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Improving Energy Performance through Whole Building Simulation at Sandia National Laboratories New Mexico

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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company,
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Project Participants

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John Garcia	Sandia National Labs
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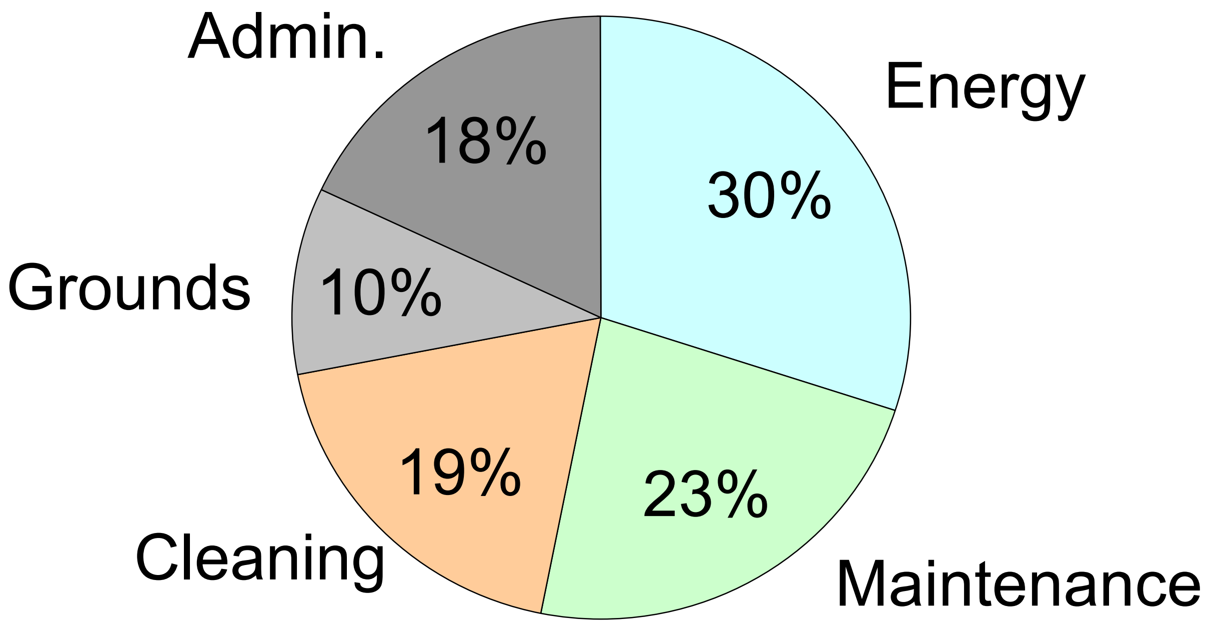
Life-Cycle FACILITY Costs



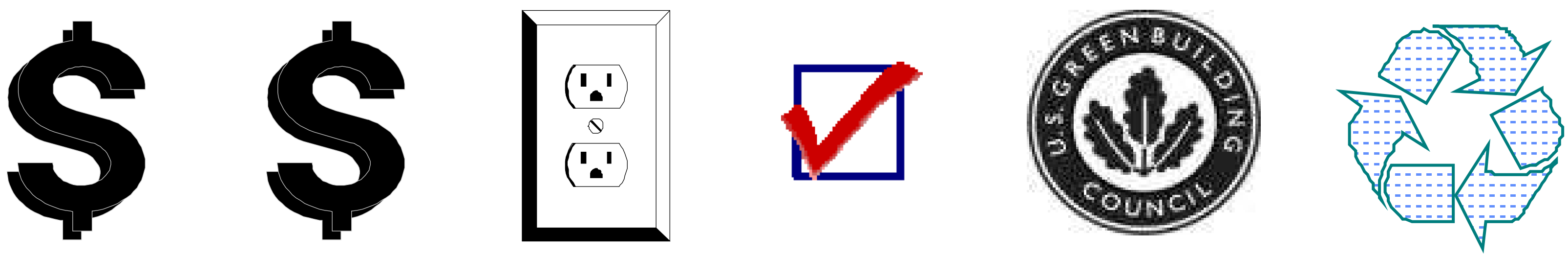
Source: BOMA 2000

"Globally Optimum" Building Design

Construction Costs

Energy Use

Above Code Performance



Operating Costs

Code Compliance

Environmental Impacts

project performance = f(informed decisions)

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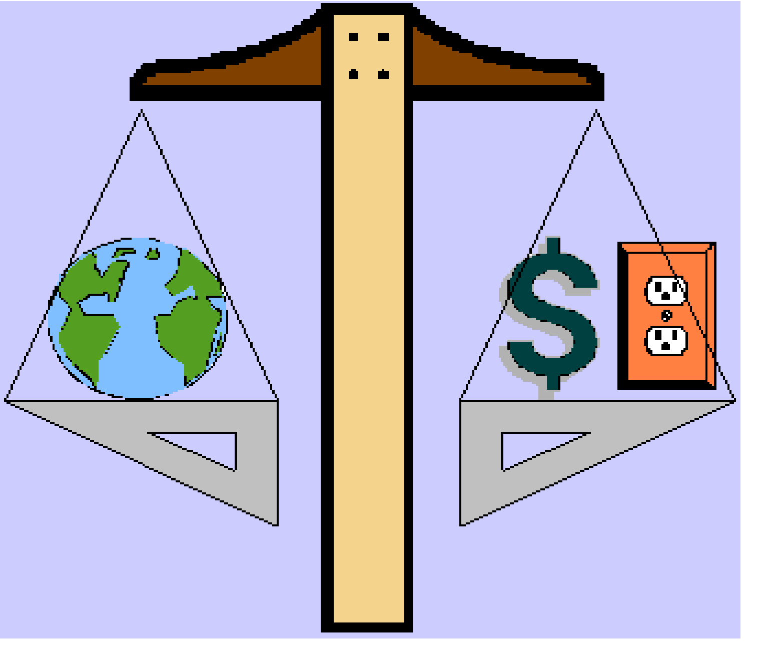
"Globally Optimum" Building Design

Increasingly, designers and facility operators must weigh the "costs" from a global perspective



Whole Building Energy Simulation

- Building are “systems of systems”
- Whole Building design seeks synergy between building systems and between design team members
- Today’s tools allow designers to ‘test drive’ their ideas
- Better tools make the process affordable for most buildings

•However… Many design firms are unfamiliar with or resistant to using the tools.

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Background

- SNL/NM is constructing GPP (< $5 million) Office Buildings. ~ 18,000 SF for 90+ occupants.
- They are all constructed using the same design-build specification (which requires an SD report and encourages energy efficient design).
- All are fast-track design-build projects executed by our pre-qualified contractor pool.
- No matter what we ask for, we get a rooftop DX HVAC unit with gas heating

Project Scope

1. Construct the Model of a representative office building at SNL/NM using eQUEST/DOE2.
2. Calibrate the Model to actual building operating conditions.
3. Evaluate the building for comparison with ASHRAE 90.1.
4. Evaluate Energy Conservation Opportunities (ECO).
5. Train the Workforce.

1.Model Construction

Modeling Information Request

ARCHITECTURAL
- floor plans (space layout/areas, surface orientations)
- elevations (surface areas, esp., windows, doors)
- window/door schedules (windows, door dimensions)
- building/wall/roof sections (envelope materials composition)
- site plans (adjacent structures and landscape)
- roof plans (skylights and overhangs)
- gross area & net conditioned area

ENVELOPE MATERIALS (from project specs, if available, else from design team)
- glazing shading coefficient, u-value, frame type, interior shading
- u-values: wall, roof, ceiling, skylight, slab & spandral

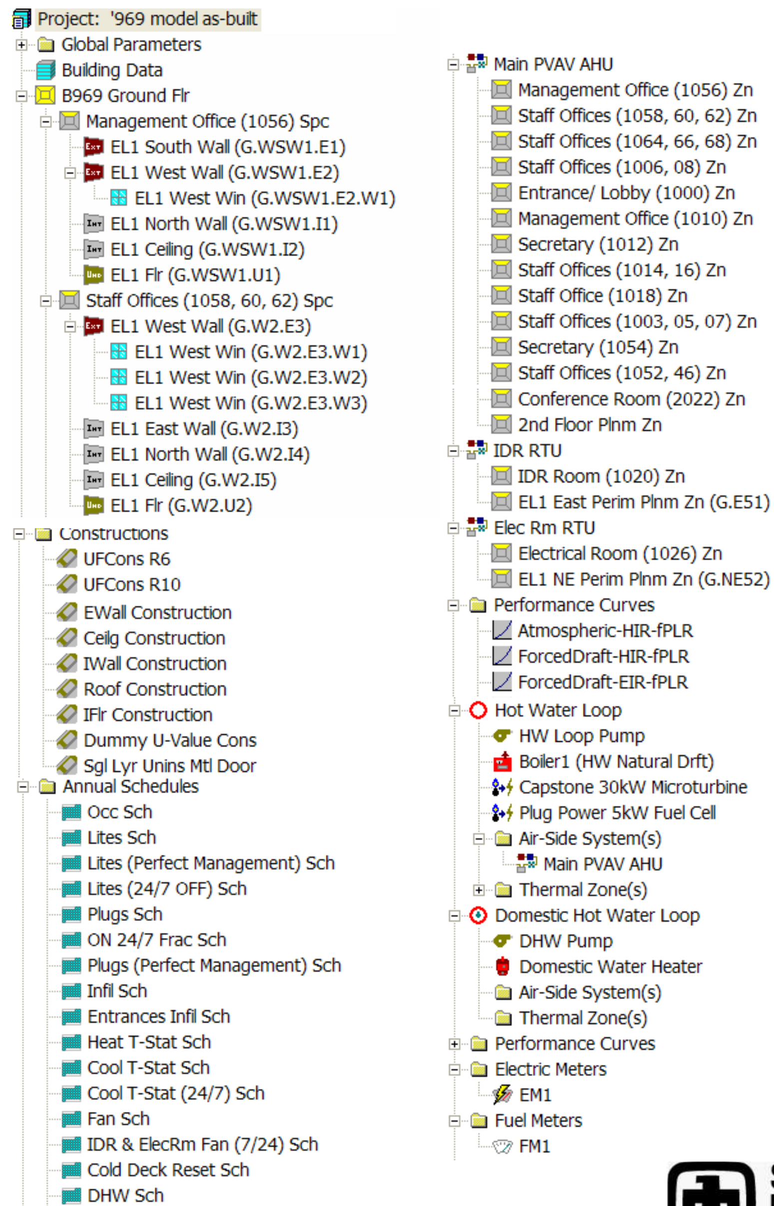
MECHANICAL
- HVAC plans (HVAC zoning layout)
- equipment schedule (equipment design data)
- approx. equipment sizes, design conditions, & efficiencies
- anticipated or existing control sequences

