# High Performance Computing with High Efficiency

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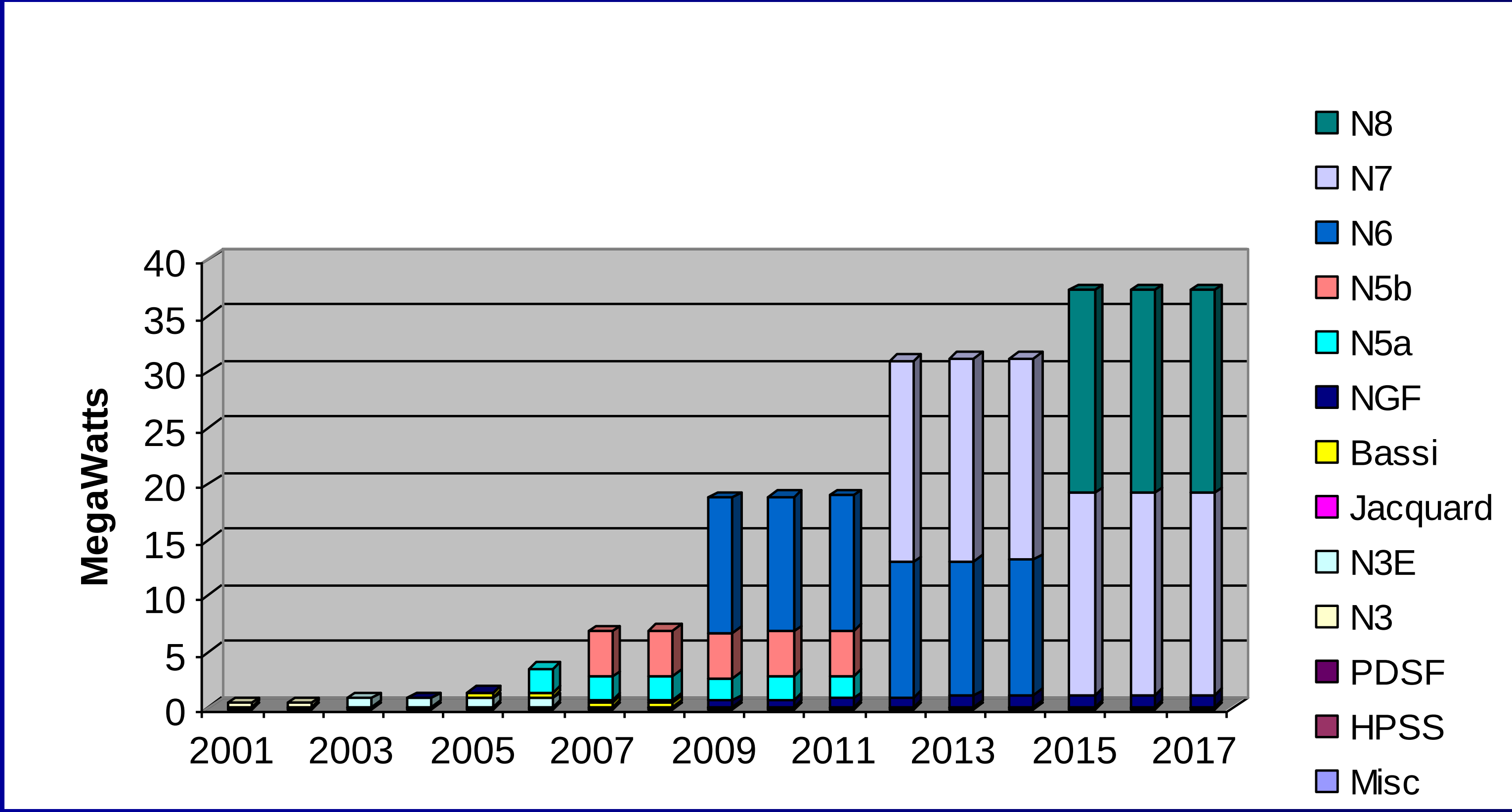
# UC Berkeley's Computational Research and Theory (CRT) Facility

- **A new high performance supercomputer center for scientific computing in Berkeley, California**
- **High Performance Computing (HPC) center on first floor**
  - 32,000 square feet computer room
  - 7.5 MW initial total power requirement, expanding to 17 MW
- **Offices on second and third floors**
- **Mechanical space below HPC, chiller plant adjacent**
- **Total gross square feet 126,000**
- **2012 occupancy ?**

