Higher Education Energy Efficiency Partnership Program

BEST PRACTICES AWARDS

UC / CSU Sustainability Conference, June 2005

CSU

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An EDISON INTERNATIONAL® Company

Pacific Gas and Electric Company®

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Southern California Gas Company
A Sempra Energy utility™

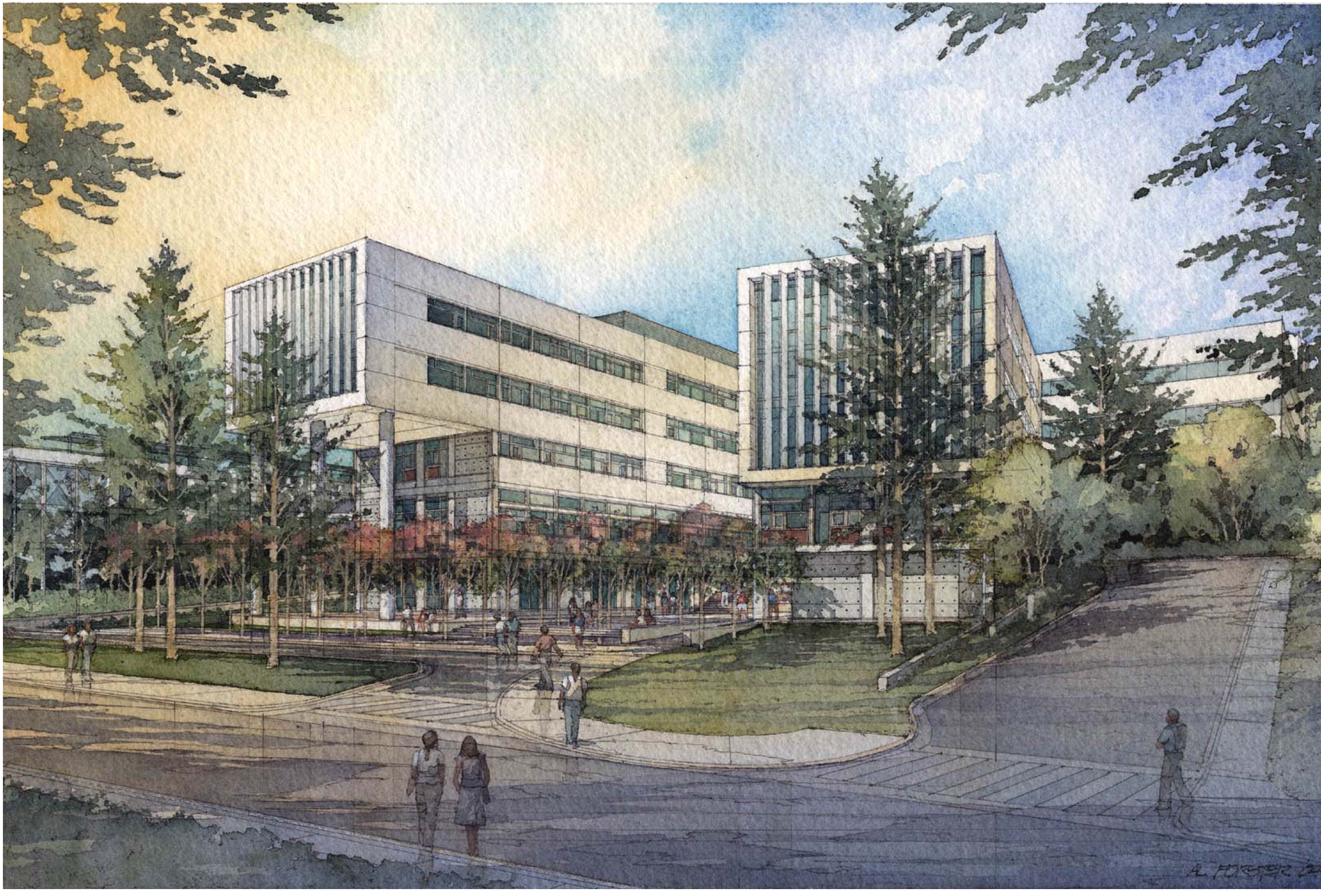
pier
"Research Powers the Future"

A program created by the
UC/CSU/IOU Partnership
and under the auspices of the
California Public Utilities Commission

UC San Diego

Supercomputer Center

Craig Johnson, PE



Rumsey Engineers Inc

Peter Rumsey, Cindy Regnier

EHDD Architecture

Richard Feldman

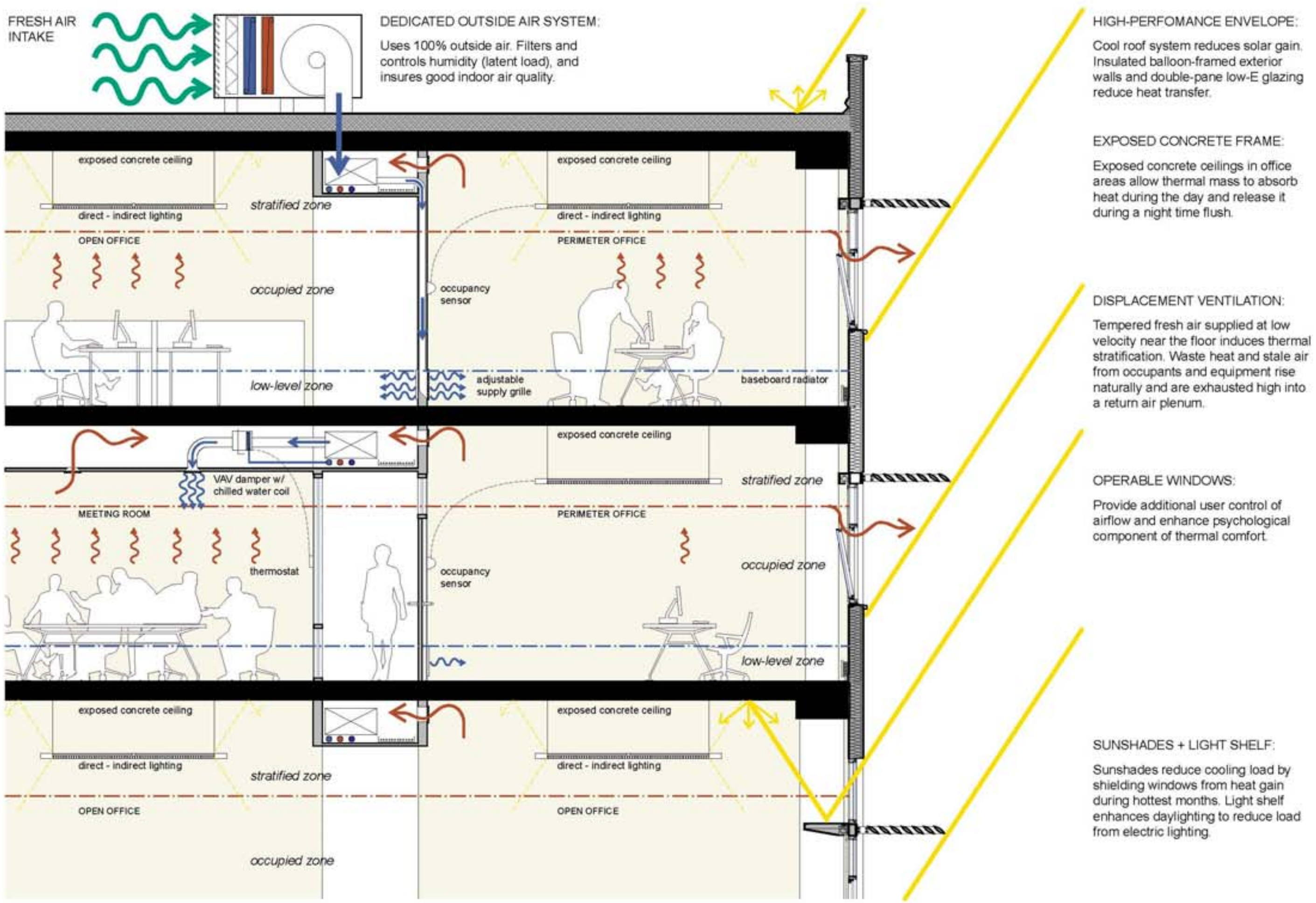
NaturalWorks Engineering Consultants

Paul F. Linden, Guilherme Carrilho da Graça.

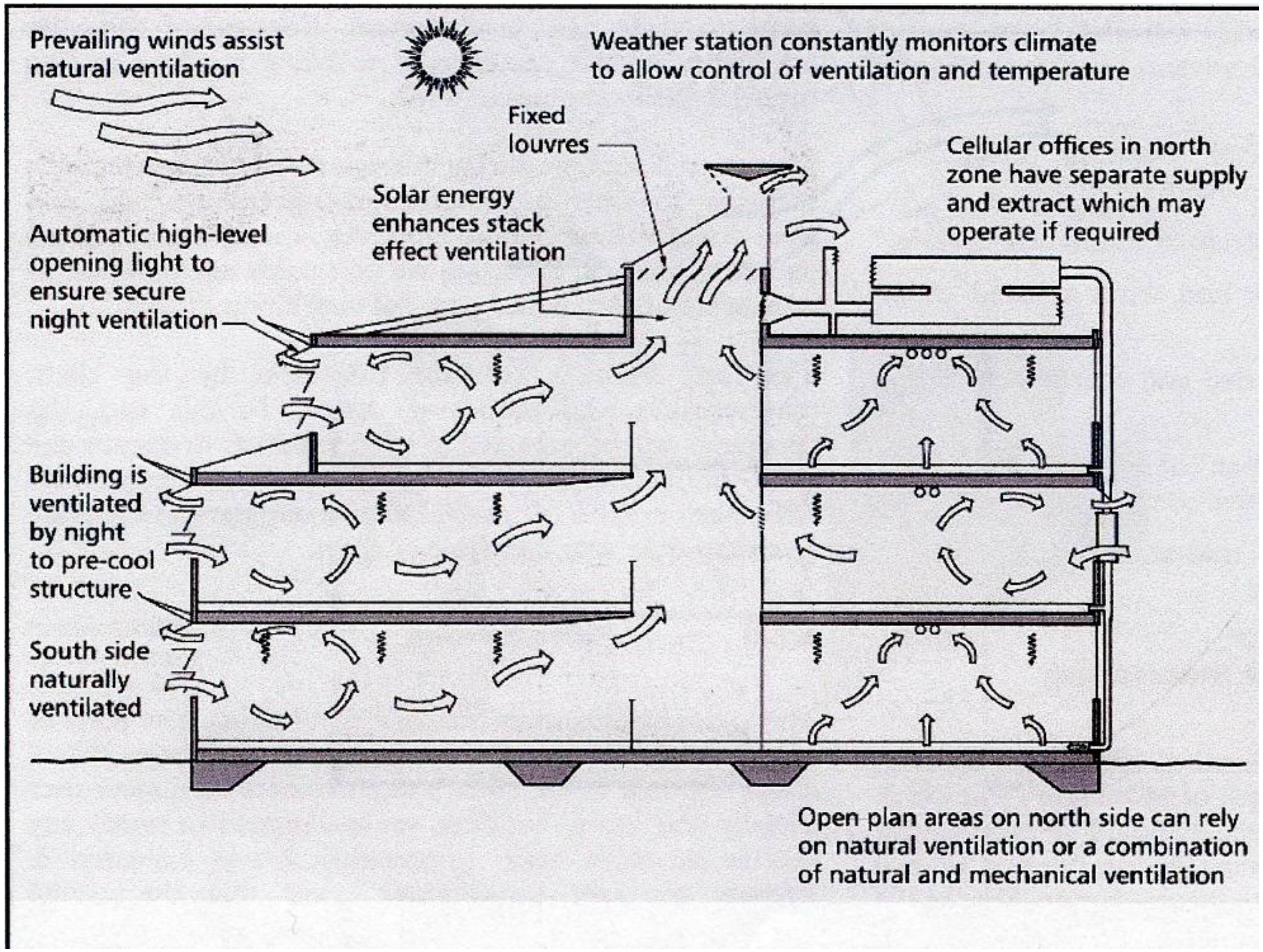
L B N L - Commercial Building Systems Group

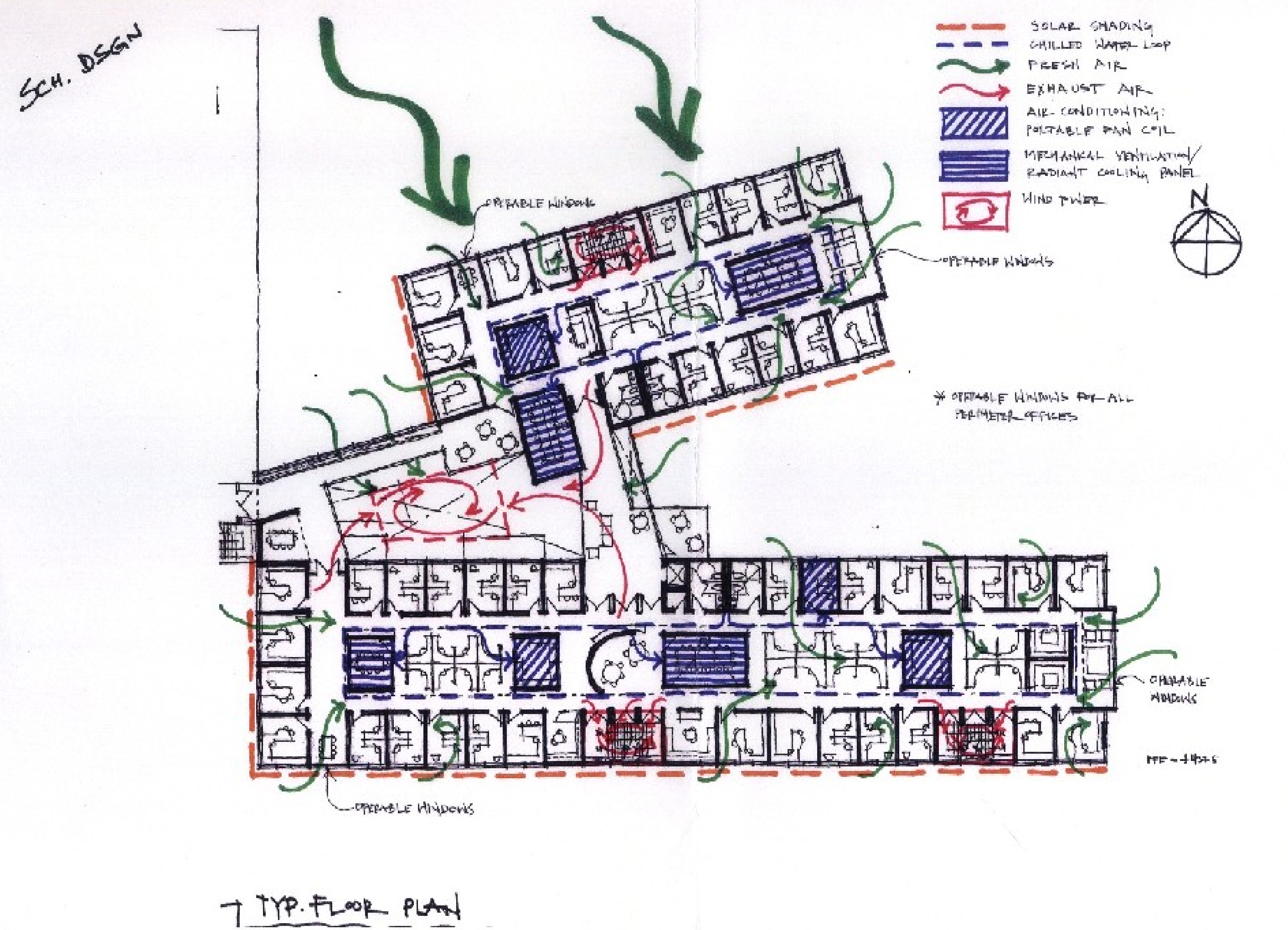
Philip Haves

Displacement Ventilation with Hot Water Radiators



typical section : displacement ventilation

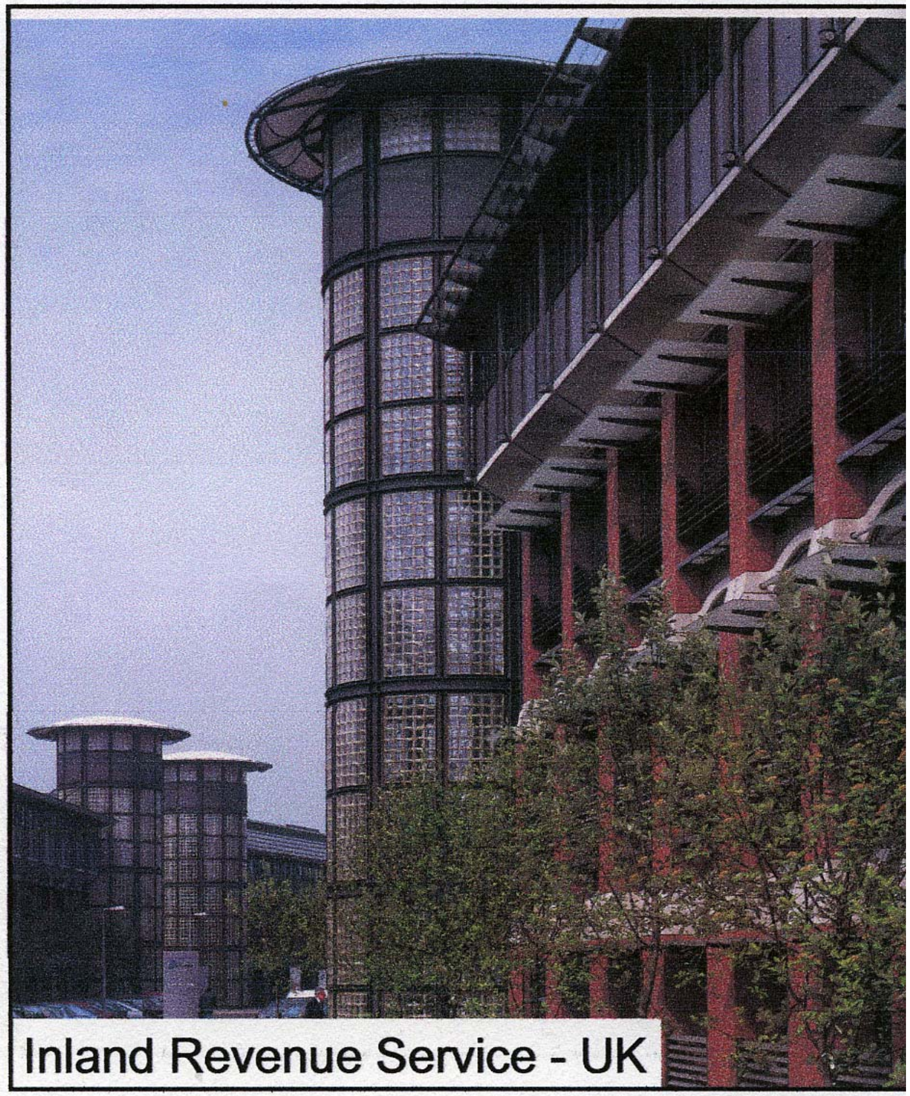

Prevailing winds assist natural ventilation
Weather station constantly monitors climate to allow control of ventilation and temperature
Fixed louvres
Cellular offices in north zone have separate supply and extract which may operate if required
Solar energy enhances stack effect ventilation
Automatic high-level opening light to ensure secure night ventilation
Building is ventilated by night to pre-cool structure
South side naturally ventilated
Open plan areas on north side can rely on natural ventilation or a combination of natural and mechanical ventilation



san diego supercomputer center

NATURAL VENTILATION

4



Inland Revenue Service - UK

Saga Group, Folkestone, UK

Cambridge, UK

Ceramique Office, Maastricht, NL


Saga Group, Folkestone, UK

Engineering

- Creativity
- Science

Engineering

- Creativity
- Every building is a new opportunity

- Science
- Prove it

Generic design objectives

- First, ensure that the HVAC system meets the needs of the building occupants
- Second, deliver this environment as efficiently as possible

Environmental Issues

- Fog
- Airborne salt
- Airborne particles
- Santa Ana conditions
- Solar loads (esp. in winter)


HHWS
HHWR


CHS
CHR
AH-5
3rd Flr South

Supercomputer design objectives

- Create an acceptable indoor environment throughout the year
- Construction cost to be equal to, or below, what a conventional system would cost (VAV – terminal reheat)
- HVAC system that is more efficient than a conventional system

$$PMV = (0.303e^{-0.036M} + 0.028)\{(M - W) - 3.05 \times 10^{-3} \times [5733 - 6.99(M - W) - p_a] - 0.42 \times [(M - W) - 58.15] - 1.7 \times 10^{-5} M(5867 - p_a) - 0.0014M(34 - t_a) - 3.96 \times 10^{-8} f_{cl} \times [(t_{cl} + 273)^4] - (t_r + 273)^4] - f_{cl} h_c (t_{cl} - t_a)\}$$


Nierenberg Hall
8810

Significant design factors

- To produce simple and efficient designs we need to hire wiser designers (wisdom is more critical than knowledge)
- The mechanical engineering firm is accountable for indoor comfort levels
- The University needs to play a role in the selection of the mechanical consultant

San Diego Supercomputer Center

Performance simulation of the indoor climate control system

Optimization of the shading design

NaturalWorks Engineering Consultants

Paul F. Linden, Guilherme Carrilho da Graça.

