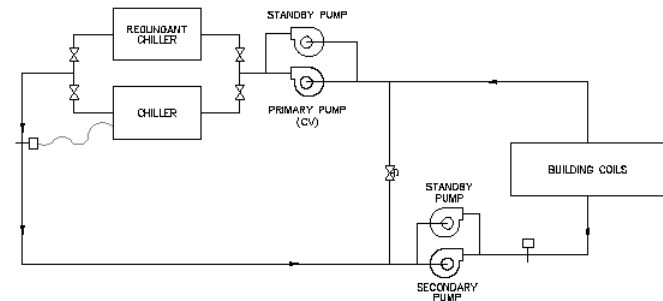


Existing Mechanical Systems

- Primary/secondary chilled water system
- (2) Air-Cooled Chillers on roof
- (2) Primary Pumps in Mech. room
- Rooftop AHUs & Scattered FCUs
- CV and VAV terminals
- PRVs step down HPS to LPS
- HX makes HW for building coils

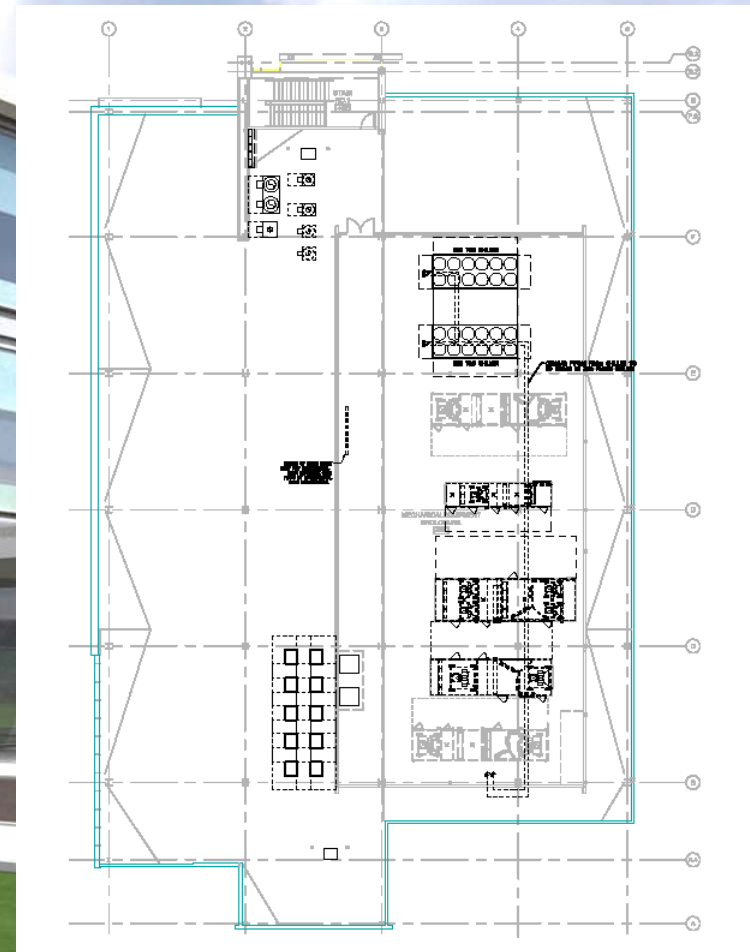
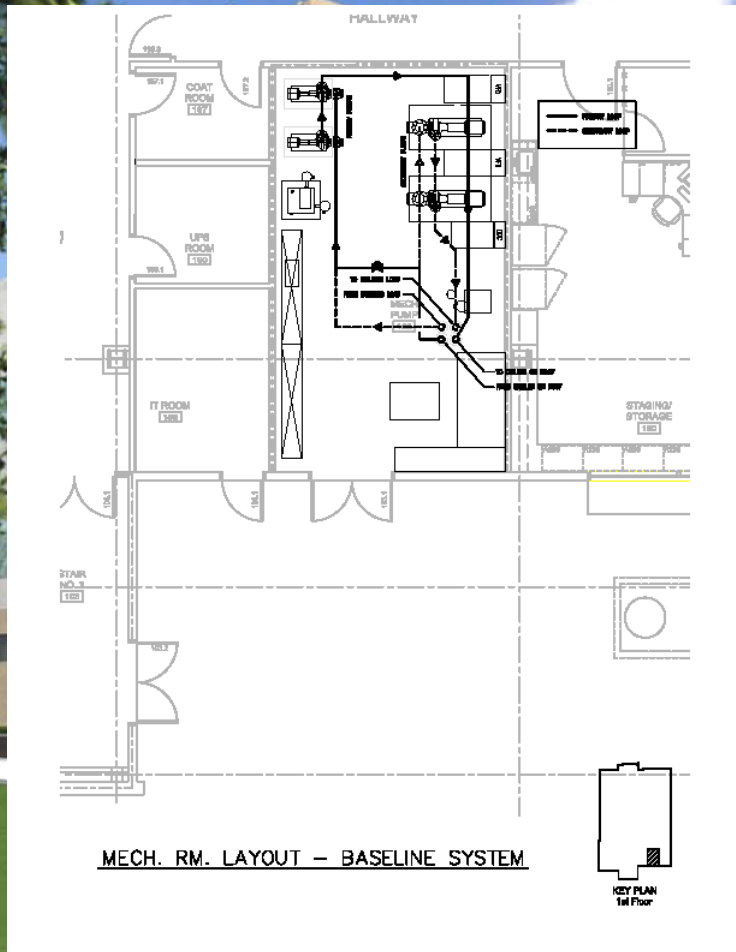
Existing CHW System Flow Diagram

- 185 Ton Chillers
- 7.5 HP Primary Pumps
- 2-way control valve
- 296 gpm
- 5" CHW piping
- 42 deg. F CHWS
- Loop Fluid = Water



EXISTING SYSTEM FLOW DIAGRAM

Existing Primary Loop



Annual Energy Consumption

MONTHLY ENERGY CONSUMPTION

By META Engineers

----- Monthly Energy Consumption -----

| Utility | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec | Total |
|---|--------|--------|---------|--------|---------|--------|--------|--------|--------|---------|--------|--------|-----------|
| Alternative: 1 Baseline AC Chiller | | | | | | | | | | | | | |
| Electric | | | | | | | | | | | | | |
| On-Pk Cons. (kWh) | 0 | 0 | 0 | 0 | 0 | 60,996 | 59,893 | 69,063 | 58,323 | 0 | 0 | 0 | 248,264 |
| Off-Pk Cons. (kWh) | 68,416 | 63,535 | 66,966 | 72,695 | 72,162 | 66,999 | 82,530 | 74,472 | 76,549 | 73,446 | 67,610 | 73,018 | 857,999 |
| Mid-Pk Cons. (kWh) | 88,924 | 83,597 | 102,955 | 92,411 | 105,809 | 57,543 | 55,540 | 65,791 | 54,142 | 109,295 | 96,794 | 86,920 | 1,000,122 |
| On-Pk Demand (kW) | 0 | 0 | 0 | 0 | 0 | 507 | 546 | 545 | 536 | 0 | 0 | 0 | 546 |
| Off-Pk Demand (kW) | 406 | 420 | 418 | 425 | 442 | 472 | 510 | 507 | 496 | 465 | 427 | 412 | 510 |
| Mid-Pk Demand (kW) | 444 | 460 | 460 | 468 | 485 | 484 | 519 | 523 | 508 | 503 | 472 | 453 | 523 |
| Purchased Steam | | | | | | | | | | | | | |
| On-Pk Cons. (therms) | 0 | 0 | 0 | 0 | 0 | 47 | 41 | 47 | 40 | 0 | 0 | 0 | 175 |
| Off-Pk Cons. (therms) | 159 | 105 | 78 | 50 | 26 | 23 | 24 | 22 | 26 | 28 | 63 | 141 | 745 |
| Mid-Pk Cons. (therms) | 135 | 105 | 116 | 94 | 100 | 51 | 46 | 54 | 48 | 101 | 104 | 113 | 1,066 |
| On-Pk Demand (therms/hr) | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 |
| Off-Pk Demand (therms/hr) | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 |
| Mid-Pk Demand (therms/hr) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

Energy Consumption

| | |
|----------|-------------------------------------|
| Building | 139,126 Btu/(ft ² -year) |
| Source | 411,184 Btu/(ft ² -year) |

Floor Area 53,101 ft²

Environmental Impact Analysis

| | |
|-----|-------------------|
| CO2 | No Data Available |
| SO2 | No Data Available |
| NOX | No Data Available |

Utility Rate

| Amini Center Input Rate Structure | | |
|-----------------------------------|-----------------|--------------|
| Utility | Customer Charge | Rate |
| Electric Demand | | |
| On Peak (Oct. - May) | 275.69 \$/month | - |
| Mid Peak (Oct. - May) | | 10.36 \$/KW |
| Off Peak (Oct. - May) | | 10.36 \$/KW |
| On Peak (Jun. - Sept.) | | 25.84 \$/KW |
| Mid Peak (Jun. - Sept.) | | 15.6 \$/KW |
| Off Peak (Jun. - Sept.) | | 10.36 \$/KW |
| Electric Consumption | | |
| On Peak (Oct. - May) | - | - |
| Off Peak (Oct. - May) | - | 0.139 \$/kwh |
| Mid Peak (Oct. - May) | - | 0.174 \$/kwh |
| On Peak (Jun. - Sept.) | - | 0.199 \$/kwh |
| Off Peak (Jun. - Sept.) | - | 0.172 \$/kwh |
| Mid Peak (Jun. - Sept.) | - | 0.135 \$/kwh |

* Rates are based on SCE rate schedule

| Utility Schedule | | | | |
|------------------|---------------|------|----------|----------|
| | Time | Hour | Summer | Winter |
| AM | 12:00 - 1:00 | 1 | OFF-PEAK | OFF-PEAK |
| | 1:00 - 2:00 | 2 | | |
| | 2:00 - 3:00 | 3 | | |
| | 3:00 - 4:00 | 4 | | |
| | 4:00 - 5:00 | 5 | | |
| | 5:00 - 6:00 | 6 | | |
| | 6:00 - 7:00 | 7 | MID-PEAK | MID-PEAK |
| | 7:00 - 8:00 | 8 | | |
| | 8:00 - 9:00 | 9 | | |
| | 9:00 - 10:00 | 10 | | |
| | 10:00 - 11:00 | 11 | | |
| | 11:00 - 12:00 | 12 | | |
| PM | 12:00 - 1:00 | 13 | PEAK | MID-PEAK |
| | 1:00 - 2:00 | 14 | | |
| | 2:00 - 3:00 | 15 | | |
| | 3:00 - 4:00 | 16 | | |
| | 4:00 - 5:00 | 17 | | |
| | 5:00 - 6:00 | 18 | | |
| | 6:00 - 7:00 | 19 | MID-PEAK | OFF-PEAK |
| | 7:00 - 8:00 | 20 | | |
| | 8:00 - 9:00 | 21 | | |
| | 9:00 - 10:00 | 22 | | |
| | 10:00 - 11:00 | 23 | | |
| | 11:00 - 12:00 | 24 | | |