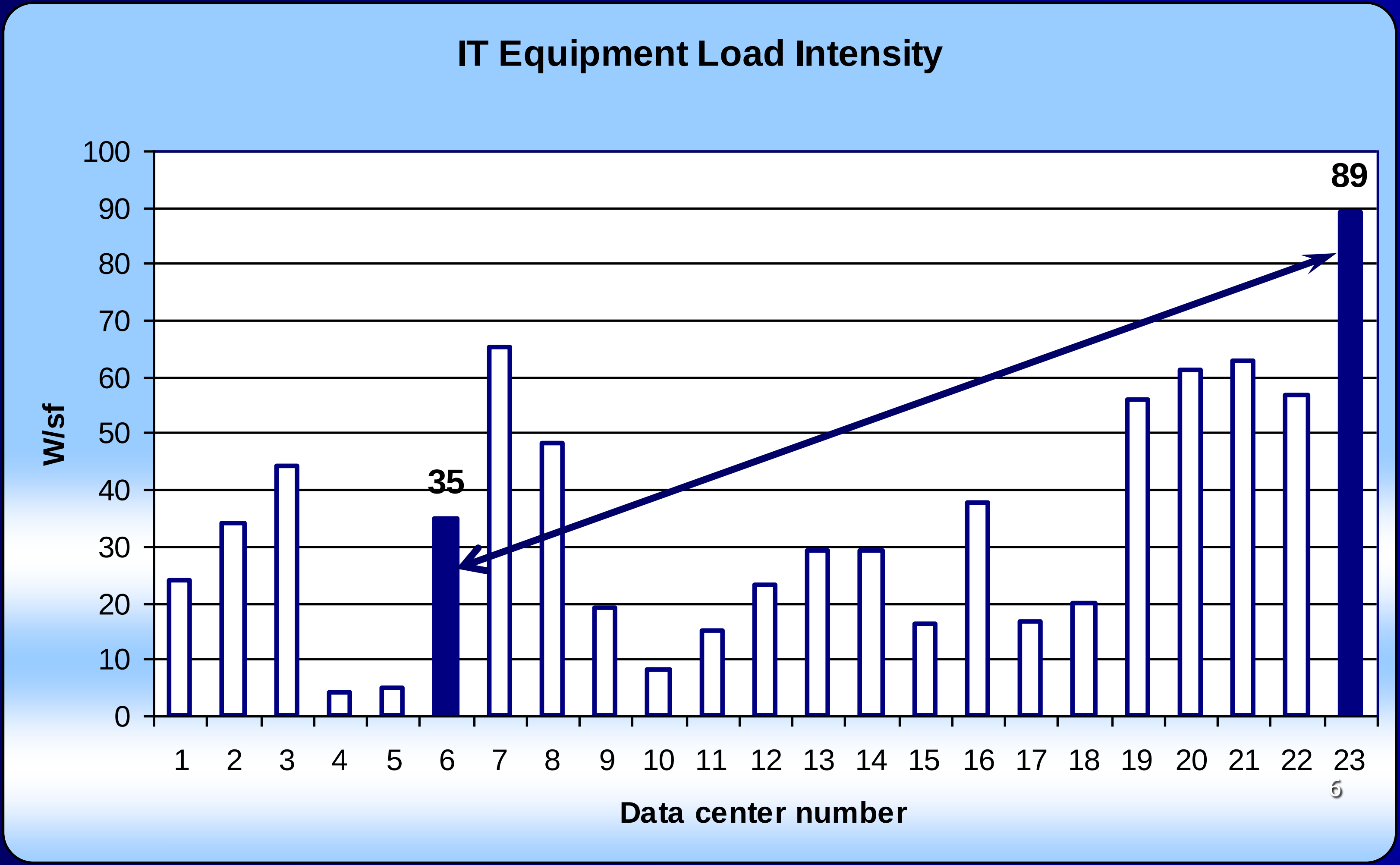
# Computational Research and Theory (CRT) Facility