L B N L - Commercial Building Systems Group

Philip Haves

Presentation Contents

Introduction

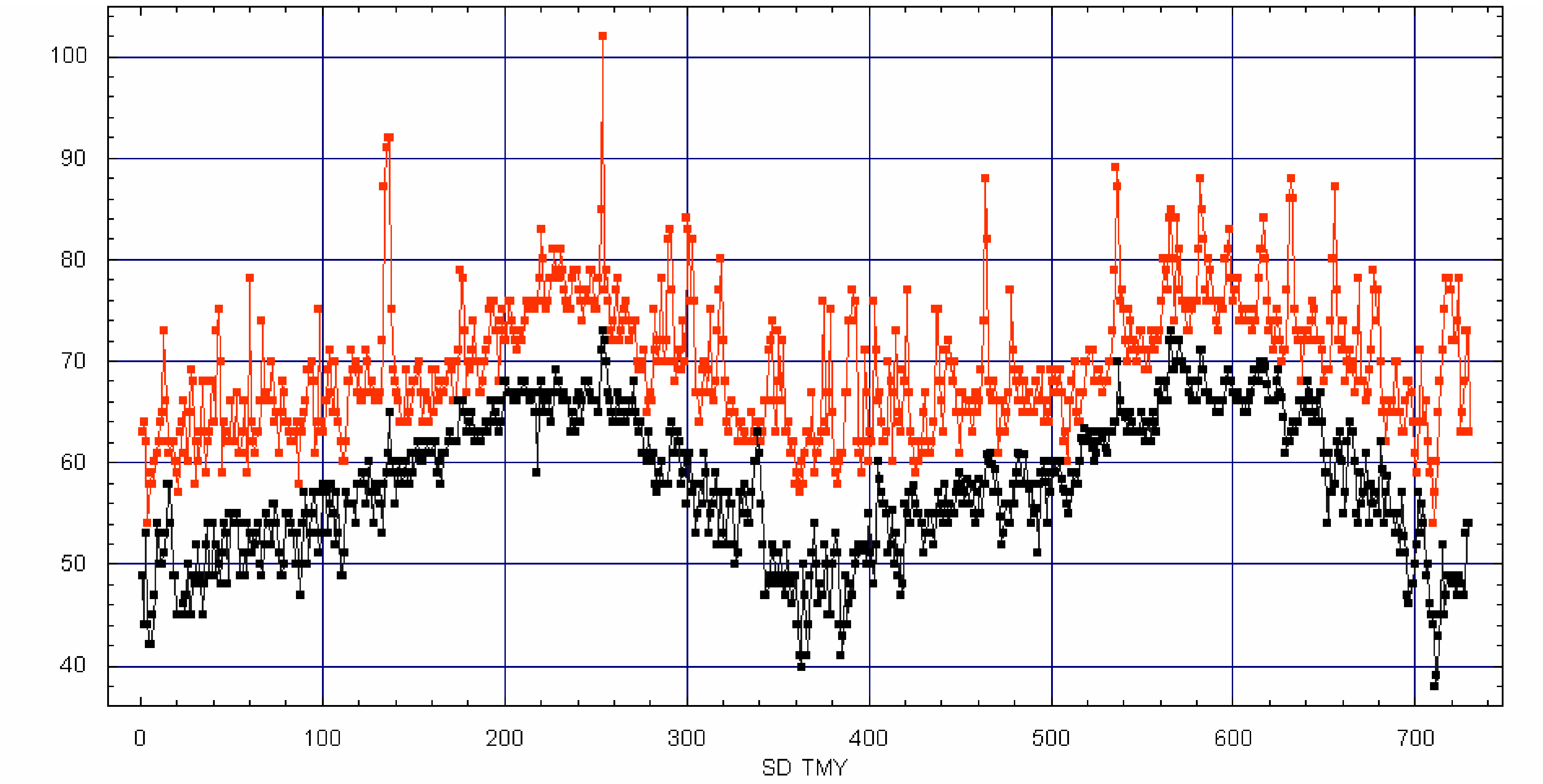
1- Site climate analysis

2- EnergyPlus simulation of indoor conditions

3- Analysis of external shading systems

Conclusions

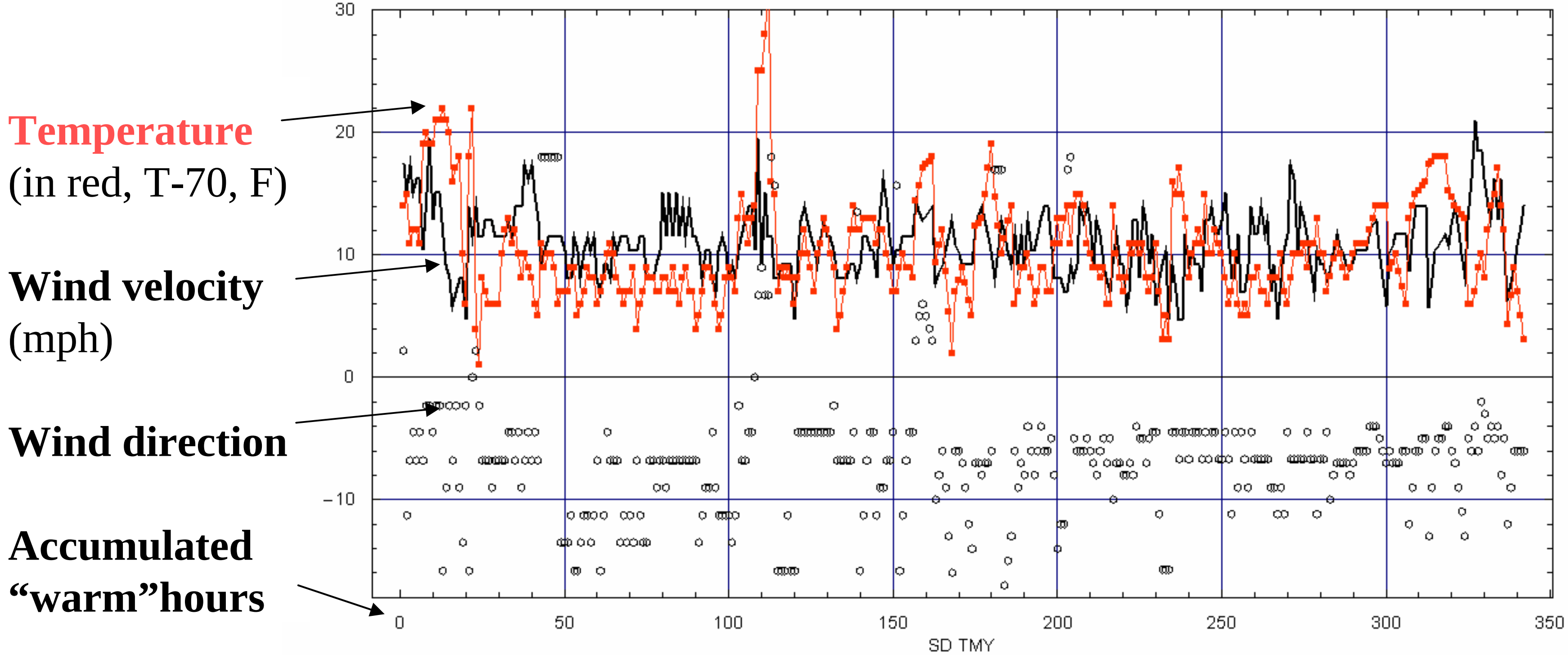
1 - Climate analysis



Variation of maximum and minimum temperature (degrees F) in San Diego for the two typical weather years, measured at San Diego airport, used in the analysis (1966 and a composition of 1988 and other years).

1 - **Climate analysis**:

….where does the wind blow during warm hours?



Daytime analysis only considered hours in “warm” days where wind is significant i.e when the wind velocity is above 3mph.

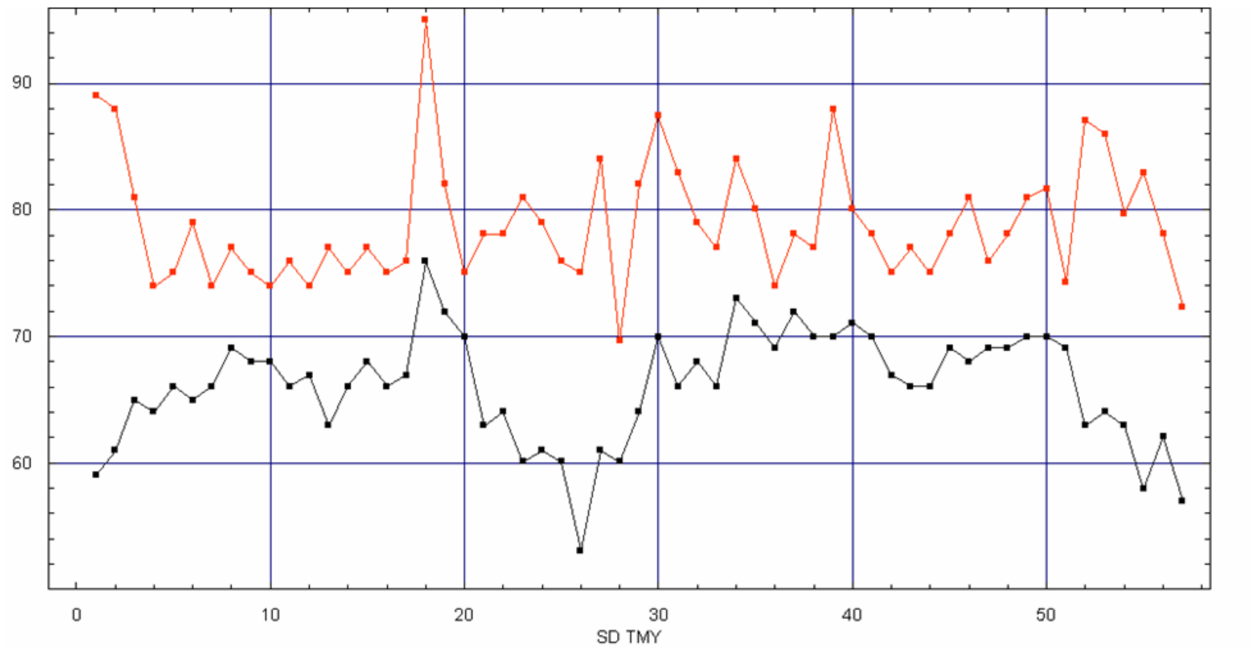
A day is considered warm if the maximum outside dry bulb temperature is higher than 26^{o}C (79^{o}F).

1 - Climate analysis - night cooling:

….what is the minimum temperature at night after each warm day?

Daily variation of **maximum** (**red**) and **minimum** (**black**) temperature for “warm” and mildly warm days (max. *Tout>70ºF*).

The data consist of selected days for the second weather year shown in figure 1.



Potential for night cooling in San Diego is moderate. Still, since the climate is generally mild during the day, the small amount of night cooling that can be achieved in most days may be sufficient.

Post processing of the data in the previous slide shows that the wind blows from an angle (A): 340>A>160 (i.e from northwest to south) for 72% of the time.

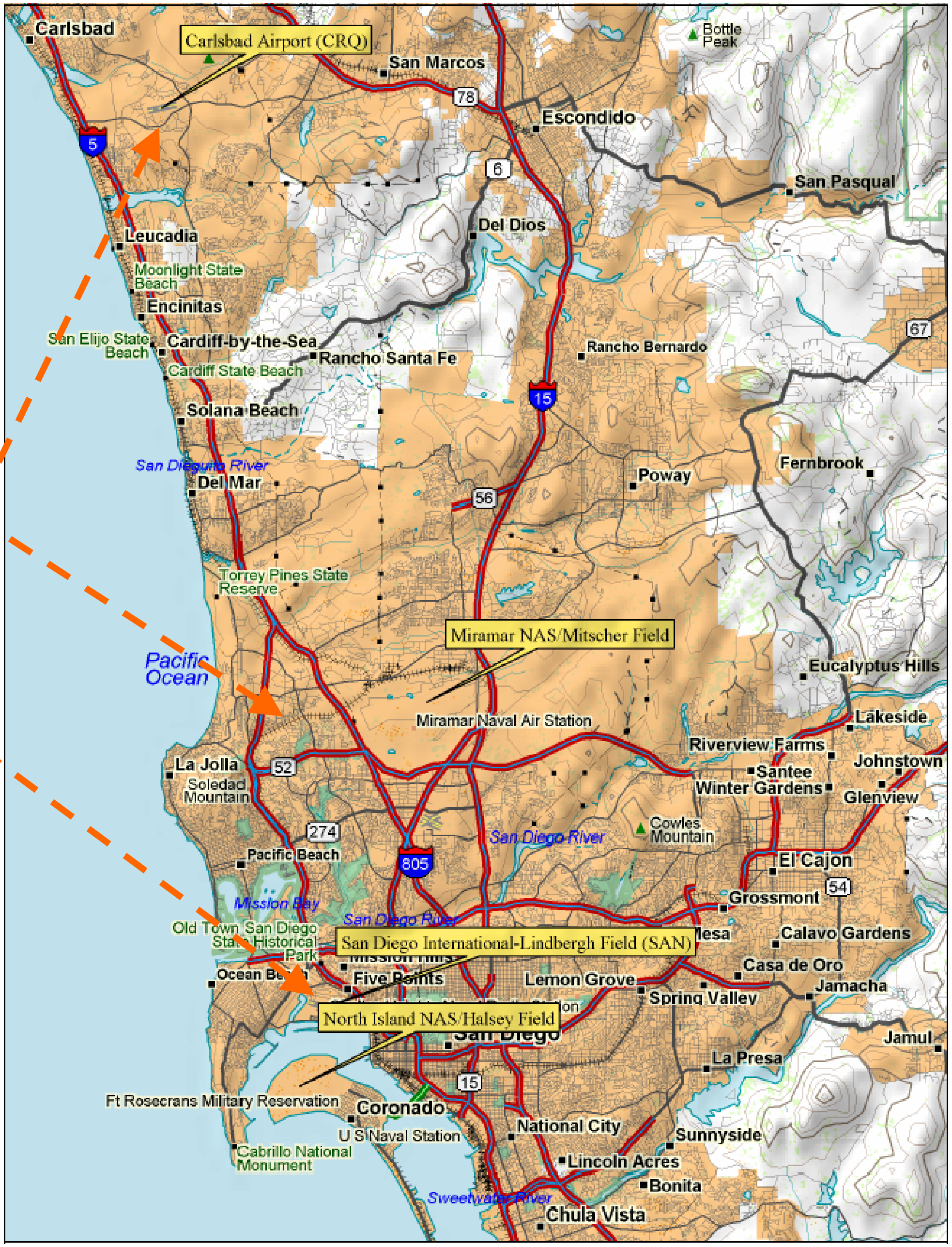
1 - ”Onsite” climate analysis

There are no systematic historic weather data records for UCSD campus locations

Local topography influence and proximity to the sea make Carlsbad a close representation to campus, sea influenced conditions

Available typical weather files use data measured at SAN

As expected San Diego Airport temperature measurements are higher than Carlsbad, how much…?



Data and method used in the analysis

Two typical weather data years, using data measured at the San Diego Airport (SAN): 1966 and a composition of1988 and other years (the year used changes on a monthly basis)

Five years of temperature and wind data measured in the Carlsbad weather station (1999, 2000, 2001, 2002 and 2003)

Steps taken:

1- A representative year for the Carlsbad (KCRQ) weather data was selected (conservatively we used one of the warmer years)

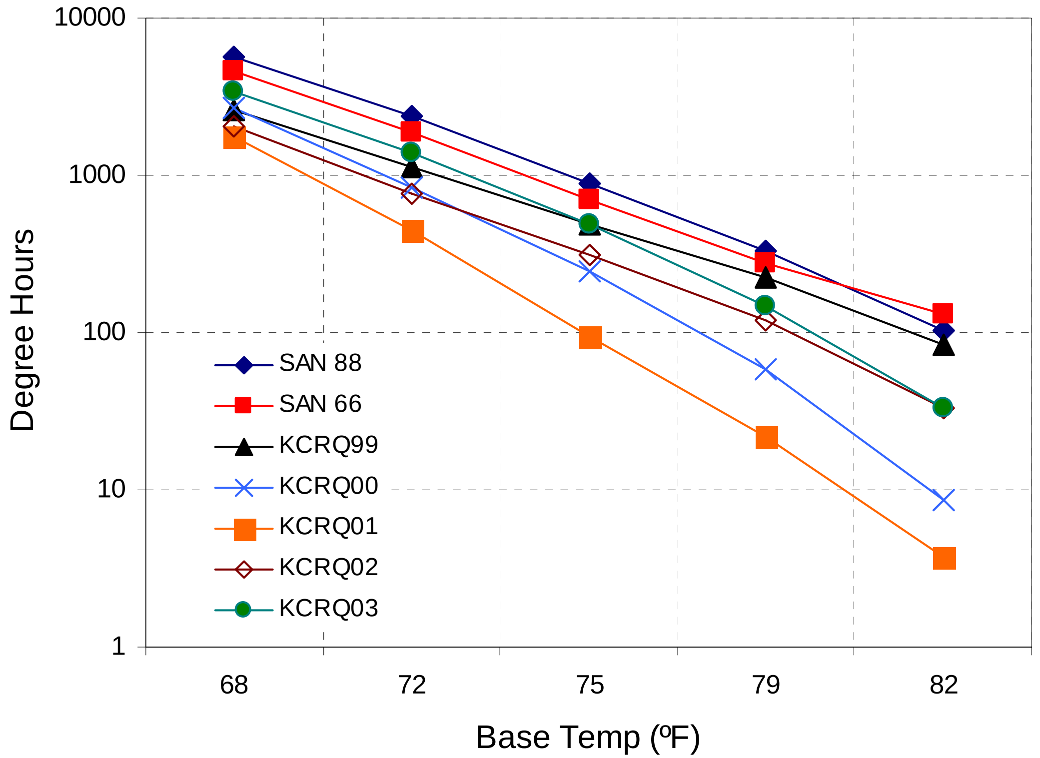
2- The two SAN and the representative KCRQ year where compared (analysis of maximum and minimum daily temperatures, running averages and degree hours above different temperatures)

3- A matching of degree hours above relevant cooling analysis temperatures (Tout above 26^{o}C, 79^{o}F) was obtained by decreasing the SAN 1988 dry bulb temperature

Degree-hour analysis

Variation of degree hours above a given base temperature for the 7 years analysed

As discussed above, KCRQ03 is cooler than SAN (1988) and SAN (1966).