Annual Energy Cost

MONTHLY UTILITY COSTS

By META Engineers

| Utility | ----- Monthly Utility Costs ----- | | | | | | | | | | | | Total |
|----------------------------|-----------------------------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|----------------|
| | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec | |
| Alternative 1 | | | | | | | | | | | | | |
| Electric | | | | | | | | | | | | | |
| On-Pk Cons. (\$) | 276 | 276 | 276 | 276 | 276 | 12,424 | 12,206 | 14,033 | 11,894 | 276 | 276 | 276 | 52,762 |
| Off-Pk Cons. (\$) | 9,800 | 9,120 | 9,542 | 10,396 | 10,321 | 9,347 | 11,450 | 10,359 | 10,640 | 10,500 | 9,688 | 10,440 | 121,605 |
| Mid-Pk Cons. (\$) | 15,795 | 14,856 | 18,232 | 16,393 | 18,730 | 10,219 | 9,807 | 11,566 | 9,567 | 19,338 | 17,158 | 15,435 | 177,086 |
| On-Pk Demand (\$) | 0 | 0 | 0 | 0 | 0 | 13,098 | 14,121 | 14,089 | 13,846 | 0 | 0 | 0 | 55,154 |
| Off-Pk Demand (\$) | 4,207 | 4,348 | 4,325 | 4,407 | 4,574 | 4,890 | 5,280 | 5,249 | 5,138 | 4,813 | 4,428 | 4,266 | 55,924 |
| Mid-Pk Demand (\$) | 4,602 | 4,765 | 4,762 | 4,848 | 5,021 | 7,553 | 8,097 | 8,162 | 7,928 | 5,216 | 4,891 | 4,693 | 70,538 |
| Total (\$): | 34,670 | 33,365 | 37,137 | 36,320 | 38,922 | 57,531 | 60,961 | 63,458 | 59,014 | 40,142 | 36,440 | 35,111 | 533,070 |
| Monthly Total (\$): | 34,670 | 33,365 | 37,137 | 36,320 | 38,922 | 57,531 | 60,961 | 63,458 | 59,014 | 40,142 | 36,440 | 35,111 | 533,070 |

Building Area = 53,101 ft²

Utility Cost Per Area = 10.04 \$/ft²

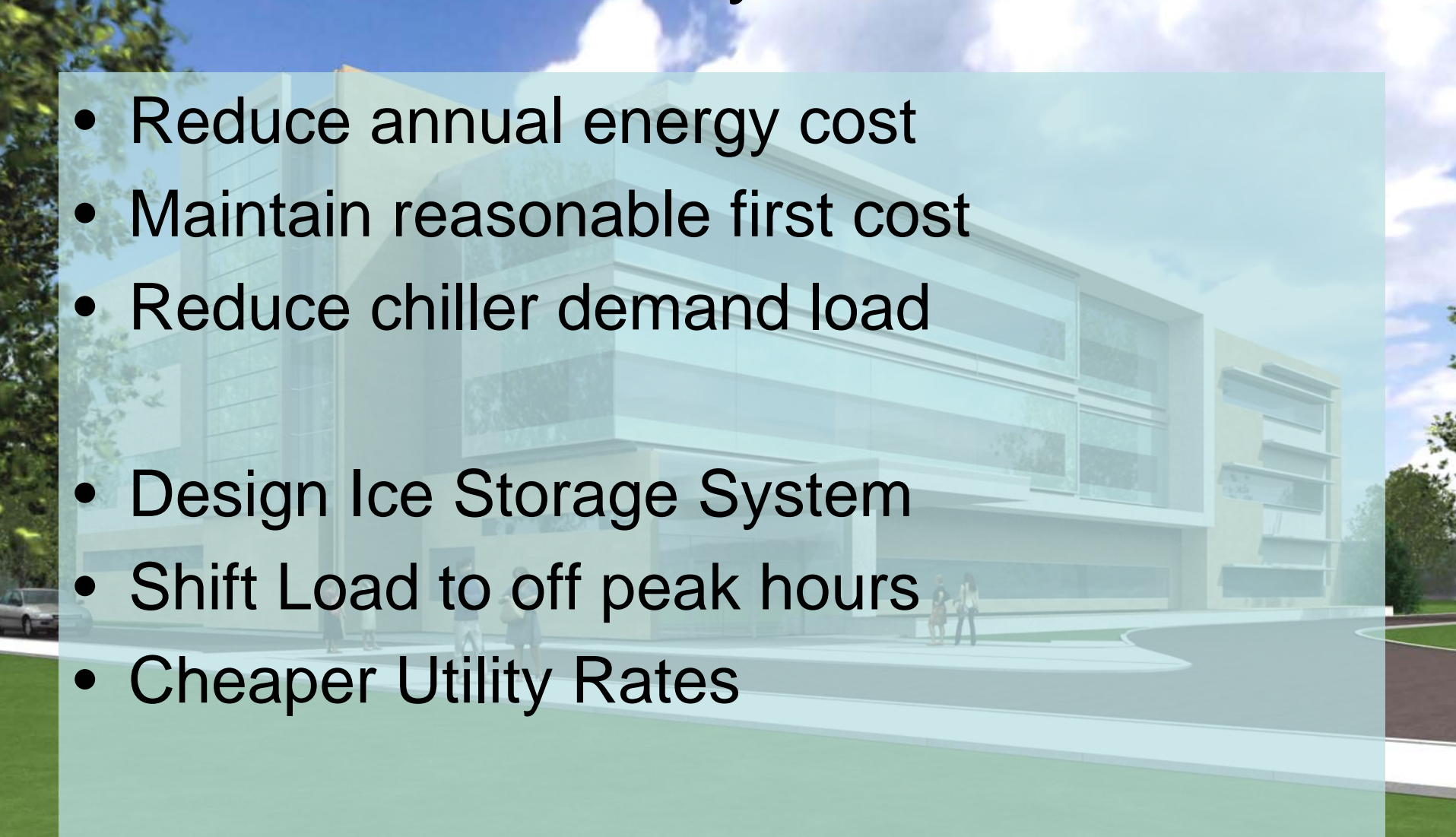
Primary Loop First Cost

| Description | Baseline First Costs | | | | |
|---|----------------------|-------|----------|--------------|------------|
| | Product Total | Units | Quantity | Cost/Unit | Sub-Total |
| Chiller Incl. Labor + O&P (185 Ton) | 1 | EA | 2 | \$118,500.00 | \$237,000 |
| CHW Piping - 5" Incl. Labor + O&P | 574 | LF | 1 | \$70.00 | \$40,180 |
| CHW 90 deg Fittings - 5" Incl. Labor + O&P | 1 | EA | 24 | \$370.00 | \$8,880 |
| CHW 45 deg Fittings - 5" Incl. Labor + O&P | 1 | EA | 1 | \$455.00 | \$455 |
| CHW Tee Fittings - 5" Incl. Labor + O&P | 1 | EA | 6 | \$655.00 | \$3,930 |
| CHW Piping Insulation - 2" on 5"d Incl. Labor + O&P | 574 | LF | 1 | \$14.00 | \$8,036 |
| Valves Incl. Labor + O&P | 1 | LS | 1 | \$4,800.00 | \$4,800 |
| Control Valve Incl. Labor + O&P | 1 | EA | 1 | \$1,225.00 | \$1,225 |
| Vibration/Seismic Restraints Incl. Labor + O&P | 1 | LS | 1 | \$4,000.00 | \$4,000 |
| CHW Pump - 300 gpm @ 7.5 Hp Incl. Labor + O&P | 1 | EA | 2 | \$3,950.00 | \$7,900 |
| Trace Wiring Incl. Labor + O&P | 40 | LF | 1 | \$2.50 | \$100 |
| DDC Controls | 1 | LS | 1 | \$12,000.00 | \$12,000 |
| Electrical - CHWP Hook-up | 1 | EA | 2 | \$1,750.00 | \$3,500 |
| Electrical - Chiller Hook-up | 1 | EA | 2 | \$2,500.00 | \$5,000 |
| Pipe Testing - 500-1000 LF | 1 | EA | 1 | \$1,750.00 | \$1,750 |
| Water Balancing (Pumps) | 1 | EA | 2 | \$1,700.00 | \$3,400 |
| Water Chemical Treatment | 1 | LS | 1 | \$5,000.00 | \$5,000 |
| Commissioning | 1 | TC | 1 | 0.75% | \$2,603.67 |

Total: \$349,760
Escalation: 15% \$402,224

Mechanical Redesign Objectives & Analyses

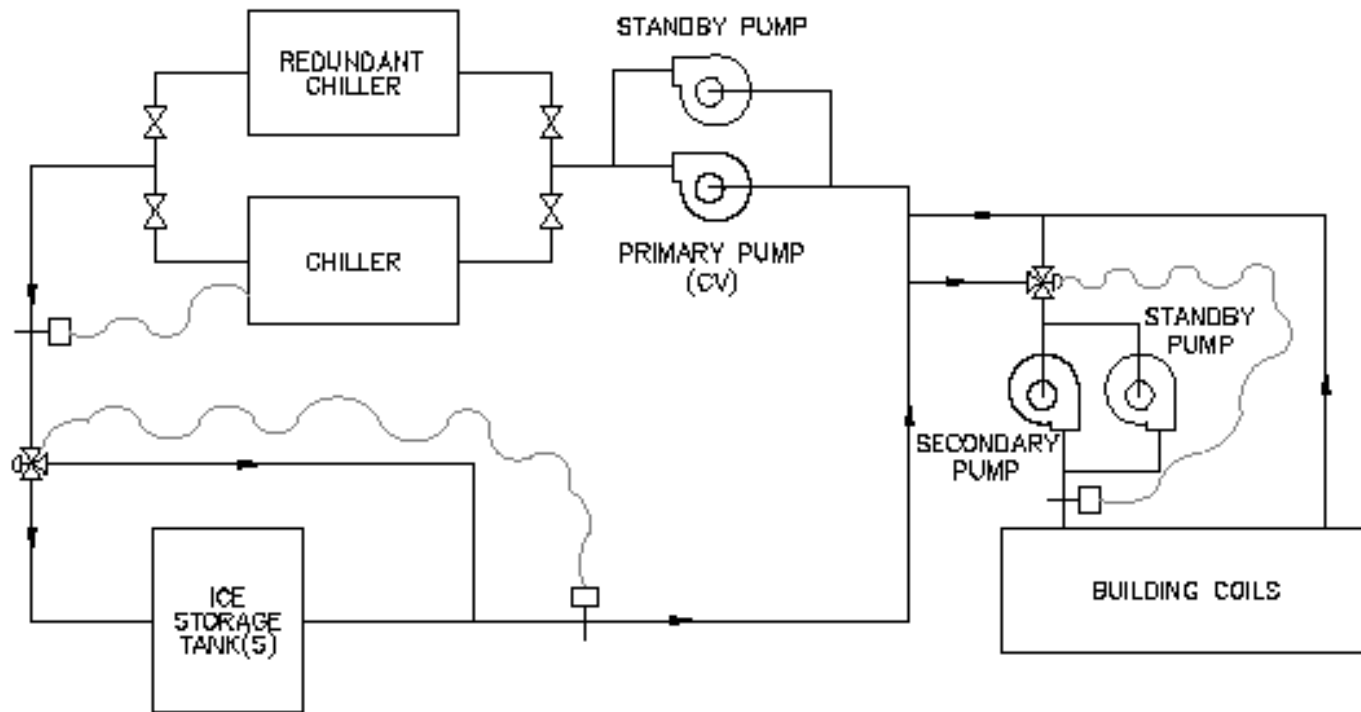
- Reduce annual energy cost
- Maintain reasonable first cost
- Reduce chiller demand load
- Design Ice Storage System
- Shift Load to off peak hours
- Cheaper Utility Rates