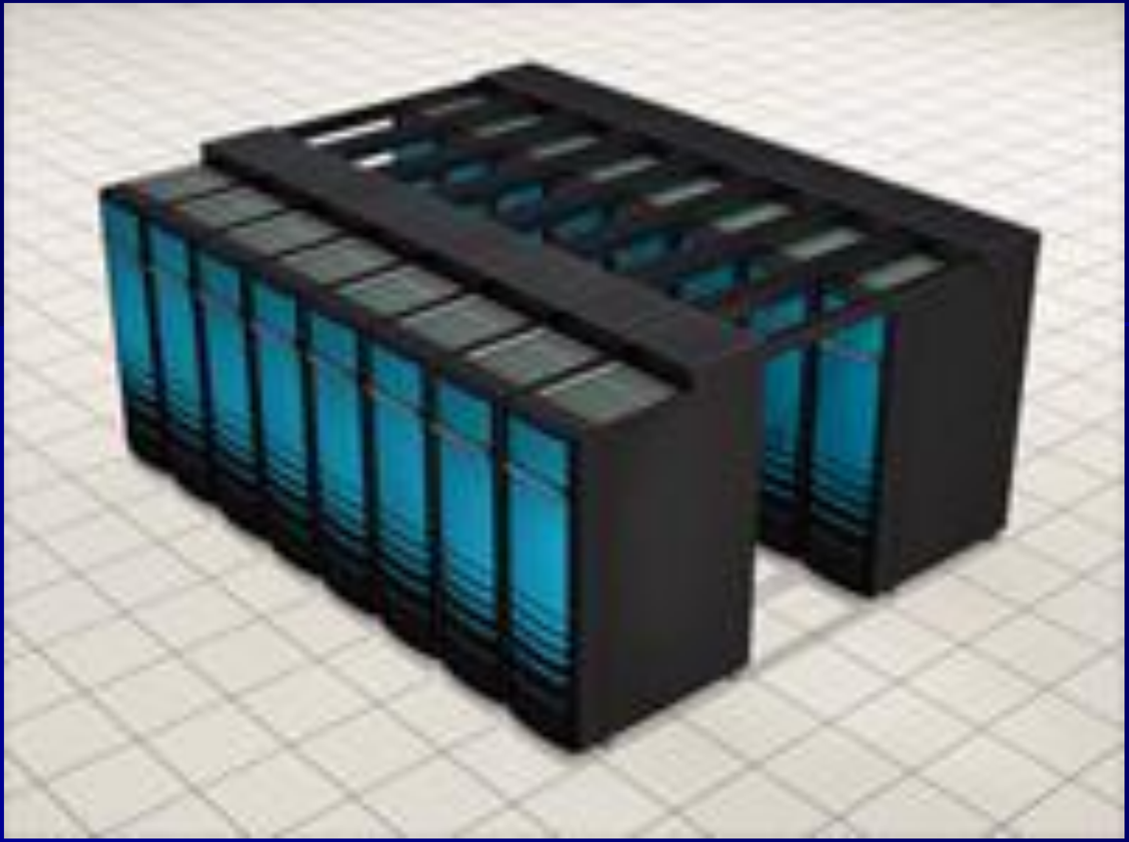
# *Computational Research and Theory (CRT) Facility rendering*