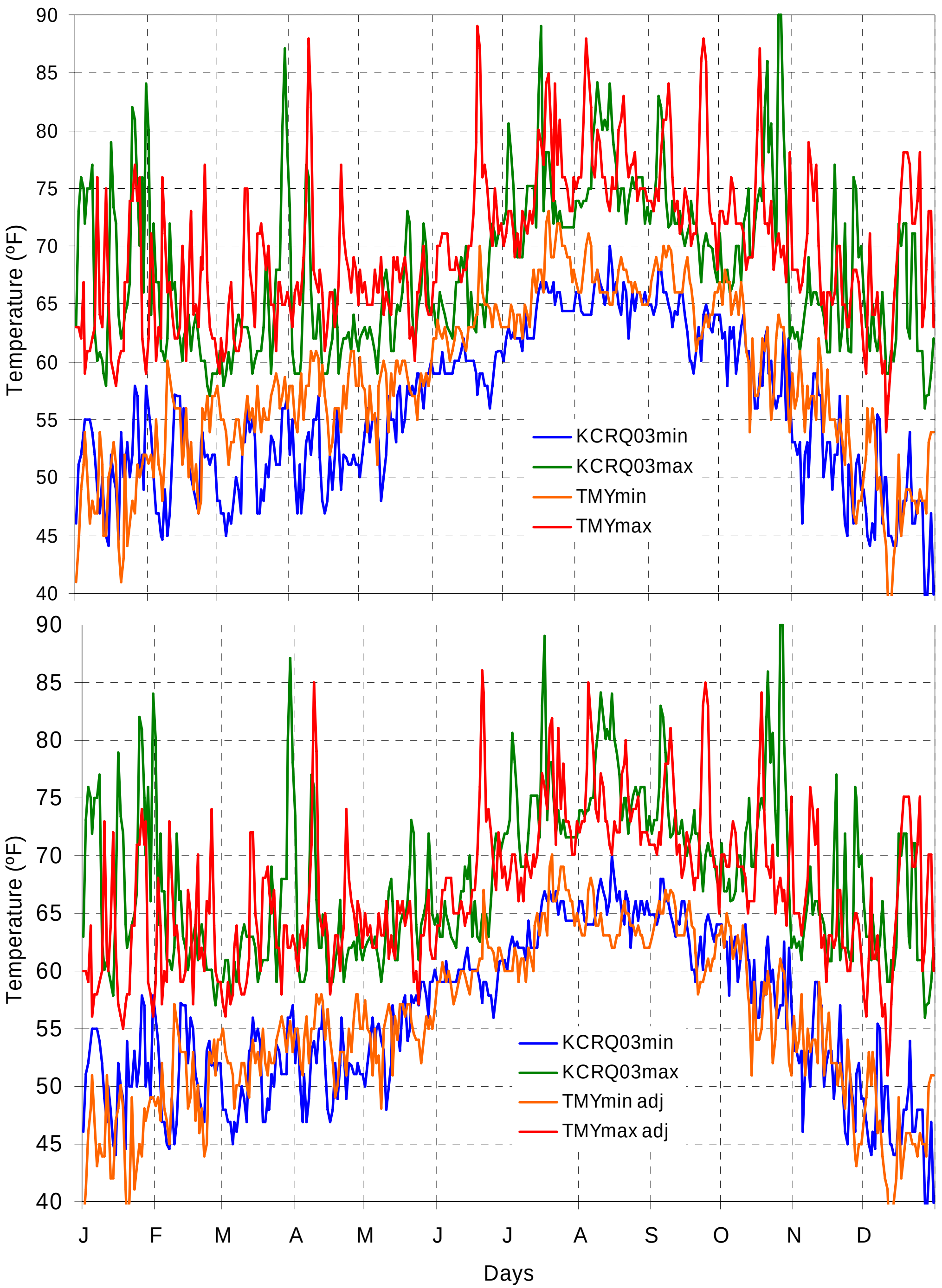
Base T (ºF)	SAN 88	SAN 66	KCRQ03
68	5684	4536	3442
72	2363	1898	1369
75	887	689	494
79	**334**	**276**	**147**
82	104	131	33

TMY adjustment

TMY (SAN 1988) and KCRQ03 maximum and minimum daily temperatures

Before adjustment

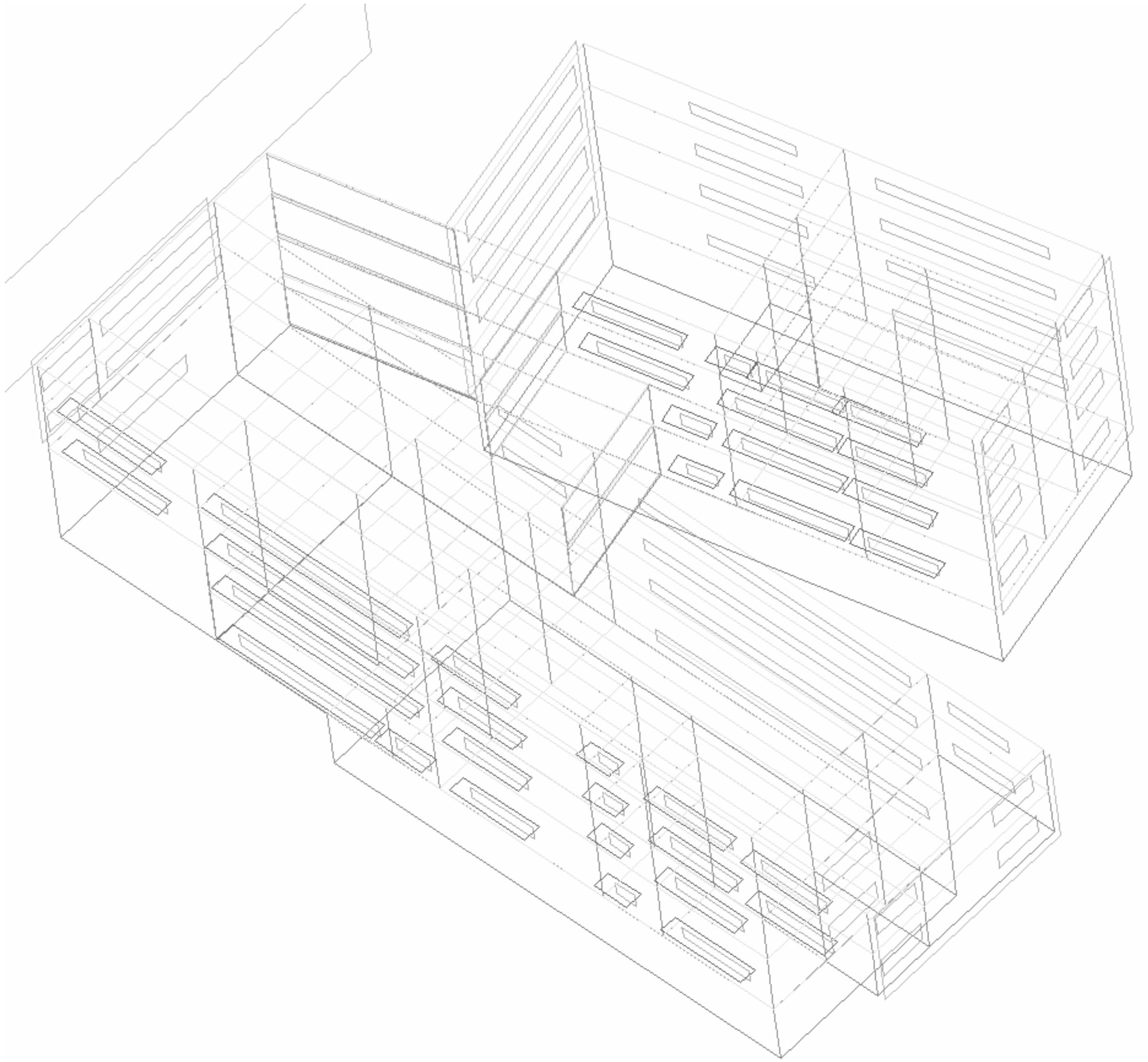
After adjustment



The typical colder climate of the site is approximately represented by the SAN 1988 data by using a negative offset in the air temperature, obtaining an adjust weather year:

Adjusted = SAN – 2.5 ºF

2- EnergyPlus simulation of indoor conditions



2- EnergyPlus Simulations

The proposed design was modelled using EnergyPlus (closely following design documentation and usage schedules)

The model has 77 independent thermal zones, and more than 700 surfaces

The geometry was “zoned” as shown in the next slides

Two weather files were used: SAN TMY 1988 and SAN TMY 1988 Adjusted to Carlsbad

2- EnergyPlus Simulations

In all zones, internal gains where set to approximately:

Occupants: one occupant every 100sft/10 m^2 =>13 W/ m^2
Lights: 10 W/ m^2
Equipment: 33 W/ m^2

Each occupant introduces a gain of 120W and uses a PC/Printer of 300W

In order to test the ability to support higher gains one of the single occupant offices tested was loaded with two occupants

In addition other design variations were tested:

Standard clear glazing (**SG**)
No external insulation in the vertical envelope walls (**NI**)
Optimized, smaller shading devices (**SS**)
Lower gains: one occupant per office (in all closed offices) and half occupancy in the core zones (**LG**)

Outside air / ventilation scenarios considered, free running building:

In order to access the importance of the ventilation strategy in the cooling period we analysed three ventilation strategies:

Standard fixed flow:

V00: day 1.5 Ach/h night 0.5 Ach/h

Variable ventilation (depends on temp. difference):

VD0: day 1.5-5 Ach/h night 10-15 Ach/h

Variable ventilation with maximum night cooling (depends on temp. difference):

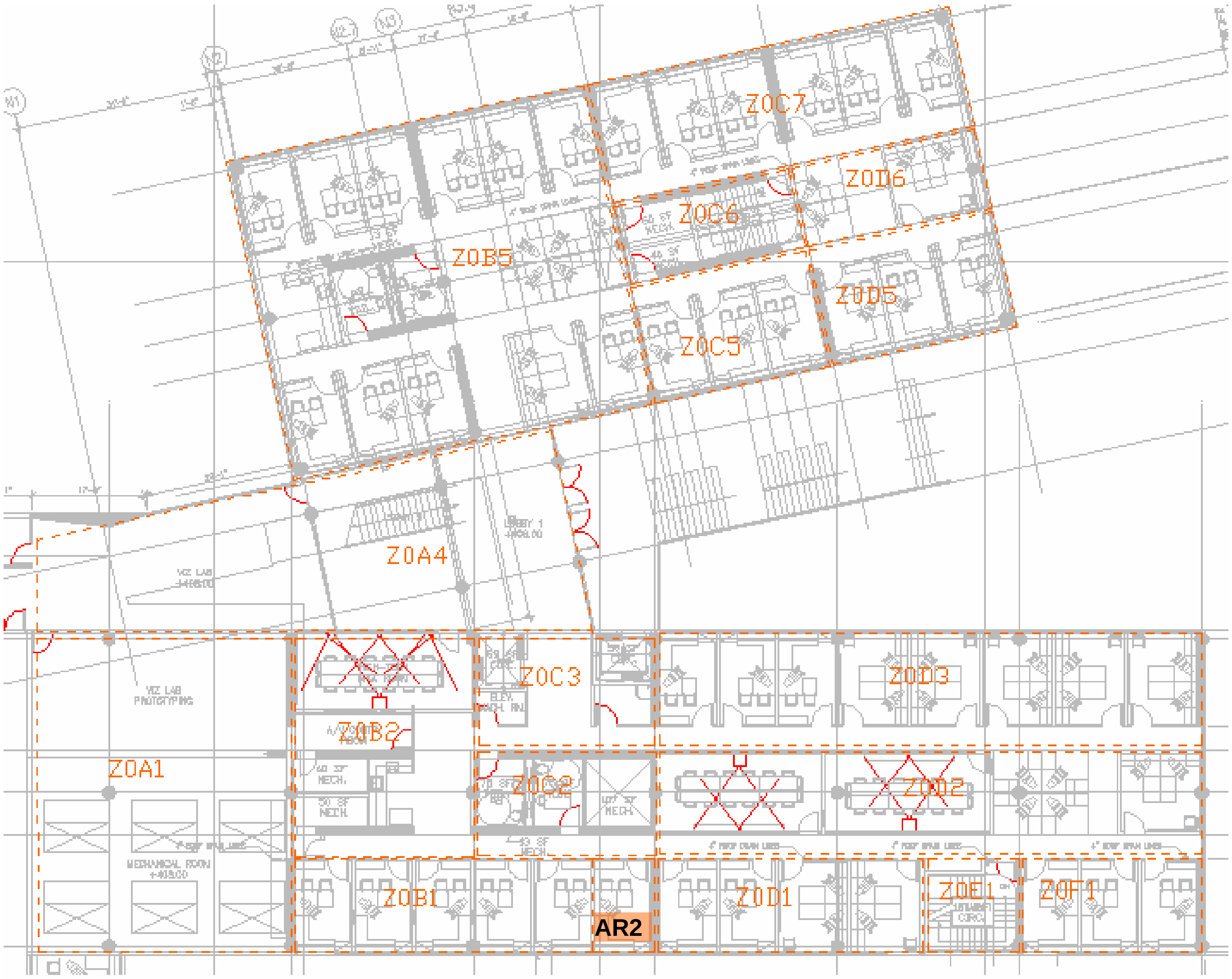
VDN: day 1.5-5 Ach/h night 15-30 Ach/h

Mechanical cooling (can be cooled inflow air, fan coil, chilled/heated slab…):

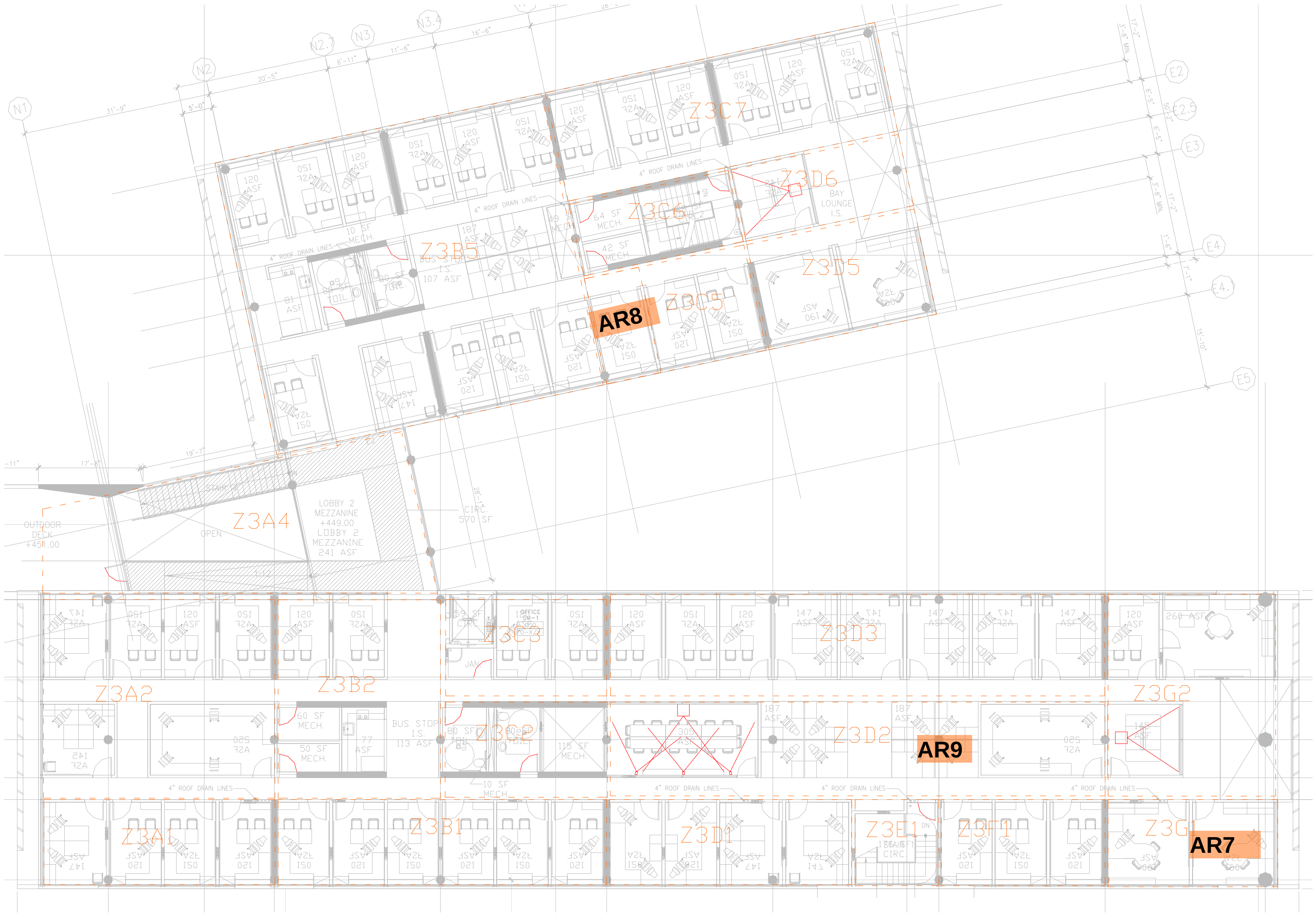
PA: In this case inside temperature is kept between 65 and 77^{o}F. Minimum outside air is always insured (15l/s per occupant).

In order to access the advantages of hybrid cooling the mechanical system can be combined with any of the three ventilation scenarios above.