Mechanical Redesign

- Ice Storage System
- Ice making chillers & storage tanks
- Primary Pumps
- 25% Ethylene Glycol
- (2) 3-way modulating valves
- Internal melt ice-on-coil system
- Control Sequencing
 - Full Storage
 - Load Leveling Partial Storage
 - Demand Limiting Partial Storage

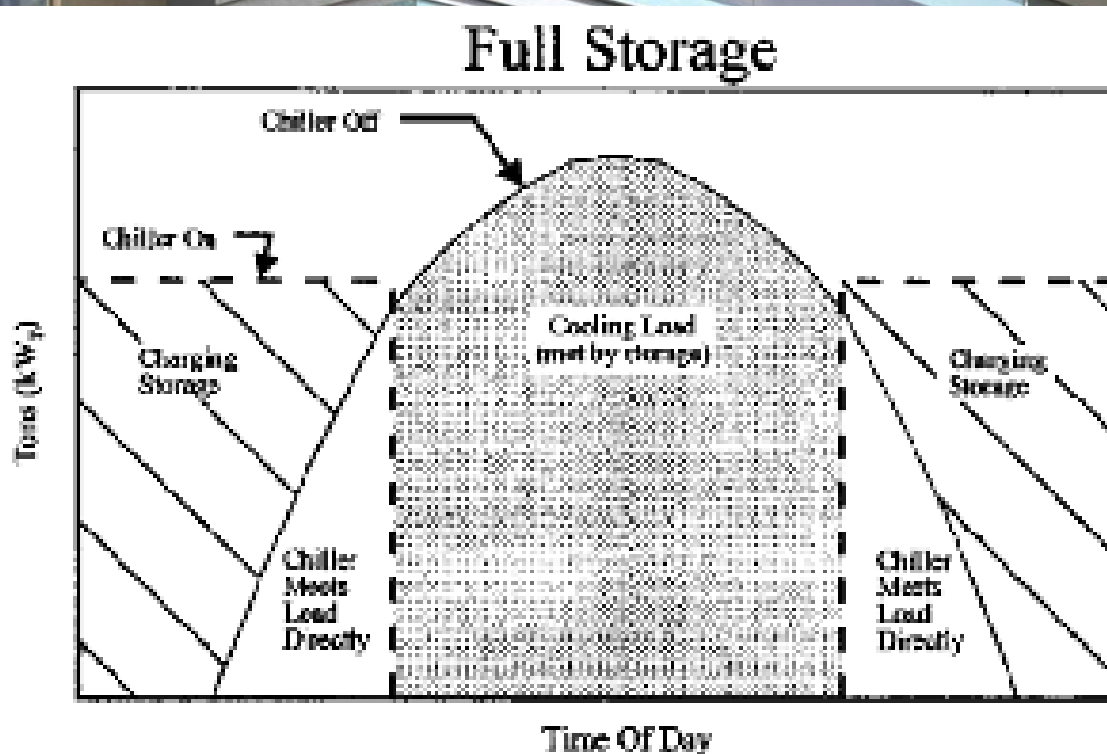
Ice Storage Flow Diagram



ICE STORAGE FLOW DIAGRAM

Full Ice Storage System

- Entire on-peak capacity shifted to off-peak hours
- Large chillers and storage capacity



Full Ice Storage System

| COH Full Storage Scenario | | | Summer | Winter |
|---------------------------|------------|-----------------------|----------|----------|
| Hour | Clg (Tons) | Cooling Mode | | |
| 1 | 24.7 | Satisfy Load & Charge | OFF-PEAK | OFF-PEAK |
| 2 | 23.6 | " | | |
| 3 | 22.8 | " | | |
| 4 | 22.0 | " | | |
| 5 | 21.5 | " | | |
| 6 | 22.0 | " | | |
| 7 | 23.5 | " | | |
| 8 | 138.5 | Satisfy Load | MID-PEAK | MID-PEAK |
| 9 | 131.1 | " | | |
| 10 | 148.1 | " | | |
| 11 | 156.4 | " | PEAK | |
| 12 | 162.5 | " | | |
| 13 | 160.3 | Discharging | | |
| 14 | 166.7 | " | | |
| 15 | 173.4 | " | | |
| 16 | 175.1 | " | | |
| 17 | 174.0 | " | | |
| 18 | 166.9 | " | | |
| 19 | 125.2 | " | MID-PEAK | |
| 20 | 29.9 | Satisfy Load & Charge | | |
| 21 | 28.5 | " | | |
| 22 | 26.9 | " | OFF-PEAK | |
| 23 | 26.6 | " | | |
| 24 | 25.8 | " | OFF-PEAK | |

On-Peak Ton-hr = 1,016.4
 Non-Peak Ton-hr = 1,159.6
 Total Ton-hr = 2,176.0

Full Ice Storage Sizing

Assumptions:

Total Cooling Load = Total Chiller Capacity (1) (No heat or pump losses)

Total Chiller Capacity = $H_{Chg}CR_{Chg} + H_{Cool,On}CR_{Cool,On} + H_{Cool,Off}CR_{Cool,Off}$ (2)

H_{Chg} hours charging storage
 CR_{Chg} capacity when charging storage
 $H_{Cool,On}$ hours direct cooling during on-peak period
 $CR_{Cool,On}$ capacity when cooling during on-peak period
 $H_{Cool,Off}$ hours direct cooling during off-peak period
 $CR_{Cool,Off}$ capacity when cooling during off-peak period

Quick Chiller Sizing Equation (Combine (1) and (2))

Nominal Chiller Size = Total Cooling Load / ($H_{Chg}CR_{Chg} + H_{Cool,On}CR_{Cool,On} + H_{Cool,Off}CR_{Cool,Off}$) (3)

H_{Chg} hours charging storage
 CR_{Chg} capacity ratio when charging storage
 $H_{Cool,On}$ hours direct cooling during on-peak period
 $CR_{Cool,On}$ capacity ratio when cooling during on-peak period
 $H_{Cool,Off}$ hours direct cooling during off-peak period
 $CR_{Cool,Off}$ capacity ratio when cooling during off-peak period

Full Storage System $H_{Cool,On}CR_{Cool,On} = 0$

COH Assumptions:

Supply 38 deg. solution to load

Chiller Upstream tanks provides 23 deg solution during ice making



COH Nominal Chiller Capacity (3) = 172 Tons

H_{Chg} 12
 CR_{Chg} 0.7 Assumed
 $H_{Cool,On}$ 5
 $CR_{Cool,On}$ 0.85 Assumed

Quick Storage Size

Storage Capacity = Total Cooling load - ($TC_{Cool,On} + TC_{Cool,Off} + TH_{Chg}$) (4)

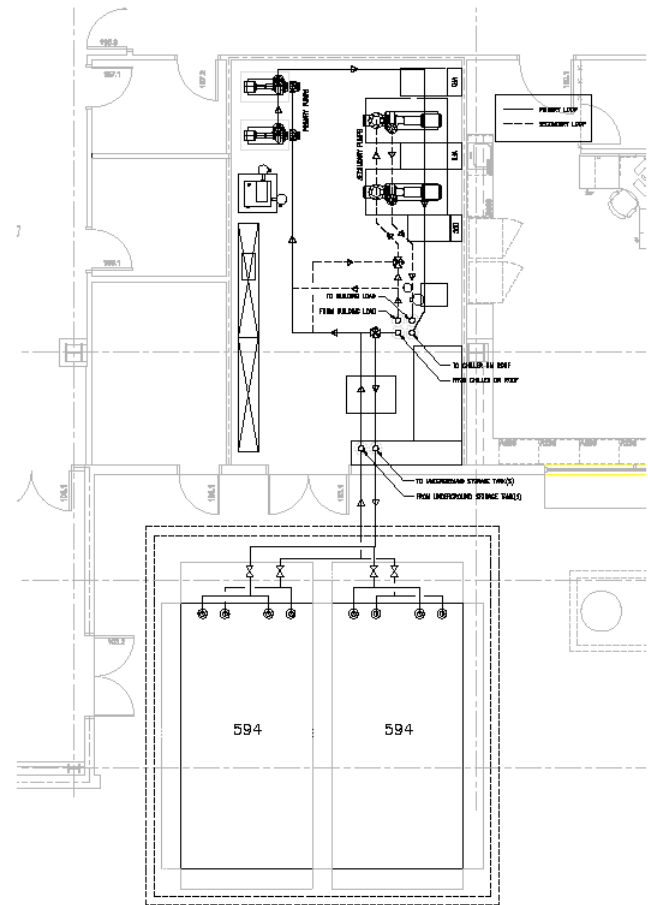
$TC_{Cool,On}$ total capacity when direct cooling during on-peak (Ton-hrs)
 $TC_{Cool,Off}$ total capacity when direct cooling during off-peak (Ton-hrs)
 TH_{Chg} ton-hours direct cooling while simultaneously charging (Ton-hrs)

$TC_{Cool,On}$ 0
 $TC_{Cool,Off}$ 736.7
 TH_{Chg} 297.8

Storage Capacity = 1,143 Ton-hrs

Full Ice Storage System

- 185 Ton Chillers
- 5 HP Primary Pumps
- (2) 594 Ton-hour Tanks
- (2) 3-way modulating control valves
- 232 gpm
- 5" CHW piping
- 38 deg. F CHWS
- Loop Fluid = 25% Ethylene Glycol



MECH. RM. LAYOUT — ICE STORAGE SYSTEM

Annual Energy Consumption

MONTHLY ENERGY CONSUMPTION

By META Engineers

----- Monthly Energy Consumption -----

| Utility | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec | Total |
|---|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|---------|
| Alternative: 3 Thermal Storage - Full Load Storage | | | | | | | | | | | | | |
| Electric | | | | | | | | | | | | | |
| On-Pk Cons. (kWh) | 0 | 0 | 0 | 0 | 0 | 41,556 | 38,052 | 43,812 | 37,977 | 0 | 0 | 0 | 161,397 |
| Off-Pk Cons. (kWh) | 73,771 | 71,433 | 76,371 | 82,446 | 84,919 | 77,958 | 96,122 | 91,057 | 89,782 | 87,607 | 77,657 | 79,663 | 988,798 |
| Mid-Pk Cons. (kWh) | 81,384 | 75,121 | 82,555 | 82,252 | 92,592 | 84,699 | 80,574 | 71,537 | 59,391 | 93,014 | 86,206 | 78,833 | 938,168 |
| On-Pk Demand (kW) | 0 | 0 | 0 | 0 | 0 | 327 | 329 | 329 | 329 | 0 | 0 | 0 | 329 |
| Off-Pk Demand (kW) | 406 | 420 | 418 | 426 | 443 | 474 | 513 | 510 | 499 | 466 | 428 | 412 | 513 |
| Mid-Pk Demand (kW) | 424 | 438 | 439 | 446 | 463 | 487 | 523 | 524 | 512 | 487 | 450 | 431 | 524 |
| Purchased Steam | | | | | | | | | | | | | |
| On-Pk Cons. (therms) | 0 | 0 | 0 | 0 | 0 | 47 | 41 | 47 | 40 | 0 | 0 | 0 | 175 |
| Off-Pk Cons. (therms) | 159 | 105 | 78 | 50 | 26 | 23 | 24 | 22 | 26 | 28 | 63 | 141 | 745 |
| Mid-Pk Cons. (therms) | 135 | 105 | 116 | 94 | 100 | 51 | 46 | 54 | 48 | 101 | 104 | 113 | 1,056 |
| On-Pk Demand (therms/hr) | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 |
| Off-Pk Demand (therms/hr) | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 |
| Mid-Pk Demand (therms/hr) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

