Campus Energy Benchmarking

with Applications to Infrastructure Planning and Building Design

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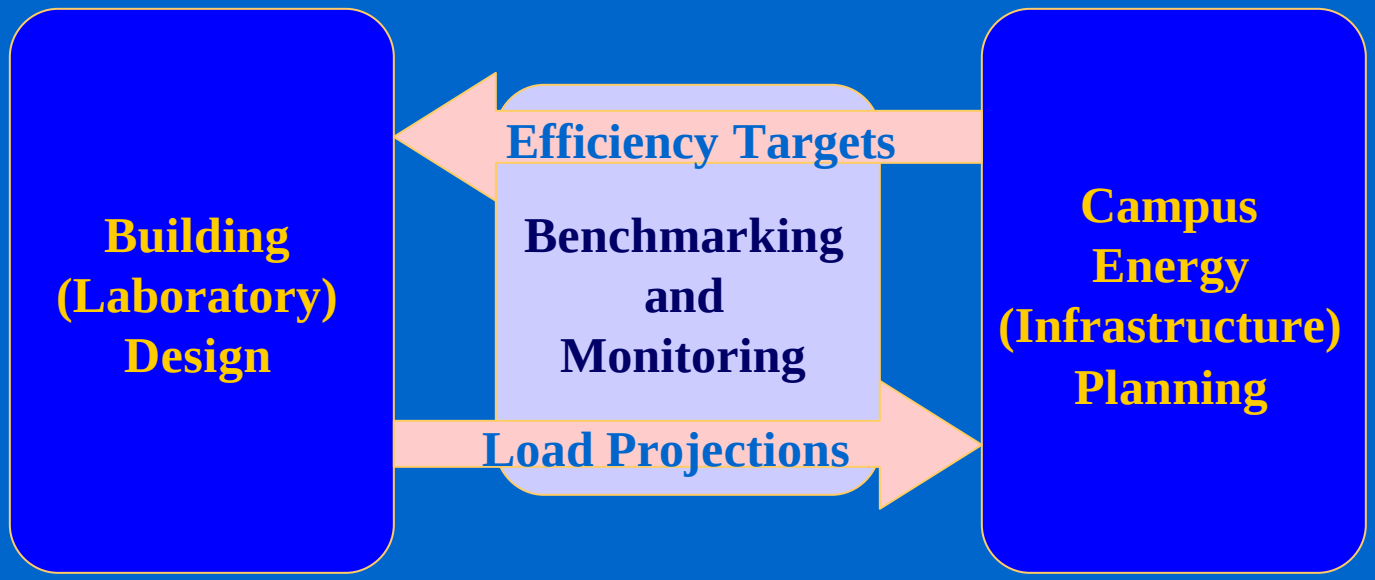
Closing the Loop



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Infrastructure Planning

Load Projection Applications

- Plant Configuration
  - Centralization?
  - Steam or Hot Water?
- Plant Sizing
- Load Management Strategy
- Cogeneration Potential
- Grid Connections

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Infrastructure Planning

Potential Load Projection Methods for a New Campus

- Explicit calculation
  - Requires completed design
- Engineering estimate
  - Systematic over-estimation from multiple “margins of safety”
- **Benchmarking of existing campuses**

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Benchmarking for Facilities with Laboratories

- Intuitive
  - Laboratory (and cleanroom) space is more energy intensive than classrooms and offices
- Hypotheses
  - The relationship between laboratory space and campus energy intensity can be quantified
  - A parameter for laboratory density will improve benchmark-derived models for energy use indices
- Challenges
  - Mapping energy use onto space
  - Differentiating laboratory space

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Method Summary

- Inspired by Paul Black's 1996 study of energy/water use by UC campuses
- Identify 5-8 benchmark UC and CSU campuses
  - with good whole campus data available
- Adjust to standard benchmark case
  - All cooling loads served by electricity
  - No thermal energy storage
  - No cogen
- Correlate with laboratory space and climate
  - "Complex" space category from UC Facilities Renewal Resource Model as proxy
- Develop predictive model based on regression analysis of benchmarks