ELECTRICAL / INTERNAL LOADS
- lighting plans
- lighting power density (by HVAC zone, from lighting plans if available)
- design illuminance (by HVAC zone, from design team)
- peak occupancy (by HVAC zone, from design team or owner)
- peak equipment/process (by HVAC zone, from design team or owner)

OPERATIONS (from design team or owner)
- per HVAC zone
  - occupancy, lights, equipment, & process schedules
  - thermostat settings and schedules
  - exhaust fan static pressure, efficiency, operations schedule, & control sequences
- per air handler
  - anticipated coil leaving air temperatures
  - minimum outside air
  - supply fans static pressure, efficiency, operations schedule, & control sequences
  - return fans static pressure, efficiency, operations schedule, & control sequences
- central plant (if applicable)
  - chilled & hot water temperatures
  - equipment control sequences

ECONOMIC
- base case first costs (for equipment & systems affected by ECM's)
- ECM first costs
- applicable & optional utility rates, existing utility bills, if available

POTENTIAL ECM's
- envelope
- lighting
- mechanical



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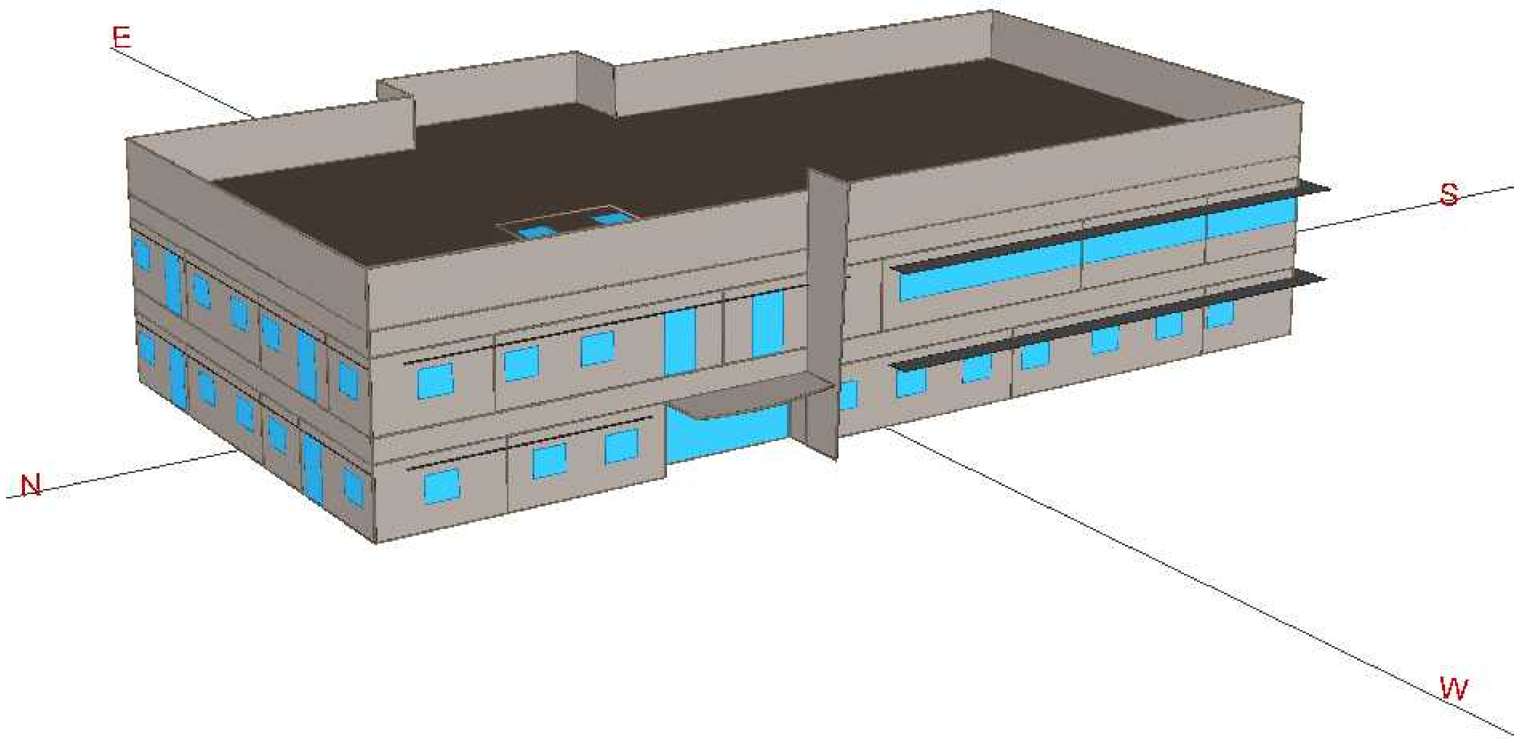
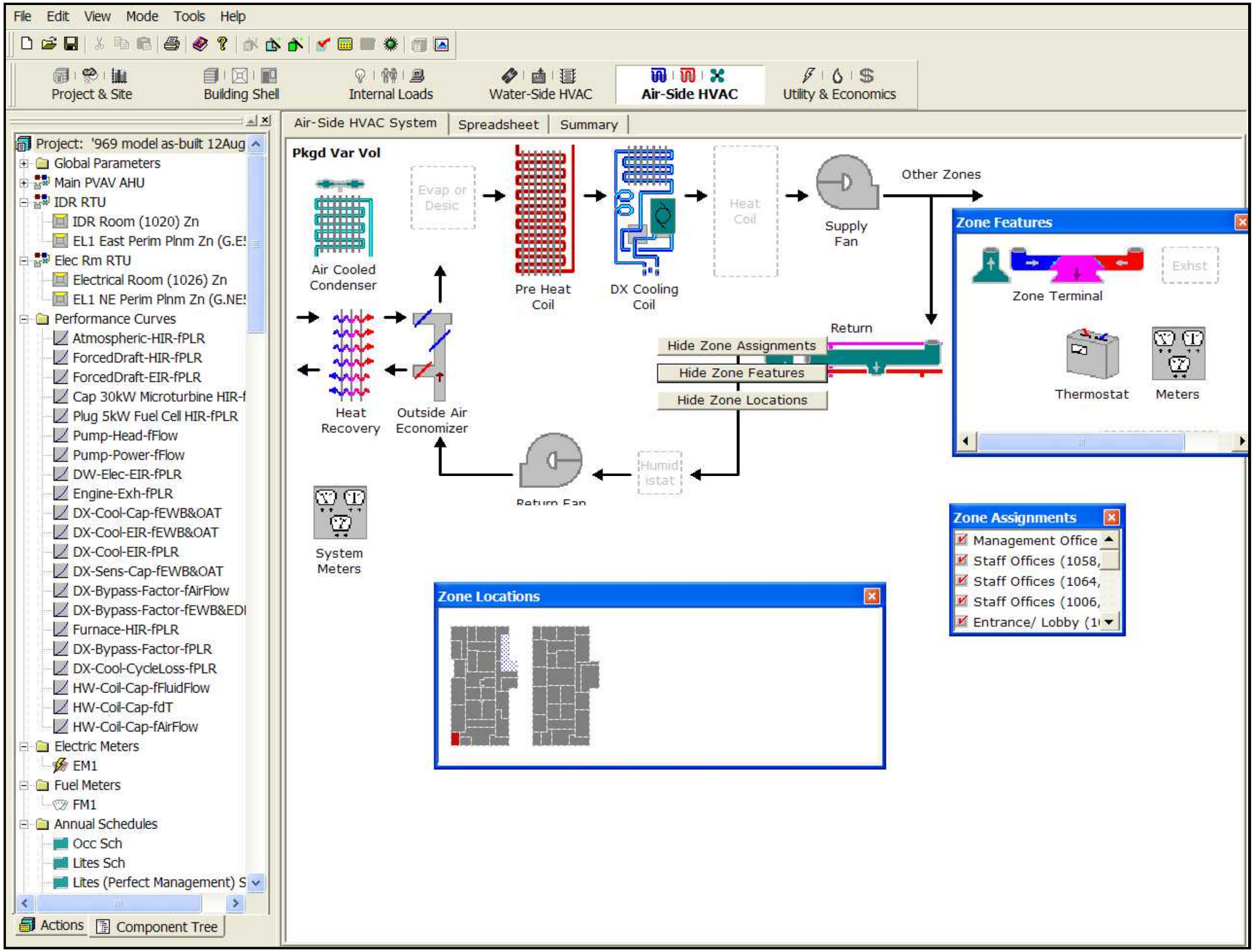
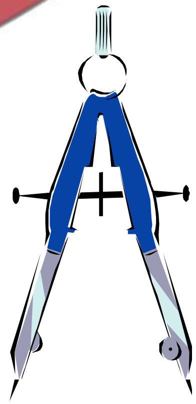
3-D Building Schematic