# Supercomputer systems power



# Historical change in supercomputer intensity





Site: 12 MW; 77 GWh; 2,132k GSf
CRT building: 17 MW; 150 GWh; 32k computer room

Effect of CRT: peak power x 2.4
annual electricity x 2.9

# CRT Project objectives

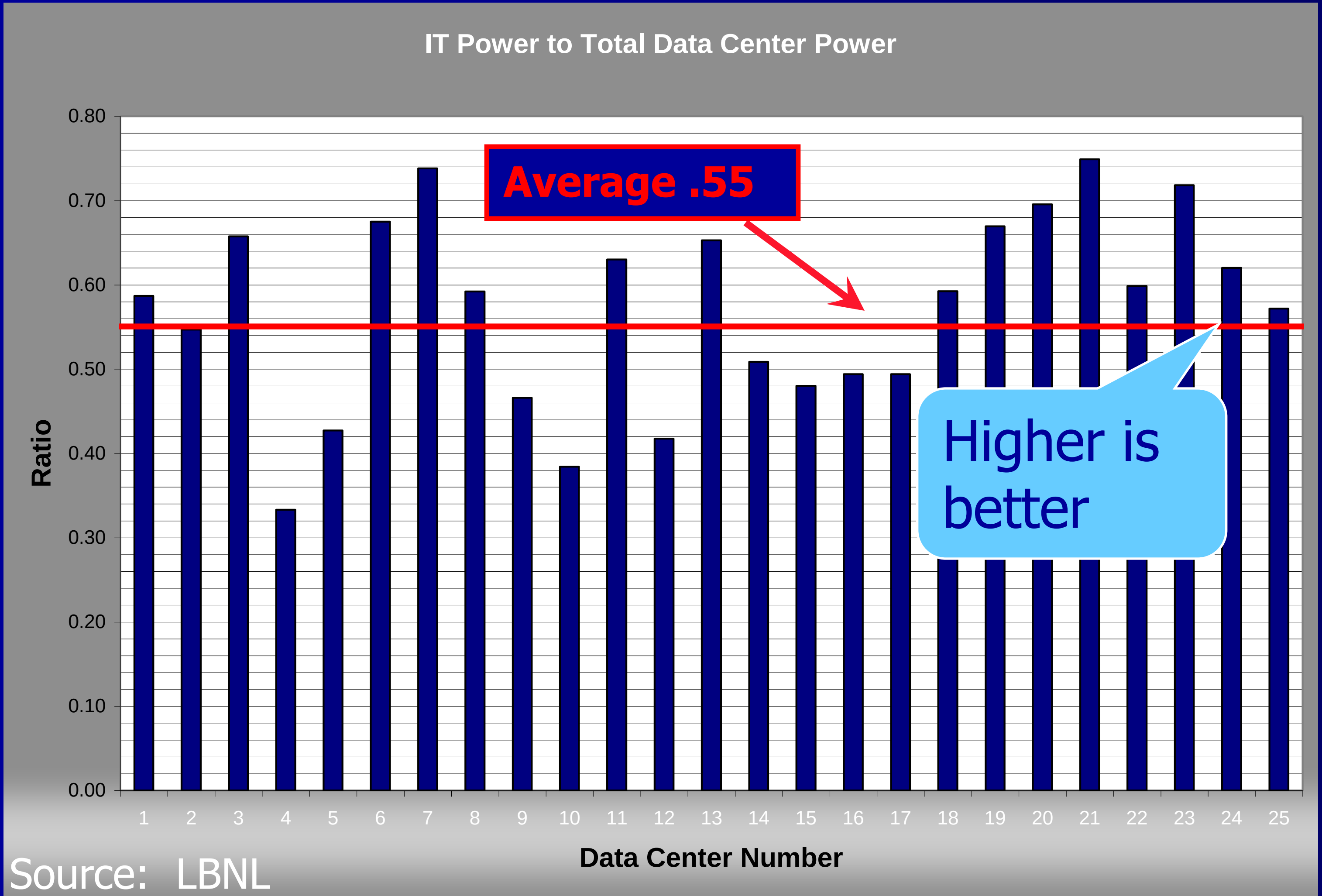
## Major Project Objectives

- Leading HPC capability
- Model of energy efficiency
- Maximum flexibility for future systems
  - Computer systems layout
  - Air and/or liquid cooling
  - Front to back or bottom to top airflow
- Energy efficient infrastructure
  - DCiE 0.83 or higher based on annual energy
  - Efficient system design
  - Use of waste heat

$$\text{DCiE} = \frac{\text{IT energy}}{\text{Total energy}}$$

# DCiE design goal

DCiE higher than any benchmarked centers = .83




Source: LBNL

# *Mechanical design challenges*

- Many generations of high performance computers over several decades
- High computing load densities: 20 – 30 kW/rack
- Potential mix of air, liquid, or hybrid cooling
- Potentially different temperature and humidity requirements for different computer systems and other IT equipment
- Budget: must be life cycle cost effective

# *Design advantages for efficiency*

- **Minimal requirements for Uninterruptible Power Supplies (UPS) since work involves only scientific computing**
- **Mild climate suitable for economizer cooling**
- **Ability to use full ASHRAE TC 9.9 range of recommended temperature and expanded humidity range**
- **Integrated Architectural - MEP design**

# *Design features*

- Flexibility for air or liquid cooling
- Large efficient air handlers
- Integrated modular design
- Liquid cooling capability
- Part load modulation
- Environmental conditions
- Air side economizers and evaporative cooling
- Integrated water side economizer
- Air management
- Power distribution
- Use of heat recovery

# *Flexibility for air or liquid cooling*

- Advanced HPC systems pushing limits of air cooling
- Systems could be built that:
  - Continue to be air cooled
  - Have liquid cooled cabinets removing some or all of the heat
  - Have liquid cooling to the processors
  - Use combination of refrigerant and liquid
  - Others?
- Network or storage equipment may continue air cooling even if servers require liquid