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Benchmark Model

- **General Form**

  Energy (per sq. ft.) = a + b (% lab) + c (climate variable)

- **Example: Maximum Electric Demand**

  Watts/gsf = 0.85 Watts/gsf +
  4.0 Watts/gsf (% Lab) +
  0.067 Watts/gsf/degF (CD65)

  CD65 = Cooling Design Temp - 65 degF

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Campus Energy Benchmarking

Model Matrix: California Campus Electric Demand

	Cooling Design Temperature (0.4% or 35 hours per year)		
Fraction of Lab-Type Buildings on Campus (Fresno)	65 deg F (Base)	102 deg F (Merced)	104 deg F
0% Lab Bldgs	0.9 Watts/gsf	3.3 Watts/gsf	3.5 Watts/gsf
35% Lab Bldgs	2.3 Watts/gsf	4.7 Watts/gsf	4.9 Watts/gsf
100% Lab Bldgs Watts/gsf	4.9 Watts/gsf	7.3 Wats/gsf	7.5

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Benchmarks as a Reality Check

	"Ungrounded" estimates for baseline energy intensity Benchmarks of new laboratory design: both based on Title-24/DOE-2 (same building)		Measured	
	Estimate A	Estimate B	Average UC lab buildings in similar climate (90% diversity)	Campus average
Watts/gsf	11	7.8	6.9	3.2
kWh/yr-gsf	67	23	37	17
Th/yr-gsf	4.4	0.5	1.8	0.65

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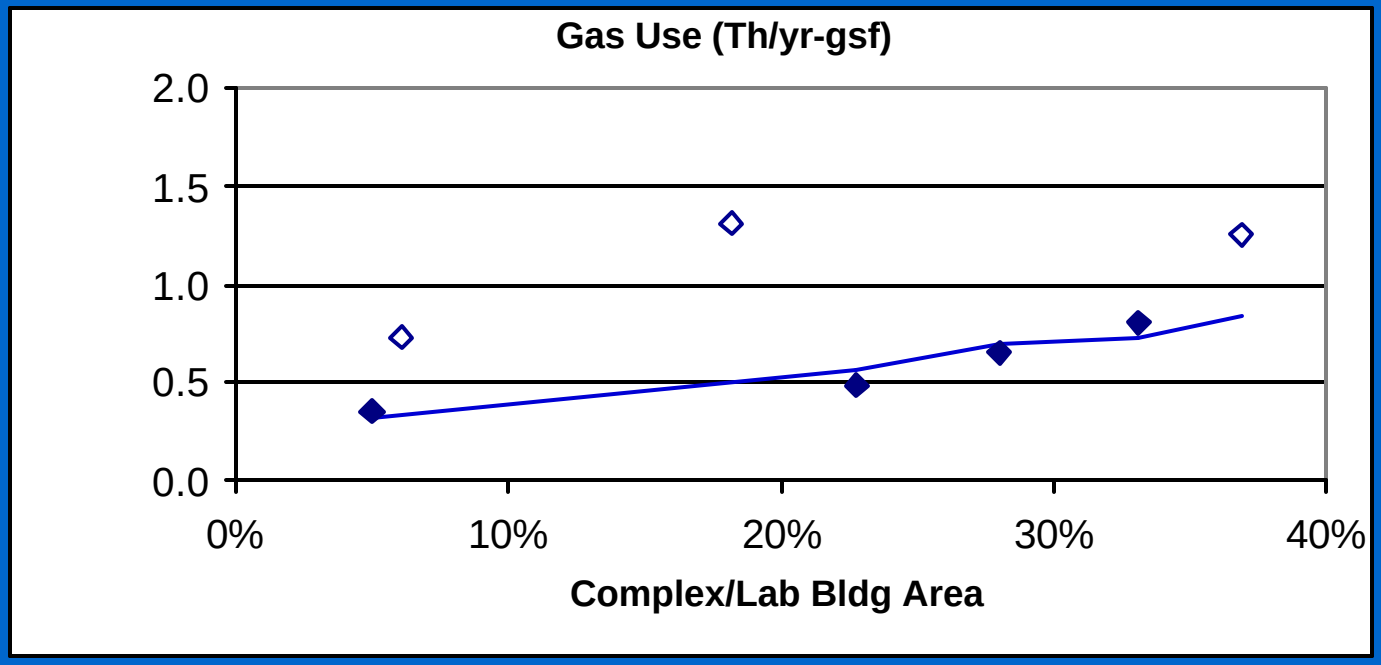
Campus Energy Benchmarking Applications
District Steam (?) vs. Other Thermal Systems (◆)
Coastal and Central California Climate