HVAC Zoning

eQUEST Component tree and HVAC layout





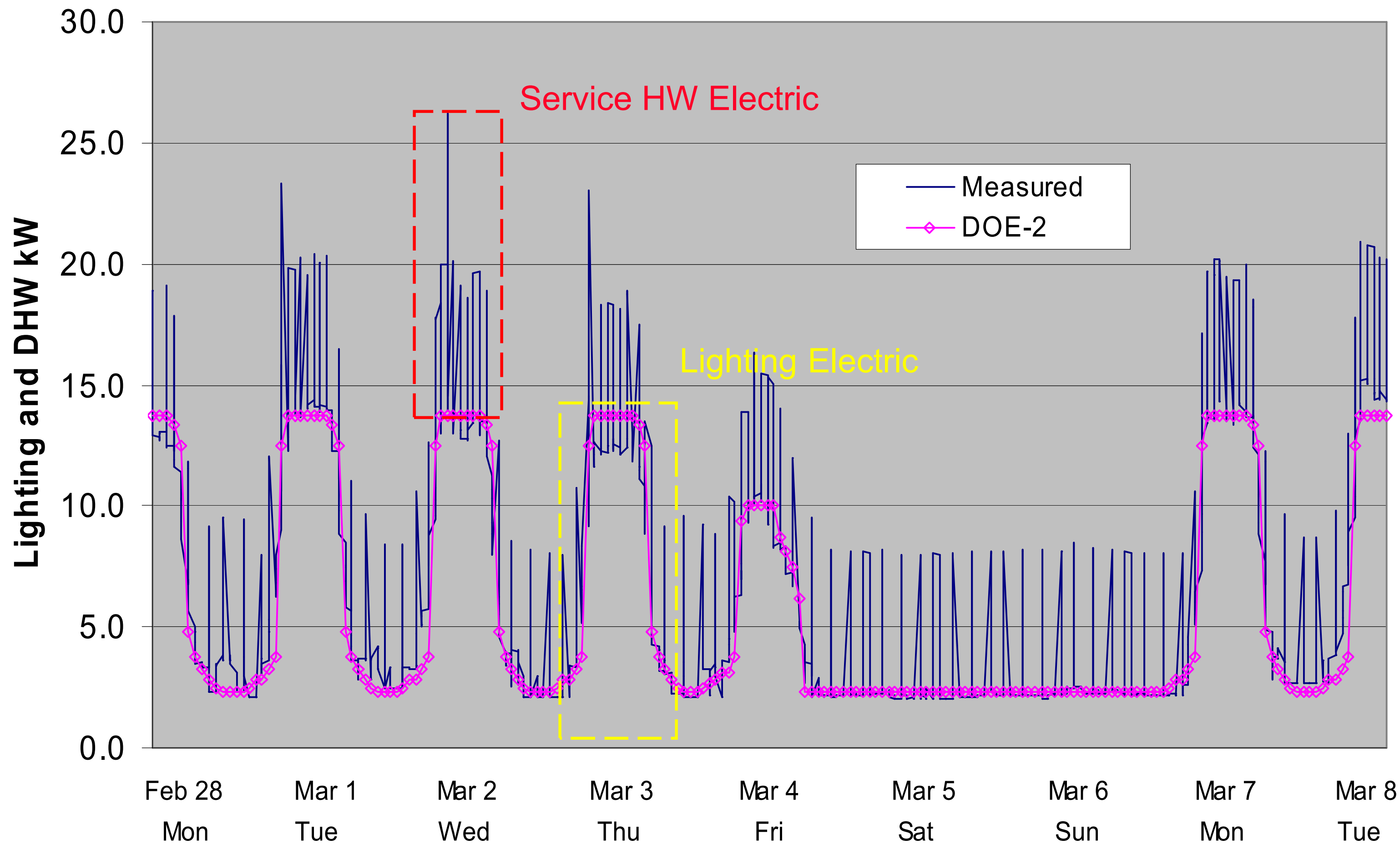
Calibrating the Model

- Necessary to insure that the simulation model accurately represents the actual building operations
- Confirm key model inputs by first measuring selected building and operational characteristics
  - Don't blindly turn simulation 'knobs'
- Then update the model & compare predicted results with actual building energy use
  - Compare results at the end use level and by month to avoid fortuitous cancellation of errors

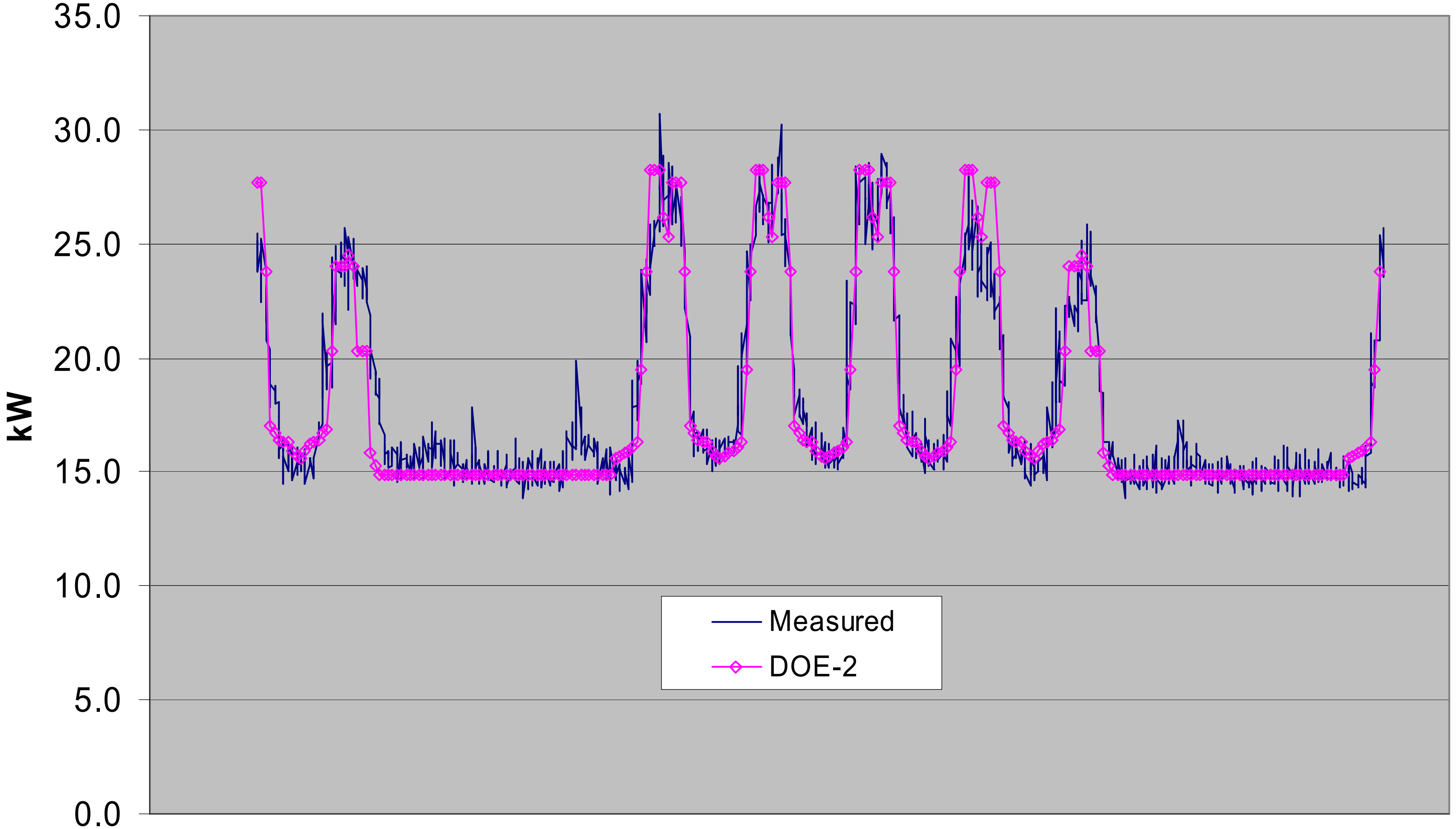
Data Collection

- **Facilities Control System (FCS) Trending.** The FCS was used to monitor HVAC operating temperatures & times and electrical use.
- **Dranetz Spot Metering**. Dranetz meters were installed for short time intervals (one to two weeks) at electric panels to isolate lighting loads, plug loads and the domestic hot water load.
- **Whole Building Electrical Data**. SNL/NM uses ‘Square D’ meters to continuously collect whole building electric data hourly and every 15 minutes.
- **Hobos**. Handheld devices to gather temperature, on/off and solar irradiance data.

