The Business Case for Commissioning New and Existing Buildings

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BERKELEY LAB

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Outline

- What is Commissioning?
- The Value Proposition
- Prospecting: Benchmarking to Identify Opportunities
- Cost-effectiveness Analysis Methods

Break

- LBNL Study
- Best Practices
- Evaluation Tool

What is Commissioning?

Commissioning is *Quality Assurance*

A coordination process to optimize building performance (comfort, reliability, safety, energy)

- Articulating/verifying energy-related design intent
- Construction observation; warranty enforcement
- Controlling first cost
- Training operators
- Enhancing safety and risk management
- Creating more cohesion among team members

Commissioning is ….

- … one of the most cost-effective means of improving energy efficiency in commercial buildings.

- … not an added cost. Rather it is a barometer of the cost of errors promulgated by others involved in design, construction, or operation. Commissioning agents are just the “messengers”.

- … common sense, but not common in practice.

Differences between Energy Auditing and Commissioning

- Begins earlier in building "lifecycle"
- More continuous (re-commissioning should be routine)
- Emphasizes no/low-cost improvements to existing systems
- Does not evaluate or recommend major capital retrofits
- Uses measurement and functional testing rather than simulation/stipulation of savings
- Builds capacity of in-house team (via training, better data logging, etc.)
- Strong emphasis on systems interactions and optimization
- More emphasis on non-energy benefits

History

- Born in ship-building industry:
  - “Does the engine start?” *versus* “Will it float?”

- Originally applied in buildings in early 1980s to ensure performance of energy efficiency measures
  - “Does a fan work?” *versus* “Should it be on?”

- It was later realized that “ordinary” buildings could achieve energy savings by correcting deficiencies

History (cont'd)

- 1989: ASHRAE developed HVAC commissioning guideline
- 1991: First utilities launched commissioning programs
- 1992: US Energy Policy Act required federal agencies to develop commissioning plans for their own buildings
- 1990s: ENERGY STAR Buildings and LEED (required)
- 1990s: R&D - e.g., DOE (federal) California PIER (state)
- 1998: PECI "National Strategy"
- 1998: Building Commissioning Association
- 2001: International Energy Agency "Annex 40"
- c.2003: California Commissioning Collaborative
- 2004: California Green Buildings Executive Order and Green Buildings Action Plan
- Many corporate initiatives, e.g. one of J&J's "Top-10"

Is there a Need?

- All buildings are “Complex Prototypical Machines” (David Sellers)
- Many problems are masked by energy-wasting process (e.g., a stuck economizer is compensated for by over-running chiller)
- The process of designing, building, documenting, and operating buildings has become increasingly fragmented
- Design and operation often is done without regard to system interactions [moisture problems as evidence]
- Energy Efficient technologies tend to be more sophisticated (error prone?) than traditional techniques
- Hardware” does not equal “Hard Savings”

Is There a Need? (cont'd)

- Building problems (a.k.a. "deficiencies") are ***pervasive***
  - *These include Design flaws; Construction defects; Malfunctioning equipment; Deferred maintenance*

:.

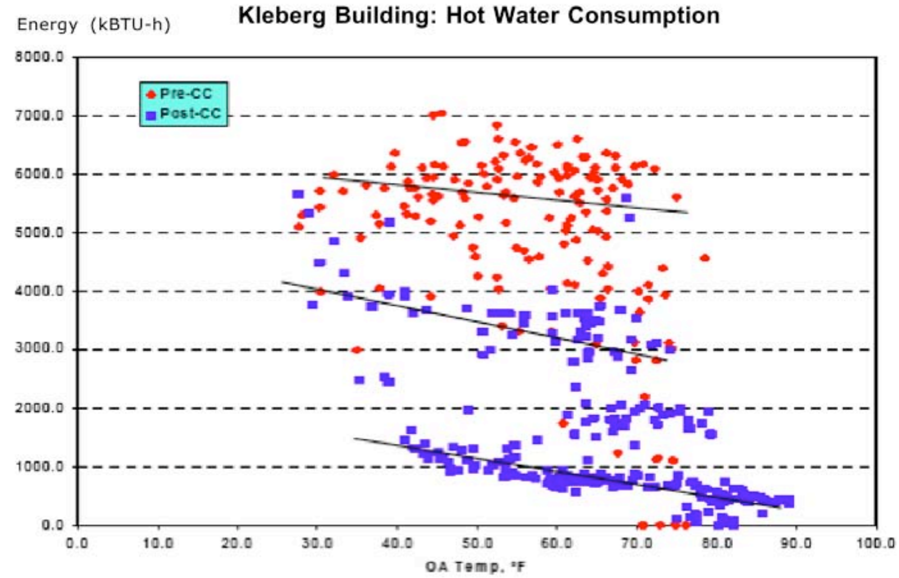
EXISTING BUILDINGS	**NEW CONSTRUCTION**
Simultaneous heating+cooling	Oversized equipment
Mis-sized valves/dampers, chillers	Unnecessary components (valves)
Low-quality or clogged filters	Construction debris blocking ventilation
VFD or economizer overridden/stuck	Specified equipment not installed
Dumb alarms (false; ignored)	Wrong set points or control sequences
Circuitous duct or piping runs	Wrong sensors (inappropriate sensitivity)
Bad or inaccurate sensors	Improper startup (e.g. daylighting sensors)
Supply fans running; return not (or visa-versa)	

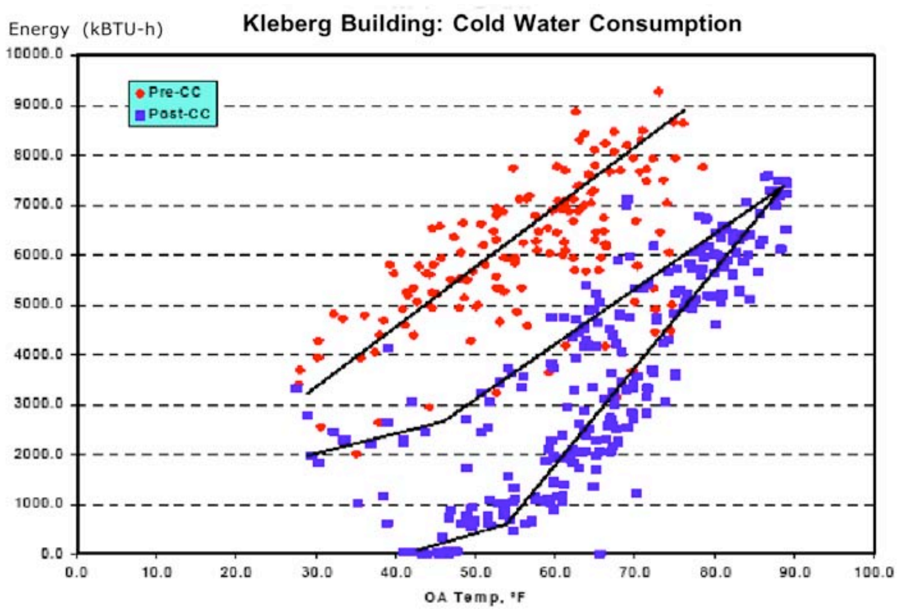
- *Don't shoot the messenger: problems a combined result of fragmentation/specialization of trades, "value" engineering, increasingly complex building design and operation requirements, lack of clear design-intent documentation and performance targets, etc.*

Problems Identified in THIS Building (the PG&E Energy Center)

- Pumping head too high: Can result in excessive throttling or pumping
- Doglegs in ducting (unnecessary pressure drop)
- Oversized economizer damper
- Bad outdoor air temperature sensors (reported 99.9% RH on a sunny day)
- Ice storage pump starters set on manual (should be auto)
- Poorly located ice storage temperature sensors

Case Study: Kleberg Building





INITIAL CONDITION - upper [red] clouds

- Continuous preheat - 105F (intentional)

PHASE 1 MEASURES - middle [blue]

- Preheat off

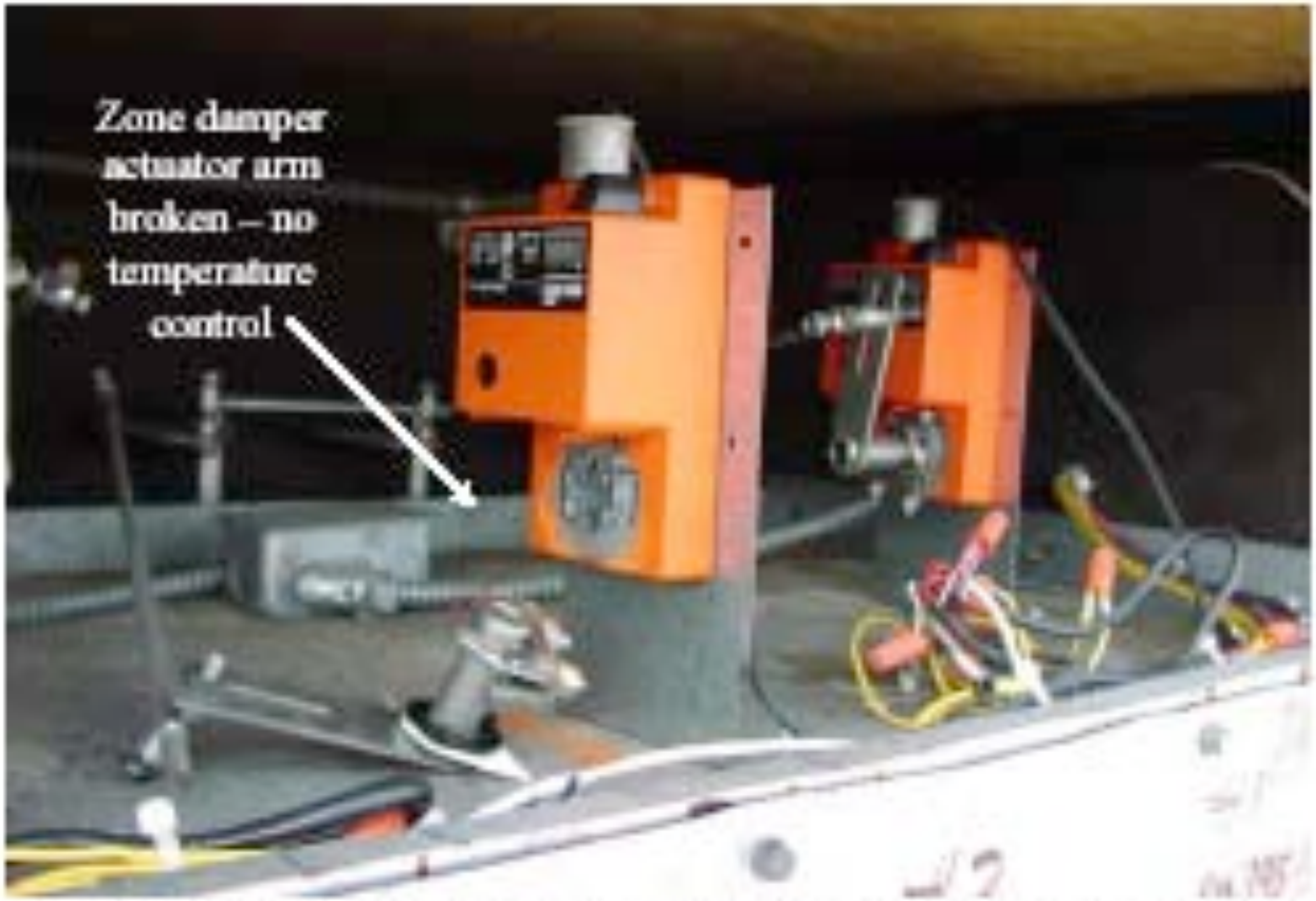
PHASE 2 MEASURES - lower [blue]