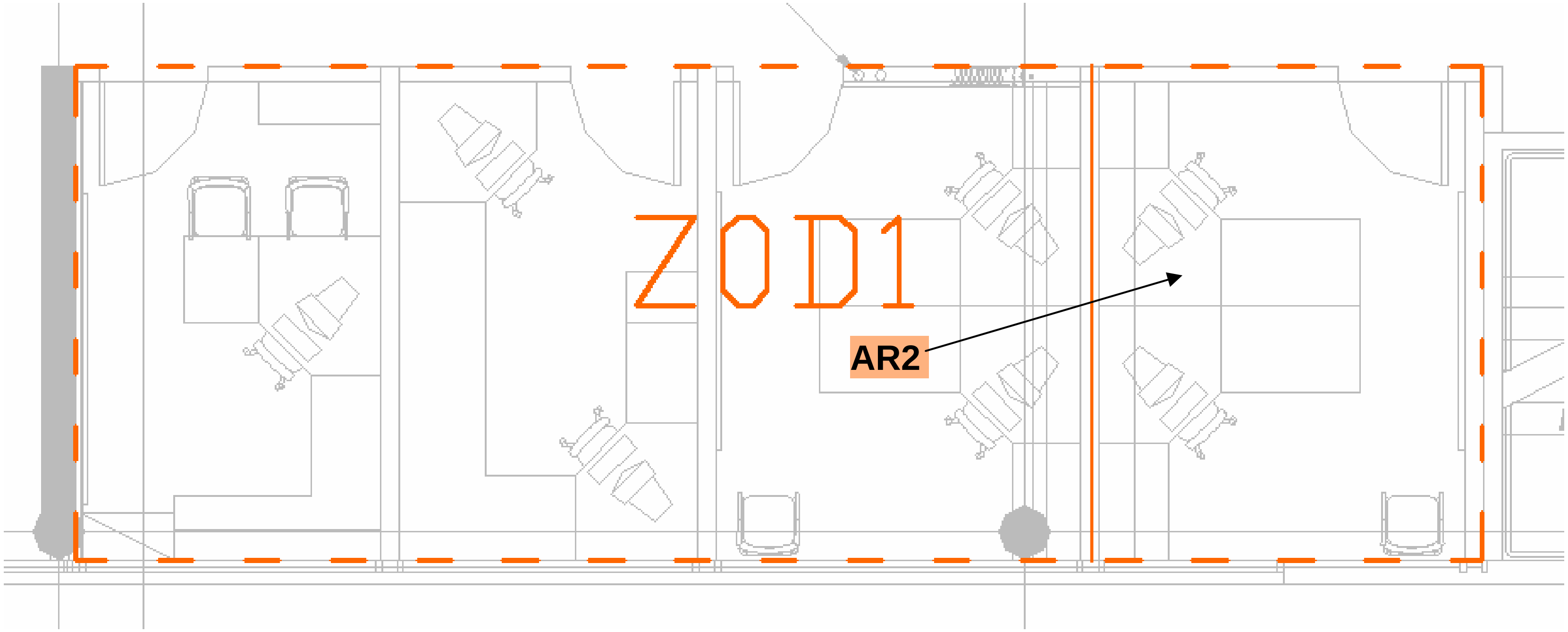
Zoning of floors 0&1



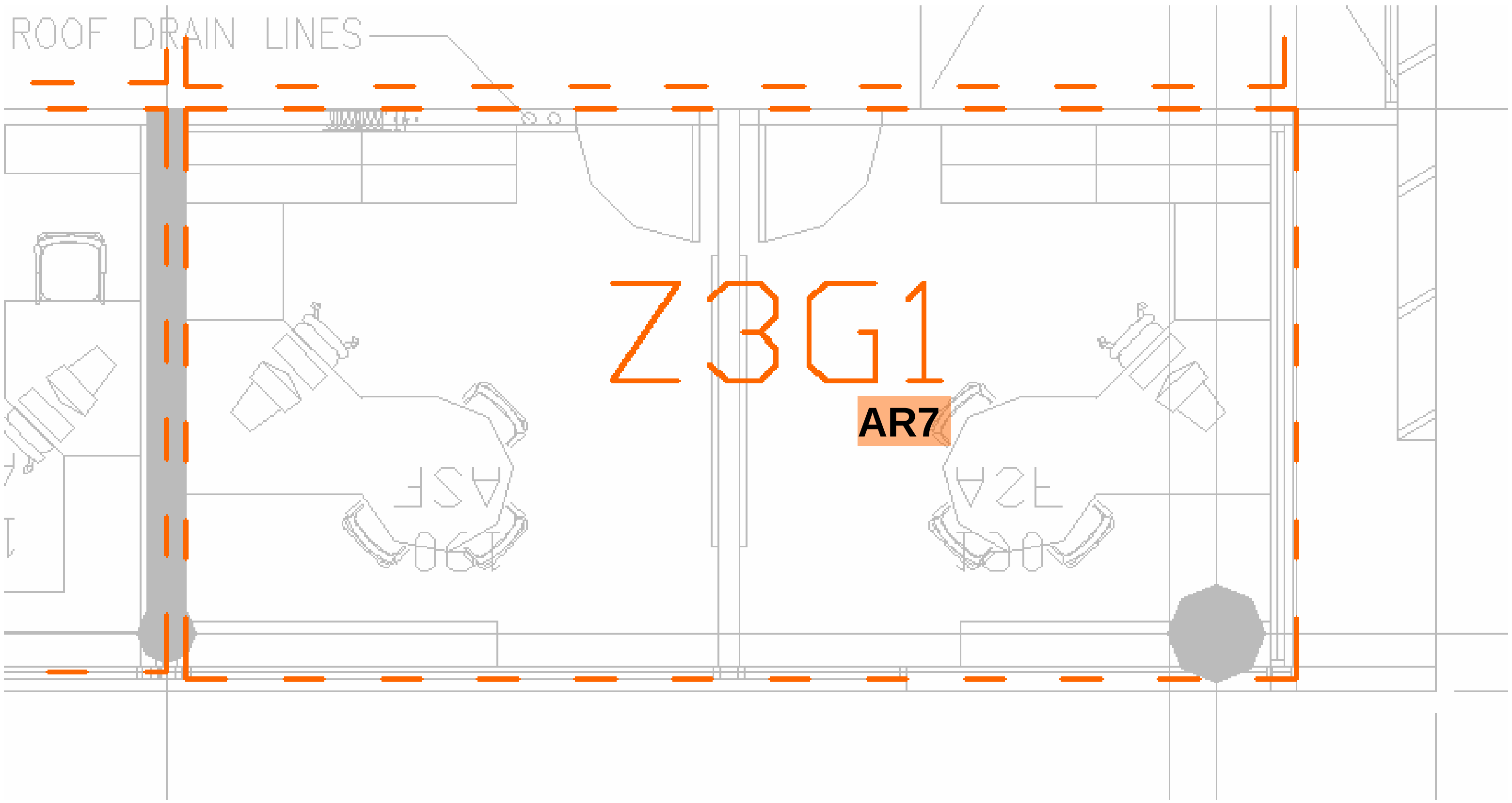
Zoning of floors 2&3



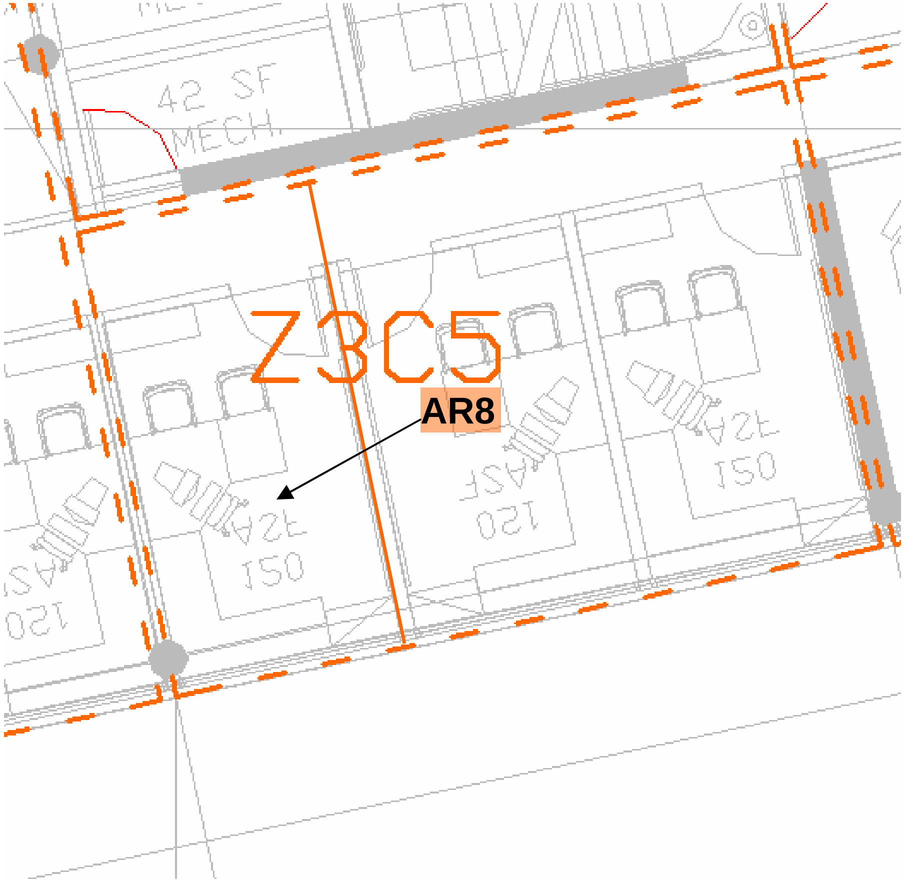
Zone AR02 SOUTH BUILDING, FLOOR 0



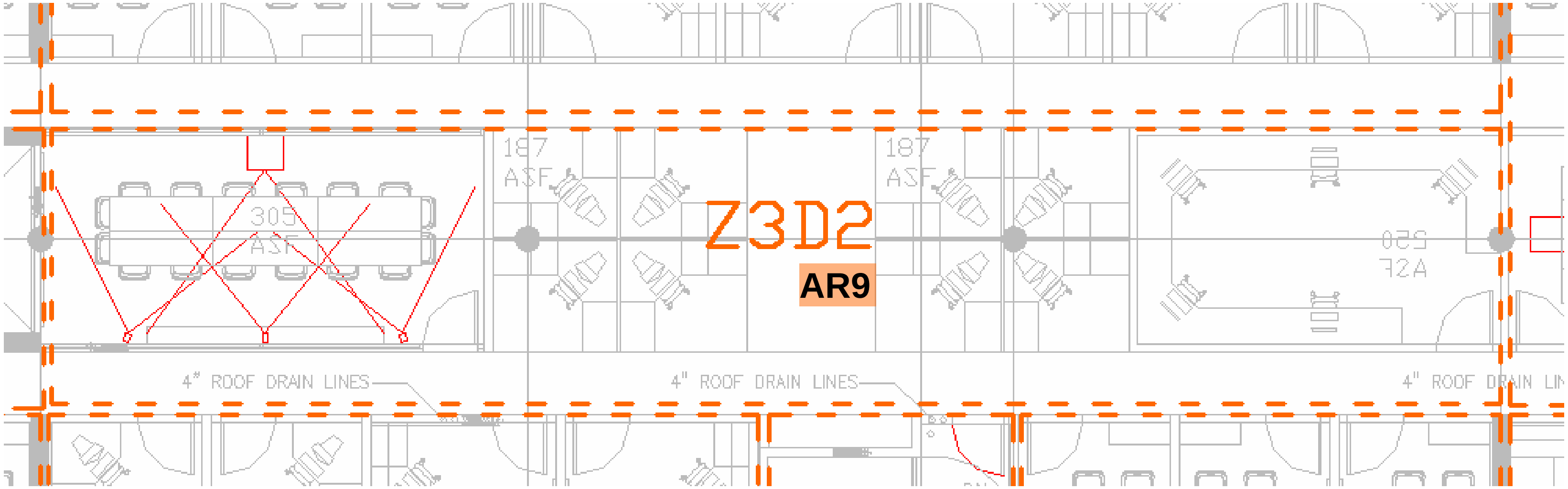
Zone AR07 SOUTH BUILDING, FLOOR 3



Zone AR08 NORTH BUILDING, FLOOR 3

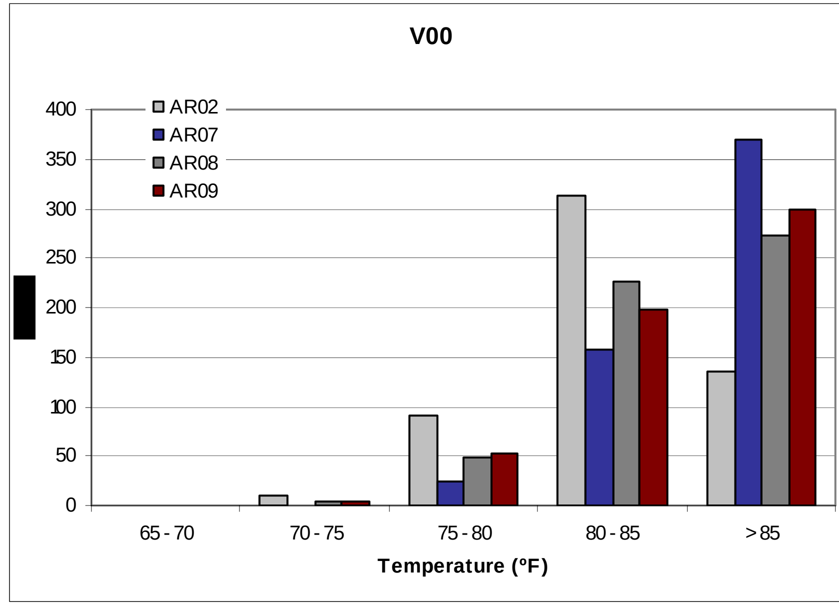


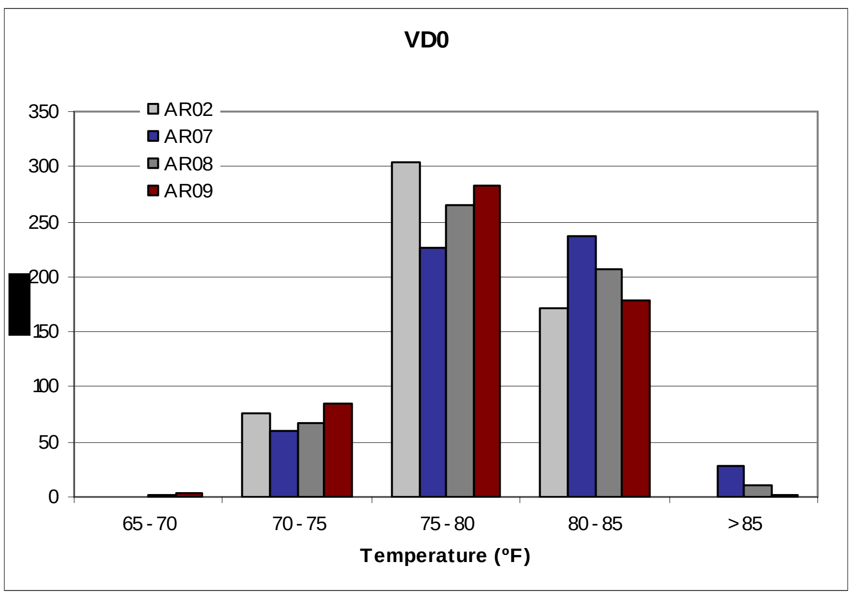
Zone AR09 SOUTH BUILDING, FLOOR 3

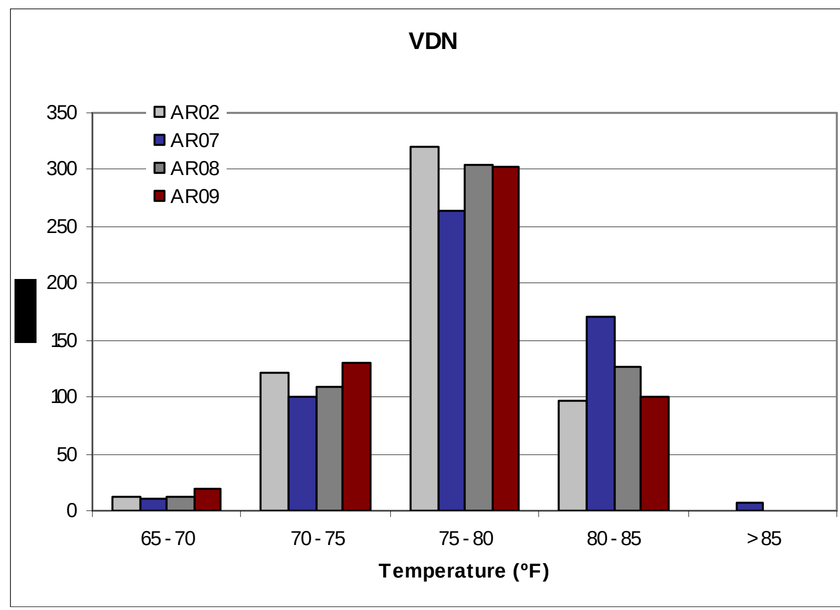


Base case:
Standard weather
No mechanical cooling
Variable ventilation strategy

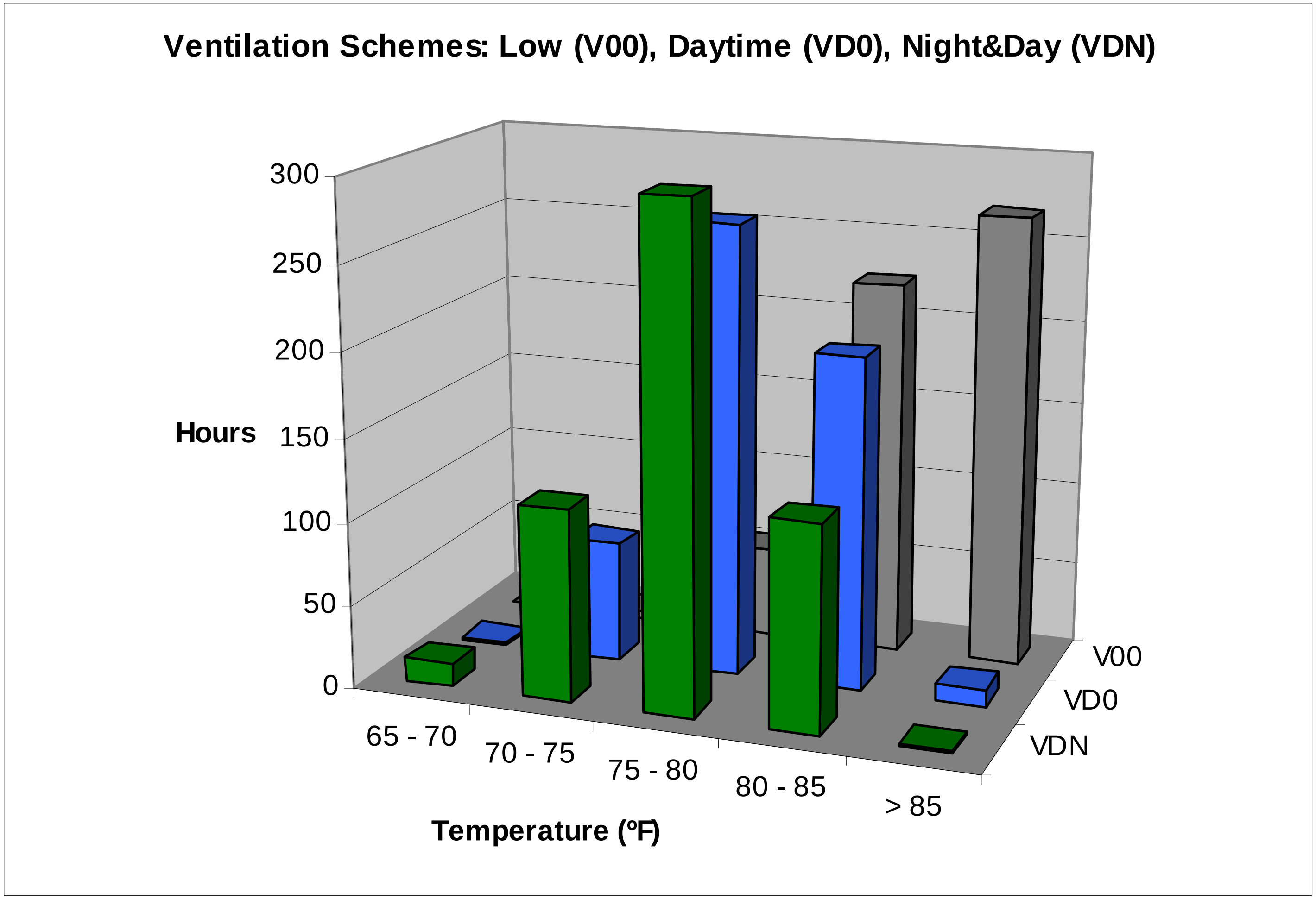
Number of hours in a given
Temperature interval