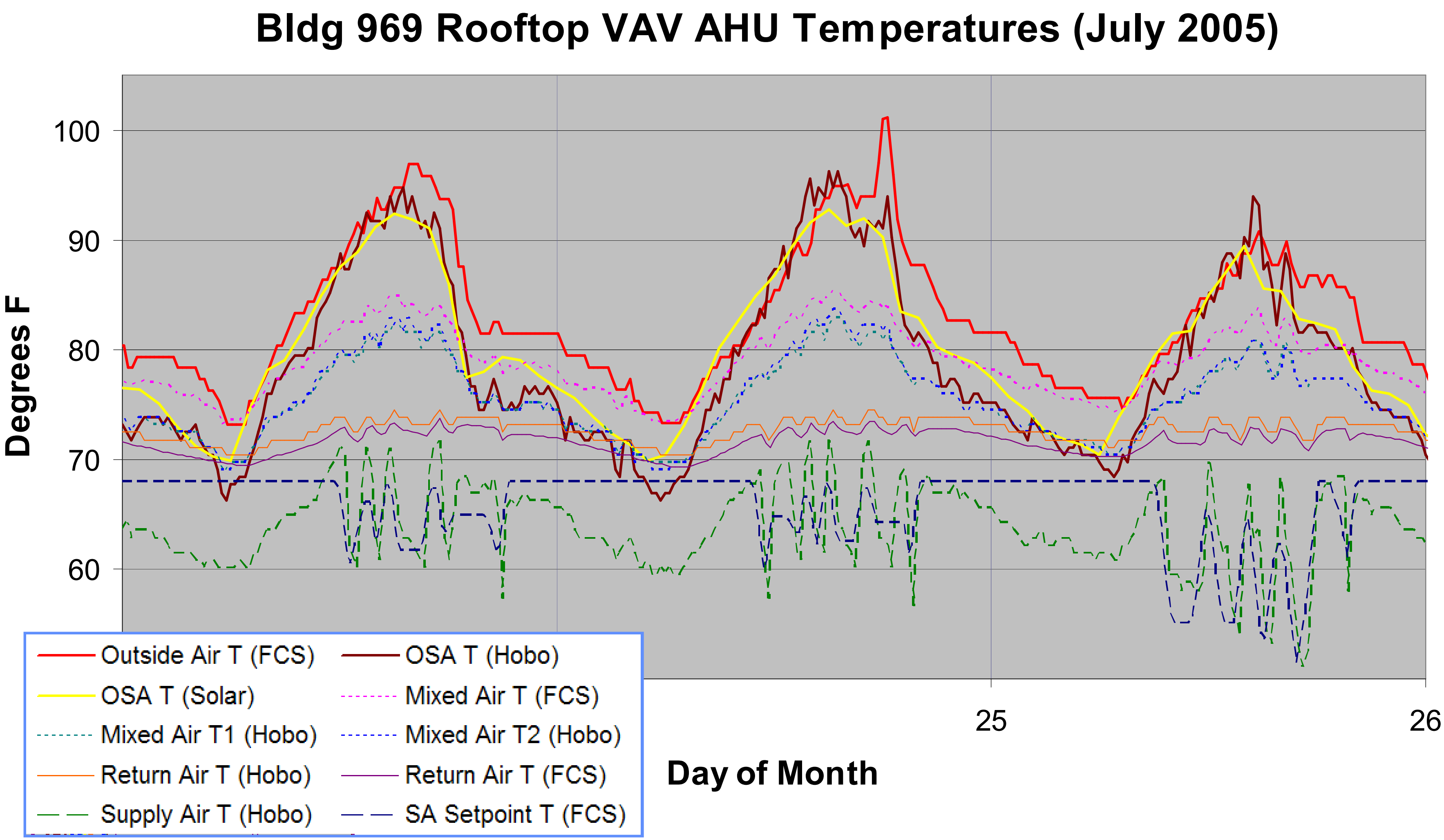
Lighting and Service HW Energy



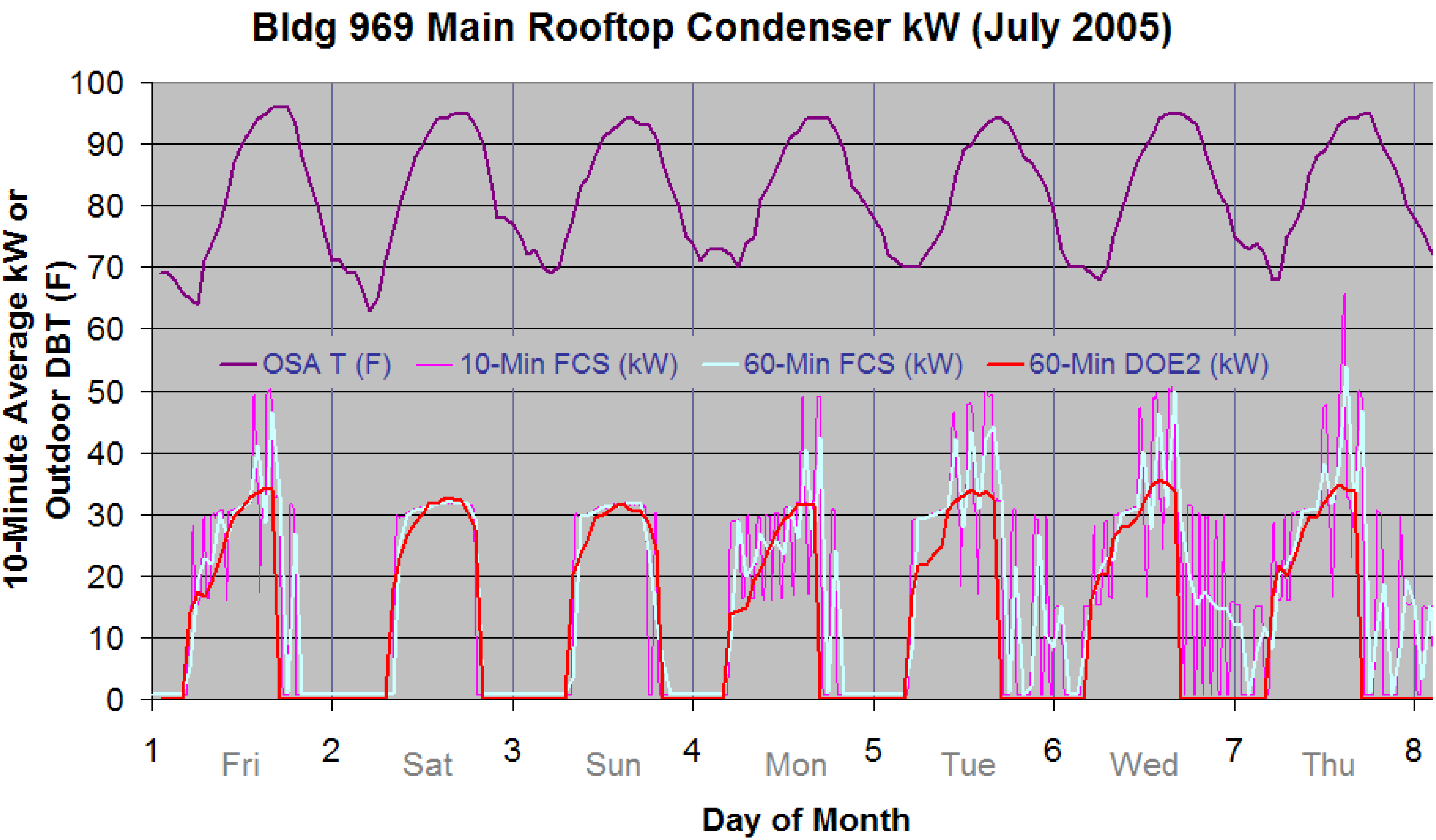
Office Equipment (Plug Load) Energy



Air Handler Temperatures



Compressor Electric



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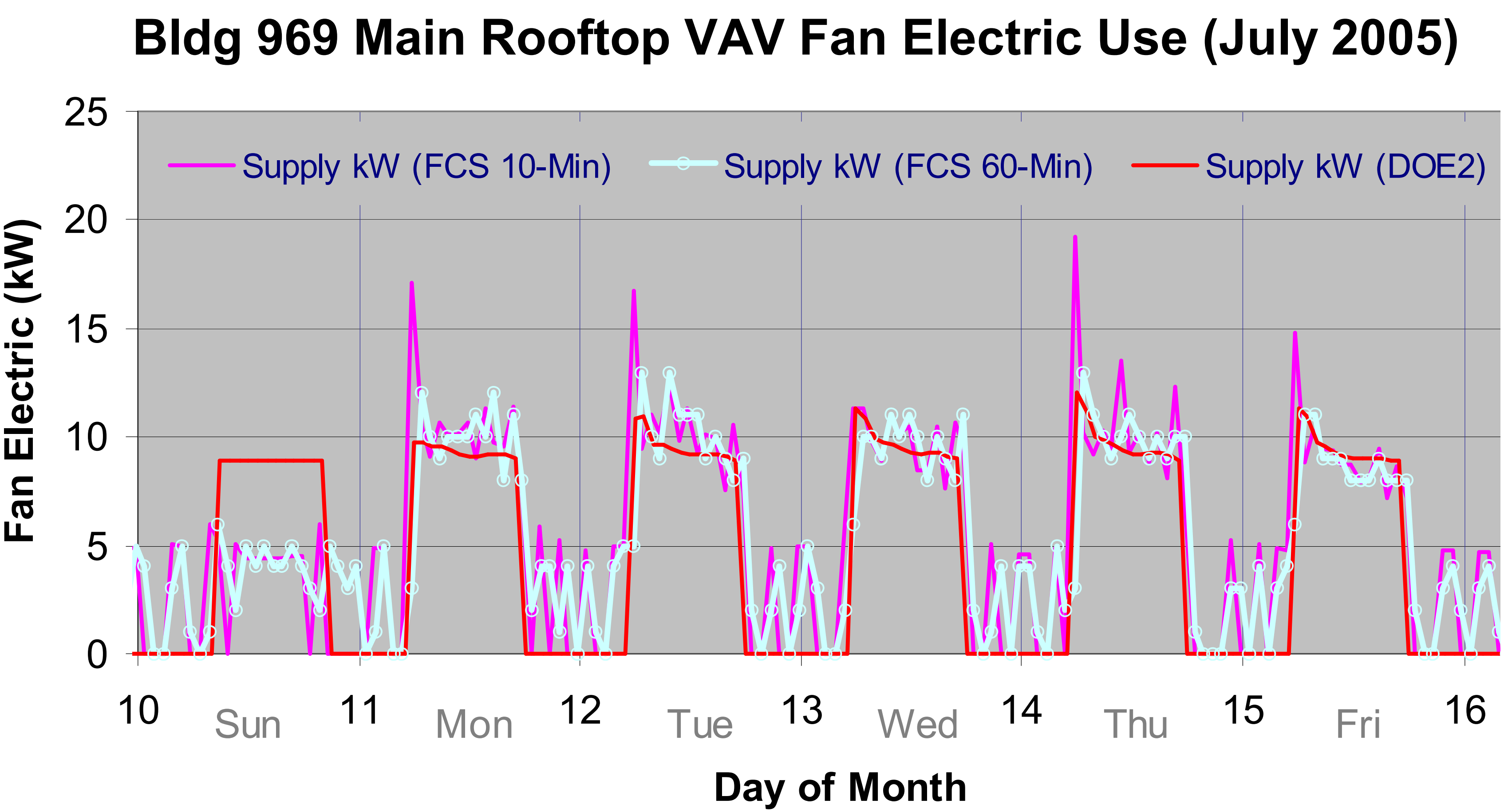
VAV Supply Fan Electric