# *Large efficient air handlers*

**Applying sound HVAC engineering to air movement:**

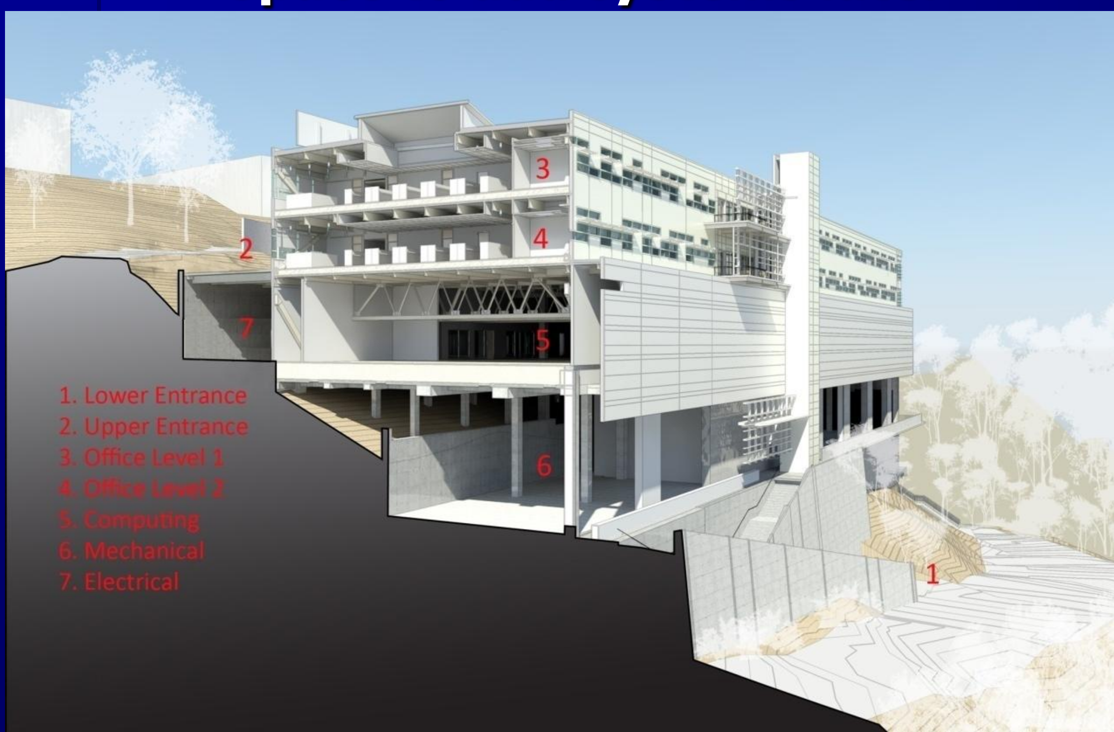
- **Efficient fans and motors**
- **Low system pressure drop/ face velocity**
- **Variable speed**
- **Modular layout**
- **Effective air management**

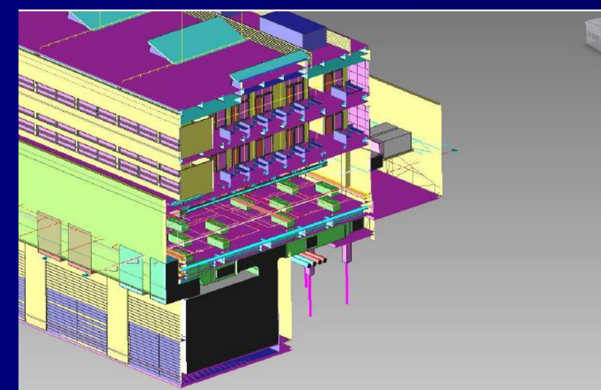
| Design Pressure Drops Across Major HVAC Components | |
|---|---|
| **Components** | **Initial Pressure Drop (in. w.g.)** |
| Outside Air Louvers | 0.15 |
| Outside Air Dampers | 0.20 |
| Filters | 0.35 |
| Direct Evap. Media Pad | 0.25 |
| Chilled Water Coil | 0.25 |
| Ductwork+Plenum+Outlets | 0.30 |
| **Total** | **1.5** |

# Modular design

## Building and system modular build out

- Add as you go
- Build only what you need
- Space to add systems later



**A building information model (BIM) was developed**

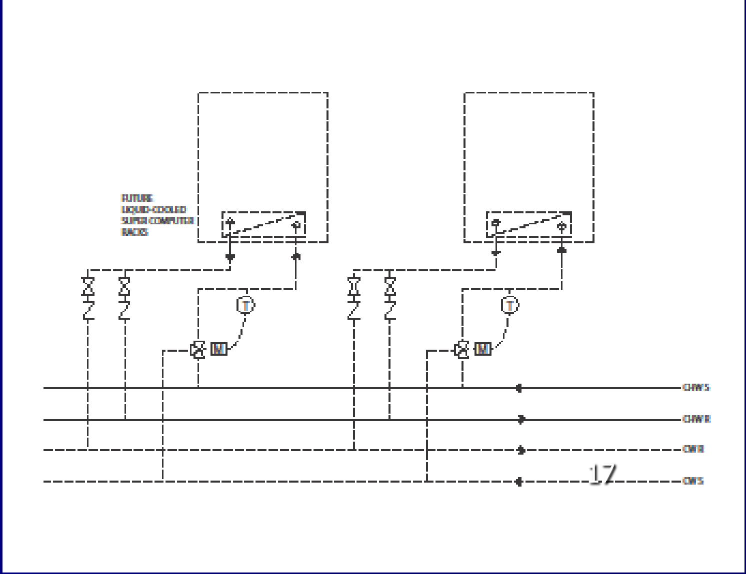
# *Modular cooling plant*

- **Large headers sized for efficient operation for future loads - even higher efficiency in the interim**
- **All pumps, fans, and compressors are variable speed**
- **Unequal chiller sizes for better turn-down and load matching**
- **Optimal control for maximum overall plant COP at any load and outdoor condition**
- **Space for additional chillers and towers for future loads**
- **Headers, valves and caps for modularity and future flexibility allow additions without shutting down**