- Preheat to 40F
- Optimize cold deck temps
- Reactivate economizer mode
- Static pressure optimization
- Night-time setback
- Replaced or repaired VFD boxes
- Restarted chilled water VFD
- CHW pump control staging
- Building stack pressure reduced
- Fume hood exhaust pressure reduced

IMPACTS

- **Chilled water: 64% reduction**
- **Hot water: 84% reduction**
- **$314,000 annual energy cost savings**

Broken Dampers

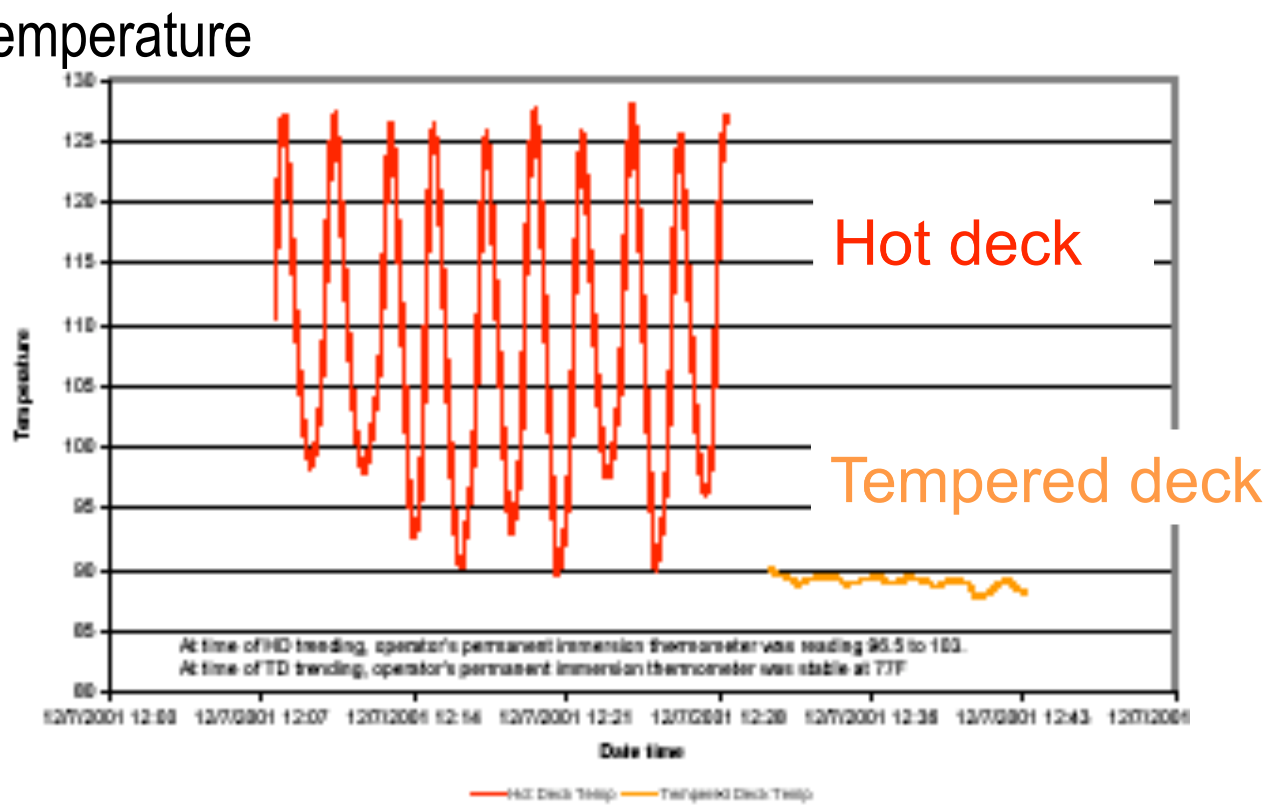


Broken actuator arm on damper of multizone unit, elementary school

Fouled Filters

Condensation damage from DX fan coil unit due to plugged filter and low air flow. Large high school.

Faulty Controls



Hunting of hot deck temperatures with pneumatic control due to sensor thermal mass, steam valve sizing, and controller proportional band. Older high-rise office building.

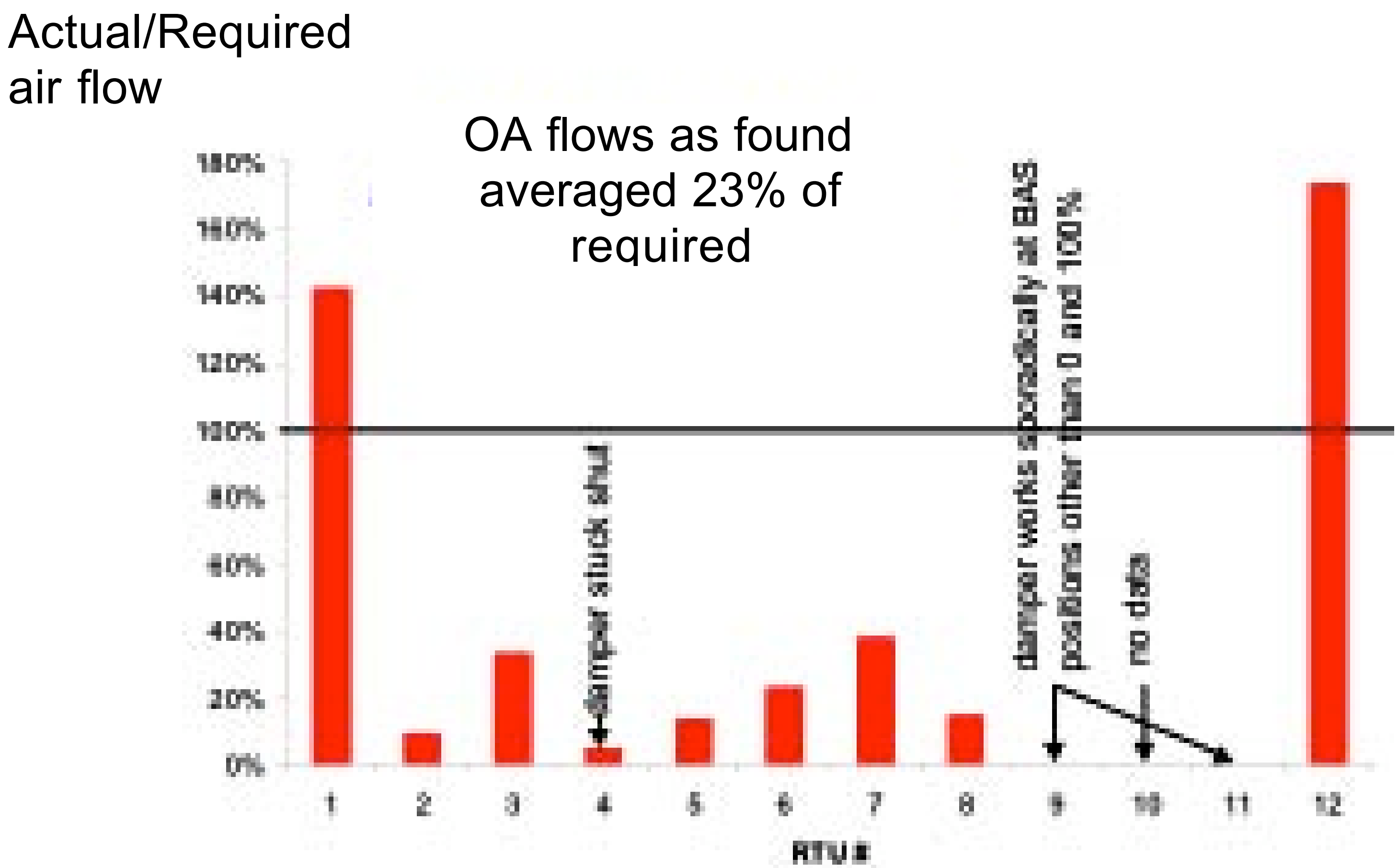
Poor Coordination Among Trades

Inadequate cooling and excessive fan power consumption due to poor fit between light troffer diffusers and duct boot provided by a different supplier, allowing up to 25% of flow at diffuser to bypass directly into ceiling plenum. Highrise office tower.