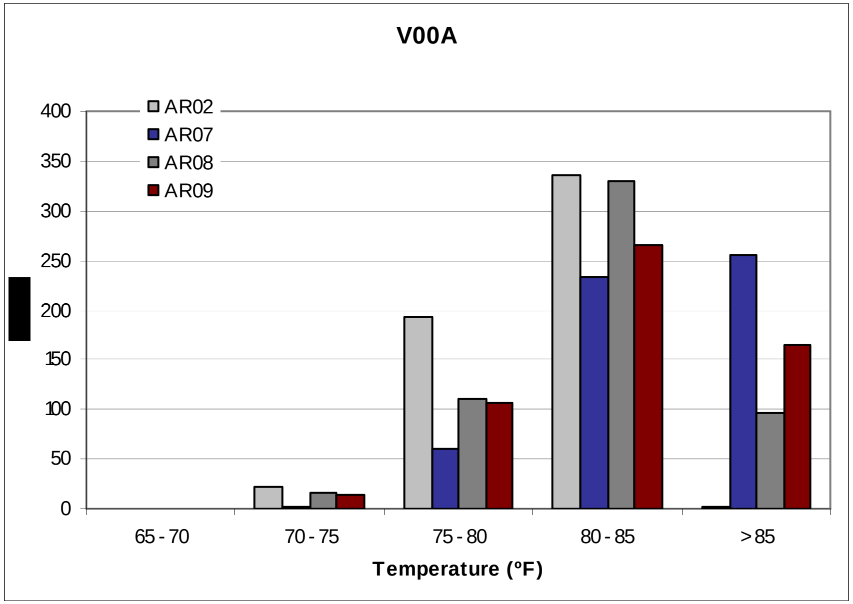


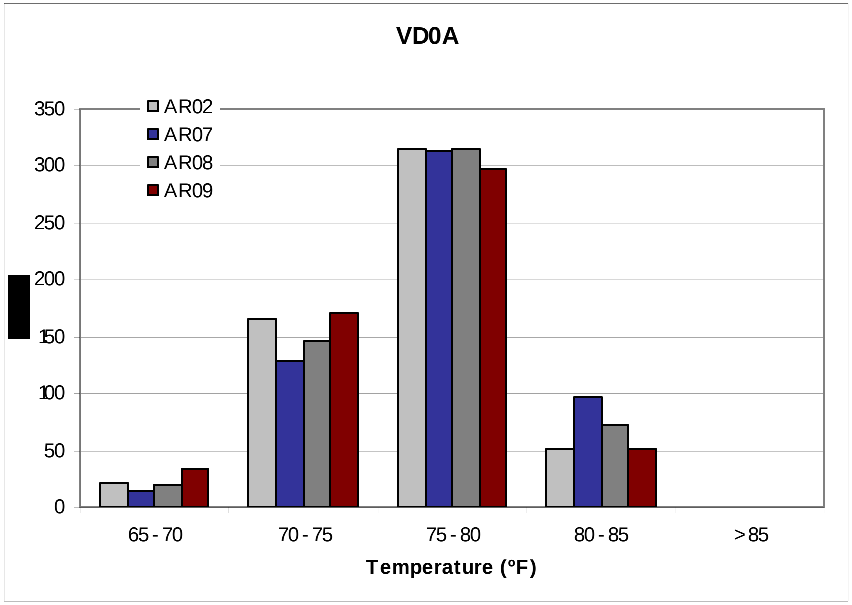
Average impact of the ventilation scheme

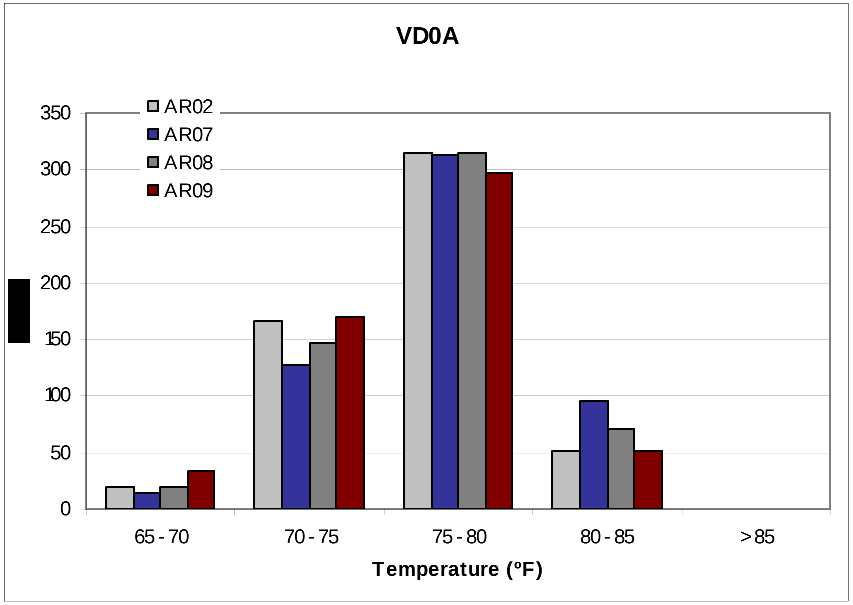


Adjusted weather
No mechanical cooling
Variable ventilation strategy

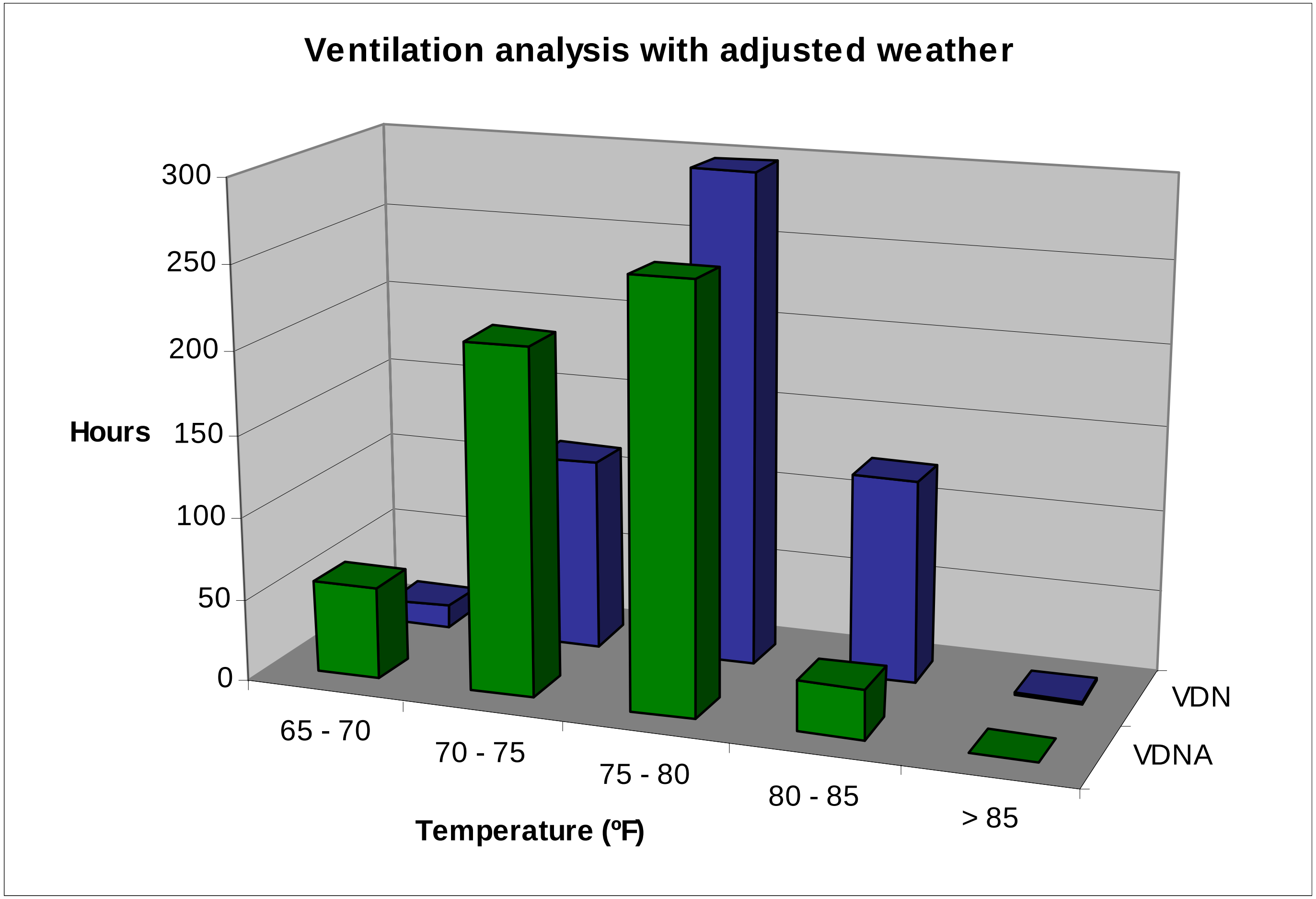
Number of hours in a given
Temperature interval