Energy Consumption

Building 137,967 Btu/(#2-year)
 Source 407,707 Btu/(#2-year)

Floor Area 53,101 #2

Environmental Impact Analysis

CO2 No Data Available
 SO2 No Data Available
 NOX No Data Available

Utility Rate

| Amini Center Input Rate Structure | | |
|-----------------------------------|-----------------|--------------|
| Utility | Customer Charge | Rate |
| Electric Demand | | |
| On Peak (Oct. - May) | 256.19 \$/month | - |
| Mid Peak (Oct. - May) | | 0 \$/KW |
| Off Peak (Oct. - May) | | 10.36 \$/KW |
| On Peak (Jun. - Sept.) | | 0 \$/KW |
| Mid Peak (Jun. - Sept.) | | 0 \$/KW |
| Off Peak (Jun. - Sept.) | | 10.36 \$/KW |
| Electric Consumption | | |
| On Peak (Oct. - May) | - | - |
| Off Peak (Oct. - May) | - | 0.139 \$/kwh |
| Mid Peak (Oct. - May) | - | 0.174 \$/kwh |
| On Peak (Jun. - Sept.) | - | 0.199 \$/kwh |
| Off Peak (Jun. - Sept.) | - | 0.172 \$/kwh |
| Mid Peak (Jun. - Sept.) | - | 0.135 \$/kwh |

* Rates are based on SCE rate schedule with CPP incentive

- Utility Rate Incentives

| Utility Schedule | | | | |
|------------------|---------------|------|----------|----------|
| | Time | Hour | Summer | Winter |
| AM | 12:00 - 1:00 | 1 | OFF-PEAK | OFF-PEAK |
| | 1:00 - 2:00 | 2 | | |
| | 2:00 - 3:00 | 3 | | |
| | 3:00 - 4:00 | 4 | | |
| | 4:00 - 5:00 | 5 | | |
| | 5:00 - 6:00 | 6 | | |
| | 6:00 - 7:00 | 7 | | |
| | 7:00 - 8:00 | 8 | MID-PEAK | MID-PEAK |
| | 8:00 - 9:00 | 9 | | |
| | 9:00 - 10:00 | 10 | | |
| | 10:00 - 11:00 | 11 | | |
| | 11:00 - 12:00 | 12 | | |
| 12:00 - 1:00 | 13 | | | |
| PM | 1:00 - 2:00 | 14 | PEAK | MID-PEAK |
| | 2:00 - 3:00 | 15 | | |
| | 3:00 - 4:00 | 16 | | |
| | 4:00 - 5:00 | 17 | | |
| | 5:00 - 6:00 | 18 | | |
| | 6:00 - 7:00 | 19 | | |
| | 7:00 - 8:00 | 20 | MID-PEAK | MID-PEAK |
| | 8:00 - 9:00 | 21 | | |
| | 9:00 - 10:00 | 22 | | |
| | 10:00 - 11:00 | 23 | | |
| | 11:00 - 12:00 | 24 | | |

Full Storage Annual Energy Cost

| Utility | Jan | Feb | Mar | Apr | ----- Monthly Utility Costs ----- | | | | Sept | Oct | Nov | Dec | Total |
|----------------------------|-------------------------|---------------|---------------|---------------|-----------------------------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|----------------|
| | | | | | May | June | July | Aug | | | | | |
| Alternative 3 | | | | | | | | | | | | | |
| Electric | | | | | | | | | | | | | |
| On-Pk Cons. (\$) | 256 | 256 | 256 | 256 | 256 | 8,534 | 7,836 | 8,984 | 7,821 | 256 | 256 | 256 | 35,224 |
| Off-Pk Cons. (\$) | 10,526 | 10,200 | 10,888 | 11,733 | 12,078 | 10,812 | 13,271 | 12,585 | 12,413 | 12,452 | 11,067 | 11,346 | 139,371 |
| Mid-Pk Cons. (\$) | 14,452 | 13,358 | 16,399 | 14,602 | 16,405 | 11,359 | 10,651 | 12,533 | 10,448 | 16,479 | 15,291 | 14,005 | 165,993 |
| Off-Pk Demand (\$) | 4,207 | 4,351 | 4,328 | 4,413 | 4,586 | 4,913 | 5,316 | 5,285 | 5,170 | 4,831 | 4,434 | 4,267 | 56,101 |
| Mid-Pk Demand (\$) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total (\$): | 29,441 | 28,166 | 31,871 | 31,004 | 33,325 | 35,619 | 37,075 | 39,387 | 35,852 | 34,018 | 31,048 | 29,875 | 396,679 |
| Monthly Total (\$): | 29,441 | 28,166 | 31,871 | 31,004 | 33,325 | 35,619 | 37,075 | 39,387 | 35,852 | 34,018 | 31,048 | 29,875 | 396,679 |
| Building Area = | 53,101 ft ² | | | | | | | | | | | | |
| Utility Cost Per Area = | 7.47 \$/ft ² | | | | | | | | | | | | |



Full Storage Primary Loop First Cost

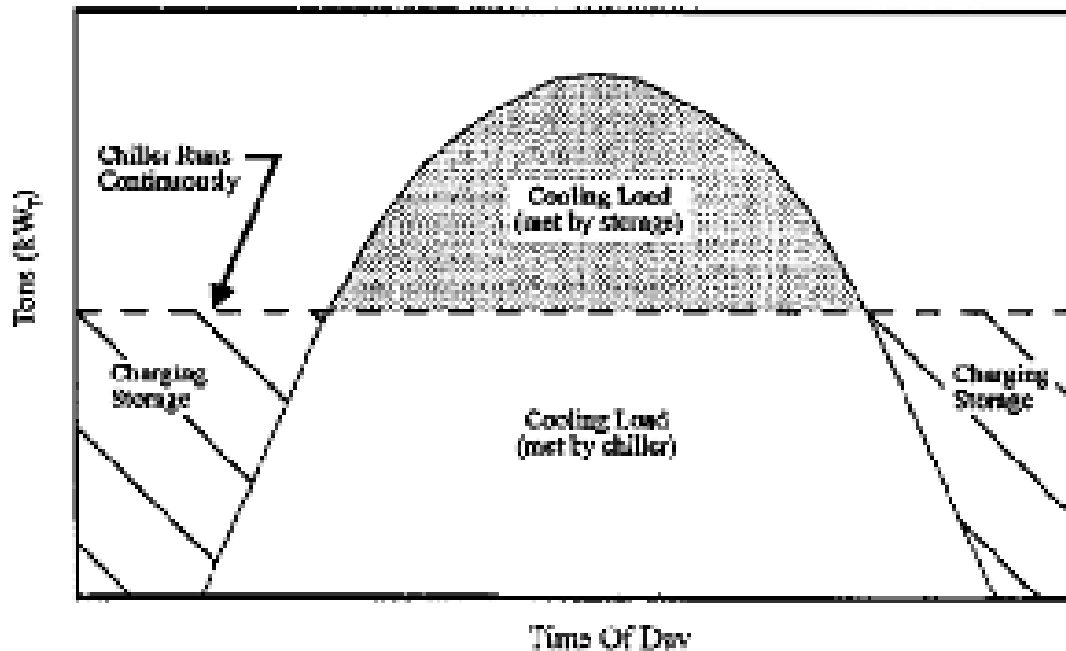
| Full Storage First Costs | | | | | |
|---|---------------|-------|----------|--------------|------------|
| Description | Product Total | Units | Quantity | Cost/Unit | Sub-Total |
| Chiller Incl. Labor + O&P (185 Ton) | 1 | EA | 2 | \$118,500.00 | \$237,000 |
| CHW Piping - 5" Incl. Labor + O&P | 721 | LF | 1 | \$70.00 | \$50,470 |
| CHW 90 deg Fittings - 5" Incl. Labor + O&P | 1 | EA | 47 | \$370.00 | \$17,390 |
| CHW 45 deg Fittings - 5" Incl. Labor + O&P | 1 | EA | 1 | \$455.00 | \$455 |
| CHW Tee Fittings - 5" Incl. Labor + O&P | 1 | EA | 13 | \$655.00 | \$8,515 |
| CHW Piping Insulation - 2" on 5"d Incl. Labor + O&P | 721 | LF | 1 | \$14.00 | \$10,094 |
| Valves Incl. Labor + O&P | 1 | LS | 1 | \$6,000.00 | \$6,000 |
| Control Valve Incl. Labor + O&P | 1 | EA | 2 | \$1,885.00 | \$3,770 |
| Vibration/Seismic Restraints Incl. Labor + O&P | 1 | LS | 1 | \$4,500.00 | \$4,500 |
| CHW Pump - 232 gpm @ 5.0 Hp Incl. Labor + O&P | 1 | EA | 2 | \$3,825.00 | \$7,650 |
| | | | | | |
| DDC Controls | 1 | LS | 1 | \$15,000.00 | \$15,000 |
| Electrical - CHWP Hook-up | 1 | EA | 2 | \$1,750.00 | \$3,500 |
| Electrical - Chiller Hook-up | 1 | EA | 2 | \$2,500.00 | \$5,000 |
| | | | | | |
| Excavation and Hauling | 413 | CY | 1 | \$20.18 | \$8,341 |
| Gravel Fill Incl. Labor + O&P | 744 | SF | 1 | \$0.45 | \$335 |
| Formwork SOG Incl. Labor + O&P | 110 | LF | 1 | \$4.35 | \$479 |
| Formwork Walls Incl. Labor + O&P | 1560 | SFCA | 1 | \$6.65 | \$10,374 |
| Concrete SOG Incl. Labor + O&P | 744 | SF | 1 | \$3.41 | \$2,537 |
| Concrete Walls Incl. Labor + O&P | 39 | CY | 1 | \$25.50 | \$1,006 |
| Steel Beam Incl. Labor + O&P | 28 | LF | 1 | \$51.00 | \$1,428 |
| Steel Grating Incl. Labor + O&P | 744 | SF | 1 | \$15.00 | \$11,160 |
| Ethylene Glycol | 2040 | GAL | 1 | \$10.05 | \$20,502 |
| Ice Storage Units | 1 | EA | 2 | \$74,500.00 | \$149,000 |
| | | | | | |
| Pipe Testing - 500-1000 LF | 1 | EA | 1 | \$1,750.00 | \$1,750 |
| Water Balancing (Pumps) | 1 | EA | 2 | \$1,700.00 | \$3,400 |
| | | | | | |
| Commissioning | 1 | TC | 1 | 0.75% | \$4,347.41 |