Envelope: air leakage and moisture management

Damage to brick facade of pool building due to lack of specification for (a) sealing of air leakage paths in exterior envelope and (b) balancing to assure negative pressurization of pool area. Large newer middle school.

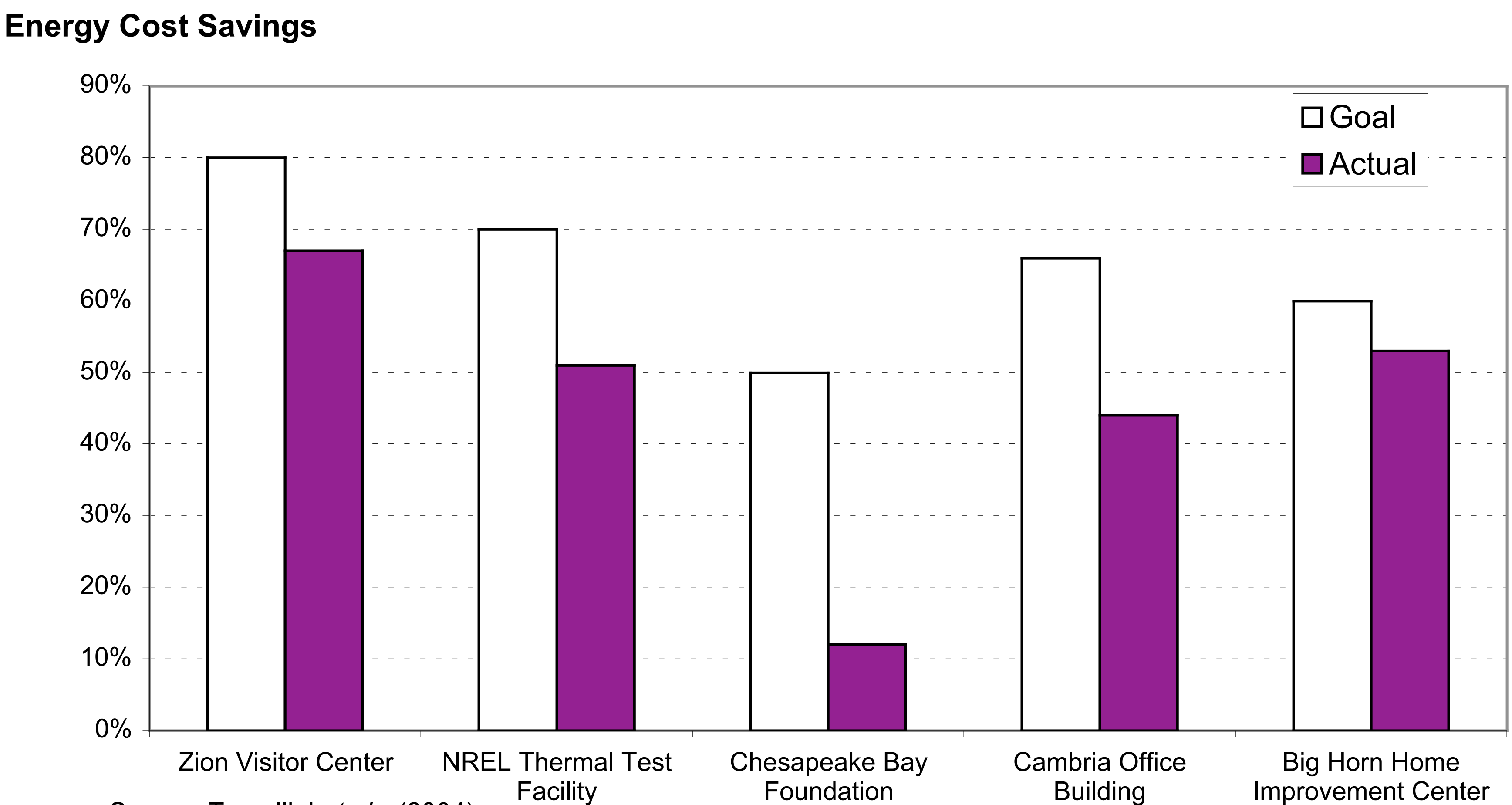
Design-operation Mismatch



Outside air flows as a percent of required air flow for current occupancy and ventilation standards. Twelve rooftop units at an elementary school.

Energy Consequences

DOE High-Performance Buildings Case Studies: Goals vs. Actual



Source: Torcellini *et al.* (2004)

The Value Proposition

Value Proposition - Perspectives

- For Building Owners/Occupants
    - Comfort/productivity; continuous occupancy
    - Warranty enforcement
    - Reduced construction time
    - Occupant/tenant satisfaction
    - Enhanced equipment life
    - Reduced maintenance costs
- For Trades
    - – Improved information flow among team members
    - – Reduced call-backs or change orders
    - – Increased likelihood of client satisfaction
- For Utilities/"Policy People"
    - – Program success: e.g. customer acceptance
    - – Meeting and maintaining targeted savings

Value Proposition - Sources of Value

- Energy Savings
  - Improved efficacy of EEMs
  - Even “Ordinary Buildings” can get savings
- Securing the achievement of O&M goals
- Non Energy Benefits
- Risk Management

Value Proposition - Sources of Value

- Not attending to problems can cause:
  - Discomfort --> Eroded productivity, absenteeism
  - Indoor air quality problems
  - Premature equipment failure
  - Litigation
  - Excessive energy and construction costs

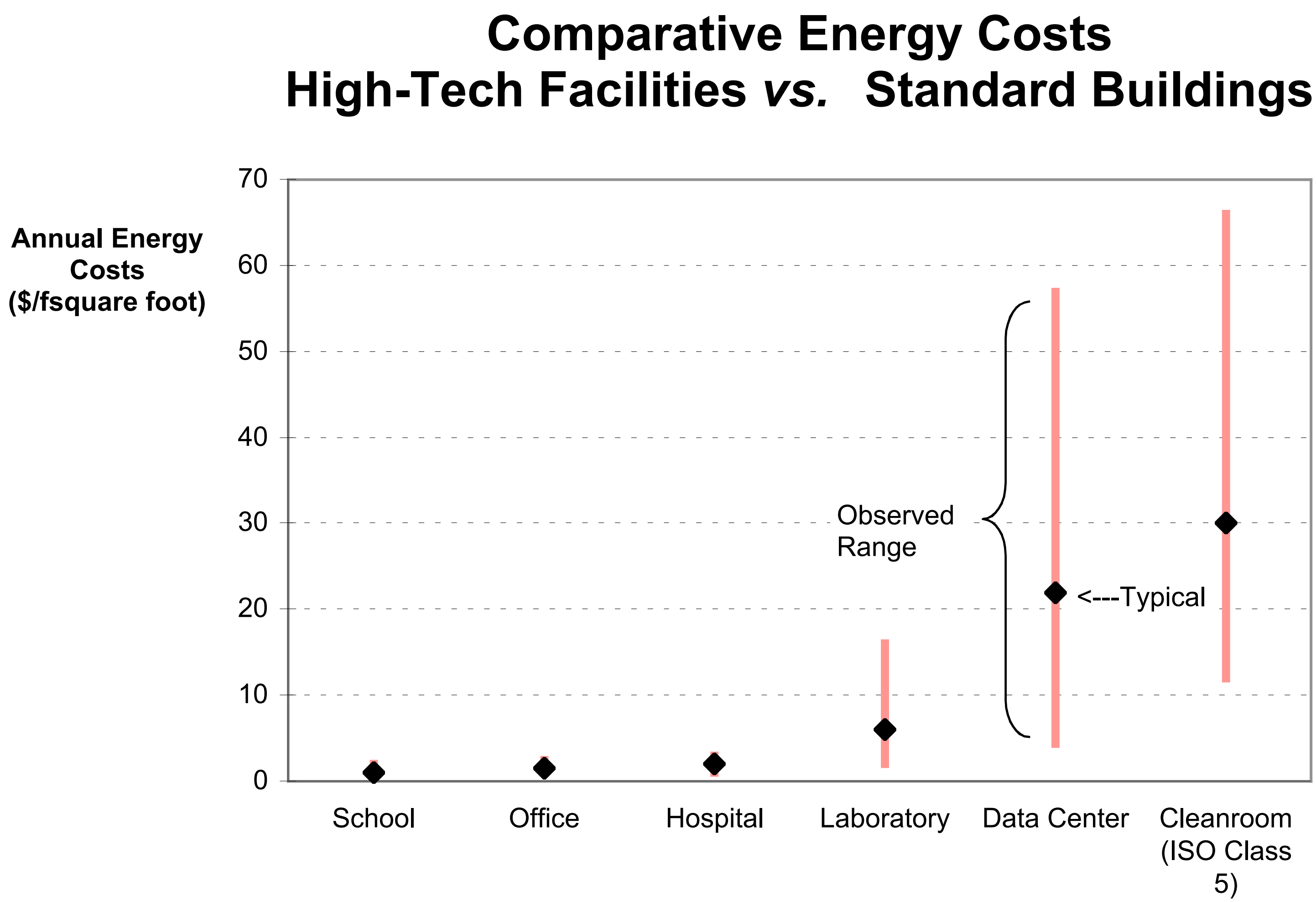
Energy & Non-Energy Impacts

	Cost	Benefit	Comment
Direct			
Cost of (retro)commissioning service	x	x	Cost can be partially or completely offset by the indirect effects listed below
Energy consumption	x	x	In rare circumstances, energy use can increase if equipment is found in "off" or under-utilized state
Indirect			
Accelerated repair of a problem (assuming it would have been identified and corrected, eventually, without commissioning)		x	
Avoided premature equipment failure		x	
Changes in ioperations and maintenance costs	x	x	
Changes in project schedule	x	x	Can shorten or lengthen schedule
Clarified delineation of responsibilities among team members		x	
Contractor call-backs		x	
Occupant comfort/productivity		x	
Equipment right-sizing	x	x	
Impacts on indoor environment		x	
Documentation	x	x	
In-house staff knowledge	x	x	
Disruption to occupancy and operations	x	x	Early detection of problems
More vigilant contractor behavior (knowing that Cx will follow their work)		x	
Operational efficacy		x	
Potential for reduced liability/litigation		x	
Change orders	x	x	Timely introduction of commissioning (early in process); otherwise potential for increase
Disagreement among contractors		x	
Testing and balancing (TAB) costs		x	Can be reduced by solving problems that the TAB contractor would otherwise have encountered
Safety impacts		x	
Warranty claims		x	
Water utilization		x	
Worker productivity		x	