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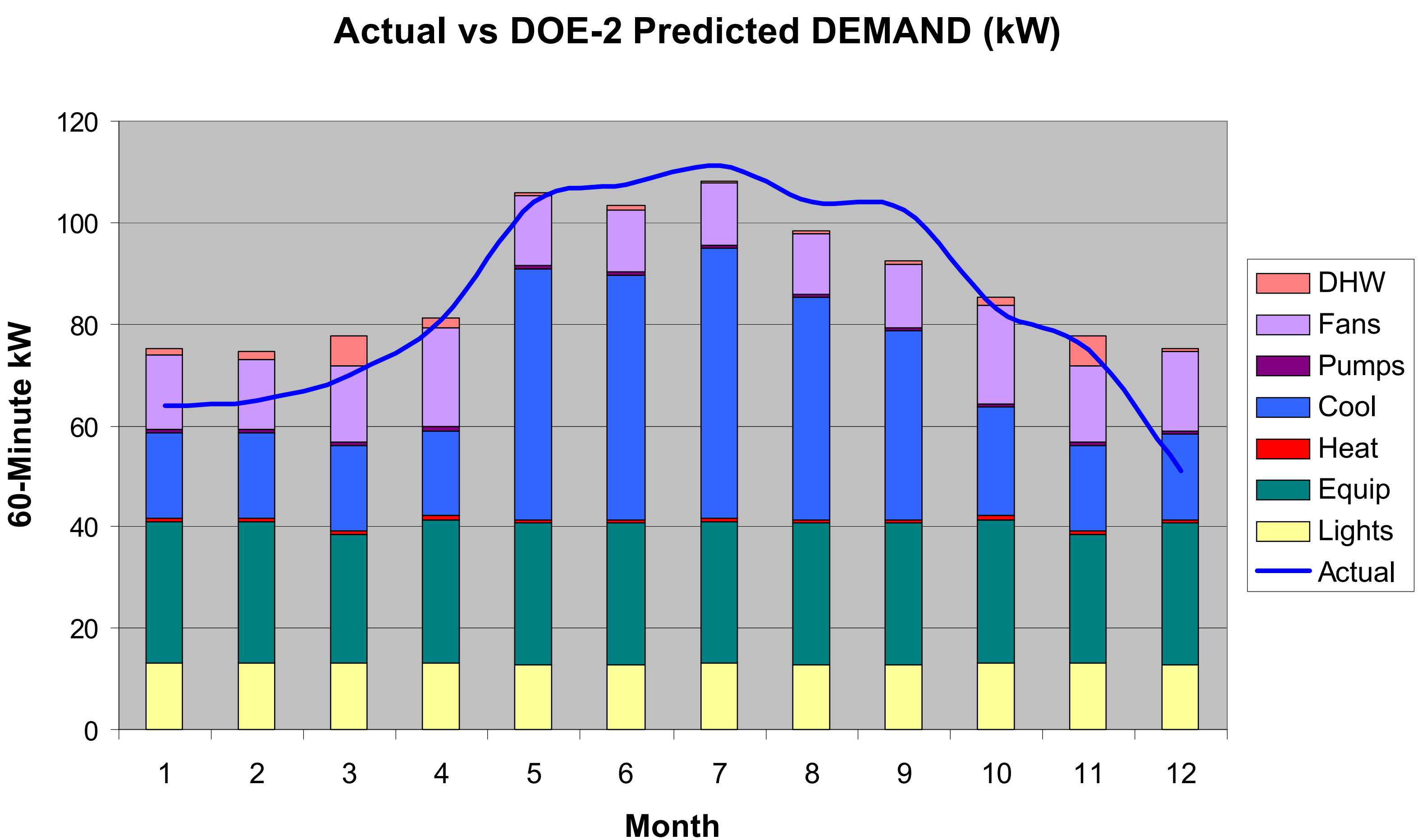
Calibration Results
Monthly Electric Peak Demand (kW)



Monthly: - 5% / + 12%

Annual: + 7%

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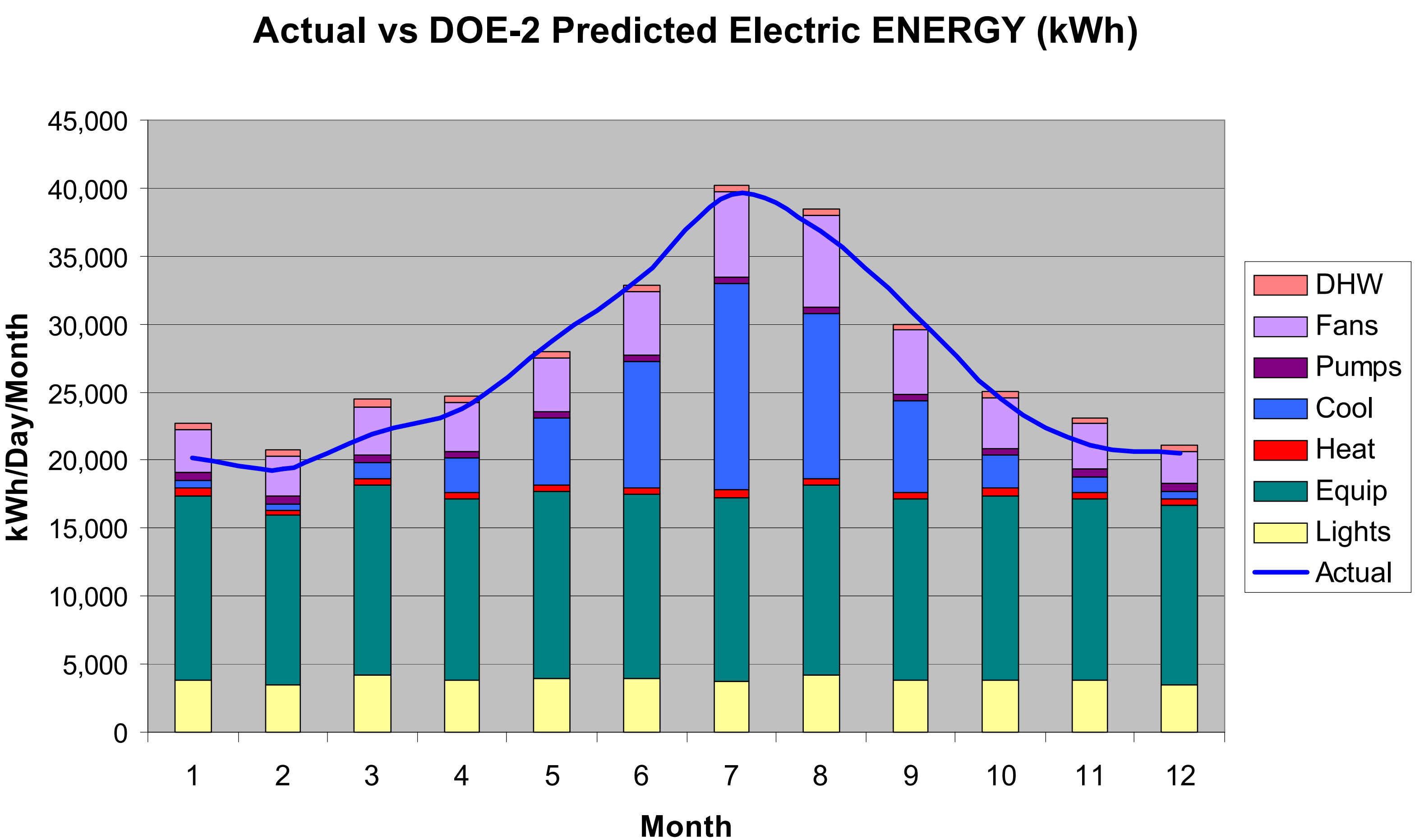
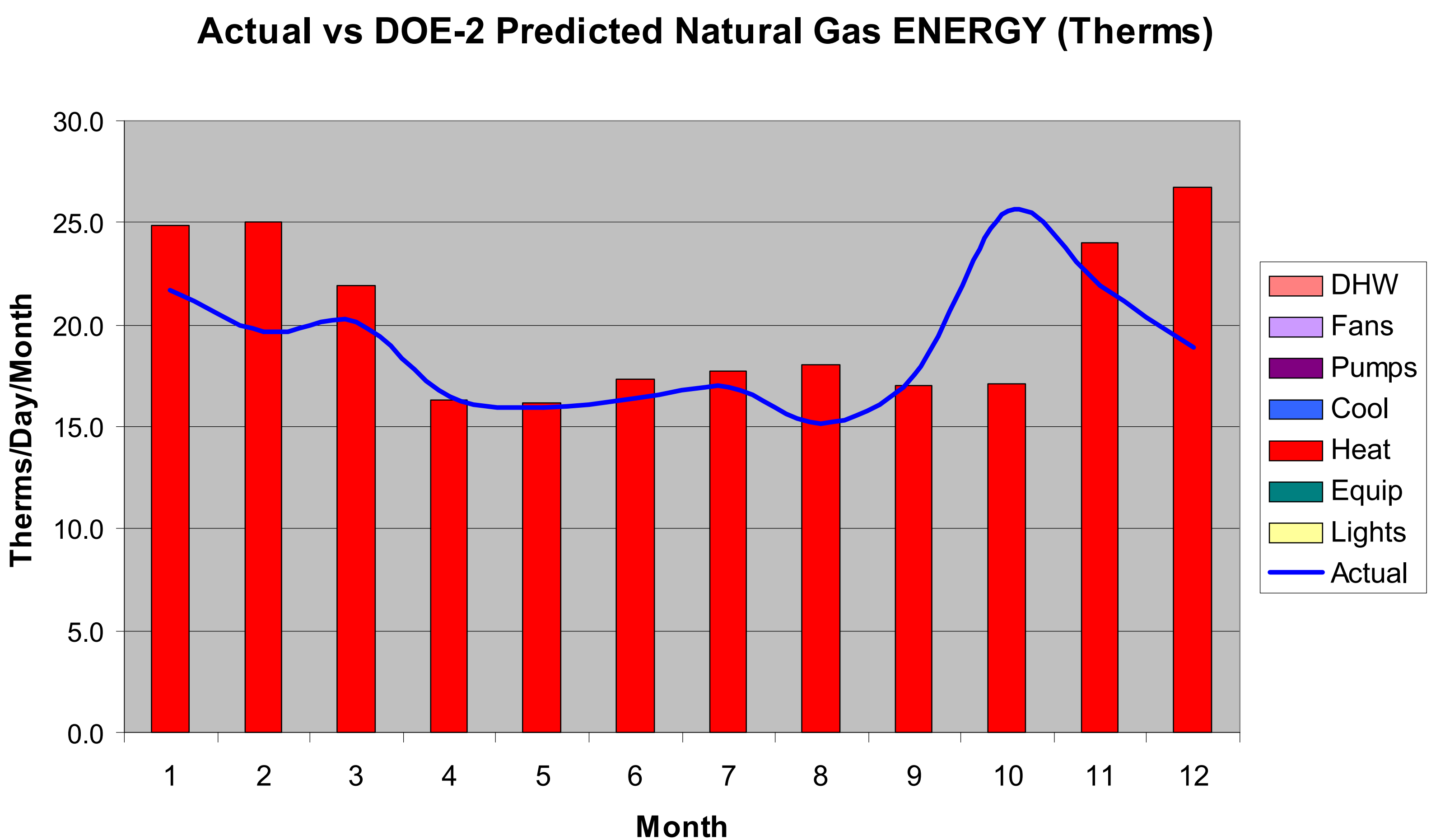
Calibrated Results
Monthly Electric Energy (kWh)