Total: \$584,003
Escalation: 15% \$671,603

Load Leveling Partial Ice Storage System

- Partial on-peak capacity shifted to non-peak hours
- Design Day: chiller Operates at full capacity 24-7
- Bldg. Load < Chiller capacity – chiller stores excess capacity
- Bldg. Load > Chiller capacity – storage capacity discharges to supplement chiller
- Small chillers and storage capacity

Partial Storage-Load Leveling



Load Leveling Partial Ice Storage System

| COH Load Leveling Scenario | | | | |
|----------------------------|------------|--------------------------|----------|----------|
| Hour | Clg (Tons) | Cooling Mode | Summer | Winter |
| 1 | 24.7 | Satisfy Load & Charge | OFF-PEAK | OFF-PEAK |
| 2 | 23.6 | " | | |
| 3 | 22.8 | " | | |
| 4 | 22.0 | " | | |
| 5 | 21.5 | " | | |
| 6 | 22.0 | " | | |
| 7 | 23.5 | " | | |
| 8 | 138.5 | Satisfy Load & Discharge | MID-PEAK | MID-PEAK |
| 9 | 131.1 | " | | |
| 10 | 148.1 | " | | |
| 11 | 156.4 | " | | |
| 12 | 162.5 | " | | |
| 13 | 160.3 | " | | |
| 14 | 166.7 | " | | |
| 15 | 173.4 | " | PEAK | |
| 16 | 175.1 | " | | |
| 17 | 174.0 | " | | |
| 18 | 166.9 | " | MID-PEAK | |
| 19 | 125.2 | " | | |
| 20 | 29.9 | Satisfy Load & Charge | | |
| 21 | 28.5 | " | OFF-PEAK | |
| 22 | 26.9 | " | | |
| 23 | 26.6 | " | | |
| 24 | 25.8 | " | OFF-PEAK | OFF-PEAK |

On-Peak Ton-hr = 1,016.4
 Non-Peak Ton-hr = 1,159.6
 Total Ton-hr = 2,176.0

Load Leveling Partial Ice Storage Sizing

Assumptions:

Total Cooling Load = Total Chiller Capacity (1) (No heat or pump losses)

Total Chiller Capacity = $H_{\text{Chrg}}C_{\text{Chrg}} + H_{\text{DOnp}}C_{\text{DOnp}} + H_{\text{DOffp}}C_{\text{DOffp}}$ (2)

| | |
|--------------------|--|
| H_{Chrg} | hours charging storage |
| C_{Chrg} | capacity when charging storage |
| H_{DOnp} | hours direct cooling during on-peak period |
| C_{DOnp} | capacity when cooling during on-peak period |
| H_{DOffp} | hours direct cooling during off-peak period |
| C_{DOffp} | capacity when cooling during off-peak period |

Quick Chiller Sizing Equation (Combine (1) and (2))

Nominal Chiller Size = Total Cooling Load / ($H_{\text{Chrg}}CR_{\text{Chrg}} + H_{\text{DOnp}}CR_{\text{DOnp}} + H_{\text{DOffp}}CR_{\text{DOffp}}$) (3)


| | |
|---------------------|--|
| H_{Chrg} | hours charging storage |
| CR_{Chrg} | capacity ratio when charging storage |
| H_{DOnp} | hours direct cooling during on-peak period |
| CR_{DOnp} | capacity ratio when cooling during on-peak period |
| H_{DOffp} | hours direct cooling during off-peak period |
| CR_{DOffp} | capacity ratio when cooling during off-peak period |

Full Storage System $H_{\text{DOnp}}CR_{\text{DOnp}} = 0$

COH Assumptions:

Supply 38 deg. solution to load

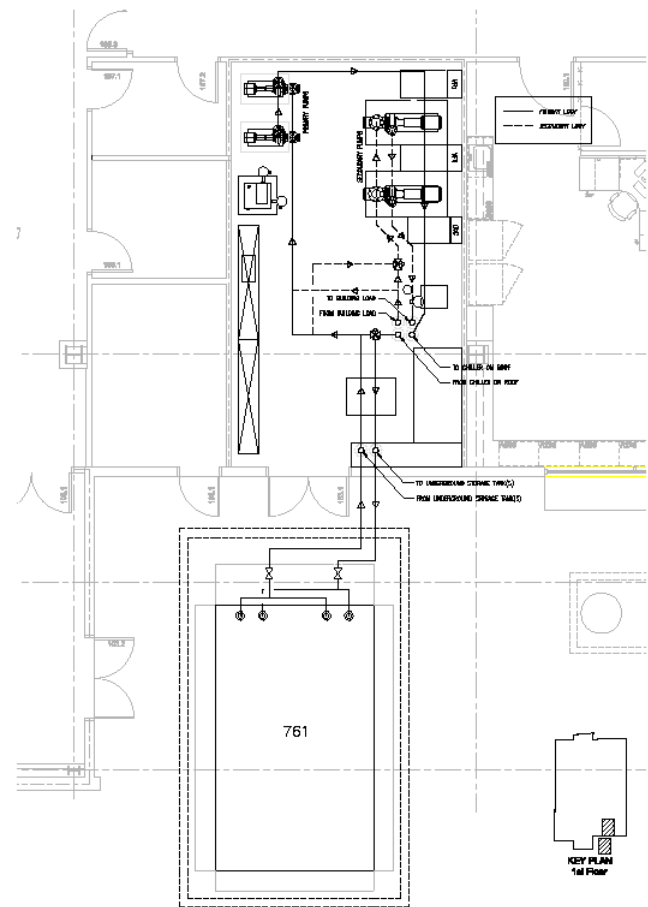
Chiller Upstream tanks provides 23 deg solution during ice making



| | | |
|--|--|--------------------|
| COH Nominal Chiller Capacity (3) = | | 117 Tons |
| H_{Chrg} | 12 | |
| CR_{Chrg} | 0.7 Assumed | |
| H_{DOnp} | 6 | |
| CR_{DOnp} | 0.85 Assumed | |
| H_{DOffp} | 6 | |
| CR_{DOffp} | 0.85 Assumed | |
| Quick Storage Size | | |
| Storage Capacity = Total Cooling load - ($TC_{\text{DOnp}} + TC_{\text{DOffp}} + TH_{\text{DChrg}}$) (4) | | |
| TC_{DOnp} | total capacity when direct cooling during on-peak | (Ton-hrs) |
| TC_{DOffp} | total capacity when direct cooling during off-peak | (Ton-hrs) |
| TH_{DChrg} | ton-hours direct cooling while simultaneously charging | (Ton-hrs) |
| Storage Capacity = | | 685 Ton-hrs |

Load Leveling Partial Ice Storage System

- 125 Ton Chillers
- 5 HP Primary Pumps
- (1) 761 Ton-hour Tank
- (2) 3-way modulating control valves
- 157 gpm
- 4" CHW piping
- 38 deg. F CHWS
- Loop Fluid = 25% Ethylene Glycol



MECH. RM. LAYOUT - ICE STORAGE SYSTEM

Annual Energy Consumption

MONTHLY ENERGY CONSUMPTION

By META Engineers

----- Monthly Energy Consumption -----

| Utility | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec | Total |
|---|--------|--------|---------|--------|---------|--------|--------|--------|--------|---------|--------|--------|---------|
| Alternative: 2 Thermal Storage - Load Leveling | | | | | | | | | | | | | |
| Electric | | | | | | | | | | | | | |
| On-Pk Cons. (KWh) | 0 | 0 | 0 | 0 | 0 | 57,105 | 53,386 | 60,897 | 52,914 | 0 | 0 | 0 | 224,302 |
| Off-Pk Cons. (KWh) | 57,568 | 52,716 | 55,675 | 71,627 | 71,024 | 65,947 | 84,817 | 75,895 | 77,487 | 72,358 | 66,699 | 72,037 | 857,853 |
| Mid-Pk Cons. (KWh) | 86,694 | 81,385 | 100,023 | 89,668 | 102,907 | 59,146 | 57,014 | 65,648 | 56,024 | 106,470 | 93,921 | 84,571 | 993,472 |
| On-Pk Demand (KW) | 0 | 0 | 0 | 0 | 0 | 453 | 464 | 461 | 460 | 0 | 0 | 0 | 464 |
| Off-Pk Demand (KW) | 384 | 408 | 405 | 413 | 430 | 438 | 451 | 447 | 447 | 440 | 415 | 389 | 451 |
| Mid-Pk Demand (KW) | 433 | 439 | 440 | 442 | 446 | 446 | 456 | 454 | 453 | 454 | 443 | 437 | 456 |
| Purchased Steam | | | | | | | | | | | | | |
| On-Pk Cons. (therms) | 0 | 0 | 0 | 0 | 0 | 47 | 41 | 47 | 40 | 0 | 0 | 0 | 175 |
| Off-Pk Cons. (therms) | 159 | 105 | 78 | 90 | 26 | 23 | 24 | 22 | 26 | 28 | 63 | 141 | 745 |
| Mid-Pk Cons. (therms) | 135 | 105 | 116 | 94 | 100 | 51 | 46 | 54 | 48 | 101 | 104 | 113 | 1,066 |
| On-Pk Demand (therms/hr) | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 |
| Off-Pk Demand (therms/hr) | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 |
| Mid-Pk Demand (therms/hr) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

Energy Consumption

| | |
|------------|-----------------------|
| Building | 136,606 Btu/(#2-year) |
| Source | 403,324 Btu/(#2-year) |
| Floor Area | 53,101 #2 |

Environmental Impact Analysis

| | |
|-----|-------------------|
| CO2 | No Data Available |
| SO2 | No Data Available |
| NOX | No Data Available |

Utility Rate

| Amini Center Input Rate Structure | | |
|-----------------------------------|-----------------|--------------|
| Utility | Customer Charge | Rate |
| Electric Demand | | |
| On Peak (Oct. - May) | 256.19 \$/month | - |
| Mid Peak (Oct. - May) | | 0 \$/KW |
| Off Peak (Oct. - May) | | 10.36 \$/KW |
| On Peak (Jun. - Sept.) | | 0 \$/KW |
| Mid Peak (Jun. - Sept.) | | 0 \$/KW |
| Off Peak (Jun. - Sept.) | | 10.36 \$/KW |
| Electric Consumption | | |
| On Peak (Oct. - May) | - | - |
| Off Peak (Oct. - May) | - | 0.139 \$/kwh |
| Mid Peak (Oct. - May) | - | 0.174 \$/kwh |
| On Peak (Jun. - Sept.) | - | 0.199 \$/kwh |
| Off Peak (Jun. - Sept.) | - | 0.172 \$/kwh |
| Mid Peak (Jun. - Sept.) | - | 0.135 \$/kwh |