Prospecting: Benchmarking to Identify Opportunities

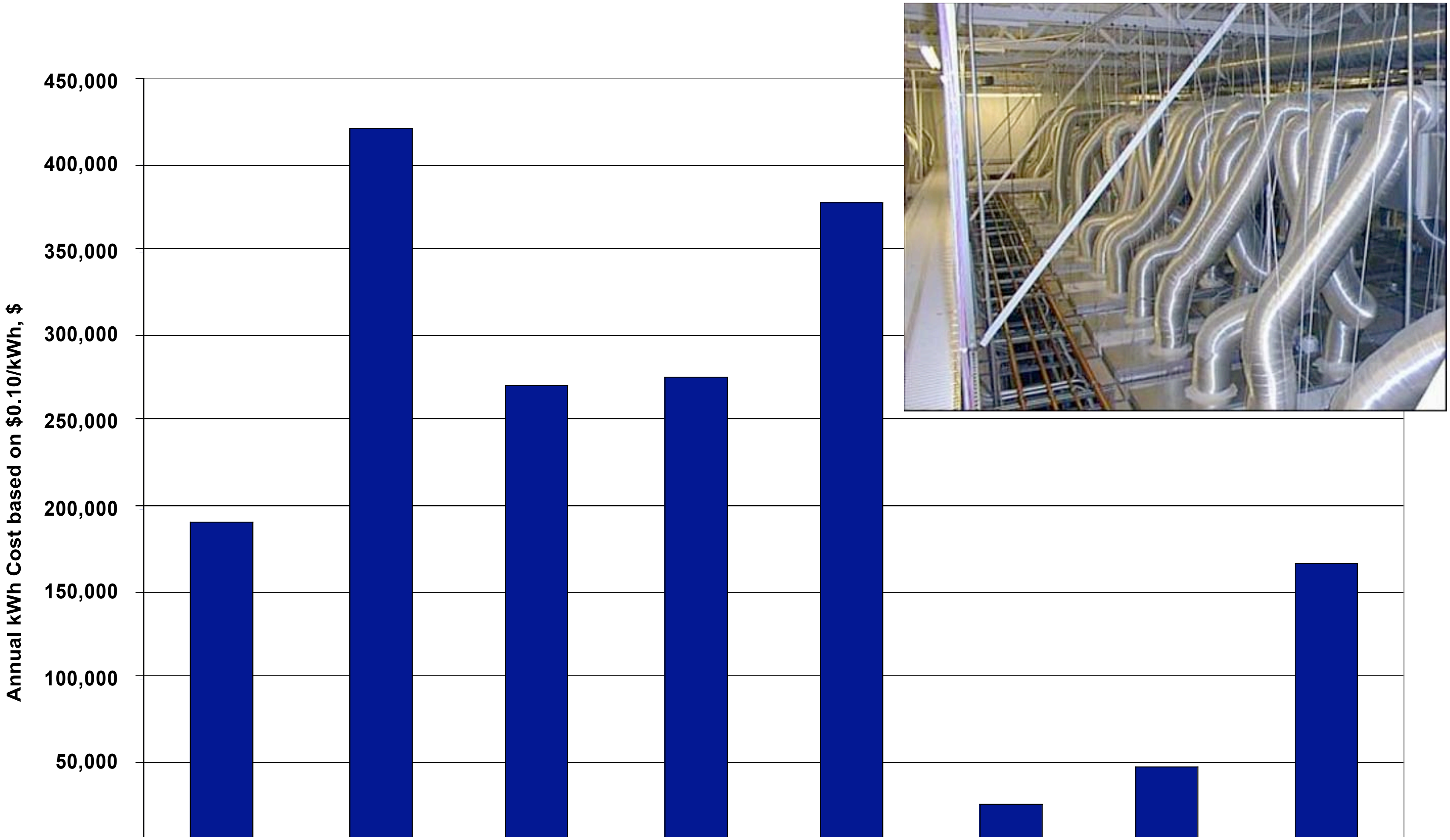
Benchmarking - High-Tech Facilities

Energy intensity varies by orders of magnitude - suggesting opportunities



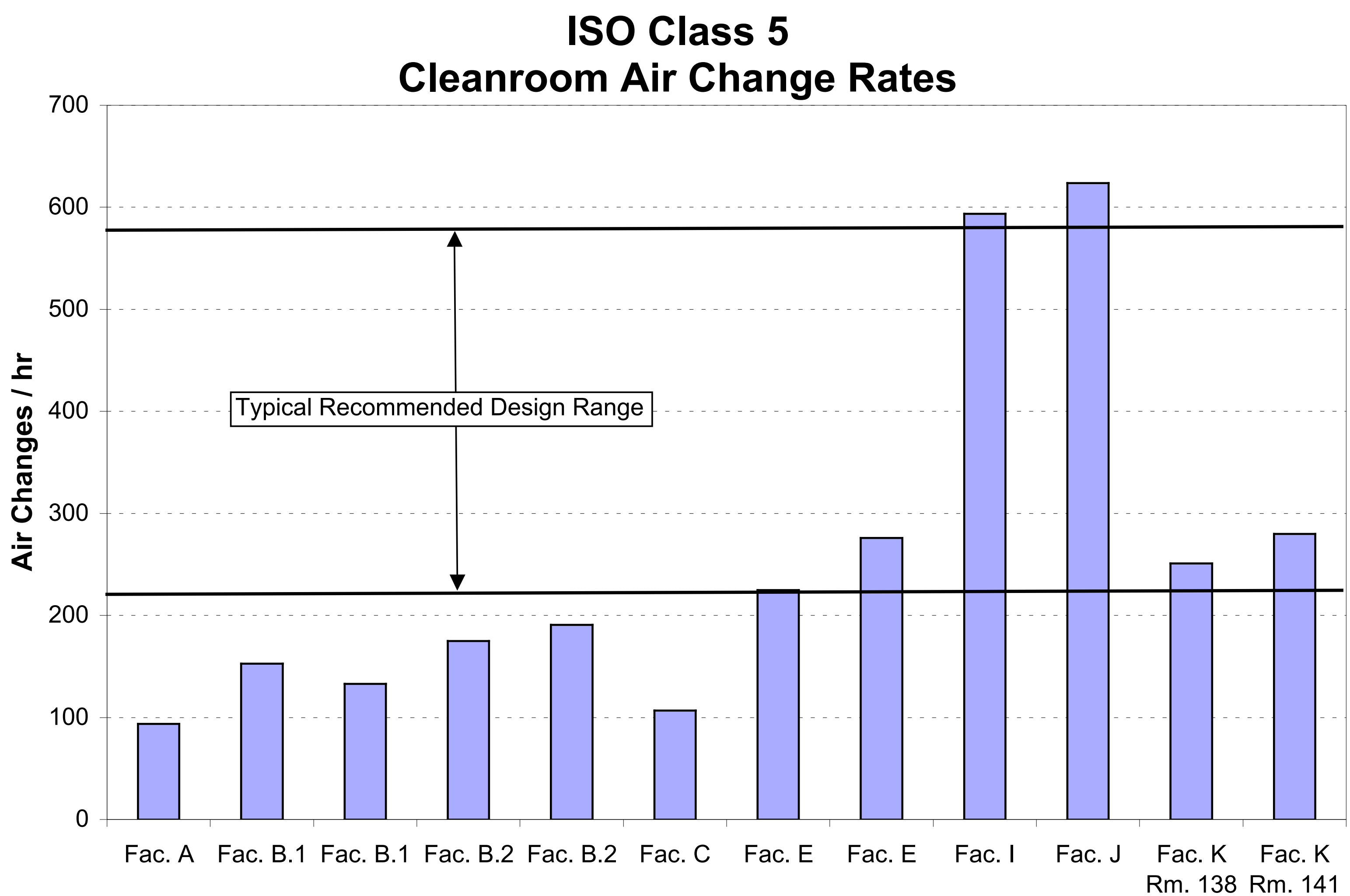
Benchmarking - Cleanrooms (1 of 2)

