What We've Learned Since 2007 - Efficiency, Load Management and De-Carbonization

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Three-Part Strategy

- Minimize demand through efficiency
- Procure biomethane to mitigate Scope 1 emissions
- Procure renewable energy to mitigate Scope 2 emissions
“Deep” Energy Efficiency

- Goal for efficiency retrofit projects = 50%
- Goal for new construction = outperform T24 by 50%
- How: “Smart” controls
- Why: 1. Efficiency = “First Principle”
  2. How can we afford decarbonized energy?
Key Components of a “Smart” Building

- Demand-controlled HVAC
- Many HVAC zones
- Right-sizing airchanges to minimize reheat, as well as cooling and ventilation energy
- Demand-controlled, high-CRI LED lighting and more efficient plug-loads
Energy Efficiency Impact Much Greater Than Expected

- Smart Labs > 60% energy reduction
- Lighting retrofits > 70% energy reduction
- Non-laboratory energy retrofits ≈ 40%
- Housing target 35% reduction
## Mechanical System Energy Performance Requirements

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Requirement Details</th>
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<tbody>
<tr>
<td>Overall building energy performance</td>
<td>U.S. Green Building Council LEED Platinum</td>
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<tr>
<td>Air-handler face velocity / air-speed through filtration</td>
<td>300 ft. (91.4 m.)/minute maximum</td>
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| Total HVAC pressure drop (supply + filtration + distribution + exhaust) | Labs: < 5 in. W.G. (1,250 pascals)  
Non-lab spaces: < 3.5 in. W.G. (875 pascals) |
| Static pressure setpoint reset (supply and exhaust)             | Reduce static setpoints based on zone voting                                         |
| Supply temperature setpoint reset                               | Raise supply setpoint based on zone voting                                          |
| Air-handler and duct sound-attenuators                          | None                                                                                |
| Minimum occupied lab air-changes per hour                       | 4 air-changes/hour with contaminant sensing (Airucity)                              |
| Minimum unoccupied lab air-changes per hour                     | 2 air-changes/hour with contaminant sensing and reduced thermal conditioning during setback |
| “Purge” laboratory air-changes per hour                         | 10-12 air-changes/hour when contaminants sensed                                    |
| Laboratory exhaust stack discharge velocity                     | Requires wind study; design goal ~1,500 FPM; > 1,500 FPM when necessary during re-entrainment conditions |
| Exhaust stack height (labs)                                    | As determined by wind study, minimum 10 ft.                                         |
| Exhaust bypass damper (outside air into exhaust header)         | Only activated by adverse wind conditions                                           |
| Laboratory illumination power density                           | < 0.5 watt / sq. ft. including bench task lighting                                  |
| Fume hoods                                                      | Occupancy controlled, low-flow/high performance                                     |
| Heat-generating equipment exhaust                               | Exhaust grilles directly over equipment such as freezers, etc.                      |
| Non-laboratory (recirculating) HVAC delivery and outside air    | HVAC delivery occupancy-based ventilation relief air CO₂-controlled                   |
25 Years of Energy Efficiency
25 Years of Energy Efficiency

- Adopted goal: Beat Title 24 by 30% in new construction
- Thermal energy storage
- Campus-funded energy projects
- Management performance improvement tool
- Statewide Energy Partnership launched
- Adopted goal: LEED Gold NC
- American College &
- University Presidents' Climate Commitment
- Statewide Energy Partnership expanded
- Inaugural partner President Obama's Better Buildings Challenge
- Combined heat and power plant
- Prioritized "deep efficiency"

Source + Site Energy (billions of BTUs)


Would have been consumed without measures indicated
Actually consumed (FY2016 projected)
25 Years of Energy Efficiency

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Adopted goal: Beat Title 24 by 30% in new construction
Management performance improvement tool

Source: Site Energy (billions of BTUs)


Legend:
- Blue line: Would have been consumed without measures indicated
- Green line: Actually consumed (FY2016 projected)
Co-Benefits of Deep Energy Efficiency

- Many HVAC deferred maintenance problems fixed/funded through energy savings
- “Information layer” provides real-time commissioning and air quality track-record
- Lighting efficacy improved (especially labs, studio arts, clinical settings, streets)
- Quieter buildings inside and outside
- Cleaner indoor air
- Longer service life for heat-producing and friction-producing building system components
- Avoided capital investments for generation, central plant chillers, and infrastructure
- Deferred maintenance problems fixed/funded through energy savings
- Safer laboratories
- More reliable research infrastructure.
Lessons Learned

- Big goals change the culture, not just results at the margin
- Deep energy efficiency was attainable
- Waste had been designed-into mechanical systems
- Sensors and software enabled a new paradigm
- Some energy retrofits/redesigns yielded highly nonlinear savings
- Co-benefits *much* greater than expected
Do “Smart” Building Controls Provide a Demand-Response Opportunity?

