COACH	**Nick Caton**, Caton Energy Consulting, Kansas City
ENERGY SIMULATORS	**Chris Jones**, WSP Toronto
	Pasha Korber-Gonzalez, Korber Energy Consultants
ENGINEERS	**Aaron Powers**, Johnson Controls Memphis
	Cara Sloat, WSP Toronto

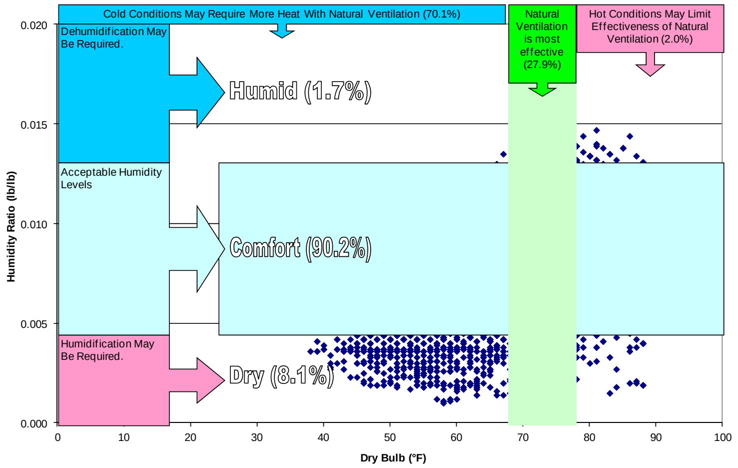
GOALS

During our 10 week design process we set out to design a building and…

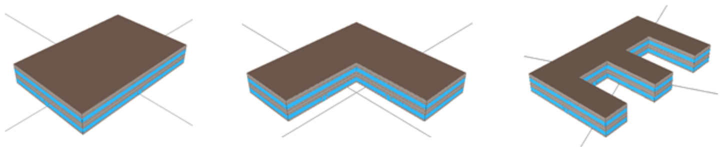
- Achieve net-zero energy and minimum carbon footprint
- Demonstrate flexibility of E-Quest/DOE-2
- Push our abilities
- Learn & share
- Have fun!

CLIMATE & GEOMETRY

We selected **San Jose, California** as the home for our new 53,000ft^2, 3 story office building. This climate zone allowed for innovation: based on exploration of available psychrometric data using Climate Consultant 6.0, and review of Pacific Energy Center local design strategy recommendations, San Jose has good passive energy opportunities for natural ventilation, solar shading and passive heating, and some potential for use of thermal mass strategies.



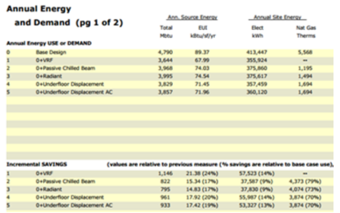
eQuest's wizard function allowed major features of the building (such as geometry) to be changed with low labour costs, providing a snapshot of the energy potential for several geometry options. We were particularly interested, due to the high insolation of the area, in investigating possibilities for different shapes to offer self-shading. On the basis of this study we selected an L-shaped footprint for the project



	Rectangle Shape	L-Shape	E-Shape
Wall Area (ft^2)	8,505	10,284	14,818
WWR	40%	40%	40%
Perimeter Access to Daylight (ft^2)	7,290	9,000	9,103

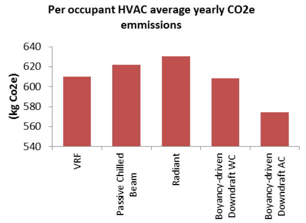
MECHANICAL SYSTEMS

For active systems, initial investigation was driven by HVAC systems we were interested in modeling. Variable refrigerant flow systems; passive chilled beam; radiant in-ceiling heating and cooling; and buoyancy-driven downdraft supplied from underfloor were examined. Although the VRF showed the strictly lowest energy use, when lifetime climate change impact of expected fugitive F-gases are included, minimum climate impact over time was achieved by passive downdraft.

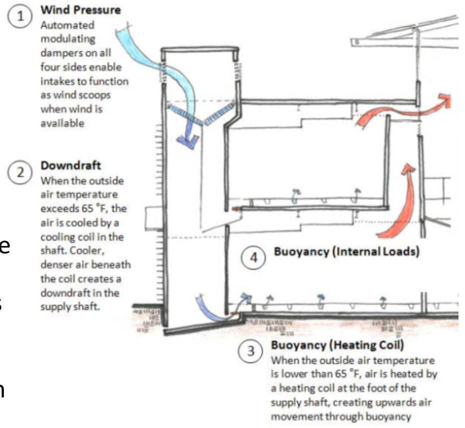


Annual Energy and Demand (pg 1 of 2)