Recirculation air costs vary by factor of 8 in similar cleanrooms



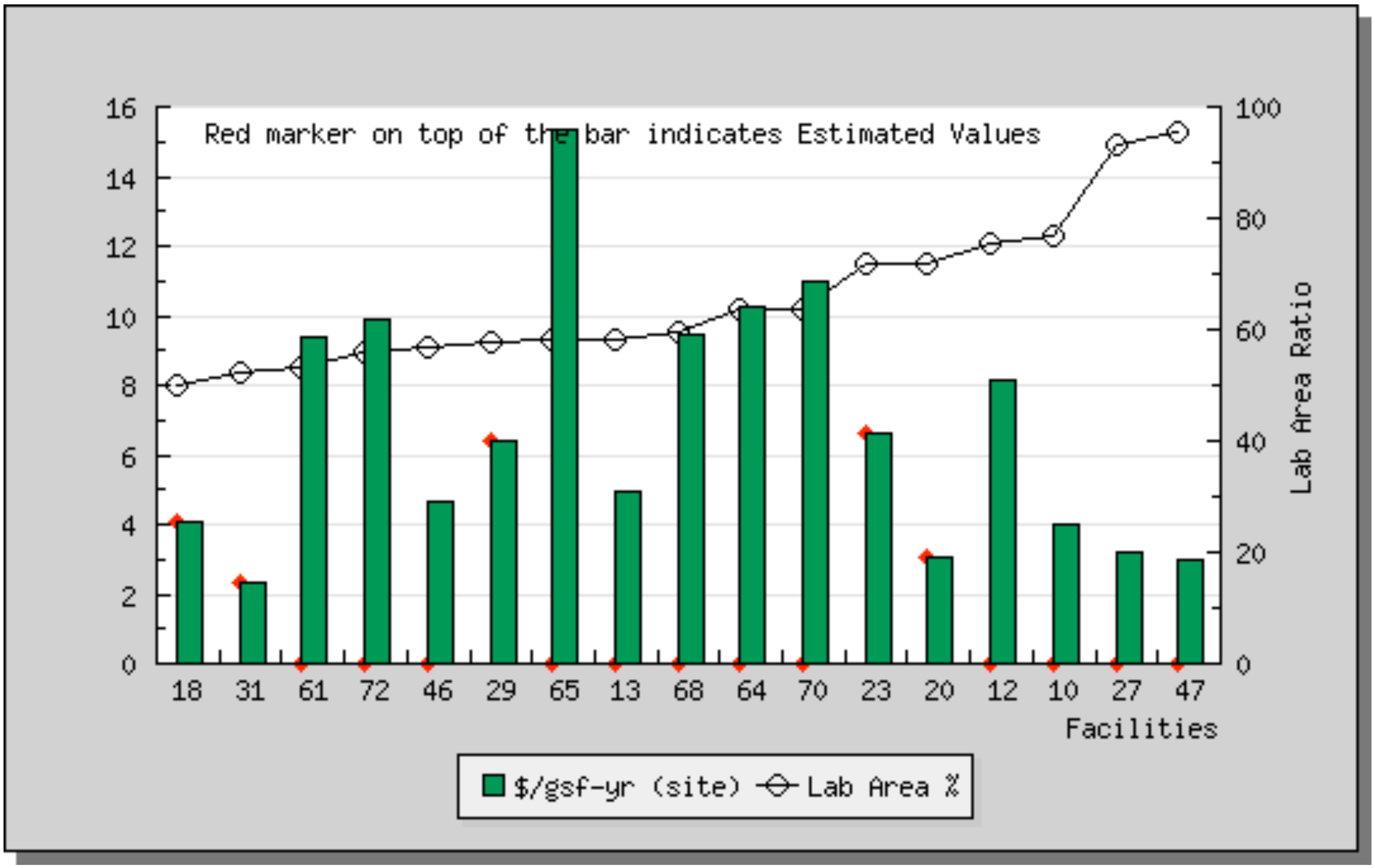
Benchmarking - Cleanrooms (2 of 2)

ACH varies by factor of 6 for similar cleanrooms



Benchmarking - Laboratories

Energy cost intensity varies by factor of 8

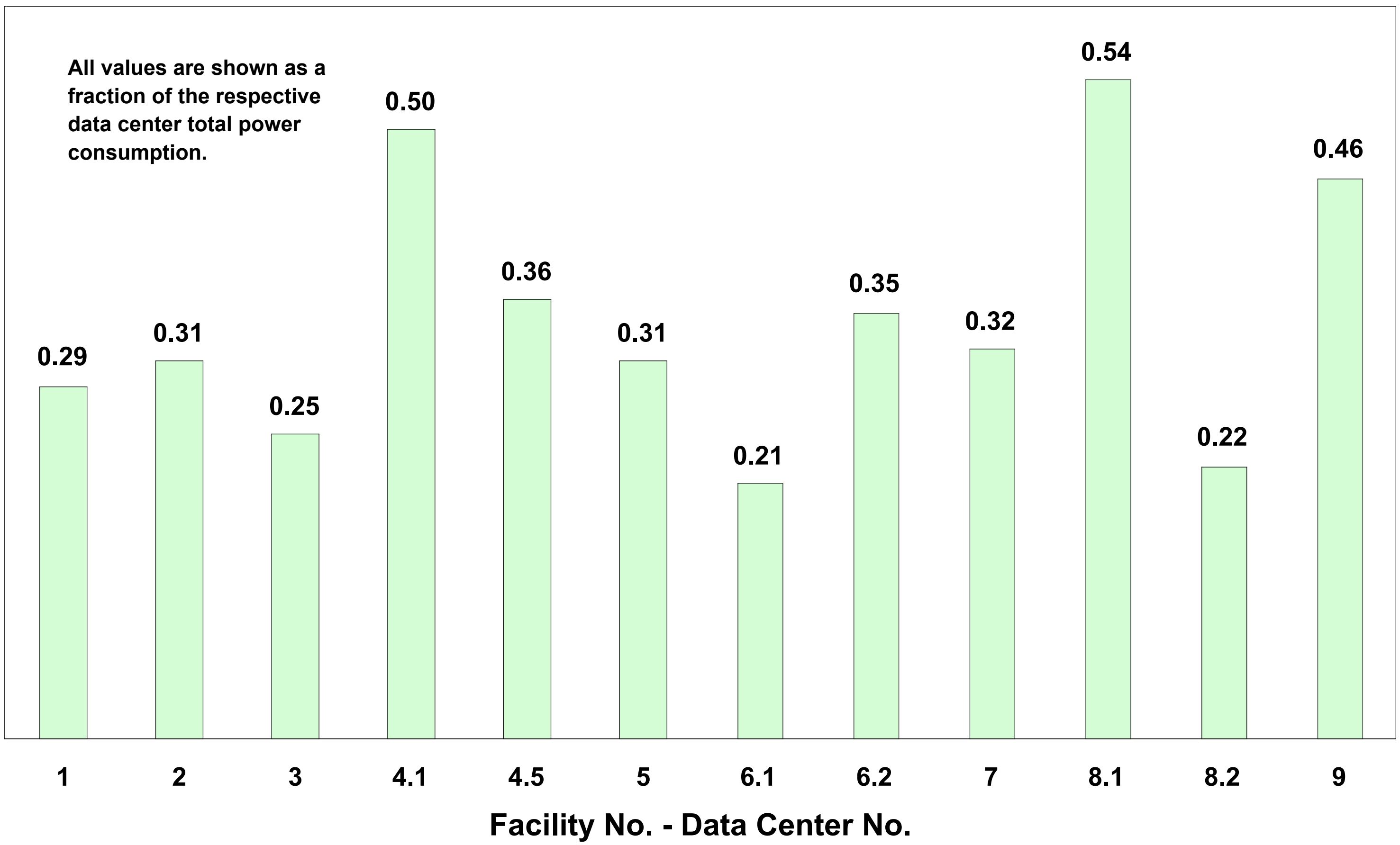


Benchmarking - Data Centers

HVAC "effectiveness" (HVAC energy/total energy) varies by 2.5x [low value is better]

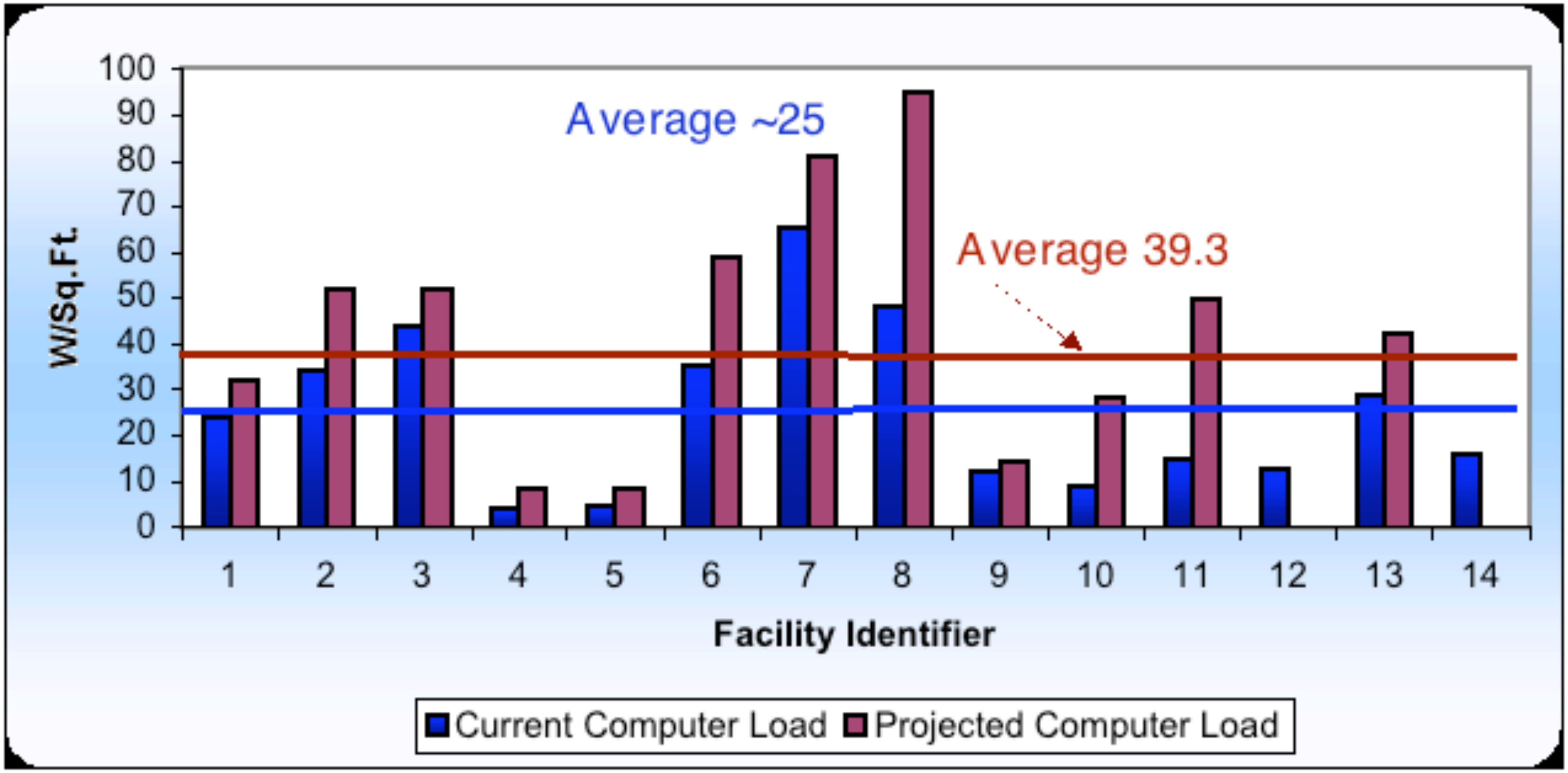
Data Center Load Characterization Project

HVAC Power Consumption



Benchmarking - Datacenters

Power density varies by 20x, and lower than rules-of-thumb in every case!