Monthly: - 3% / + 6% **Annual: + 4%**

Calibrated Results
Monthly Natural Gas (Therms/Month)



Monthly: - 12% / + 15% **Annual: + 8%**

ASHRAE COMPLIANCE

APPROACH

- Based on ASHRAE 90.1-1999
- Chapter 11 Energy Cost Budget Method
- Consistent with LEED-NC

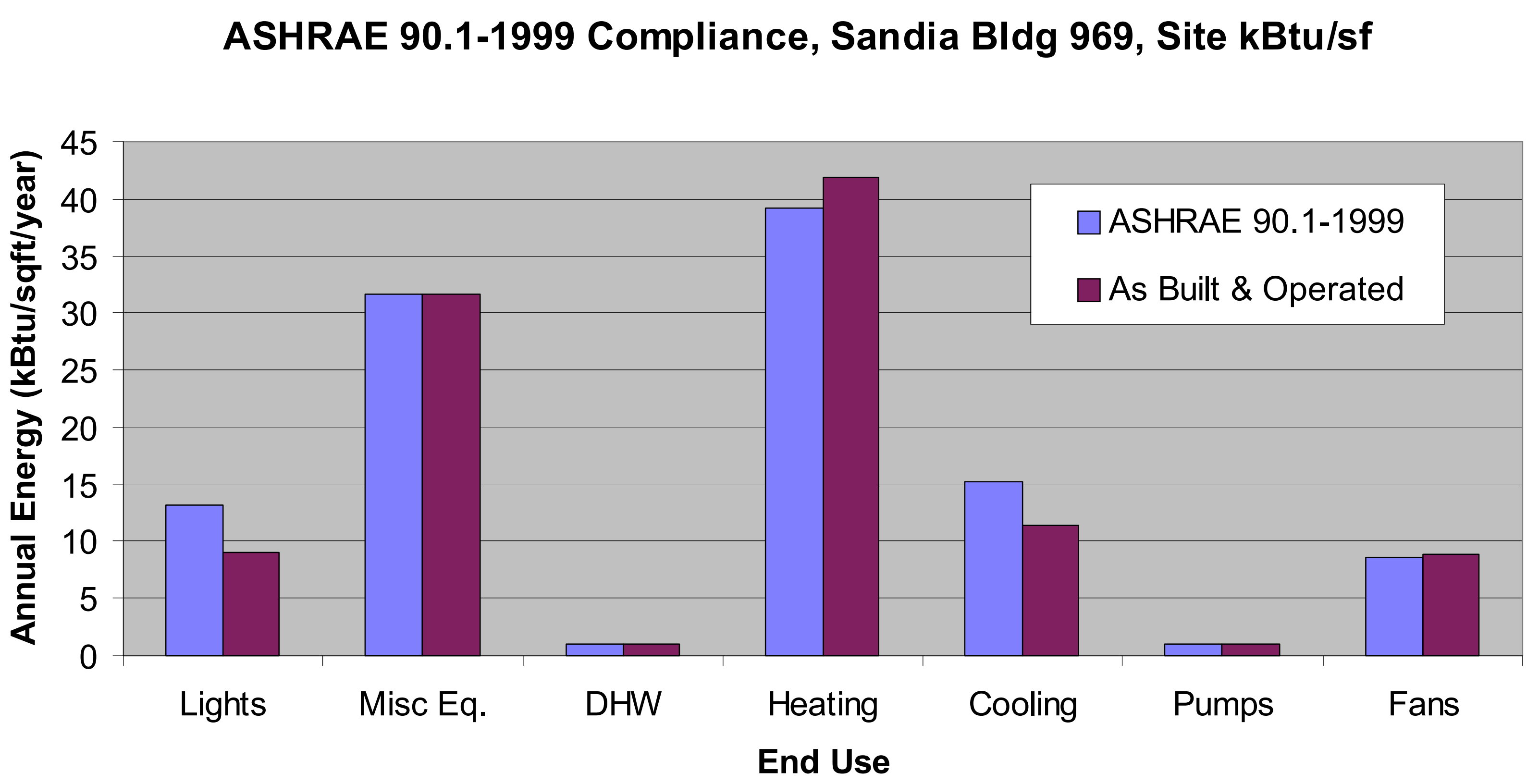
RESULTS

- 10% Better than ASHRAE (all loads)
- 12.5% Better than ASHRAE (regulated loads only)

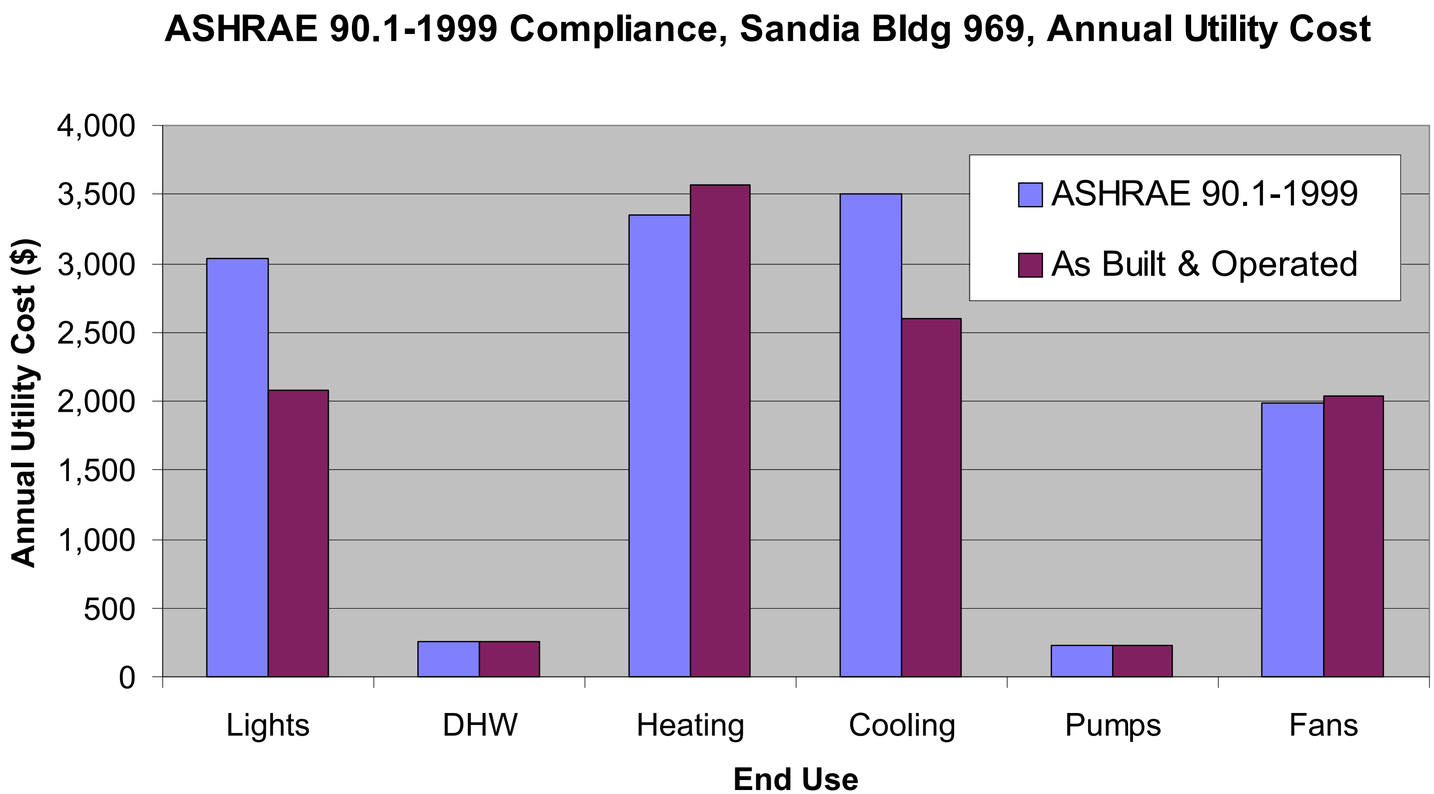
ASHRAE COMPLIANCE

ARCHITECTURE	ASHRAE 90.1-1999	Bldg 969 As Constructed
Exterior Wall Type	2x6 Mtl Frm R-13 (U_{avg}=0.124)	*EIFS: R-25 (U_{avg}=0.061)
Roof U-value (R-value)	0.063 (15)	0.033 (30-nominal)
Roof Albedo	0.3	0.65/0.5 (3-yr aged)
Slab-on-Grade	uninsulated	2ft R5 inside stem wall
Window Type	single-pane, light tint	Double low-e tinted
Window Frame Type	thermally broken alum	thermally un-broken alum
Window U-Value	.57 (incl. frame effects)	0.34, ctr glass (0.55 w bad frm)
Shading Coefficient	north: SHGC=0.49 (SC=0.62) other: SHGC=0.39 (SC = 45)	SHGC=0.38 (SC=0.44)
Window Area	< 50% WWR	11% WWR
HVAC SYSTEM		
HVAC System Type	Package VAV w HW reheat	Package VAV w HW reheat
Ventilation Air	15 CFM/person (10%)	46 CFM/person (31%)
Fan Static, Supply	3.0 in WG	3.0 in WG
Economizer	Temperature (dry-bulb)	Temperature (dry-bulb)
Cooling Efficiency (EER)	10.1	10.5
Heating Efficiency	75%	81%
Motor Efficiency	high efficiency	high efficiency

ASHRAE ENERGYCOMPARISON (all loads)



ASHRAE UTILITY COST COMPARISON (only regulated loads)



As-Built Exceeds ASHRAE 90.1-1999 by 12.5%
(Per LEED – ECB)