* Rates are based on SCE rate schedule with CPP incentive

- Utility Rate Incentives

| Utility Schedule | | | | |
|------------------|---------------|----------|----------|----------|
| | Time | Hour | Summer | Winter |
| AM | 12:00 - 1:00 | 1 | OFF-PEAK | OFF-PEAK |
| | 1:00 - 2:00 | 2 | | |
| | 2:00 - 3:00 | 3 | | |
| | 3:00 - 4:00 | 4 | | |
| | 4:00 - 5:00 | 5 | | |
| | 5:00 - 6:00 | 6 | | |
| | 6:00 - 7:00 | 7 | | |
| | 7:00 - 8:00 | 8 | MID-PEAK | MID-PEAK |
| | 8:00 - 9:00 | 9 | | |
| | 9:00 - 10:00 | 10 | | |
| | 10:00 - 11:00 | 11 | | |
| | 11:00 - 12:00 | 12 | | |
| 12:00 - 1:00 | 13 | PEAK | | |
| 1:00 - 2:00 | 14 | | | |
| 2:00 - 3:00 | 15 | | | |
| 3:00 - 4:00 | 16 | | | |
| 4:00 - 5:00 | 17 | | | |
| 5:00 - 6:00 | 18 | | MID-PEAK | MID-PEAK |
| 6:00 - 7:00 | 19 | | | |
| 7:00 - 8:00 | 20 | | | |
| 8:00 - 9:00 | 21 | | | |
| 9:00 - 10:00 | 22 | | | |
| 10:00 - 11:00 | 23 | OFF-PEAK | | |
| 11:00 - 12:00 | 24 | | | |

Load Leveling Partial Ice Storage Annual Energy Cost

Alternative 2

Electric

| | | | | | | | | | | | | | |
|----------------------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|----------------|
| On-Pk Cons. (\$) | 256 | 256 | 256 | 256 | 256 | 11,632 | 10,891 | 12,387 | 10,797 | 256 | 256 | 256 | 47,755 |
| Off-Pk Cons. (\$) | 9,662 | 8,987 | 9,399 | 10,227 | 10,144 | 9,185 | 11,740 | 11,074 | 10,748 | 10,329 | 9,541 | 10,284 | 121,322 |
| Mid-Pk Cons. (\$) | 15,377 | 14,451 | 17,701 | 15,895 | 18,204 | 10,406 | 10,040 | 11,522 | 9,870 | 18,826 | 16,637 | 15,006 | 173,936 |
| Off-Pk Demand (\$) | 4,079 | 4,222 | 4,199 | 4,283 | 4,456 | 4,538 | 4,673 | 4,627 | 4,631 | 4,556 | 4,304 | 4,138 | 52,705 |
| Mid-Pk Demand (\$) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total (\$): | 29,374 | 27,916 | 31,556 | 30,661 | 33,060 | 35,761 | 37,344 | 39,610 | 36,046 | 33,966 | 30,738 | 29,685 | 395,718 |
| Monthly Total (\$): | 29,374 | 27,916 | 31,556 | 30,661 | 33,060 | 35,761 | 37,344 | 39,610 | 36,046 | 33,966 | 30,738 | 29,685 | 395,718 |

Building Area = 53,101 ft²

Utility Cost Per Area = 7.45 \$/ft²



Load Leveling Partial Ice Storage Primary Loop First Cost

| Load Leveling Partial Storage First Costs | | | | | |
|---|---------------|-------|----------|-------------|------------|
| Description | Product Total | Units | Quantity | Cost/Unit | Sub-Total |
| Chiller Incl. Labor + O&P (125 Ton) | 1 | EA | 2 | \$65,000.00 | \$170,000 |
| CHW Piping - 4" Incl. Labor + O&P | 693 | LF | 1 | \$48.50 | \$33,611 |
| CHW 90 deg Fittings - 4" Incl. Labor + O&P | 1 | EA | 36 | \$240.00 | \$9,120 |
| CHW 45 deg Fittings - 4" Incl. Labor + O&P | 1 | EA | 1 | \$278.00 | \$278 |
| CHW Tee Fittings - 4" Incl. Labor + O&P | 1 | EA | 9 | \$360.00 | \$3,240 |
| CHW Piping Insulation - 2" on 4"d Incl. Labor + O&P | 693 | LF | 1 | \$13.00 | \$9,009 |
| Valves Incl. Labor + O&P | 1 | LS | 1 | \$5,200.00 | \$5,200 |
| Control Valve Incl. Labor + O&P | 1 | EA | 2 | \$1,885.00 | \$3,770 |
| Vibration/Seismic Restraints Incl. Labor + O&P | 1 | LS | 1 | \$4,500.00 | \$4,500 |
| CHW Pump - 157 gpm @ 5.0 Hp Incl. Labor + O&P | 1 | EA | 2 | \$3,700.00 | \$7,400 |
| DDC Controls | 1 | LS | 1 | \$15,000.00 | \$15,000 |
| Electrical - CHWP Hook-up | 1 | EA | 2 | \$1,750.00 | \$3,500 |
| Electrical - Chiller Hook-up | 1 | EA | 2 | \$2,500.00 | \$5,000 |
| Excevation and Hauling | 269 | CY | 1 | \$20.18 | \$5,426 |
| Gravel Fill Incl. Labor + O&P | 484 | SF | 1 | \$0.45 | \$218 |
| Formwork SOG Incl. Labor + O&P | 91 | LF | 1 | \$4.35 | \$396 |
| Formwork Walls Incl. Labor + O&P | 1275 | SFCA | 1 | \$6.65 | \$8,479 |
| Concrete SOG Incl. Labor + O&P | 484 | SF | 1 | \$3.41 | \$1,650 |
| Concrete Walls Incl. Labor + O&P | 36 | CY | 1 | \$25.50 | \$921 |
| Steel Beam Incl. Labor + O&P | 28 | LF | 1 | \$51.00 | \$1,428 |
| Steel Grating Incl. Labor + O&P | 484 | SF | 1 | \$15.00 | \$7,260 |
| Ethylene Glycol | 1339.6 | GAL | 1 | \$10.05 | \$13,463 |
| Ice Storage Units | 1 | EA | 1 | \$84,000.00 | \$84,000 |
| Pipe Testing - 500-1000 LF | 1 | EA | 1 | \$1,750.00 | \$1,750 |
| Water Balancing (Pumps) | 1 | EA | 2 | \$1,700.00 | \$3,400 |
| Commissioning | 1 | TC | 1 | 0.75% | \$2,985.14 |

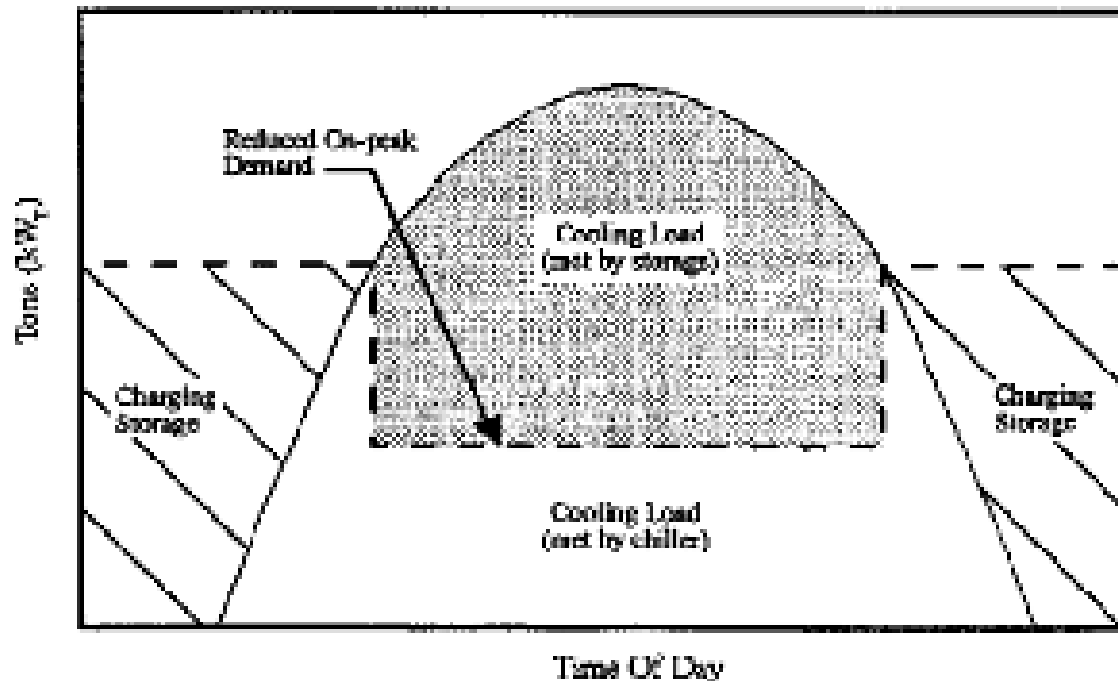
Total: \$401,003

Escalation: 15% \$461,154

Demand Limiting Partial Ice Storage System

- Partial on-peak capacity shifted to non-peak hours
- Similar to load leveling w/ on-peak exception
- Chiller capacity reduced to 45% during on-peak hours
- Middle of road chillers and storage capacity

Partial Storage-Demand Limiting



Demand Limiting Partial Ice Storage System

| COH Demand Limiting Scenario | | | | |
|------------------------------|------------|------------------------------|----------|----------|
| Hour | Clg (Tons) | Cooling Mode | Summer | Winter |
| 1 | 24.7 | Satisfy Load & Charge | OFF-PEAK | OFF-PEAK |
| 2 | 23.6 | " | | |
| 3 | 22.8 | " | | |
| 4 | 22.0 | " | | |
| 5 | 21.5 | " | | |
| 6 | 22.0 | " | | |
| 7 | 23.5 | " | | |
| 8 | 138.5 | Satisfy Load & Discharge | MID-PEAK | MID-PEAK |
| 9 | 131.1 | " | | |
| 10 | 148.1 | " | | |
| 11 | 156.4 | " | | |
| 12 | 162.5 | " | PEAK | |
| 13 | 160.3 | 45% Chiller Cap. & Discharge | | |
| 14 | 166.7 | " | | |
| 15 | 173.4 | " | | |
| 16 | 175.1 | " | | |
| 17 | 174.0 | " | MID-PEAK | |
| 18 | 166.9 | " | | |
| 19 | 125.2 | " | | |
| 20 | 29.9 | Satisfy Load & Charge | | |
| 21 | 28.5 | " | OFF-PEAK | |
| 22 | 26.9 | " | | |
| 23 | 26.6 | " | | |
| 24 | 25.8 | " | | |

On-Peak Ton-hr = 1,016.4
 Non-Peak Ton-hr = 1,159.6
 Total Ton-hr = 2,176.0

Demand Limiting Partial Ice Storage Sizing

Assumptions:

Total Cooling Load = Total Chiller Capacity (1) (No heat or pump losses)

Total Chiller Capacity = $H_{Chrg}C_{Chrg} + H_{DOnp}C_{DOnp} + H_{DOffp}C_{DOffp}$ (2)

| | |
|-------------|--|
| H_{Chrg} | hours charging storage |
| C_{Chrg} | capacity when charging storage |
| H_{DOnp} | hours direct cooling during on-peak period |
| C_{DOnp} | capacity when cooling during on-peak period |
| H_{DOffp} | hours direct cooling during off-peak period |
| C_{DOffp} | capacity when cooling during off-peak period |

Quick Chiller Sizing Equation (Combine (1) and (2))