Cost-Effectiveness Analysis

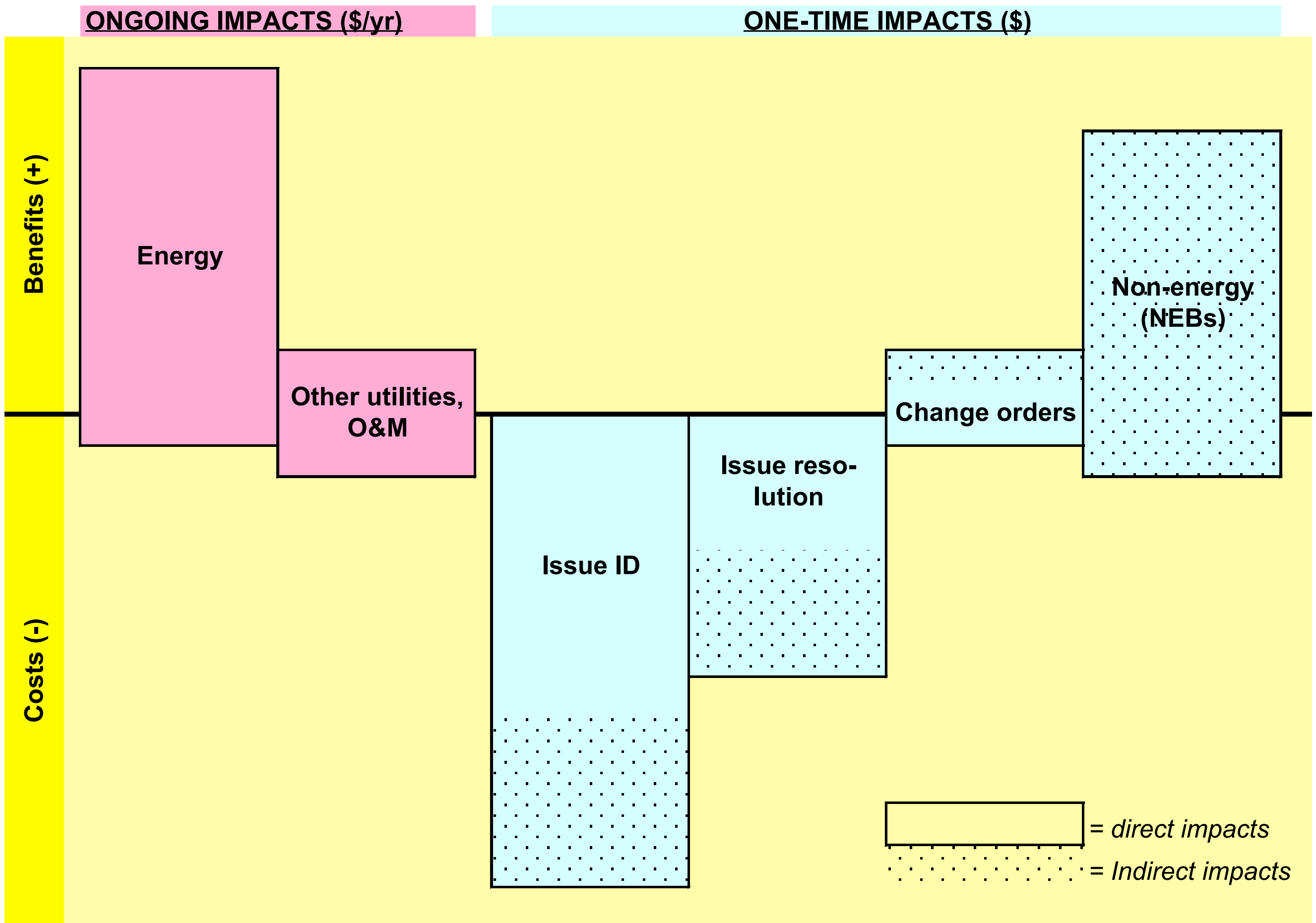
Cost-Benefit Formula

Simple Payback Time (years) =

$$\frac{\text{Commissioning cost +/- Non-energy impacts}}{\text{Annual Energy Savings +/- Non-energy benefits}}$$

Advantages of PBT: intuitive; familiar; does not rely on discounting; does not require stipulated measure life

Ways of Thinking about Costs and Savings



Source: Northeast Energy Efficiency Alliance

Saving energy is rarely the number-one driver or reason for embarking on a commissioning project, although energy systems often at the root of problems

Factors Effecting Project Cost

- Scope & thoroughness
- Available documentation
- Number of systems (sampling *vs* 100% inspection)
- System complexity
- Number of zones
- Existing metering/gauges, utility history, EMS trends
- Measurement equipment costs (purchase/rental)
- Commissioning agent involvement
- On-site staff involvement
- Reporting
- Cleverness

Factors Effecting Project Savings

- Savings persistence is uncertain (intrinsic to the kinds of issues requiring commissioning)
- Recommendations often only partly implemented at the time that evaluation often occurs
- Not all recommendations will necessarily be implemented
- Savings cannot be directly measured in new construction (lack of “baseline”)

Examples of Non Energy Impacts

- Altweis (2002): six projects in which change orders were reduced by 87%; contractor call backs by 90%; construction cost reduced 4-9%.
- Tso et al (2002): an average of 12 measures per project (new construction) and 9 measures (existing buildings) resulted in extended equipment life
- Sellers: Cleanroom filtration: One change-out fills a warehouse with media (disposal cost). Pre-Cx: changes made by calendar, not by need. Shift to extended-surface; pressure drop cut in half and filters lasted 2x as long. Better filters had no metal frames (cut recycling costs) [courtesy David Sellars]
- Sellers: 34 air handling units cycling 87,600 cycles per year (more than actuator design life; actuator replacement cost $300-$500) Replacements avoided at cost of $150-$200 in labor to diagnose and correct problem.
- Nelson (1999): twelve legal claims (aggregate award of $60 million) could have been avoided by proper commissioning.

Includable Cost Items

- Cx provider's fixed costs
- Contractor Cost: Coordination with commissioning provider
- Improving design or operations
- Functional tests
- Resolution costs related to optimizing systems
- Costs related to ensuring other trades' contract adherence
- Resolution costs related to operations and maintenance
- Minor capital improvements to resolve deficiencies
- Training of on-site staff
- Utility rebates, grants, or other external financial incentives
- Travel
- Non-energy impacts

Excludable Cost Items

- "Non-billable" in-house operations staff fixed costs
- Contractor Cost: Contract compliance
- Testing and balancing (TAB)
- Correcting design flaws
- Resolution costs related to installing a system beyond project scope
- Major capital improvements to resolve deficiencies
- Research-related costs

15-minute break

LBNL Study

LBNL Study of Cx Projects in 224 Buildings

- Meta-Analysis (some primary information)
- Focus on energy aspects, but also non-energy <u>impacts</u>
- Separate treatment of existing and newly constructed buildings
- Standardized analysis (definitions, normalized energy prices, inflation)
- Extensive statistical and correlation analyses