# *Liquid cooling capability*

**Use of chilled water or treated water connected to cooling tower through heat exchanger**

- **4 pipe system allows all of one or the other - or mixing**
- **Blanked off for future addition**
- **Space for piping  provided**
- **Reset for efficient operation**



# *Part load operation*

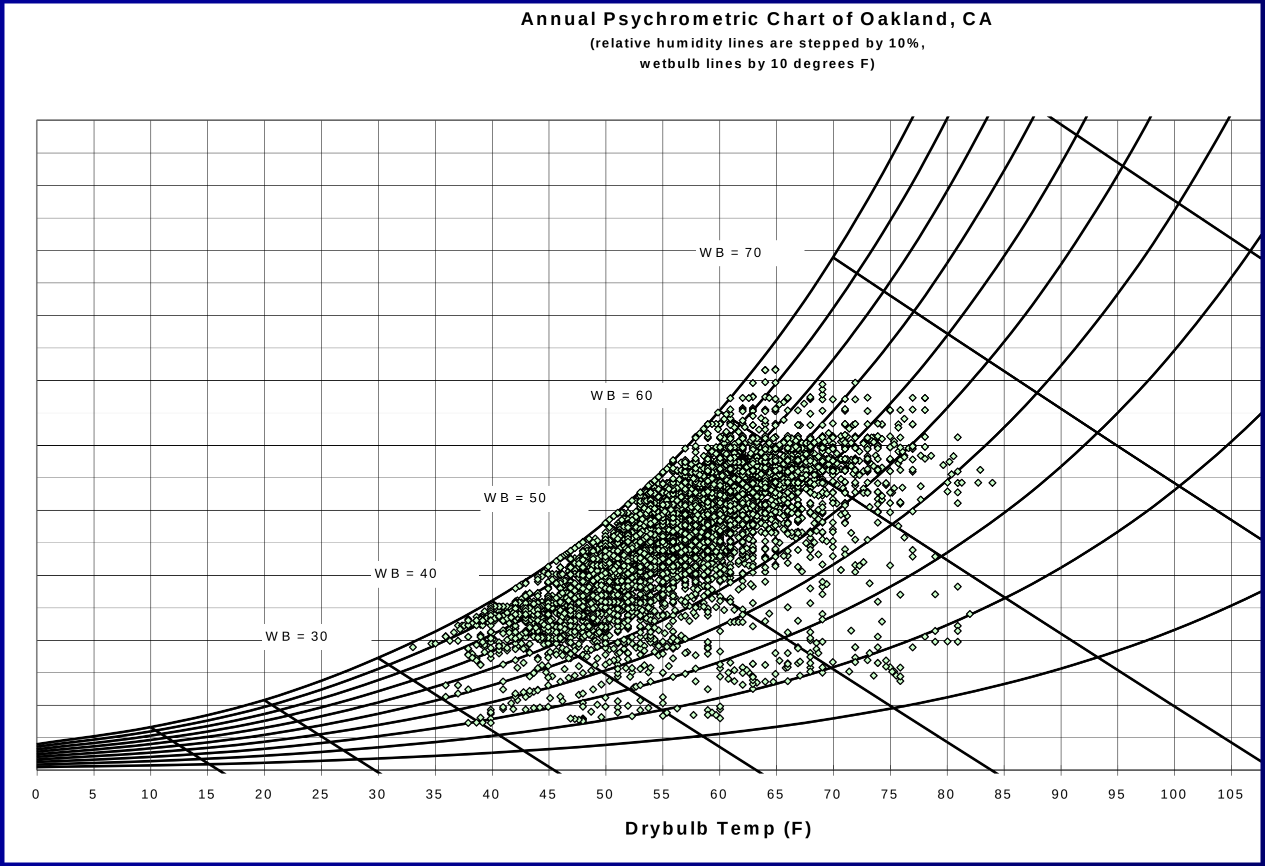
**HPC systems operate fully loaded however systems will be added and removed over the life of the facility varying the cooling requirements significantly**

- **Modular**
- **Variable speed everything**
  - **tower fans**
  - **chilled water pumps**
  - **condensing water pumps**
  - **chiller**
  - **exhaust fans**
  - **main air handler fans**
- **Controls**