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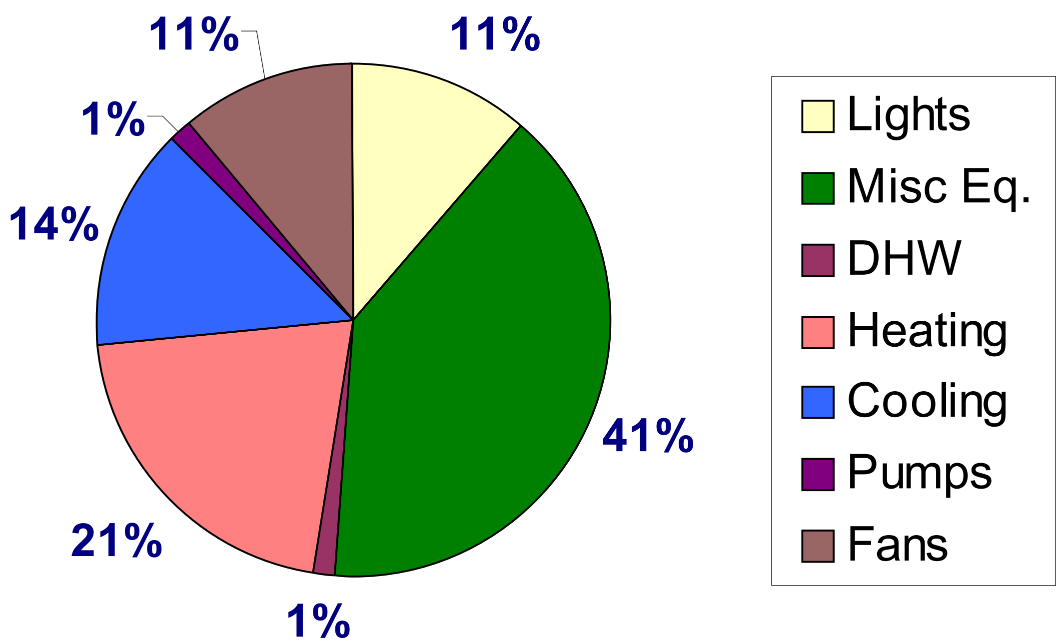
Energy Conservation Opportunities

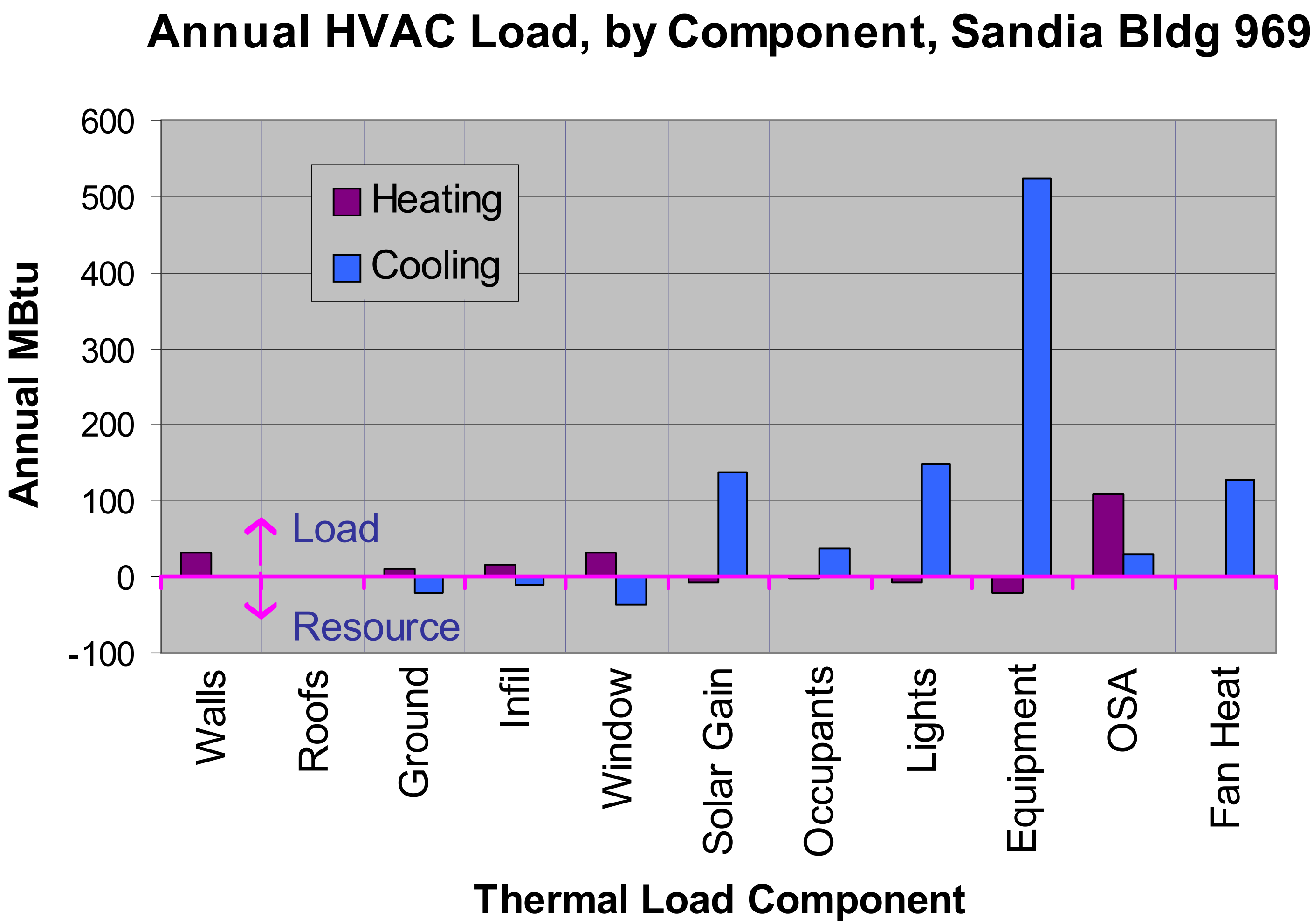
- A variety of ECOs were examined in an attempt to identify attractive design alternatives
- What end uses are using the most energy?
- What are the HVAC loads 'made of'?
- Look for specification oriented ECOs
- Include Distributed Energy Resources (DER)

Energy Conservation Opportunities

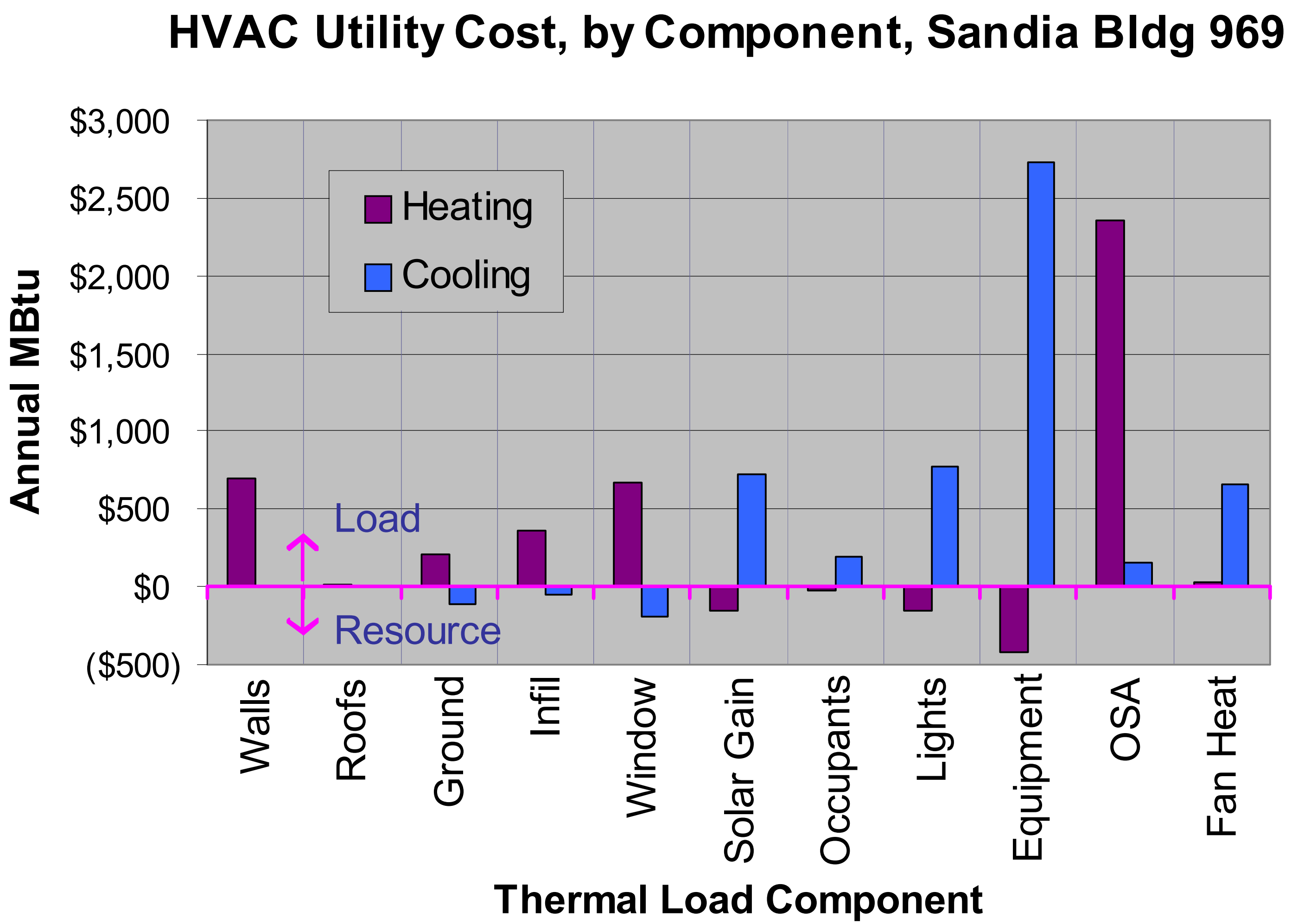
Annual Utility Cost by End Use, Sandia Bldg. 969