Smart Buildings = Precision Control of Energy

Just enough energy, at just the right place, at just the right time!
40 MWH of Storage
Managing demand as important as reducing

- Time-of-use pricing inevitable (and desirable)
- Efficient buildings provide limited demand-response
- Best form of energy storage may not be a battery!
- Demand management can radically reduce carbon footprint
Exploiting the “Duck Curve” to Reduce Carbon Footprint

Net load - March 31

Ramp need
~13,000 MW
in three hours

Megawatts

2012 (actual)
2013 (actual)
2014
2015
2016
2017
2018
2019
2020

Hour

12am 3am 6am 9am 12pm 3pm 6pm 9pm
More Subtle Lessons Learned

• Attitude is as important as technology
• “Information layer” as important as control system technologies themselves
• Demand-response concept changed radically with “smart” buildings
• Demand management requires an enterprise solution
• Batteries not the best storage solution
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Biogas procurement not as easy as renewable electricity

- Not a mature market
- Natural gas real prices at prolonged low
- Delivery infrastructure costs
Co-benefit: Methane Emissions Reduction
SoCalGas Announces Vision to Be Cleanest Natural Gas Utility in North America

Utility commits to delivering affordable and increasingly renewable energy to customers - Includes replacing 20 percent of traditional natural gas supply with renewable natural gas by 2030

Senate Bill 1383 requires 40 percent methane capture from California's waste streams -- from sewage treatment, and landfills, and agriculture, and dairies

This Could Be a Game-Changer!
UCI Carbon-Capture Symposium

• Bob Mroz, President of Bio-Tek, a Baltimore startup firm
• Jack Brouwer, Professor of Mechanical, Aerospace, and Environmental Engineering and Associate Director of the UC Irvine Advanced Power and Energy Program
• Professor Jenny Yang, UCI Chemistry
• Dr. Sahag Voskian, Chemistry Department, MIT
• Gaurav Sant, Professor of Engineering at UCLA
• Liang-Shih Fan, Distinguished University Professor of Chemical and Biomolecular Engineering, The Ohio State University
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## How Do We Pay for Exemplary Energy Efficiency in New Buildings?

### Cost-Control & Savings Opportunities

- Sensible ratios for floorplates & exterior “skin”
- Cost-effective architectural detailing and articulation strategies
- Consolidate/separate non-laboratory functions into adjoined structure
- Generic, modular approach to laboratory design
- Moderate column-spacing in laboratory structures for cost-effective vibration control
- Avoid unconventional structural, seismic, and foundation systems
- Unconditioned exterior stairways (weather-protected)
- Avoid custom-fabricated, exotic, specialized materials
- Conventional interior finishes
- No floor coverings in laboratories
- Generic acoustical materials
- No sound absorption in partial-height partitions or walls w/doors
- Downsize HVAC due to sun shading
- Essentially eliminate window coverings if electrochromic glass is used
- Eliminate exterior wall insulation, furring, sheetrock, and paint

### Areas Into Which Savings are Redirected

- “Smart Labs” energy design standards
- Small, demand-controlled HVAC zones for comfort as well as efficiency
- LEED Platinum
- Outperform Title 24 by >> 20%
- Stretch goal to outperform Title 24 by 50%
- Robust laboratory core infrastructure systems to support inexpensive future modifications
- Durable materials and system quality to avoid major maintenance expenses
- Long-life/low maintenance exterior finishes
- High-quality teaching spaces
- Stainless steel flashings
- Durable hardware and interior finishes
- Operable office windows (w/HVAC interlocks)
- Quality hardscape and landscape features
- Sound isolation where needed (e.g., offices)
- Weather-protection canopy to extend life of roof-mounted equipment
- Sun-shading 85% overall annual effectiveness
- Exterior walls ≥ 12 in. concrete integral color, exposed both sides
Feasibility Success Factors

1. Adopt a challenging goal and aggressive sub-goals
2. Technology
3. Questioned status-quo design practices
4. Targeted energy waste that was built-into building systems
5. Made intentional, explicit trade-offs to fund life-cycle performance
6. Assumed that de-carbonized energy might cost 2X status quo
UC Irvine Is a Perennial "Cool School"

What’s the secret to the Southern California school’s success?
UCI Sustainability Recognitions & Awards

- *Sierra Magazine*’s top ten “Coolest Schools” ten consecutive years
- *Princeton Review*’s Green Honor Roll six consecutive years
- *CA Governor*’s Environmental & Economic Leadership Award – Climate Change (2008)
- *CA Governor*’s Environmental & Economic Leadership Award – Leadership (2013)
- *EPA* Climate Leadership Award (2014)
- *President Obama*’s Better Buildings Challenge: first to improve efficiency 20% (7 years early)
- *Clean Air Excellence Award* in Transportation Efficiency from the U.S. EPA (2016)
- Best Practice Award for Sustainability in Academics (2016) and New Construction (2017), *California Higher Education Sustainability Conference*
- *APPA*’s Sustainability Award in Facilities Management for sustainability excellence (2012)
- *Second Nature* Climate Leadership Award (2011)
- *Urban Land Institute*’s “Best of the Best” Award for campus wide sustainability (2011)
- *NACUBO* Innovation Award for Energy Efficiency (1996)
- *National Arbor Association* “Tree Campus” designation nine years
Formal Assessment at Financial Cross-roads when Co-generator is Amortized

- Progress toward gas de-carbonization
- Feasibility of procuring more biogas
- Feasibility of on-site carbon capture
- Electrification of carbon-emitting plant equipment
- Hydrogen co-generation
- Emergent technologies