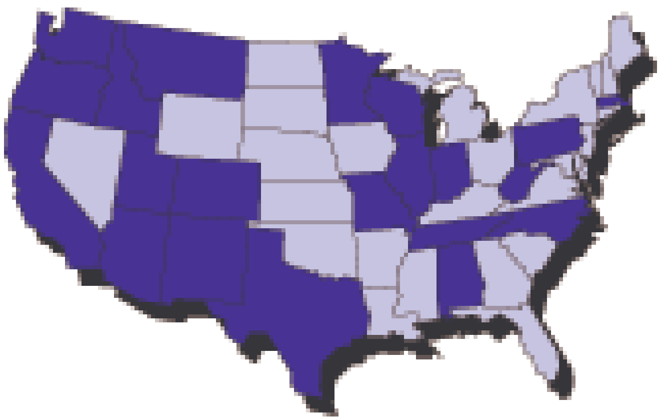
Methodology

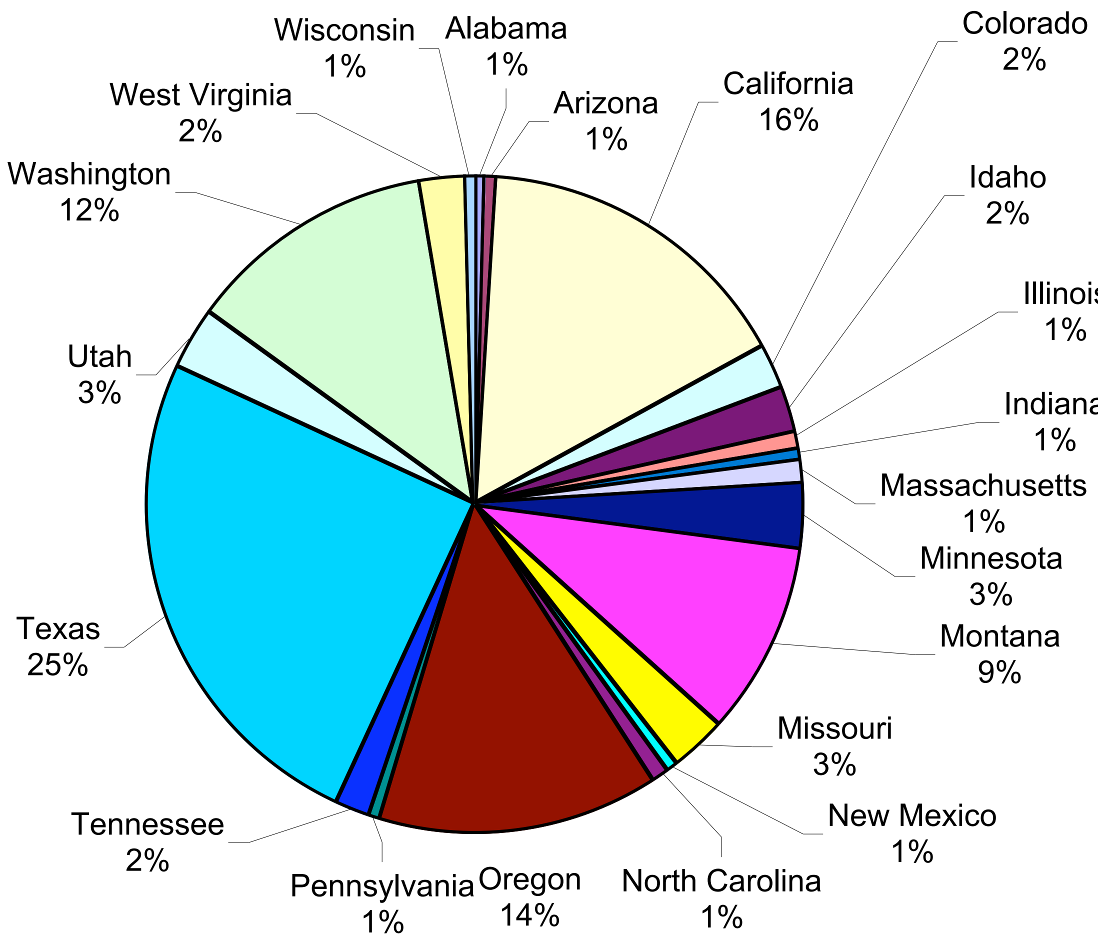
- Developed metrics to characterize performance
- Developed standardized language for describing Cx scope
- Developed standardized framework for characterizing deficiencies and measures ("Measures Matrix")
- Collected data from the literature and Cx providers
- Reviewed data quality
- Performed normalizations
  - Standardized energy prices
  - Construction costs corrected for inflation ($2003)
  - Commissioning costs corrected for inflation ($2003)
- Analysis and inter-comparisons
- Analyze subgroups (new/existing; building type)
- Identified correlations (or lack thereof)
- Identified data gaps

Resulting Sample Characteristics

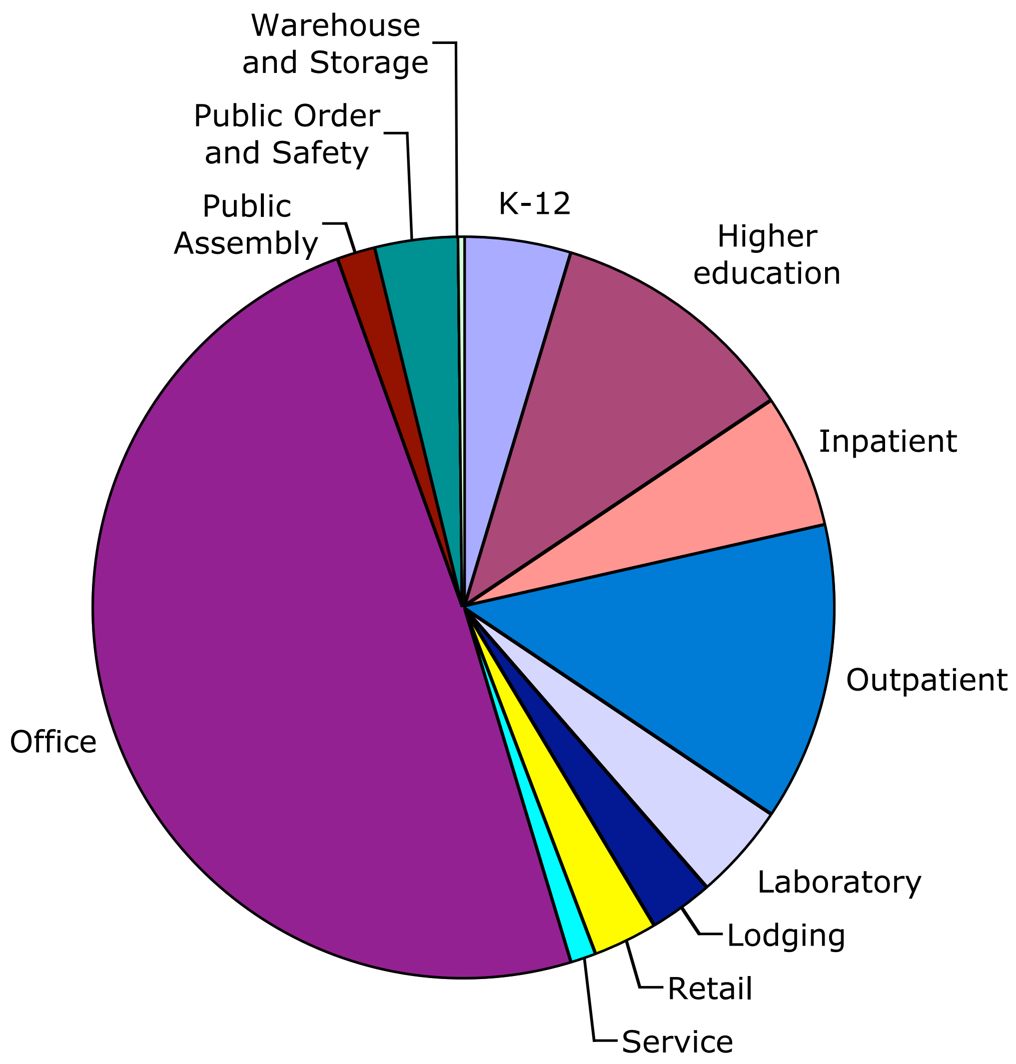
- 224 buildings (175 projects), of which 150 are existing buildings and 74 are new construction
  - 18+ commissioning providers
  - Largest sample yet compiled
- Diversity of building types
- 30.4 million square feet across 21 U.S. states
  - Existing buildings: median 151,000 ft^2
  - New construction: median 69,500 ft^2
- $17 million investment
- ~7000 problems identified
- Projects span two decades, but most done in the 1990s

Location of Projects





Types of Buildings



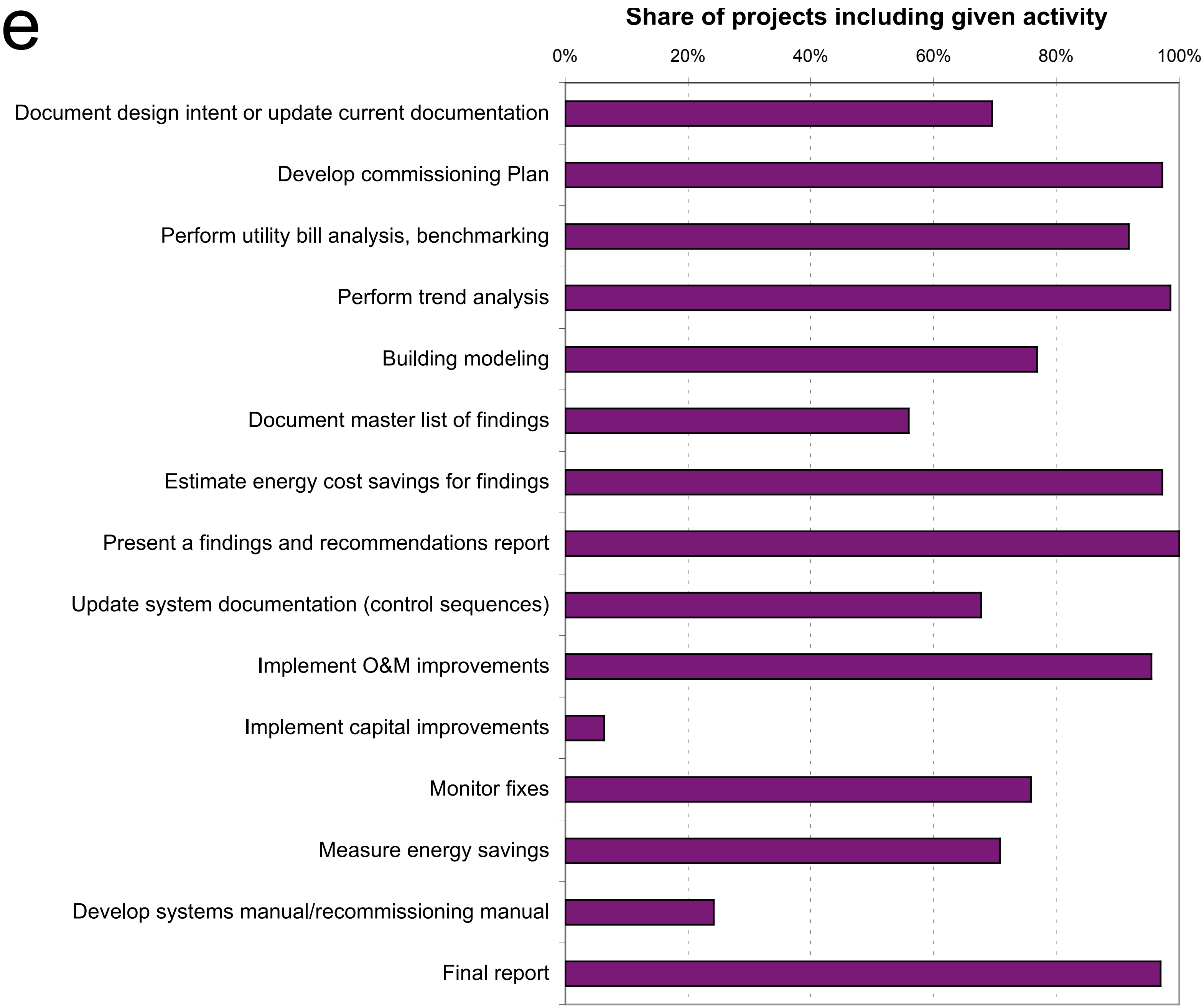
Top-level Findings

- Existing Buildings
  - Cx cost: \$0.27/ft^2 • Median NEBs: \$0.18/ft^2
  - Deficiencies: 11 per building
  - Energy Savings: 15%
  - Payback time: 8.5 months
- New Construction
  - Cx cost: \$1.00/ft^2 • Median NEBs: \$1.24/ft^2
  - Deficiencies: 28 per building
  - Payback time: 4.8 years
- Cost-effective over range of energy intensities, building types, sizes, locations
- Most successful: energy-intensive buildings
- Cost-effective outcomes harder in small buildings
- Energy savings rise with more thorough commissioning