		Ann. Source Energy		Annual Site Energy	
		Total Mbtu	EUI kBtu/sf/yr	Elect kWh	Nat Gas Therms
Annual Energy USE or DEMAND					
0	Base Design	4,790	89.37	413,447	5,568
1	0+VRF	3,644	67.99	355,924	--
2	0+Passive Chilled Beam	3,968	74.03	375,860	1,195
3	0+Radiant	3,995	74.54	375,617	1,494
4	0+Underfloor Displacement	3,829	71.45	357,459	1,694
5	0+Underfloor Displacement AC	3,857	71.96	360,120	1,694
Incremental SAVINGS	**(values are relative to previous measure (% savings are relative to base case use),**				
1	0+VRF	1,146	21.38 (24%)	57,523 (14%)	--
2	0+Passive Chilled Beam	822	15.34 (17%)	37,587 (9%)	4,373 (79%)
3	0+Radiant	795	14.83 (17%)	37,830 (9%)	4,074 (73%)
4	0+Underfloor Displacement	961	17.92 (20%)	55,987 (14%)	3,874 (70%)
5	0+Underfloor Displacement AC	933	17.42 (19%)	53,327 (13%)	3,874 (70%)



The buoyancy-driven system uses cooling coils at high level, and heating coils at the entry of the underfloor distribution system, in combination with active wind harvesting to condition and move air through the space year round, with radiant in-ceiling systems to meet auxiliary requirements. A total of 6 3'x3', 39' high towers were needed to achieve the required airflows. Both energy simulation techniques and the design were inspired by the De Anza College system, pictured above, and associated published work by the simulation team for that and other projects. (Corney, Taniguchi, 2011.)



① **Wind Pressure** Automated modulating dampers on all four sides enable intakes to function as wind scoops when wind is available

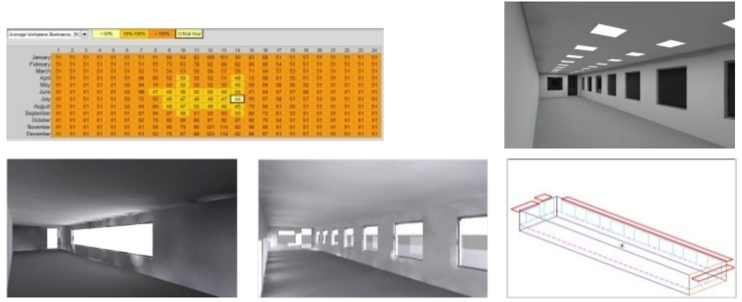
② **Downdraft** When the outside air temperature exceeds 65 °F, the air is cooled by a cooling coil in the shaft. Cooler, denser air beneath the coil creates a downdraft in the supply shaft.

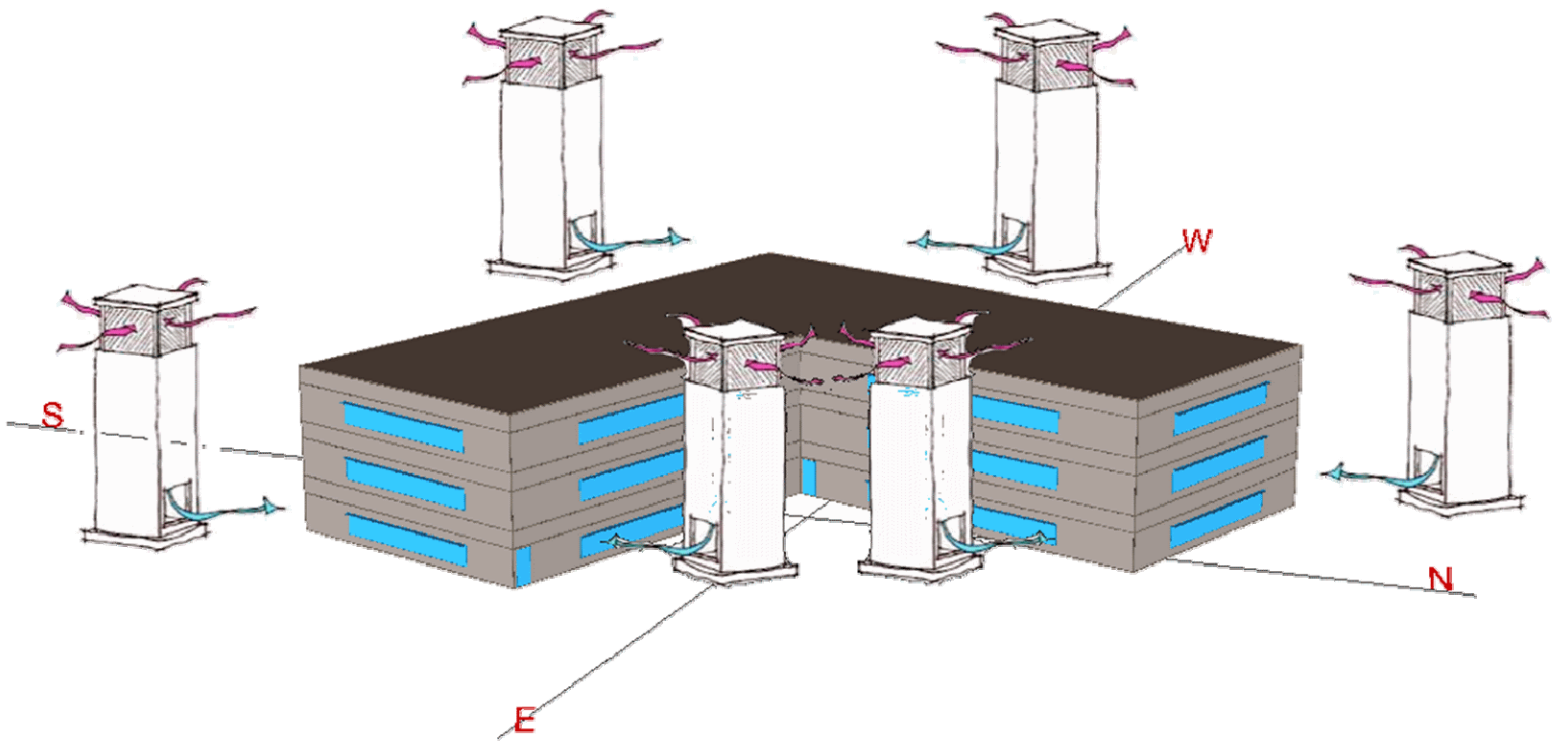
③ **Buoyancy (Heating Coil)** When the outside air temperature is lower than 65 °F, air is heated by a heating coil at the foot of the supply shaft, creating upwards air movement through buoyancy