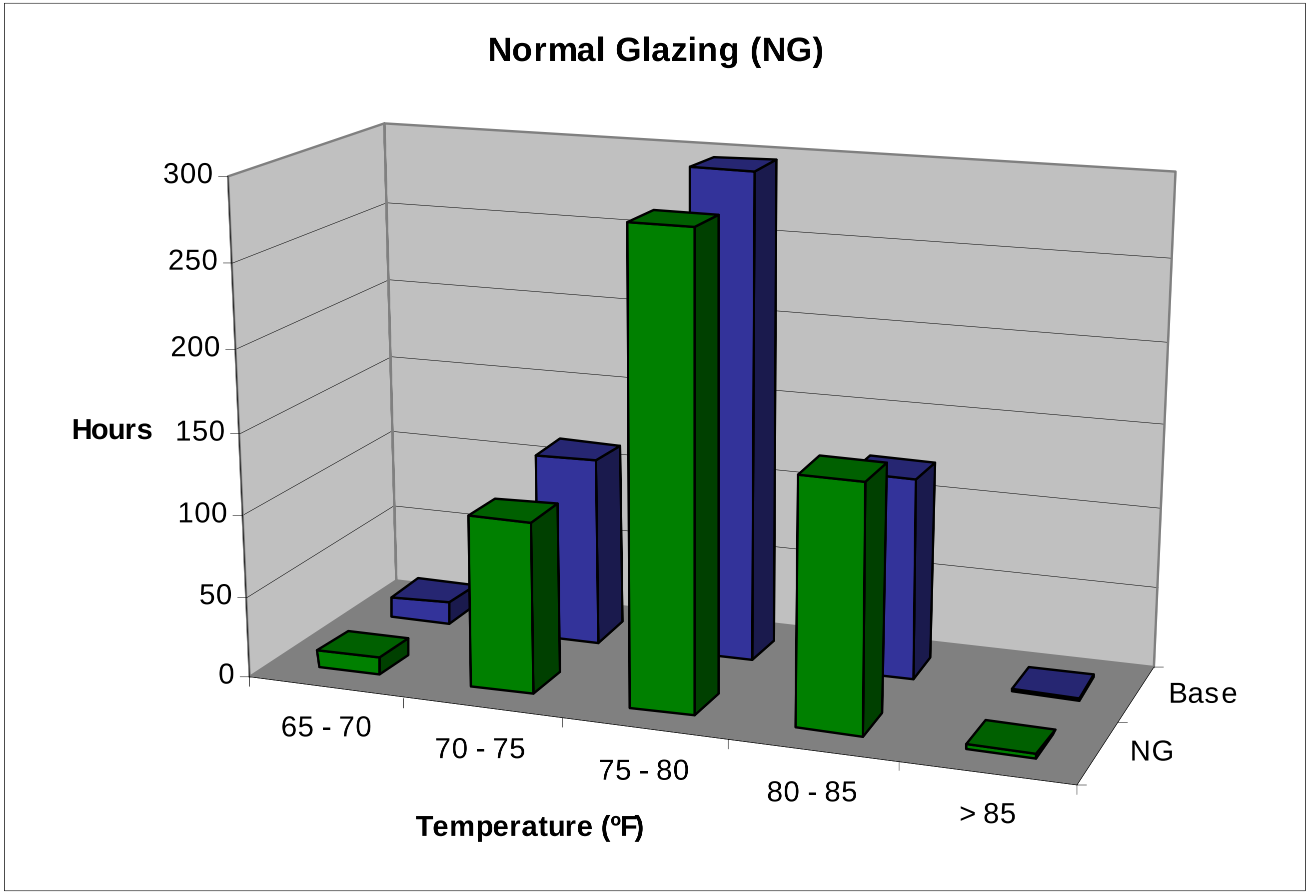




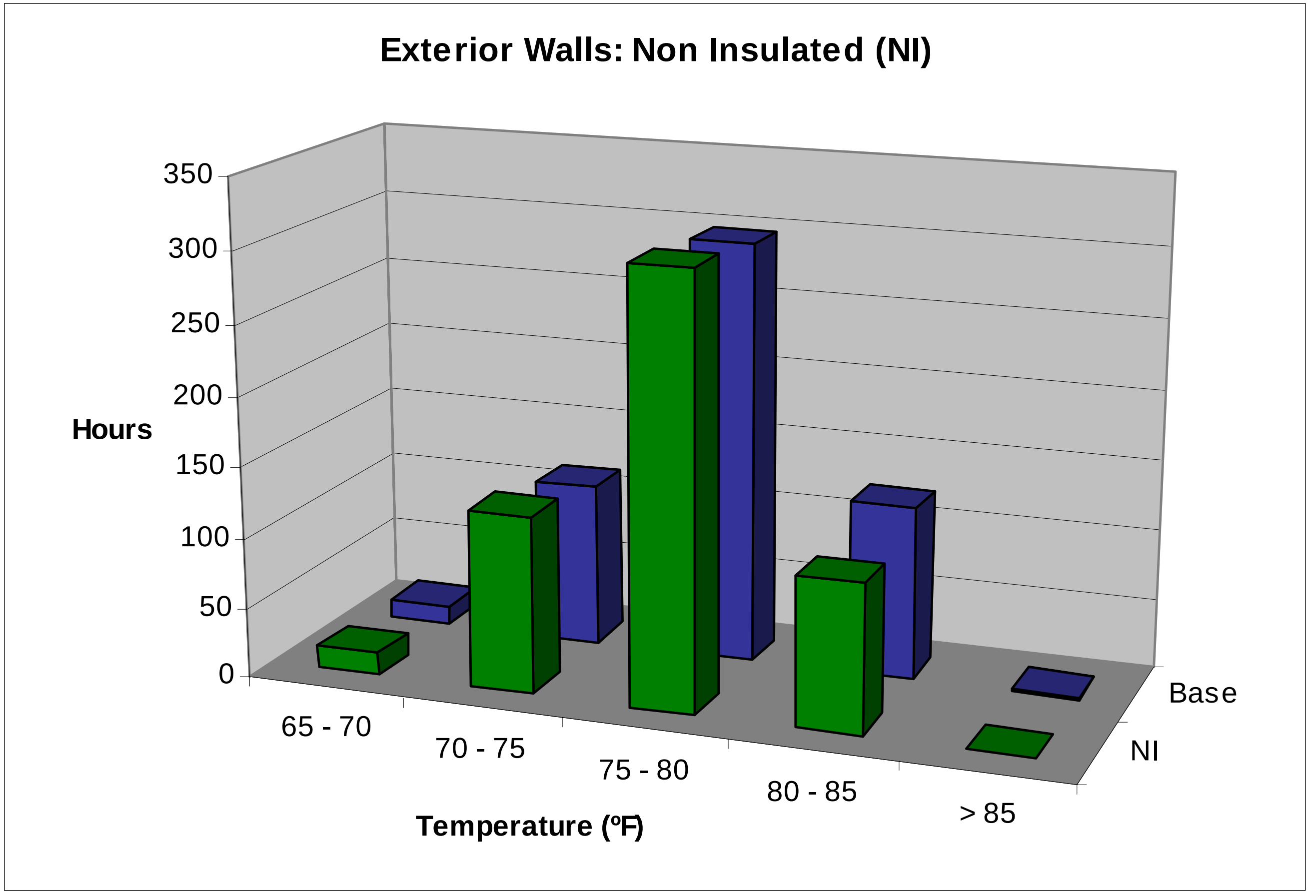
Impact of local weather



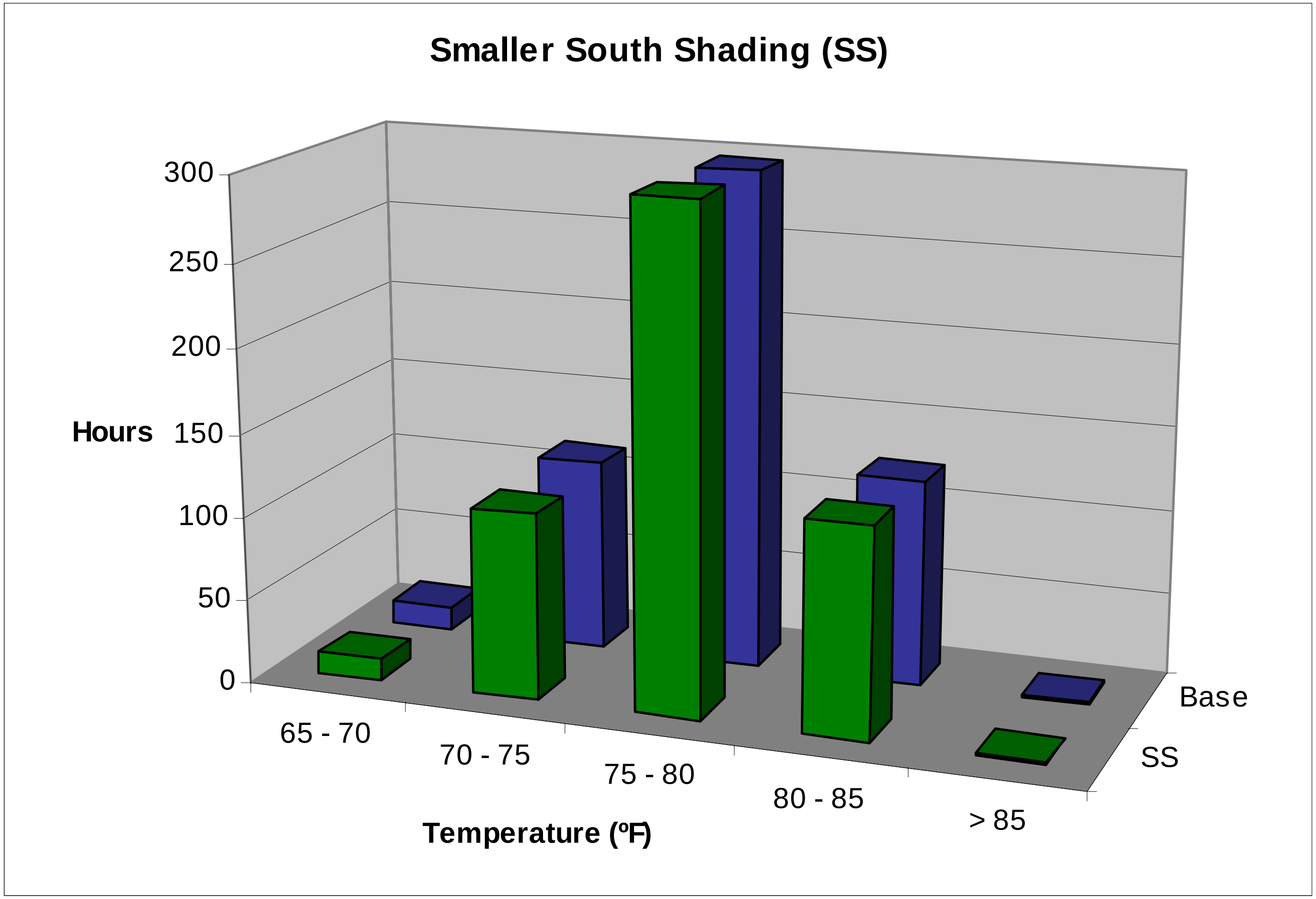
Impact of glazing system



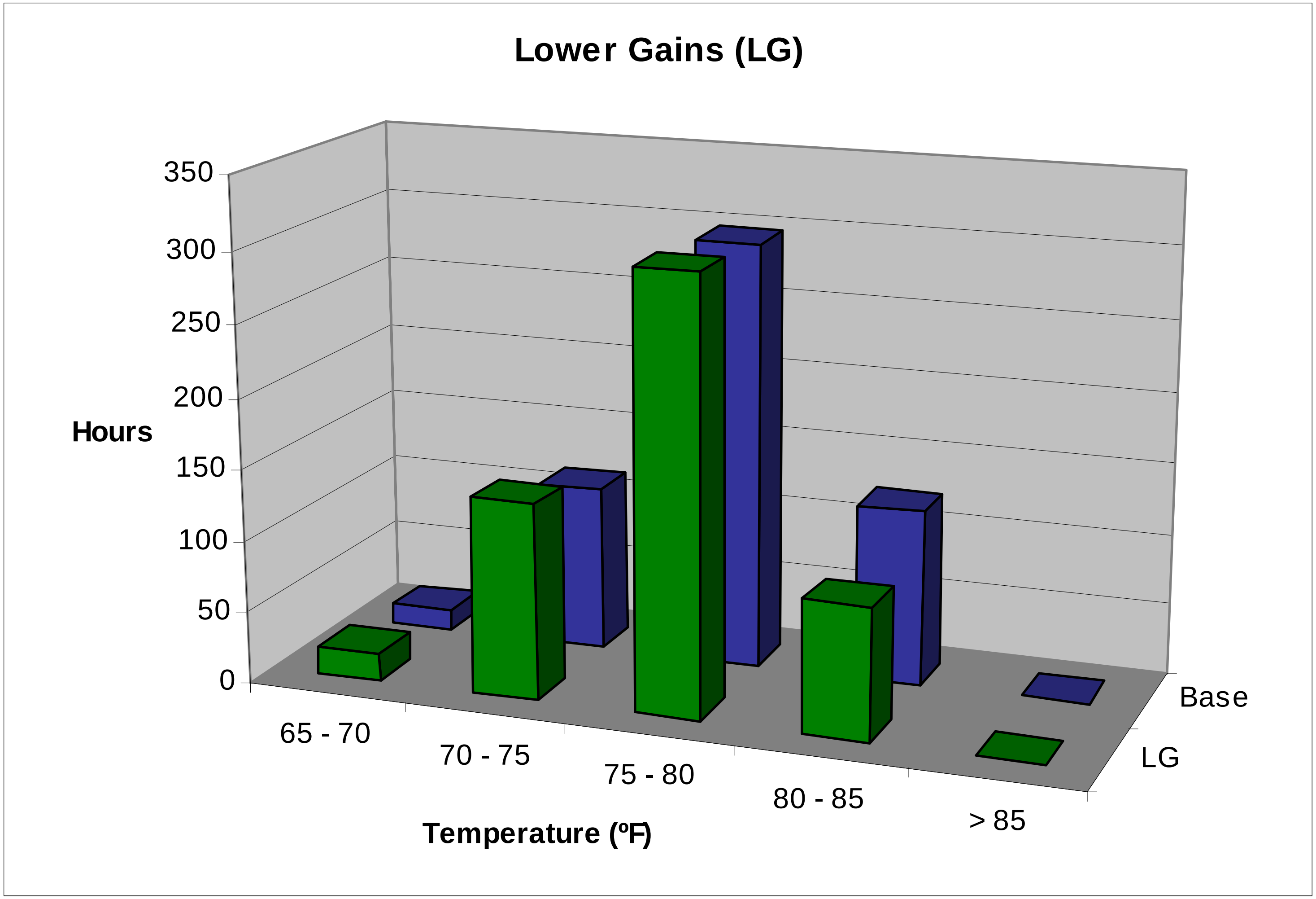
Impact of external wall insulation



Impact of optimized smaller shading (increased gains in winter)



Impact of lower gains



Mechanical heating and cooling

Maximum Cooling Load (normalized to the maximum zone load)

ZONE	V00 PA	VD0 PA	VDN PA	VDN PA LG	VDN PA SS
AR02	1.00 ($102 W/m^2$)	0.99	0.95	0.73	0.95
AR07	0.91	0.95	0.83	0.68	0.84
AR08	0.70	0.69	0.65	0.48	0.65
AR09	0.72	0.72	0.65	0.53	0.65

Total Cooling Energy (normalized to the maximum zone load)

ZONE	V00 PA	VD0 PA	VDN PA	VDN PA LG	VDN PA SS
AR02	0.89	0.61	0.55	0.32	0.56
AR07	1.00	0.62	0.51	0.36	0.52
AR08	0.74	0.45	0.38	0.22	0.39
AR09	0.72	0.43	0.37	0.26	0.37

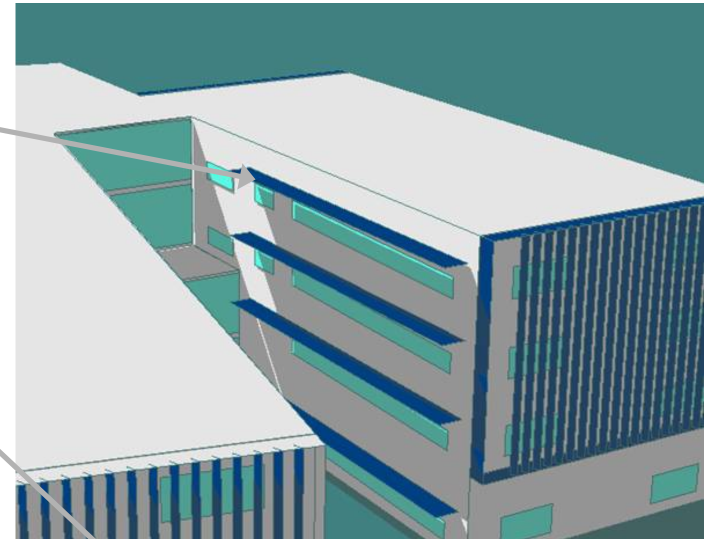
	Max. Heating Load (normalized)		Total Heating Energy (normalized)	
ZONE	V00 PA	V00 NI PA	V00 PA	V00 NI PA
AR02	0.72	1.00 ($97 W/m^2$)	0.50	1.00
AR07	0.60	0.95	0.17	0.84
AR08	0.54	0.66	0.24	0.49
AR09	0.57	0.58	0.36	0.38