# Environmental conditions

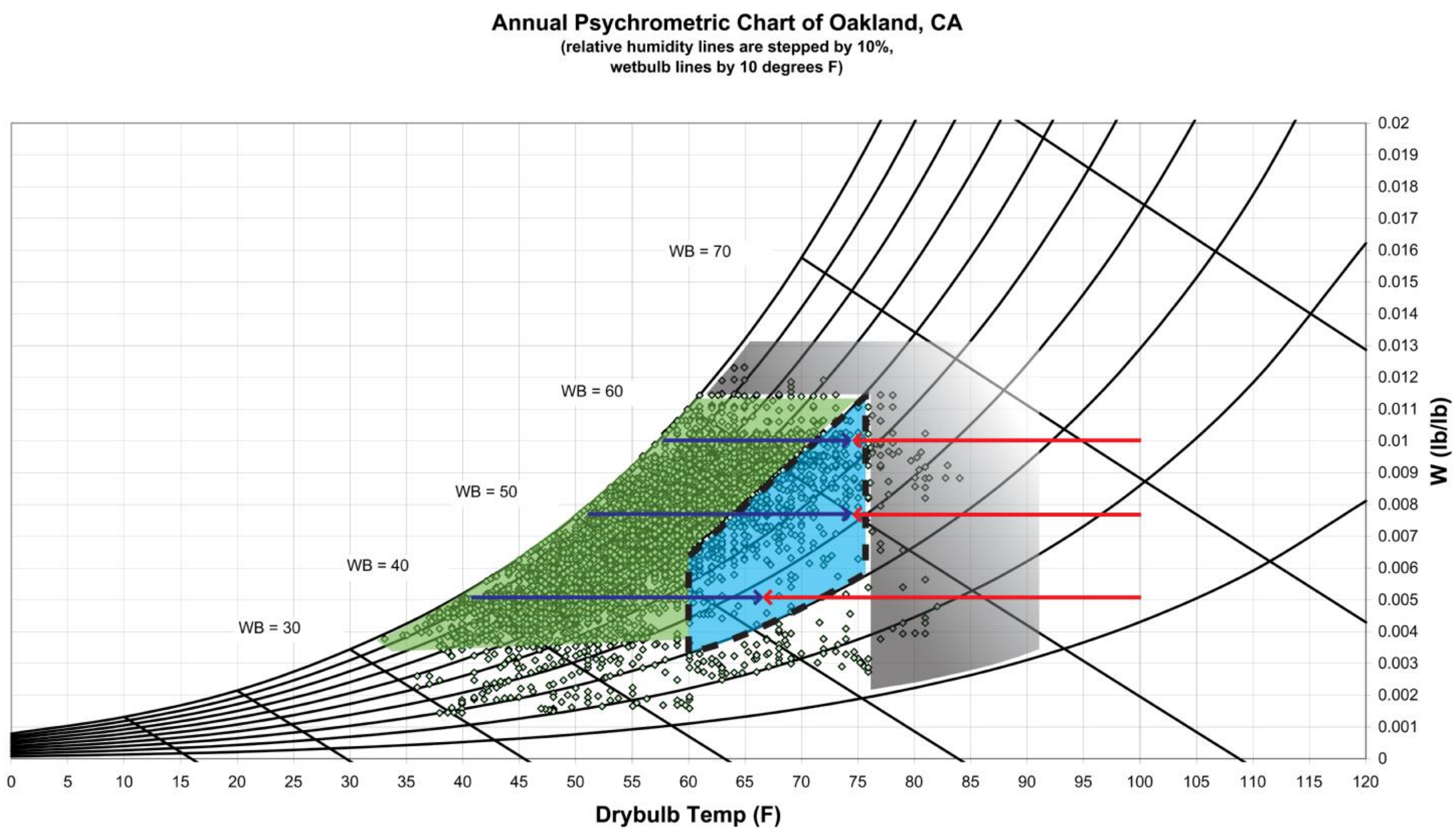
## Design Conditions:

- Summer 100F DB/ 65 MWB; Winter 37.5F (99.5% Oakland ASHRAE)