Nominal Chiller Size = Total Cooling Load / ($H_{Chrg}CR_{Chrg} + H_{DOnp}CR_{DOnp} + H_{DOffp}CR_{DOffp}$) (3)

| | |
|--------------|--|
| H_{Chrg} | hours charging storage |
| CR_{Chrg} | capacity ratio when charging storage |
| H_{DOnp} | hours direct cooling during on-peak period |
| CR_{DOnp} | capacity ratio when cooling during on-peak period |
| H_{DOffp} | hours direct cooling during off-peak period |
| CR_{DOffp} | capacity ratio when cooling during off-peak period |

Full Storage System $H_{DOnp}CR_{DOnp} = 0$

COH Assumptions:

Supply 38 deg. solution to load

Chiller Upstream tanks provides 23 deg solution during ice making



COH Nominal Chiller Capacity (3) = 138 Tons

| | |
|--------------|--------------|
| H_{Chrg} | 12 |
| CR_{Chrg} | 0.7 Assumed |
| H_{DOffp} | 5 |
| CR_{DOffp} | 0.85 Assumed |
| H_{DOnp} | 7 |
| CR_{DOnp} | 0.45 Assumed |

Quick Storage Size

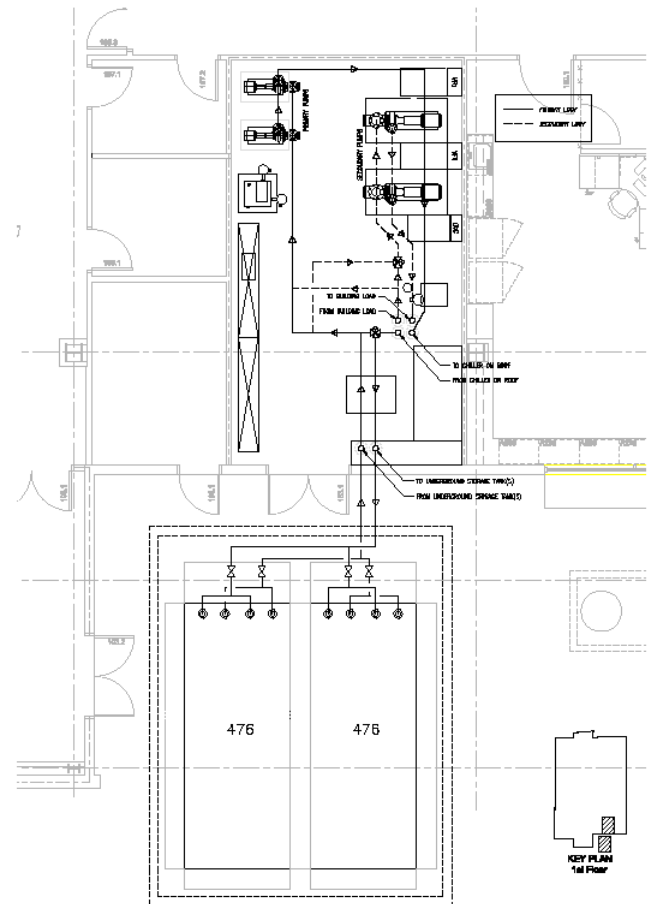
Storage Capacity = Total Cooling load - ($TC_{DOnp} + TC_{DOffp} + TH_{DChrg}$) (4)

| | | |
|--------------|--|-----------|
| TC_{DOnp} | total capacity when direct cooling during on-peak | (Ton-hrs) |
| TC_{DOffp} | total capacity when direct cooling during off-peak | (Ton-hrs) |
| TH_{DChrg} | ton-hours direct cooling while simultaneously charging | (Ton-hrs) |

Storage Capacity = 859 Ton-hrs

Demand Limiting Partial Ice Storage System

- 140 Ton Chillers
- 5 HP Primary Pumps
- (2) 476 Ton-hour Tanks
- (2) 3-way modulating control valves
- 176 gpm
- 4" CHW piping
- 38 deg. F CHWS
- Loop Fluid = 25% Ethylene Glycol



MECH. RM. LAYOUT - ICE STORAGE SYSTEM

Annual Energy Consumption

MONTHLY ENERGY CONSUMPTION

By META Engineers

----- Monthly Energy Consumption -----

| Utility | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec | Total |
|---|--------|--------|---------|--------|---------|--------|--------|--------|--------|---------|--------|--------|-----------|
| Alternative: 4 Thermal Storage - Demand Limiting | | | | | | | | | | | | | |
| Electric | | | | | | | | | | | | | |
| On-Pk Cons. (KWh) | 0 | 0 | 0 | 0 | 0 | 52,916 | 49,200 | 56,211 | 48,856 | 0 | 0 | 0 | 207,183 |
| Off-Pk Cons. (KWh) | 68,247 | 63,355 | 66,358 | 72,446 | 72,742 | 70,074 | 66,604 | 63,831 | 62,252 | 77,166 | 67,399 | 72,773 | 895,248 |
| Mid-Pk Cons. (KWh) | 87,579 | 82,476 | 101,412 | 91,109 | 103,725 | 63,717 | 59,864 | 69,291 | 58,562 | 104,902 | 95,419 | 85,692 | 1,003,749 |
| On-Pk Demand (KW) | 0 | 0 | 0 | 0 | 0 | 418 | 432 | 424 | 424 | 0 | 0 | 0 | 432 |
| Off-Pk Demand (KW) | 368 | 412 | 410 | 418 | 435 | 457 | 472 | 467 | 467 | 459 | 420 | 404 | 472 |
| Mid-Pk Demand (KW) | 416 | 430 | 431 | 438 | 455 | 466 | 478 | 475 | 474 | 466 | 442 | 423 | 478 |
| Purchased Steam | | | | | | | | | | | | | |
| On-Pk Cons. (therms) | 0 | 0 | 0 | 0 | 0 | 47 | 41 | 47 | 40 | 0 | 0 | 0 | 175 |
| Off-Pk Cons. (therms) | 159 | 105 | 78 | 90 | 26 | 23 | 24 | 22 | 26 | 28 | 63 | 141 | 745 |
| Mid-Pk Cons. (therms) | 135 | 105 | 116 | 94 | 100 | 51 | 46 | 54 | 48 | 101 | 104 | 113 | 1,066 |
| On-Pk Demand (therms/hr) | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 |
| Off-Pk Demand (therms/hr) | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 |
| Mid-Pk Demand (therms/hr) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

Energy Consumption

| | |
|------------|-----------------------|
| Building | 138,470 Btu/(#2-year) |
| Source | 409,216 Btu/(#2-year) |
| Floor Area | 53,101 #2 |

Environmental Impact Analysis

| | |
|-----|-------------------|
| CO2 | No Data Available |
| SO2 | No Data Available |
| NOX | No Data Available |

Utility Rate

| Amini Center Input Rate Structure | | |
|-----------------------------------|-----------------|--------------|
| Utility | Customer Charge | Rate |
| Electric Demand | | |
| On Peak (Oct. - May) | 256.19 \$/month | - |
| Mid Peak (Oct. - May) | | 0 \$/KW |
| Off Peak (Oct. - May) | | 10.36 \$/KW |
| On Peak (Jun. - Sept.) | | 0 \$/KW |
| Mid Peak (Jun. - Sept.) | | 0 \$/KW |
| Off Peak (Jun. - Sept.) | | 10.36 \$/KW |
| Electric Consumption | | |
| On Peak (Oct. - May) | - | - |
| Off Peak (Oct. - May) | - | 0.139 \$/kwh |
| Mid Peak (Oct. - May) | - | 0.174 \$/kwh |
| On Peak (Jun. - Sept.) | - | 0.199 \$/kwh |
| Off Peak (Jun. - Sept.) | - | 0.172 \$/kwh |
| Mid Peak (Jun. - Sept.) | - | 0.135 \$/kwh |

* Rates are based on SCE rate schedule with CPP incentive

- Utility Rate Incentives

| Utility Schedule | | | | |
|------------------|---------------|------|----------|----------|
| | Time | Hour | Summer | Winter |
| AM | 12:00 - 1:00 | 1 | OFF-PEAK | OFF-PEAK |
| | 1:00 - 2:00 | 2 | | |
| | 2:00 - 3:00 | 3 | | |
| | 3:00 - 4:00 | 4 | | |
| | 4:00 - 5:00 | 5 | | |
| | 5:00 - 6:00 | 6 | | |
| | 6:00 - 7:00 | 7 | MID-PEAK | MID-PEAK |
| | 7:00 - 8:00 | 8 | | |
| | 8:00 - 9:00 | 9 | | |
| | 9:00 - 10:00 | 10 | | |
| | 10:00 - 11:00 | 11 | | |
| | 11:00 - 12:00 | 12 | | |
| PM | 12:00 - 1:00 | 13 | PEAK | MID-PEAK |
| | 1:00 - 2:00 | 14 | | |
| | 2:00 - 3:00 | 15 | | |
| | 3:00 - 4:00 | 16 | | |
| | 4:00 - 5:00 | 17 | | |
| | 5:00 - 6:00 | 18 | | |
| | 6:00 - 7:00 | 19 | MID-PEAK | MID-PEAK |
| | 7:00 - 8:00 | 20 | | |
| | 8:00 - 9:00 | 21 | | |
| | 9:00 - 10:00 | 22 | | |
| | 10:00 - 11:00 | 23 | | |
| | 11:00 - 12:00 | 24 | | |

Demand Limiting Partial Ice Storage Annual Energy Cost

Alternative 4

Electric

| | | | | | | | | | | | | | |
|----------------------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|----------------|
| On-Pk Cons. (\$) | 256 | 256 | 256 | 256 | 256 | 10,797 | 10,057 | 11,453 | 9,988 | 256 | 256 | 256 | 44,345 |
| Off-Pk Cons. (\$) | 9,757 | 9,076 | 9,494 | 10,341 | 10,383 | 9,744 | 12,253 | 11,607 | 11,393 | 10,998 | 9,639 | 10,387 | 125,072 |
| Mid-Pk Cons. (\$) | 15,531 | 14,641 | 17,944 | 16,146 | 18,347 | 11,191 | 10,530 | 12,147 | 10,306 | 18,552 | 16,898 | 15,202 | 177,434 |
| Off-Pk Demand (\$) | 4,127 | 4,271 | 4,247 | 4,331 | 4,506 | 4,737 | 4,889 | 4,837 | 4,841 | 4,752 | 4,353 | 4,186 | 54,077 |
| Mid-Pk Demand (\$) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total (\$): | 29,671 | 28,243 | 31,941 | 31,075 | 33,491 | 36,469 | 37,728 | 40,045 | 36,529 | 34,558 | 31,146 | 30,031 | 400,928 |
| Monthly Total (\$): | 29,671 | 28,243 | 31,941 | 31,075 | 33,491 | 36,469 | 37,728 | 40,045 | 36,529 | 34,558 | 31,146 | 30,031 | 400,928 |