④ **Buoyancy (Internal Loads)**

DAYLIGHT

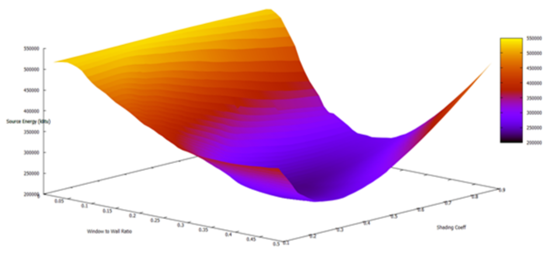
SPOT Pro was used to optimize our design to reduce glare and maximize useful daylight throughout the year. Running on a RADIANCE engine, it also exports fractional daylighting schedules directly in DOE-2 and EnergyPlus formats. This optimization reduced lighting energy use by over 60%.



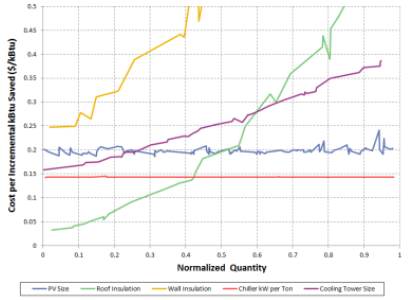


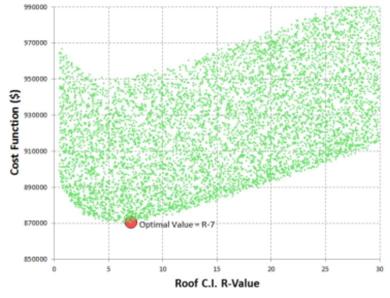
AUTOMATING OPTIMIZATION

Multi-variable optimization algorithms were used to minimize the building consumption with respect to 24 design parameters simultaneously. These parameters ranged from building envelope characteristics to control points on the chilled water plant. Using a two-variable case for demonstration purposes, the use of simultaneous algorithms resulted in 20% less consumption vs optimizing each variable individually. The algorithmic efficiency of the DOE2 engine allowed the team to run up to 60,000 simulations overnight on an ordinary PC.



The net-zero requirement afforded our team the opportunity to modify our optimization problem to minimize the building cost while requiring all simulations to be net-zero. Using market rates for insulation, PVs, and mechanical equipment, our final optimization resulted in a balance between renewables and building side efficiency based on cost. In other words, our final design resulted in the least expensive net-zero building.





RESULTS

The final design for our building achieved 23kbtu/ft^2/year before adding on-site power generation. This consumption was offset with a 135kW roof mounted PV system to bring the net consumption to zero. Without considering cost, our design would have resulted in a lower building-side consumption with less PV, but this would have resulted in a more expensive building with the same performance.