UC/CSU Campus Gas Use vs. Complex Building Fraction
(heating degree days is second variable)



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Campus Energy Benchmarking

Application of Benchmark Model to UC Merced

- Extend model to year-round operations
- Extend model to include non-building uses
  - add alternative fuel transportation scenarios
  - add potential on-site water/wastewater
- Apply model to scenarios
  - Baseline ("Business-as-Usual")
    - » All cooling loads served by electricity, no thermal energy storage or cogen
  - Conventional Load Management
    - » All cooling load shifted off-peak or switched to gas
  - add Efficient Design

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Campus Energy Benchmarking

UC Merced Efficient Design Scenario*

Energy Load as % of 1999 UC Average Benchmark for Buildings Opening in

2004	2005-2007	2008-->
80%	65%	50%

*basis of UCM/Labs21 project description

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Campus Energy Benchmarking

UC Merced Load Projection (Maximum Demand)

	2004	2007 (2004 plant)	
Space (gsf)	0.7 million	1.2 million	8.6 million
Scenario			
◆ Base (business-as-usual)	3.6 MW	6.3 MW	46 MW
◆ Load Management	2.7 MW	4.8 MW	34 MW
◆ Efficient Design	2.1 MW	3.5 MW	18 MW

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Building Design

Targets for UC Merced buildings opening in 2004 (FY2005)

		Laboratory	Classroom and Library	Housing and Services
Max Demand*	Watts/gsf	5.4	2.9	2.0
Max CHW*	tons/kgsf	3.0	1.6	1.1
Annual kWh	kWh/yr/gsf	33	12	8.5
Max Therms	th/hr/kgsf	0.34	0.10	0.14
Annual Therms	th/yr/gsf	1.5	0.14	0.22

*additive

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Building and Plant Design

Typical Scenario

1) Design engineers estimate cooling load at 1,200 tons

2) Campus engineers argue design engineers back to 600 tons

3) Fully occupied and utilized facility never uses more than 300 tons

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Innovation in HVAC Design

"Most Likely Maximum" (MLM) Method

- Make a realistic estimate of maximum loads ("most likely maximum")
  - Calibrate using benchmark targets
  - Apply appropriate level of diversity for each subsystem
- Optimize system to operate efficiently at MLM loads and part loads
- Identify "design" load conditions
- Value engineer difference between MLM and "design" equipment size
  - Identify appropriate margin of safety for each subsystem

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Campus Energy Benchmarking

Design Features for First UC Merced Facilities

Laboratories & Other Buildings

- Good Lighting Design
- (Some) Avoidance of Reheat
- Good Air System Design
  - Low Pressure Drop
  - Tight Ducts
- Indirect Evaporative Pre-Cooling (Labs)
- Control of Solar Load
  - High Performance Windows
  - Sun Shading
- (Some) Individual Office HVAC Control
- (Some) Operable Windows
- Commissioning
- Energy Performance Monitoring

Infrastructure

- No District Steam Heating
- Chilled Water Thermal Storage
- Cluster lab buildings around plant
- Large Pipes and Small Pumps
  - (not vice versa)
- Rational Plant Sizing

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