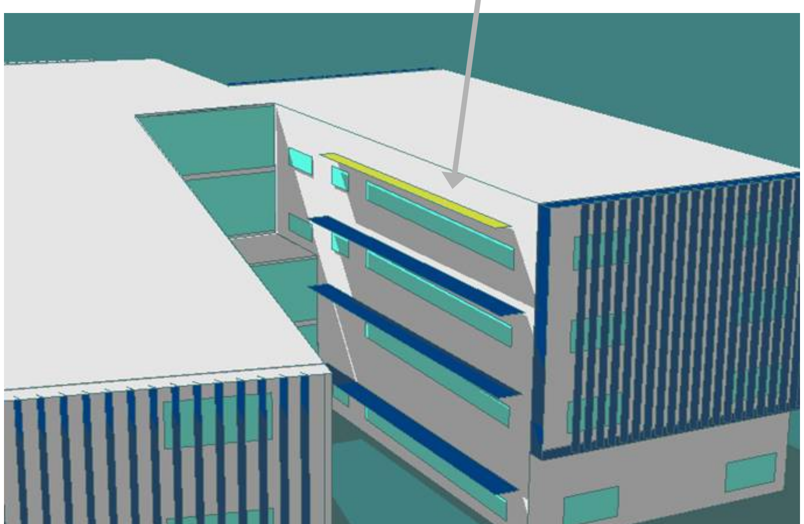
3- Shading analysis using ECOTEC

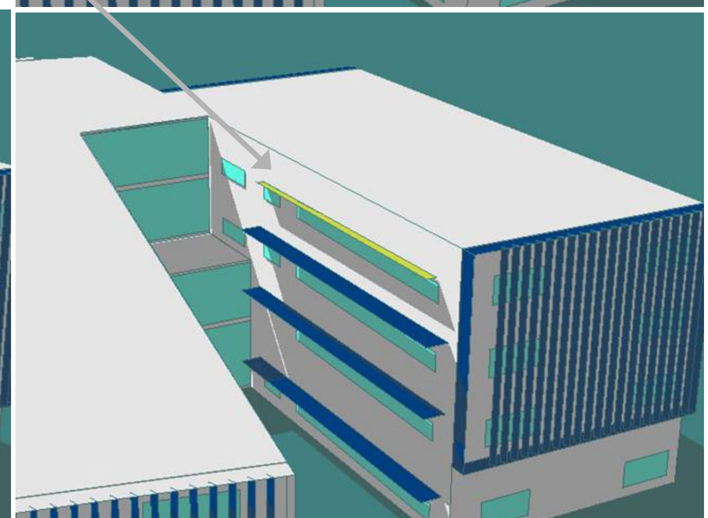
Initial proposal

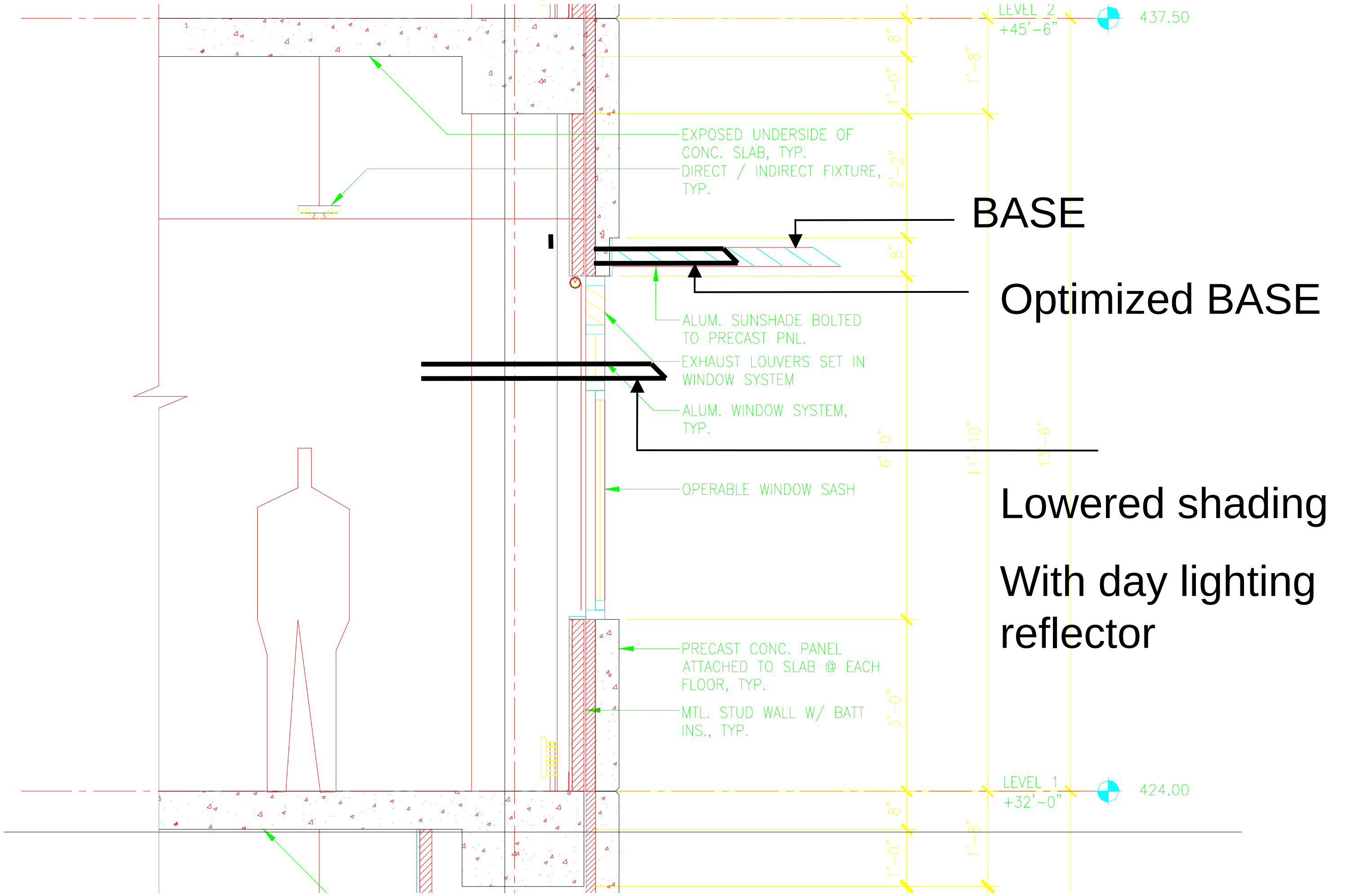
Optimized shading

Lowered shading

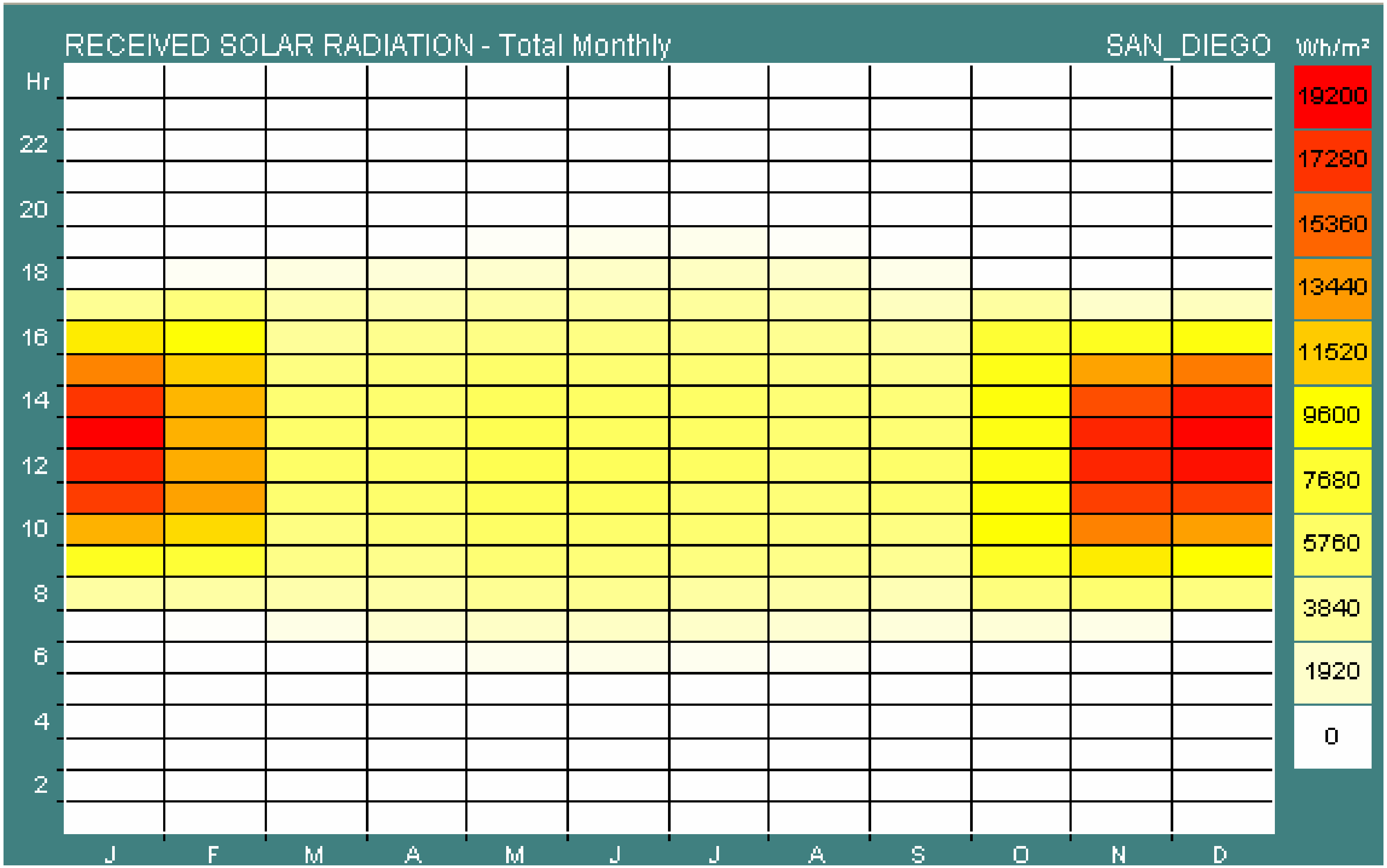




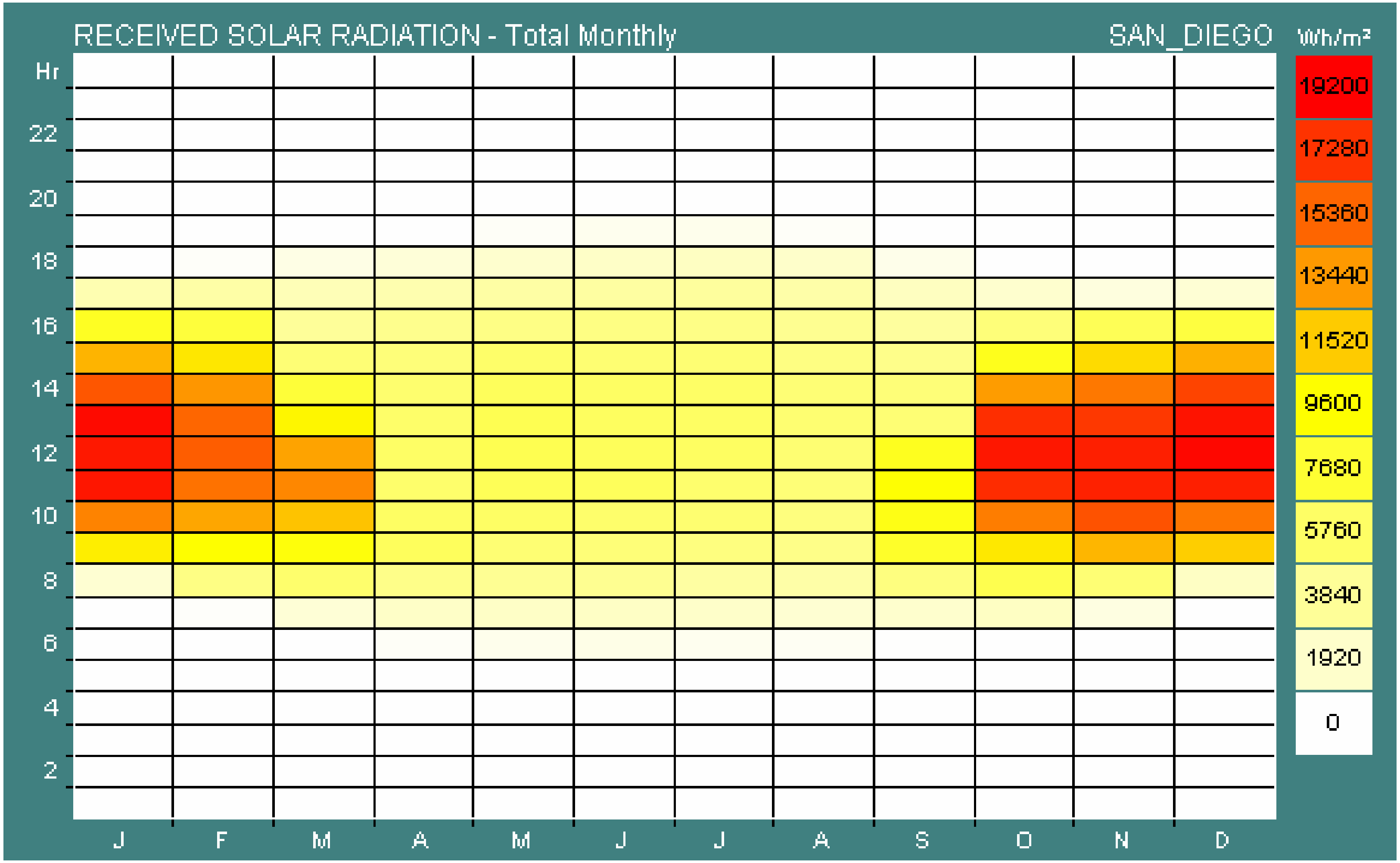



LEVEL 2
+45'-6"
437.50
EXPOSED UNDERSIDE OF CONC. SLAB, TYP.
DIRECT / INDIRECT FIXTURE, TYP.
BASE
Optimized BASE
ALUM. SUNSHADE BOLTED TO PRECAST PNL.
EXHAUST LOUVERS SET IN WINDOW SYSTEM
ALUM. WINDOW SYSTEM, TYP.
OPERABLE WINDOW SASH
Lowered shading
With day lighting reflector
PRECAST CONC. PANEL ATTACHED TO SLAB @ EACH FLOOR, TYP.
MTL. STUD WALL W/ BATT INS., TYP.
LEVEL 1
+32'-0"
424.00

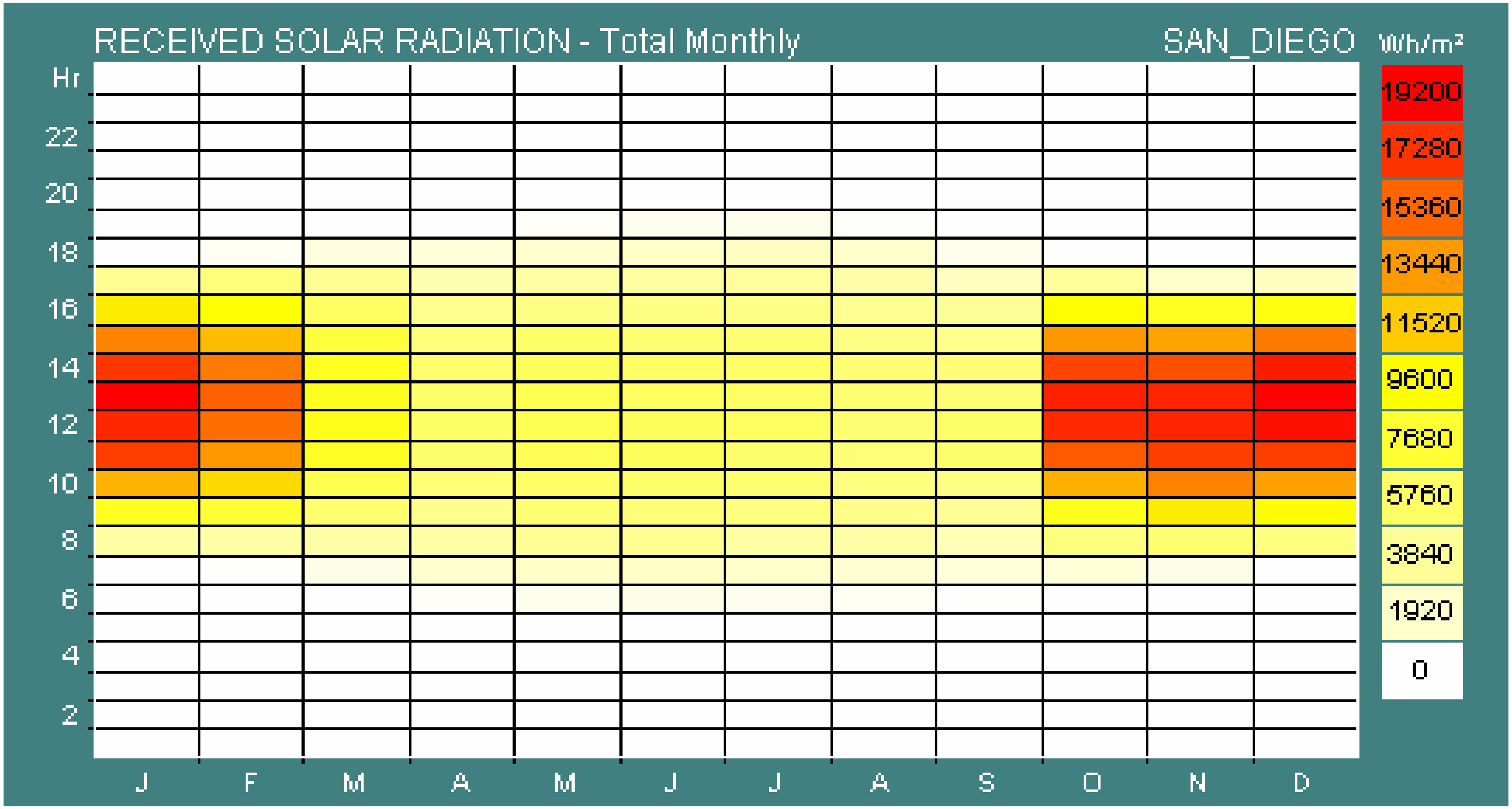
S-BASE (size 1.2m)



S-OPTIM BASE (0.75m)

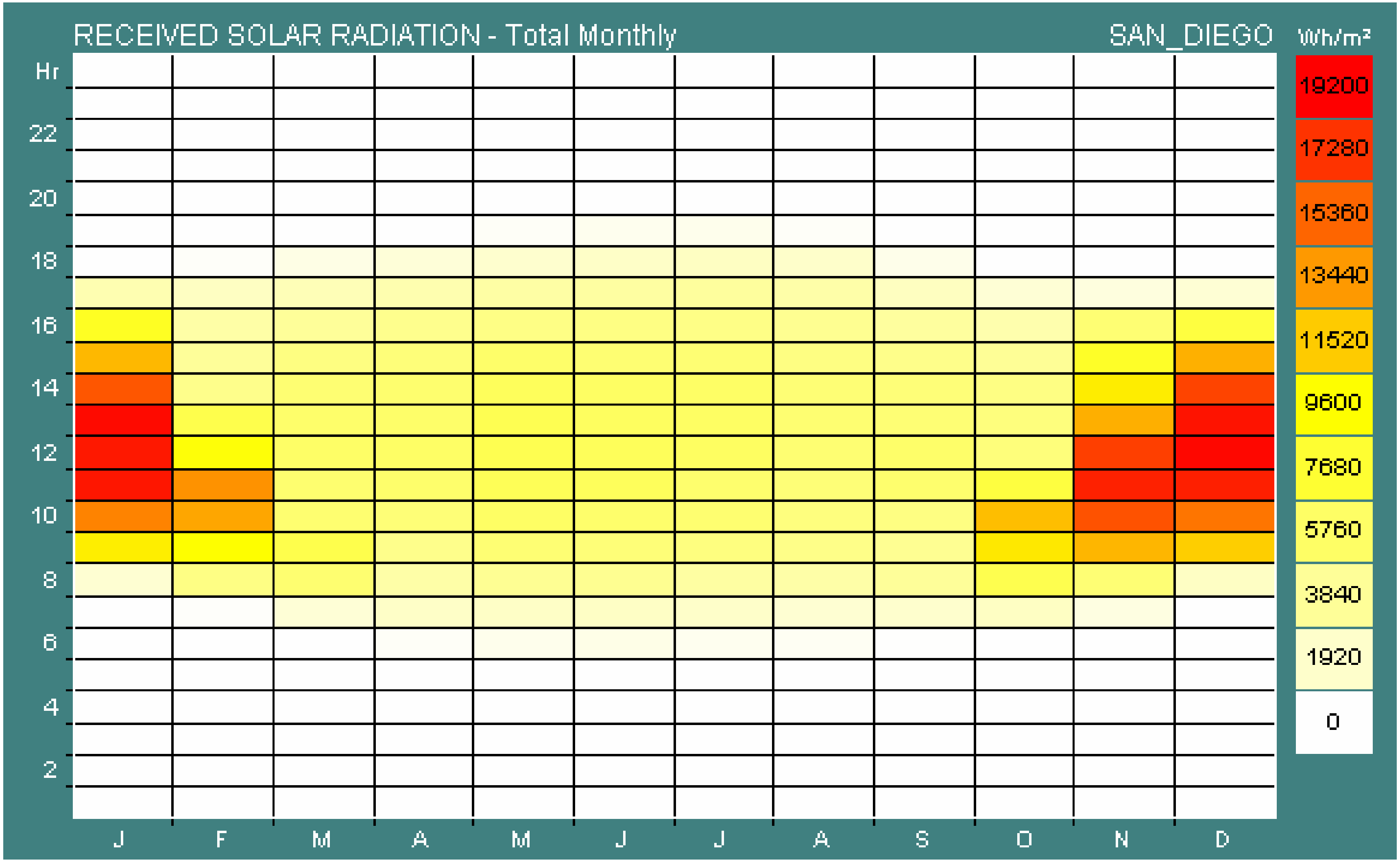


S-LOW (0.45m)



RECEIVED SOLAR RADIATION - Total Monthly
SAN_DIEGO
Wh/m²
Hr
22
20
18
16
14
12
10
8
6
4
2
J
F
M
A
M
J
J
A
S
O
N
D
19200
17280
15360
13440
11520
9600
7680
5760
3840
1920
0

N-BASE (1.2m)


RECEIVED SOLAR RADIATION - Total Monthly
SAN_DIEGO
Wh/m²
Hr
22
20
18
16
14
12
10
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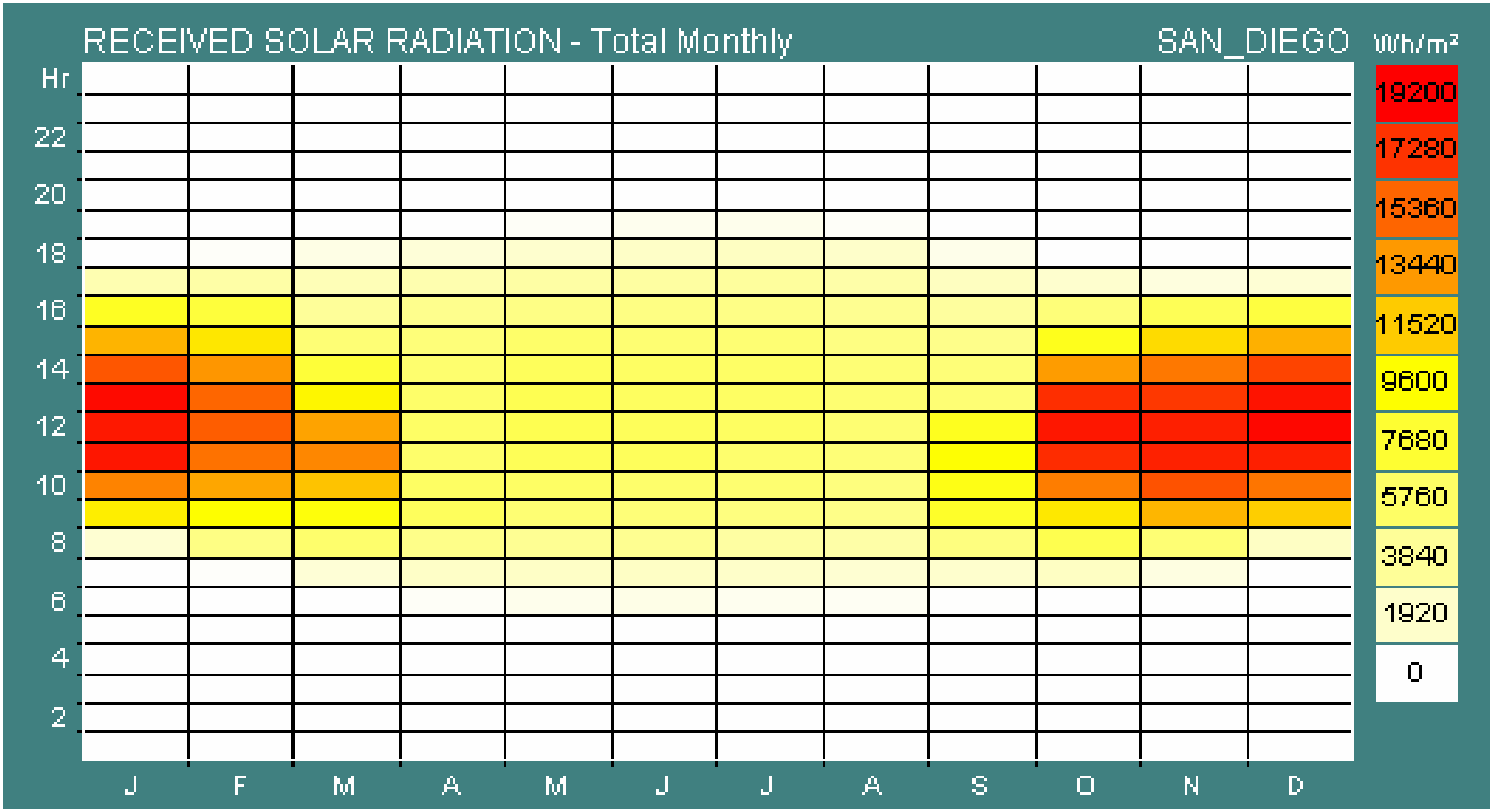
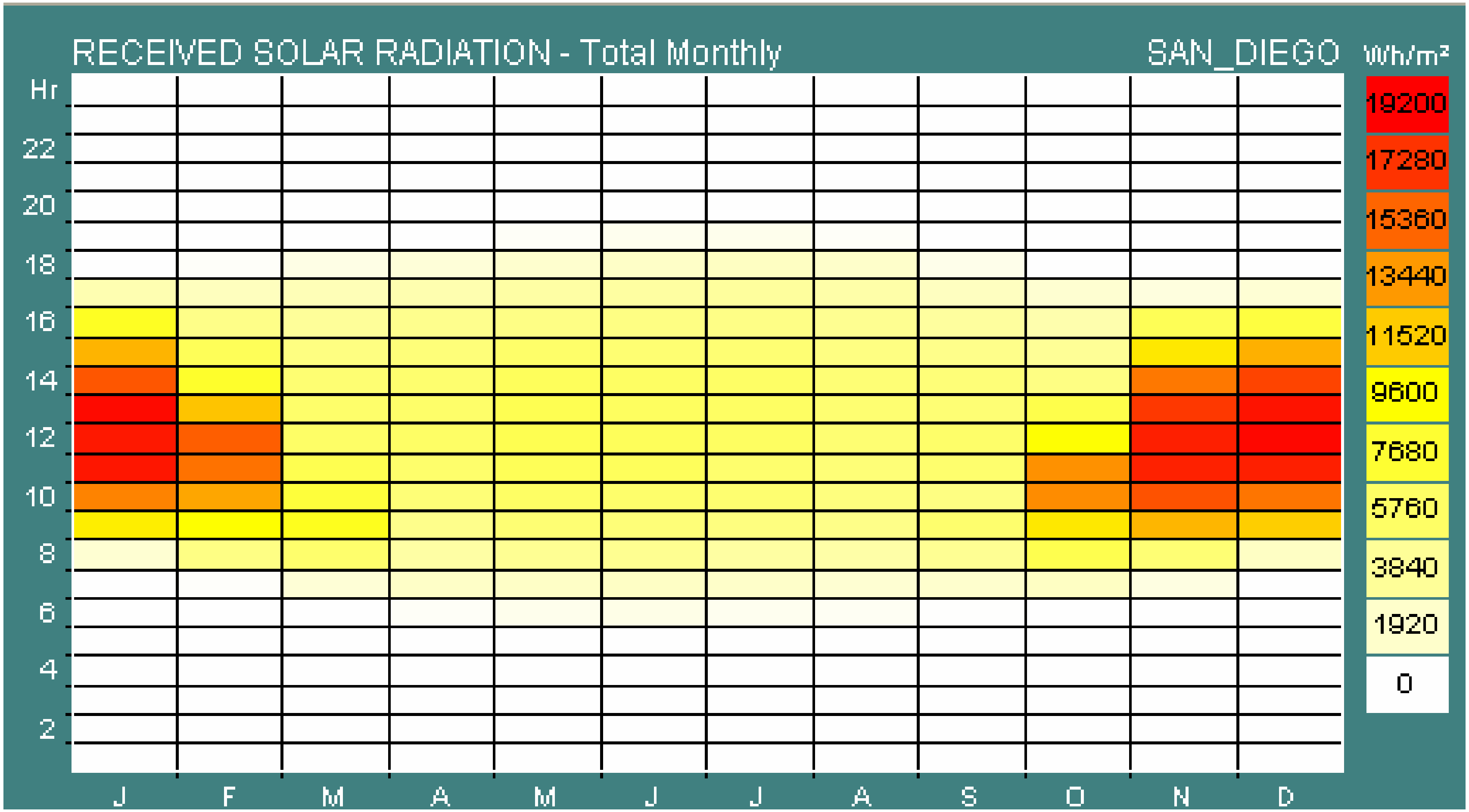
11520
9600
7680
5760
3840
1920
0

N-OPTIM BASE (.78m)



N-LOW (.47m)



RECEIVED SOLAR RADIATION - Total Monthly
SAN_DIEGO
Wh/m²
Hr
22
20
18
16
14
12
10
8
6
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2
J
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19200
17280
15360
13440
11520
9600
7680
5760
3840
1920
0

Preliminary conclusions

The San Diego climate has significant potential for low energy climate control systems

In the current design phase it may still be possible to improve performance by placing higher load spaces in the North façade (why not the computer labs?)