Energy Conservation Opportunities



Energy Conservation Opportunities

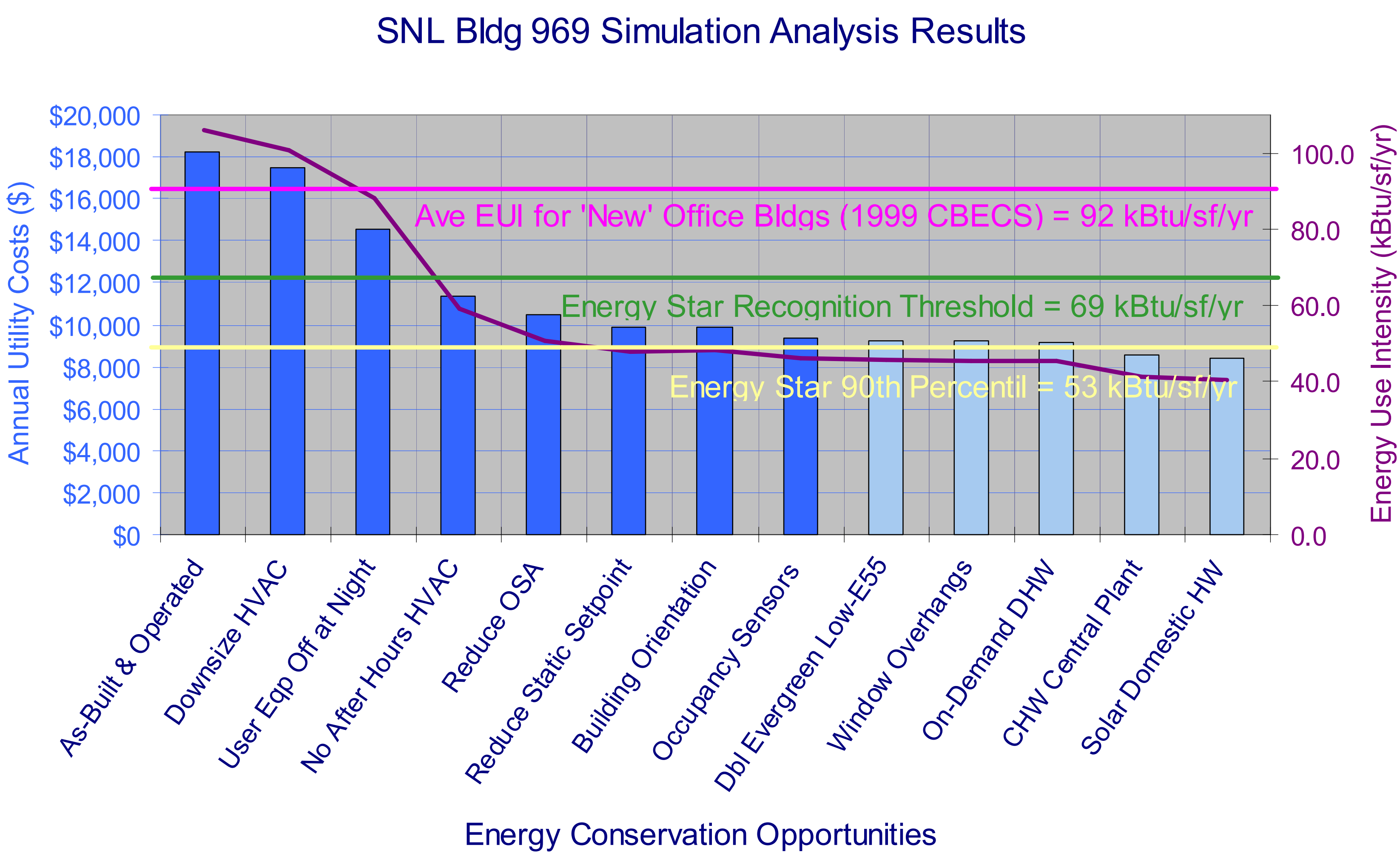


ECO	Recommend	Savings
Downsizing HVAC to provide 15% safety factor	Yes. Work with SNL Engineers	\$800/yr (4%)
Voluntary nighttime shutdown of personal office equipment	Yes. Further investigation	\$3000/yr (16%)
Eliminate after hours HVAC (HW pump on timer, reduce alarm events, reduce 24/7)	Yes. Work with SNL Engineers	\$3200/yr (17%)
Reduce outside ventilation air (from 30+% to ~10%)	Yes. Work with SNL Engineers	\$900/yr (5%)
Reduce VAV fan static pressure setpoint	Yes. Work with SNL Engineers	\$600/yr (3%)
Evaluate optimal orientation for each building	Yes. Further investigation	varies

ECO	Recommend	Savings
Occupancy Sensors	More work on daylight sensors	$1700
Glass Types	Double low-e Evergreen with thermal breaks	$400
Window Overhangs	The deeper the better	$700
Stem Wall (vertical ext. & int.) & Under Slab Insulation (int. horizontal)	Vertical interior (R-5) only	Negative LC Savings
Microturbine	Follow-up the CHP options	Negative LC Savings
Fuel Cell	Initial costs are too high	Negative LC Savings

ECO	Recommend	Savings
Connection to existing chilled water plant	Complete a detailed cost estimate	$7000
Solar Hot Water	Also evaluate SHW for use with boilers. Select best combination	$800
Tankless, point-of use water heaters		$500

Energy Conservation Opportunities



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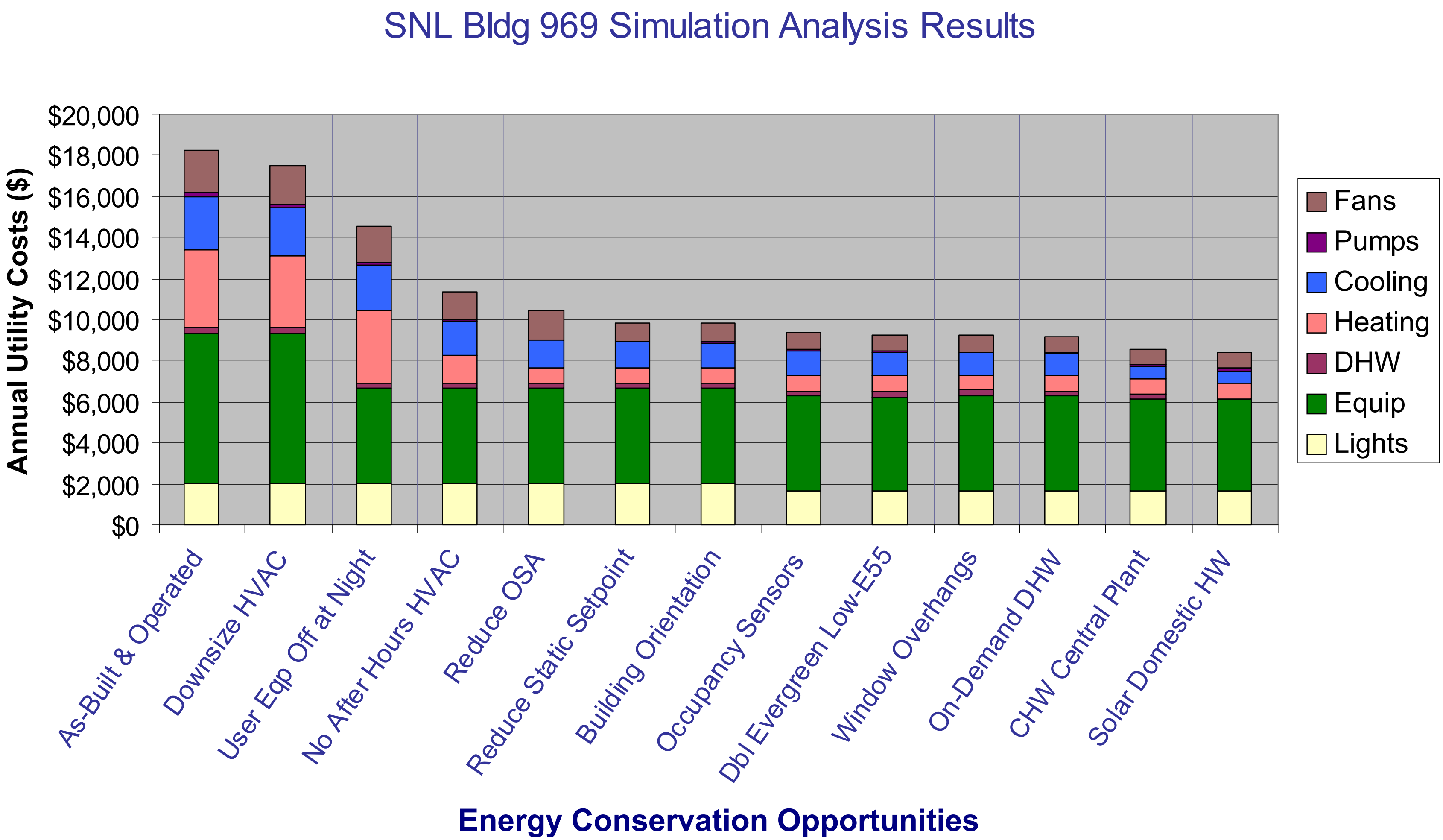
Energy Conservation Opportunities



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Training

- A three hour workshop on Energy Simulation Basics presented to 35 architects and engineers.
- A session with SNL/NM Distributed Energy personnel presenting the energy modeling basics
- Continuous hands-on training for three SNL/NM personnel
- On-hands workshop for system engineers, architects and project managers (SNL and providers)

Conclusions/Benefits

- Importance of Commissioning and continuous commissioning
- Improve whole-building data collection
  - Support 60 minute data
  - Continuous or spot metering capability for sub-metering
- Staff members are better trained on use of eQUEST
- More informed “radical fringe”.
- Better conversations with A/E service providers
- Better understanding of how our GPP Office buildings operate (OA, VAV Fan Control, Service HW, Metering, O&M ECOs)
- Revise Window spec

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Next Steps

- Publish document as a SAND document
- Continue with evaluation. Other ECOs include:
  - Wall types
  - Photovoltaics
  - Ground source heat pump
- Compare commissioned versus non-commissioned buildings
- Conduct detailed daylighting studies