Building Area = 53,101 ft²
 Utility Cost Per Area = 7.55 \$/ft²

Demand Limiting Partial Ice Storage Primary Loop First Cost

| Demand Limiting Partial Storage First Costs | | | | | |
|---|---------------|-------|----------|-------------|------------|
| Description | Product Total | Units | Quantity | Cost/Unit | Sub-Total |
| Chiller Incl. Labor + O&P (140 Ton) | 1 | EA | 2 | \$93,000.00 | \$186,000 |
| CHW Piping - 4" Incl. Labor + O&P | 721 | LF | 1 | \$48.50 | \$34,969 |
| CHW 90 deg Fittings - 4" Incl. Labor + O&P | 1 | EA | 47 | \$240.00 | \$11,280 |
| CHW 45 deg Fittings - 4" Incl. Labor + O&P | 1 | EA | 1 | \$278.00 | \$278 |
| CHW Tee Fittings - 4" Incl. Labor + O&P | 1 | EA | 13 | \$360.00 | \$4,680 |
| CHW Piping Insulation - 2" on 4"d Incl. Labor + O&P | 721 | LF | 1 | \$13.00 | \$9,373 |
| Valves Incl. Labor + O&P | 1 | LS | 1 | \$5,500.00 | \$5,500 |
| Control Valve Incl. Labor + O&P | 1 | EA | 2 | \$1,885.00 | \$3,770 |
| Vibration/Seismic Restraints Incl. Labor + O&P | 1 | LS | 1 | \$4,500.00 | \$4,500 |
| CHW Pump - 176 gpm @ 5.0 Hp Incl. Labor + O&P | 1 | EA | 2 | \$3,700.00 | \$7,400 |
| | | | | | |
| DDC Controls | 1 | LS | 1 | \$15,000.00 | \$15,000 |
| Electrical - CHWP Hook-up | 1 | EA | 2 | \$1,750.00 | \$3,500 |
| Electrical - Chiller Hook-up | 1 | EA | 2 | \$2,500.00 | \$5,000 |
| | | | | | |
| Excavation and Hauling | 353 | CY | 1 | \$20.18 | \$7,130 |
| Gravel Fill Incl. Labor + O&P | 636 | SF | 1 | \$0.45 | \$286 |
| Formwork SOG Incl. Labor + O&P | 102 | LF | 1 | \$4.35 | \$444 |
| Formwork Walls Incl. Labor + O&P | 1440 | SFCA | 1 | \$6.65 | \$9,576 |
| Concrete SOG Incl. Labor + O&P | 636 | SF | 1 | \$3.41 | \$2,169 |
| Concrete Walls Incl. Labor + O&P | 36 | CY | 1 | \$25.50 | \$921 |
| Steel Beam Incl. Labor + O&P | 28 | LF | 1 | \$51.00 | \$1,428 |
| Steel Grating Incl. Labor + O&P | 636 | SF | 1 | \$15.00 | \$9,540 |
| Ethylene Glycol | 1525 | GAL | 1 | \$10.05 | \$15,326 |
| Ice Storage Units | 1 | EA | 2 | \$61,000.00 | \$122,000 |
| | | | | | |
| Pipe Testing - 500-1000 LF | 1 | EA | 1 | \$1,750.00 | \$1,750 |
| Water Balancing (Pumps) | 1 | EA | 2 | \$1,700.00 | \$3,400 |
| | | | | | |
| Commissioning | 1 | TC | 1 | 0.75% | \$3,489.15 |
| Total: | | | | | \$468,709 |
| Escalation: 15% | | | | | \$539,015 |

Chiller Summary

185 Ton Initial Chiller Selection (Assumed Existing)

| EER | CHWS (deg F) | CHWR (deg F) | dT (deg F) | Flow Rate (GPM) | PD (ft. H ₂ O) | Cap. (Tons) | input (KW) | KW/Ton | Primary/Secondary Loop Liquid | Chiller Nominal Tonnage |
|-----|--------------|--------------|------------|-----------------|---------------------------|-------------|------------|--------|-------------------------------|-------------------------|
| 9.5 | 42 | 57 | 15 | 296 | 7 | 174.8 | 203.5 | 1.1642 | Water | 185 |

185 Ton Chiller Selection (Full Storage Scenario)

| EER | CHWS (deg F) | CHWR (deg F) | dT (deg F) | Flow Rate (GPM) | PD (ft. H ₂ O) | Cap. (Tons) | input (KW) | KW/Ton | Primary/Secondary Loop Liquid | Chiller Nominal Tonnage |
|-----|--------------|--------------|------------|-----------------|---------------------------|-------------|------------|--------|-------------------------------|-------------------------|
| 9.5 | 38 | 58 | 20 | 232 | 4.5 | 158.9 | 193 | 1.2146 | 25% Ethylene Glycol | 185 |

140 Ton Chiller Selection (Demand Limiting Partial Storage Scenario)

| EER | CHWS (deg F) | CHWR (deg F) | dT (deg F) | Flow Rate (GPM) | PD (ft. H ₂ O) | Cap. (Tons) | input (KW) | KW/Ton | Primary/Secondary Loop Liquid | Chiller Nominal Tonnage |
|-----|--------------|--------------|------------|-----------------|---------------------------|-------------|------------|--------|-------------------------------|-------------------------|
| 9.3 | 38 | 58 | 20 | 176 | 7 | 120.7 | 147.5 | 1.2220 | 25% Ethylene Glycol | 140 |

120 Ton Chiller Selection (Load Leveling Partial Storage Scenario)

| EER | CHWS (deg F) | CHWR (deg F) | dT (deg F) | Flow Rate (GPM) | PD (ft. H ₂ O) | Cap. (Tons) | input (KW) | KW/Ton | Primary/Secondary Loop Liquid | Chiller Nominal Tonnage |
|-----|--------------|--------------|------------|-----------------|---------------------------|-------------|------------|--------|-------------------------------|-------------------------|
| 9.3 | 38 | 58 | 20 | 157 | 5.75 | 106.1 | 128.7 | 1.2130 | 25% Ethylene Glycol | 125 |

Energy & Cost Summary

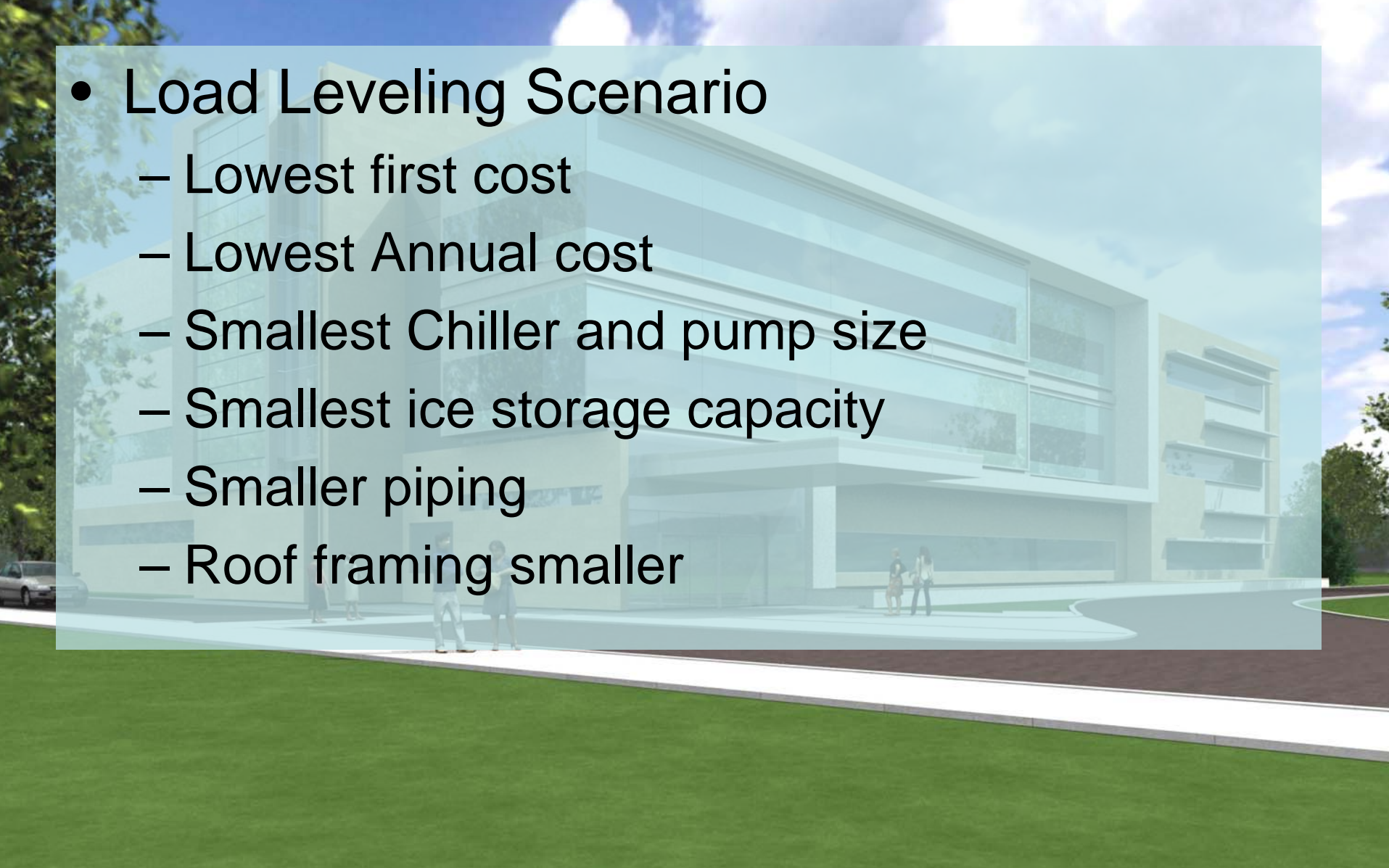
| System | Consumption (kWh) | | | Demand (kW) | | | Annual Cost (\$) | Annual Savings |
|-----------------|-------------------|----------|-----------|-------------|----------|----------|------------------|----------------|
| | Peak | Off-Peak | Mid-Peak | Peak | Off-Peak | Mid-Peak | | |
| Existing Sys | 248,264 | 857,999 | 1,000,122 | 546 | 510 | 523 | \$533,070 | \$0 |
| Load Leveling | 224,302 | 857,853 | 983,472 | 464 | 451 | 456 | \$395,718 | \$137,352 |
| Full Storage | 161,397 | 983,472 | 936,168 | 329 | 513 | 524 | \$396,679 | \$136,391 |
| Demand Limiting | 207,183 | 885,248 | 1,003,749 | 432 | 472 | 478 | \$400,928 | \$132,142 |

| System | Building Consumption (1006 BTU/ft ² /yr) | First Cost (\$) | Annual Cost (\$) | Total Cost (\$) |
|-----------------|---|-----------------|------------------|-----------------|
| Existing Sys | 7,388 | \$402,224 | \$533,070 | 935,294 |
| Load Leveling | 7,249 | \$461,154 | \$395,718 | 856,872 |
| Full Storage | 7,326 | \$671,603 | \$396,679 | 1,068,282 |
| Demand Limiting | 7,353 | \$539,015 | \$400,928 | 939,943 |



Ice Storage Redesign Recommendation

- Load Leveling Scenario
 - Lowest first cost
 - Lowest Annual cost
 - Smallest Chiller and pump size
 - Smallest ice storage capacity
 - Smaller piping
 - Roof framing smaller



Advantages / Disadvantages

- Advantages

- Lowest Annual cost
- Smaller Chiller, pump, and piping sizes
- Slight energy savings (cleaner energy off-hours)
- Utility Incentives
- Lower CHWS Temp.

- Disadvantages

- First cost
- Physical size and weight of storage tanks
- Ethylene glycol need
- Increased controls and length of piping



Questions?