In most spaces the use of natural cooling by single sided displacement ventilation (both during the day and night) may provide sufficient cooling

Due to the mildness of the climate, “special glazing” or even thermal insulation in the vertical walls may not be necessary

The use of ducted forced air in the perimeter offices may not be an appropriate solution since large flow rates are needed in order to maximize natural cooling (easier to obtain with natural ventilation)

Building features

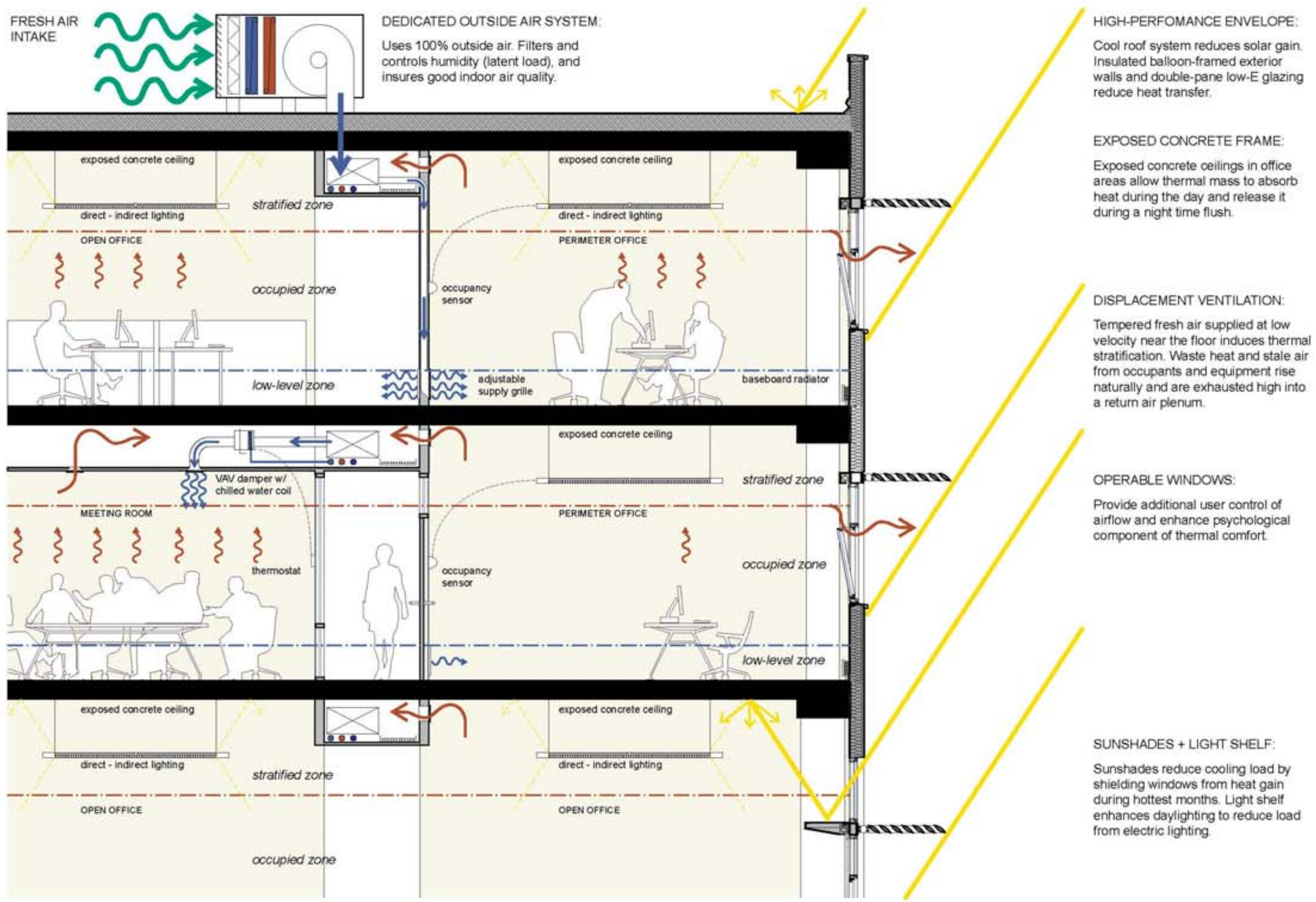
- Low capacity AHU (fan and coils)
- Mist eliminators and filters in the AHU
- No terminal boxes or controls in the distribution system
- Low sidewall diffusers with damper
- Operable windows
- Relief of all supply air

Building features (cont.)

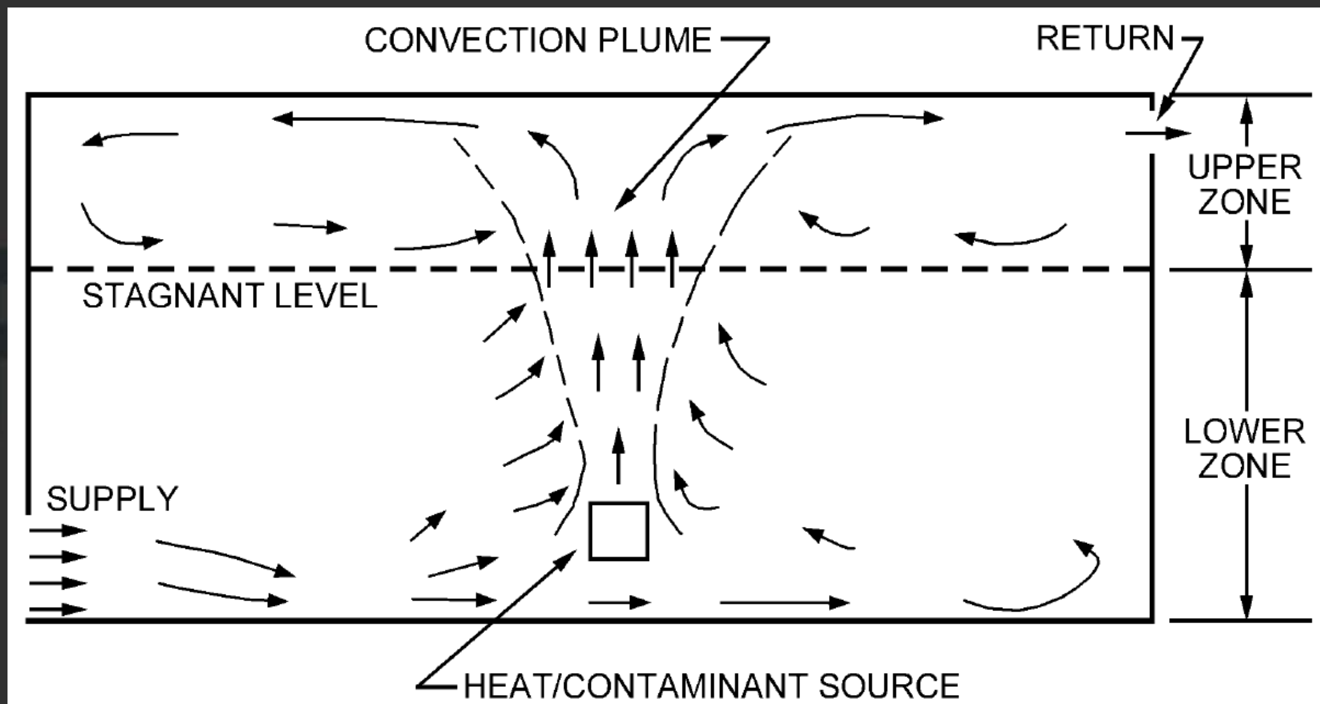
- Local chilled water loop to manage point loads
- Sun shades

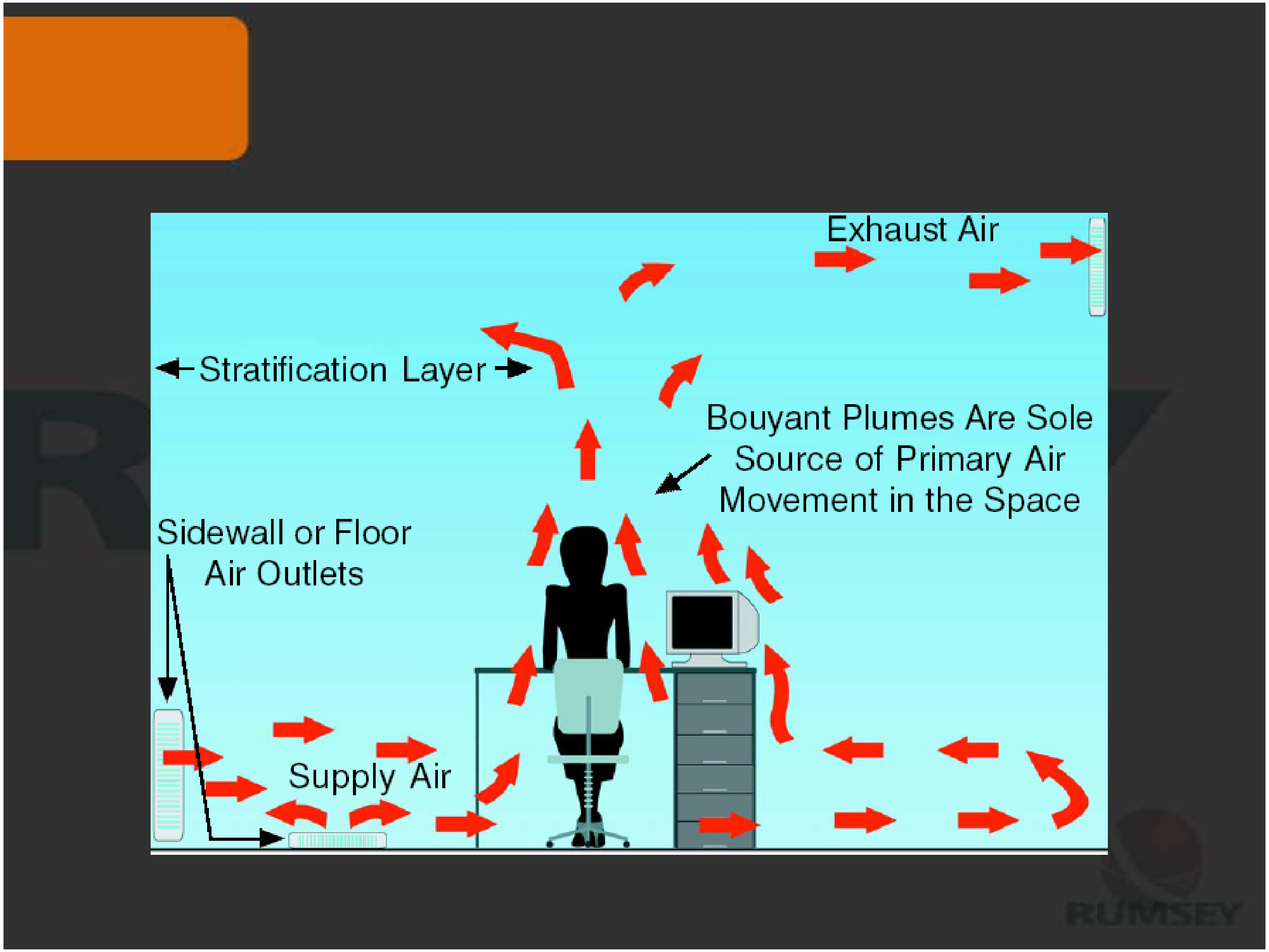
FLOOR PLAN - LEVEL 3

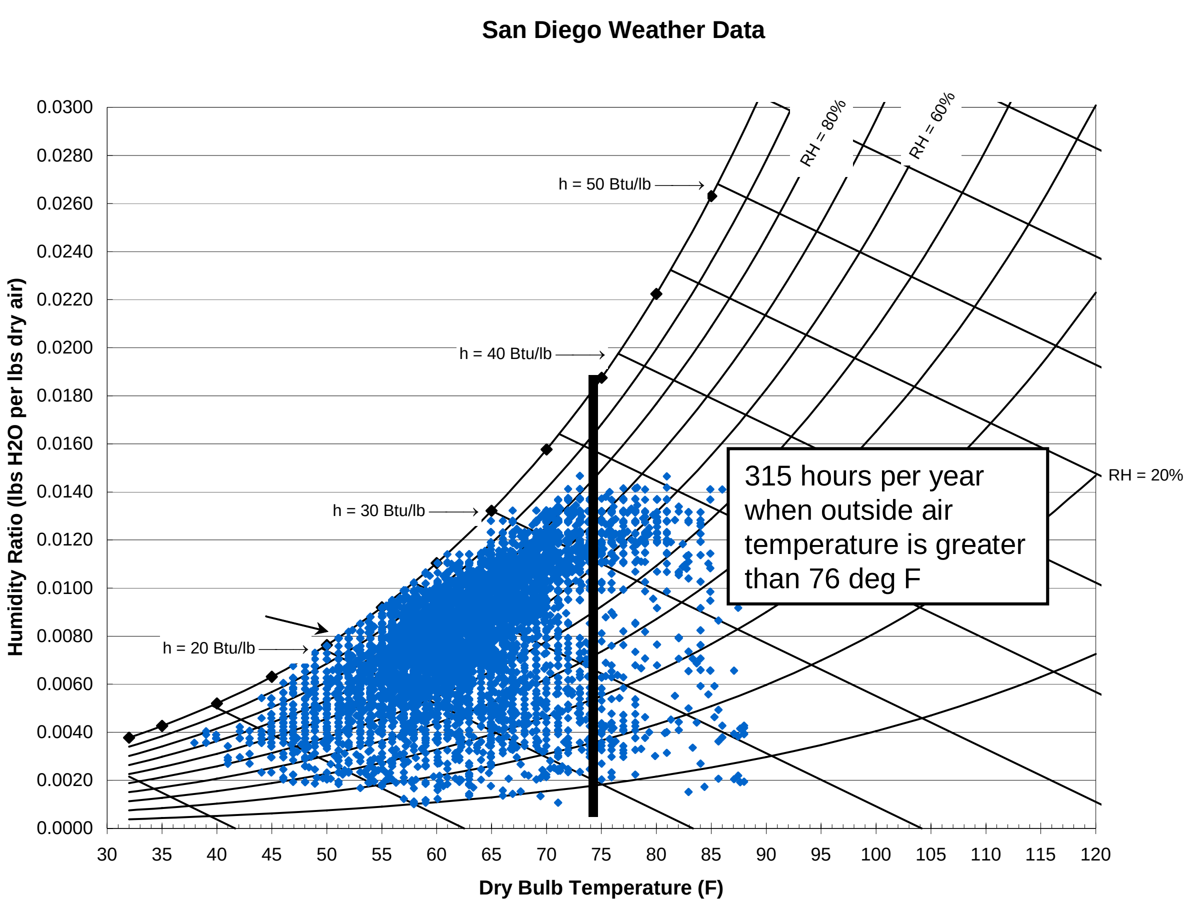
Displacement Ventilation with Hot Water Radiators



typical section : displacement ventilation


CONVECTION PLUME
RETURN
UPPER ZONE
STAGNANT LEVEL
LOWER ZONE
SUPPLY
HEAT/CONTAMINANT SOURCE


Exhaust Air
Stratification Layer
Bouyant Plumes Are Sole Source of Primary Air Movement in the Space
Sidewall or Floor Air Outlets
Supply Air
RUMSEY


San Diego Weather Data
Humidity Ratio (lbs H2O per lbs dry air)
Dry Bulb Temperature (F)
0.0300
0.0280
0.0260
0.0240
0.0220
0.0200
0.0180
0.0160
0.0140
0.0120
0.0100
0.0080
0.0060
0.0040
0.0020
0.0000
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
105
110
115
120
h = 50 Btu/lb
h = 40 Btu/lb
h = 30 Btu/lb
h = 20 Btu/lb
RH = 80%
RH = 60%
RH = 20%
315 hours per year when outside air temperature is greater than 76 deg F

Supercompter Office HVAC Features

- "Hybrid System"
- Push air through the building – use two air handlers on the roof sized for 1.5 cfm/sf, 60,000 cfm and 90,000 cfm
- Each air handler has mist eliminator, filters, heating coil and cooling coil (for cooling and/or dehumidification)
- Approximately 1,000 sf/ton, 15 btuh/sf
- On moderate temperature days air is neither heated or cooled and supplied at 1.5 cfm/sf
- On hot days air is cooled to 70-72 deg F and supplied at 0.3 cfm/sf. Night time cooling of thermal mass is used
- On cold days air is heated to 70-72 deg F and supplied at 0.3 cfm/sf
- Air is supplied down low for user operability and displacement ventilation / stratification reasons – heat from lights is excluded from occupied zone
- Alternative – supply air from above - do full mixing, heat from lighting system is included in occupied zone
- Alternative – downsize air handlers and ducting to ventilation only requirements to lower cost. Size for 0.2 – 0.4 cfm /sf

Capital Costs

UCSD Supercomputer Center - HVAC Systems

Capital Expenses

	90% Schematic Design Mechanical System - HYBRID System	Alternative - Ventilation Air Only accepting VE Items 42 and 44	Traditional Overhead VAV System
Offices	$ 2,210,000	$ 1,525,000	$ 2,540,000
Process Cooling	$ 419,000	$ 419,000	Handled with VAV system
Machine Room	$ 735,000	$ 735,000	$ 735,000
Plant	$ 644,000	$ 644,000	$ 644,000
Total Cost	**$ 4,008,000**	**$ 3,323,000**	**$ 3,919,000**
Total Cost Per SF assuming 80,000 sf	$ 50.10	$ 41.54	$ 48.99
Other Deducts - Steel Building, Lower Partition Walls			$ (490,000)
Other Adds - Drop Ceiling			$ 110,000
Effective Cost Impact	$ 4,008,000	$ 3,323,000	$ 3,539,000

Energy Costs

Energy Expenses

	90% Schematic Design Mechanical System - HYBRID System	Alternative - Ventilation Air Only accepting VE Items 42 and 44	Traditional Overhead VAV System
Estimated Annual Energy Costs - All End Uses*	$ 168,000	$ 112,000	$ 280,000
Estimated Annual Energy Costs - HVAC Only	$ 67,200	$ 44,800	$ 112,000
Anticipated HVAC Costs Savings	**$ 44,800**	**$ 67,200**	**N/A**
20 Year Cost Savings	**$ 896,000**	**$ 1,344,000**	

HVAC and Lighting Energy Savings will be possible in the as designed building

RUMSEY

Why did this happen

- Culture in FD&C
- FD&C staff engineers
- Direct communication between FD&C engineers and mechanical engineers
- Interaction with operations staff

Risks to the design approach

- Setpoint changes
- Load density
- Increase in warm weather days
- Accuracy of the model