# Environmental conditions

CRT design guidelines: 60 to 75F DB; 30-60% RH



# *Environmental conditions – operating modes for air cooling*

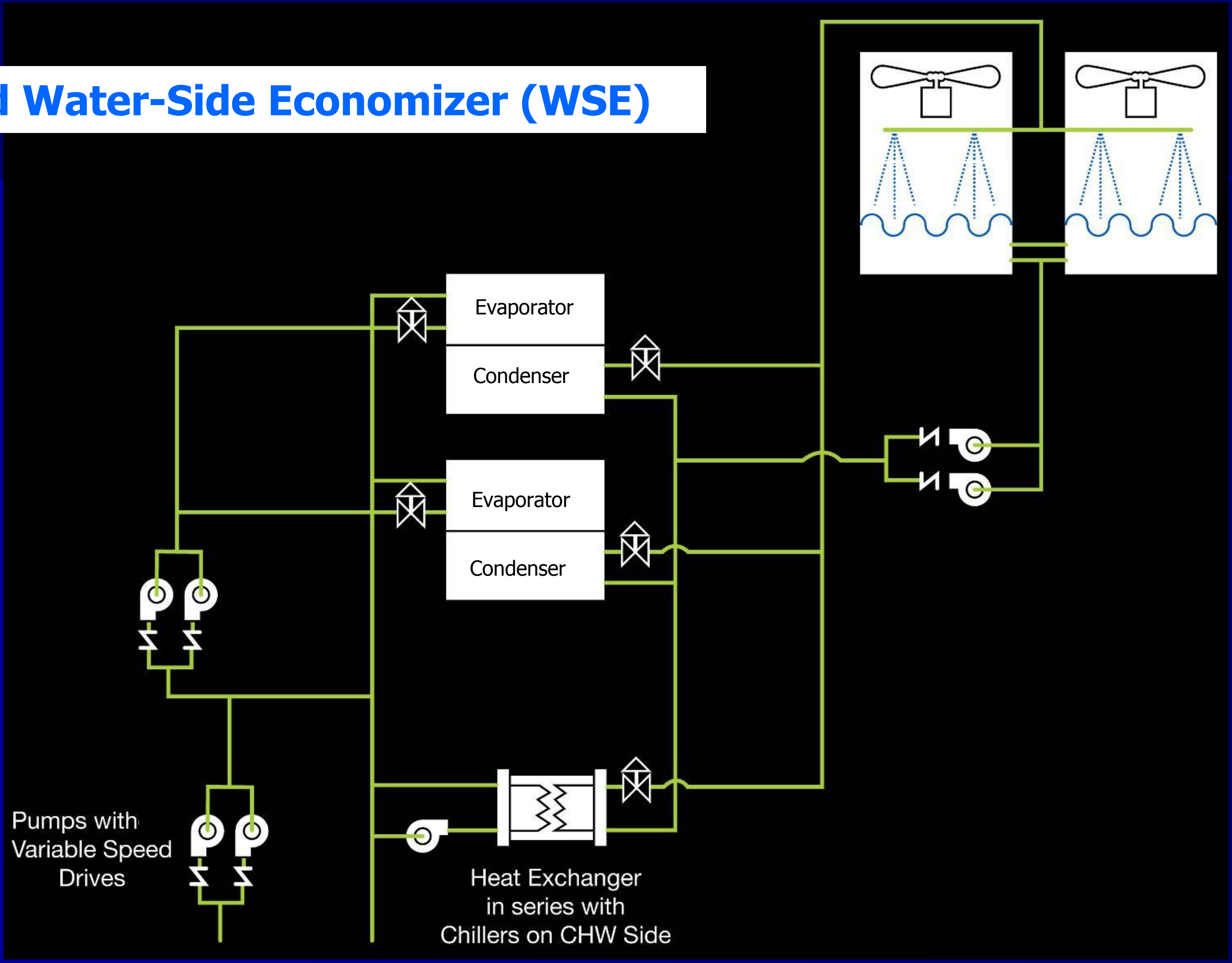
| Operating Mode | Number of Hours Per Year | Percent of Year |
| --- | --- | --- |
| Mix of outside and return air | 8200 hours | 93% |
| Direct evaporative cooling | 45 | 0.5 % |
| Direct evaporative cooling and chilled water coil | 38 | 0.4% |
| Chilled water coil | 510 | 6% |

# *Air economizer and evaporative cooling*

- **Direct evaporative cooler doubles as humidifier**
  - **Uses sensible heat from equipment**
- **Humidity allowed to float within recommended range**
- **Evaporative cooler has more pressure drop but lower life cycle cost relative to spray nozzles or ultrasonic humidifier**

# Water side economizer

## Integrated Water-Side Economizer (WSE)



# *Air management*

- **Isolation of hot and/or cold aisles on the HPC floor**
  - minimize mixing and recirculation
  - CFD model to predict air pressures for consistent air flow
- **Divisible space under and above raised floor**
  - allows for different environmental conditions for different computing systems

# *Heat recovery*

- **Hot air or water will be available**
- **Warm enough to preheat air in CRT and nearby laboratory and office buildings**
- **Enough heat available to eliminate all space heating energy usage in these buildings**
- **Interconnection also used for heating water *to* CRT (at start-up)**

# *Power distribution efficiency*

- **480 volts to the racks**
  - Minimizes conversion loss
- **Minimal UPS (under 10% coverage)**
  - Selection of delta-conversion or double-conversion with bypass to minimize losses
- **No need for redundant power supplies**

# Predicted HPC Performance

- DCiE of 0.90-0.95 based on annual energy
- DCiE of 0.83-0.90 based on peak power
- No credit taken for heat recovery

# Questions?