Commissioning Scope: Existing Buildings

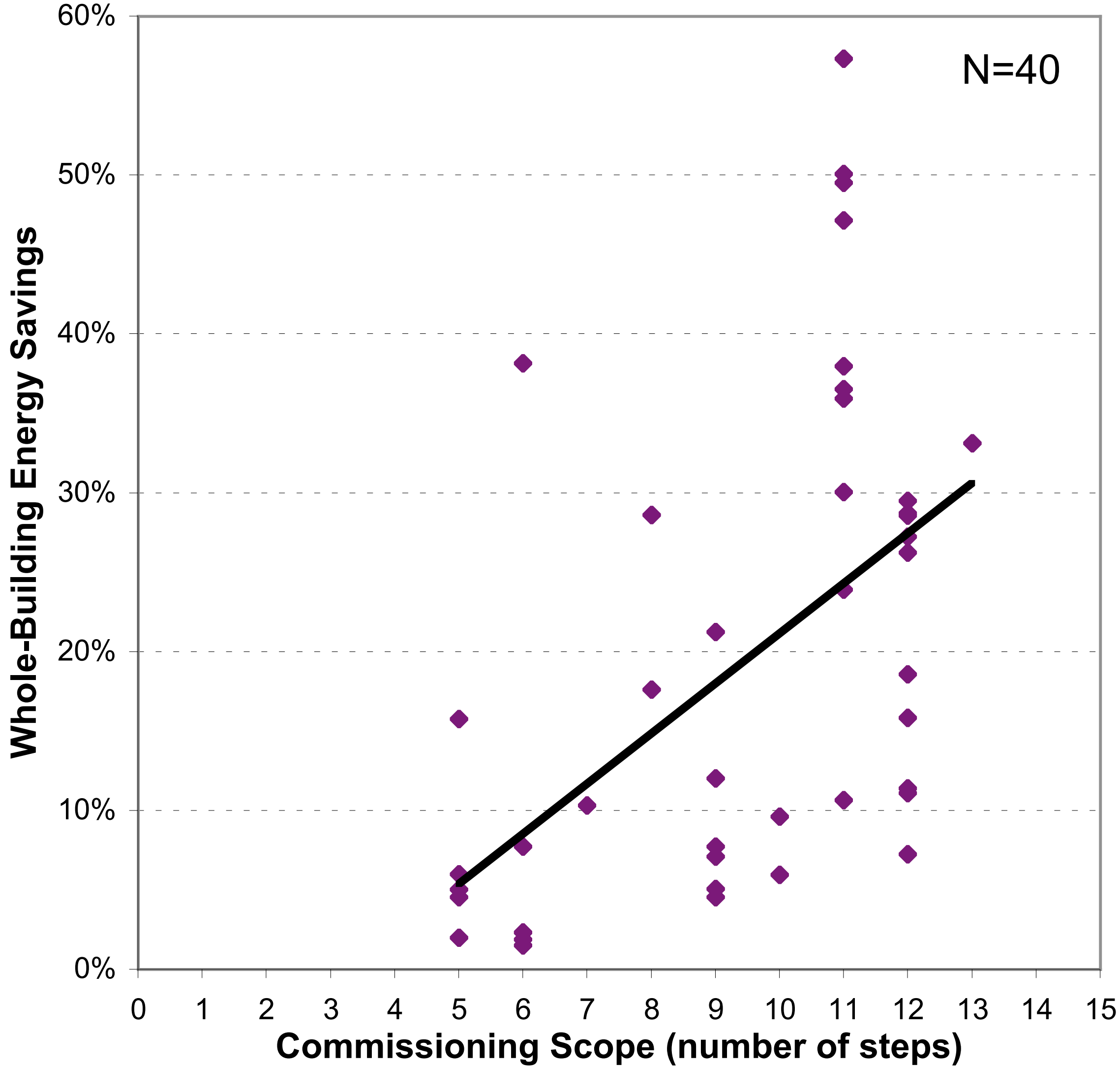
- Develop or update design intent documentation
- Plan
- Utility analysis, benchmarking
- Trend analysis
- Building modeling
- Findings
- Estimate benefits from interventions
- Update system documentation (e.g. control sequences)
- O&M improvements
- Capital improvements (grey zone)
- Monitor fixes
- Measure impacts
- Systems manual/recommissioning manual
- Report

Scope



Share of projects including given activity
0%
20%
40%
60%
80%
100%
Document design intent or update current documentation
Develop commissioning Plan
Perform utility bill analysis, benchmarking
Perform trend analysis
Building modeling
Document master list of findings
Estimate energy cost savings for findings
Present a findings and recommendations report
Update system documentation (control sequences)
Implement O&M improvements
Implement capital improvements
Monitor fixes
Measure energy savings
Develop systems manual/recommissioning manual
Final report

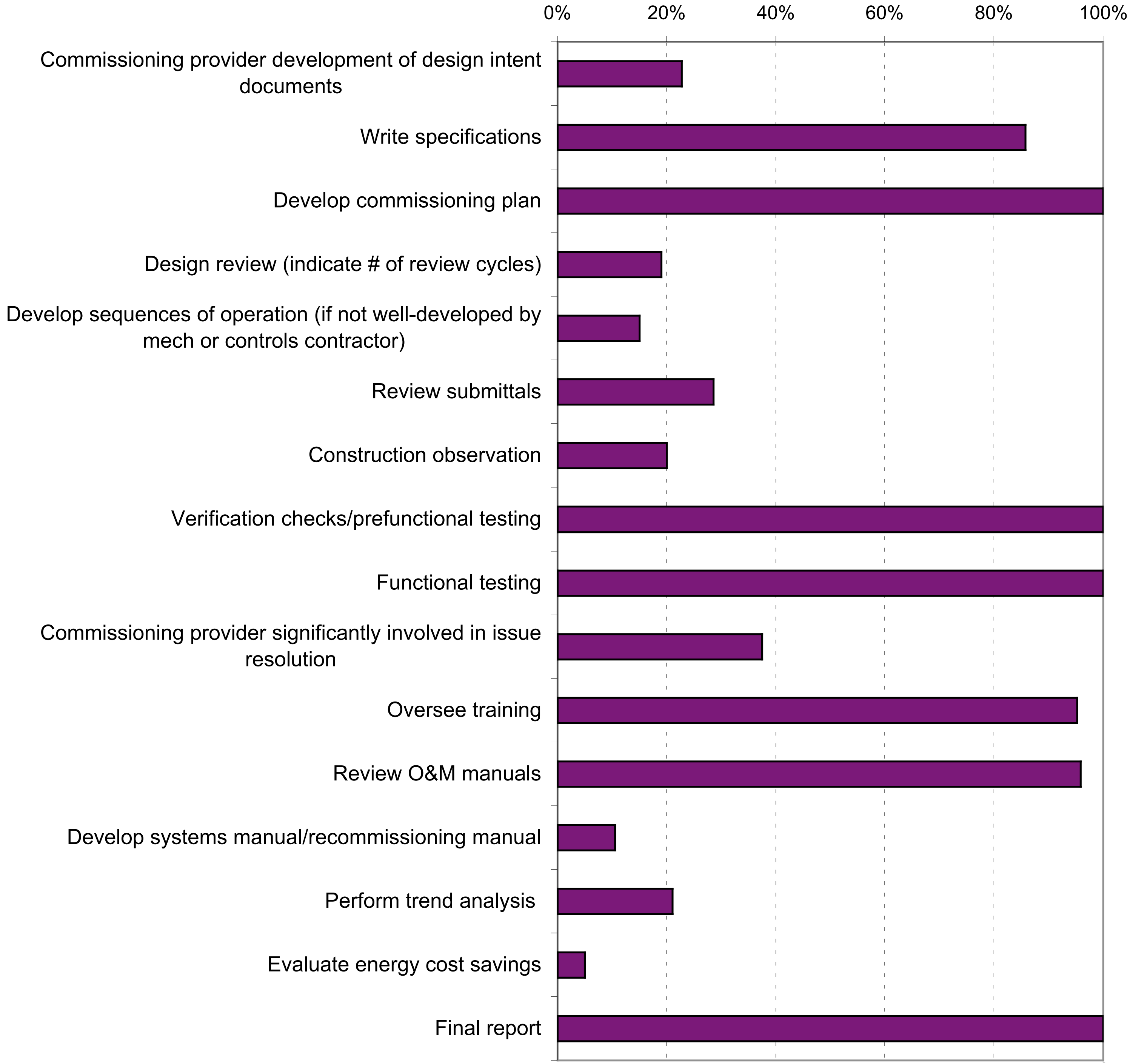
Savings Scale with Commissioning Scope (Existing Buildings)



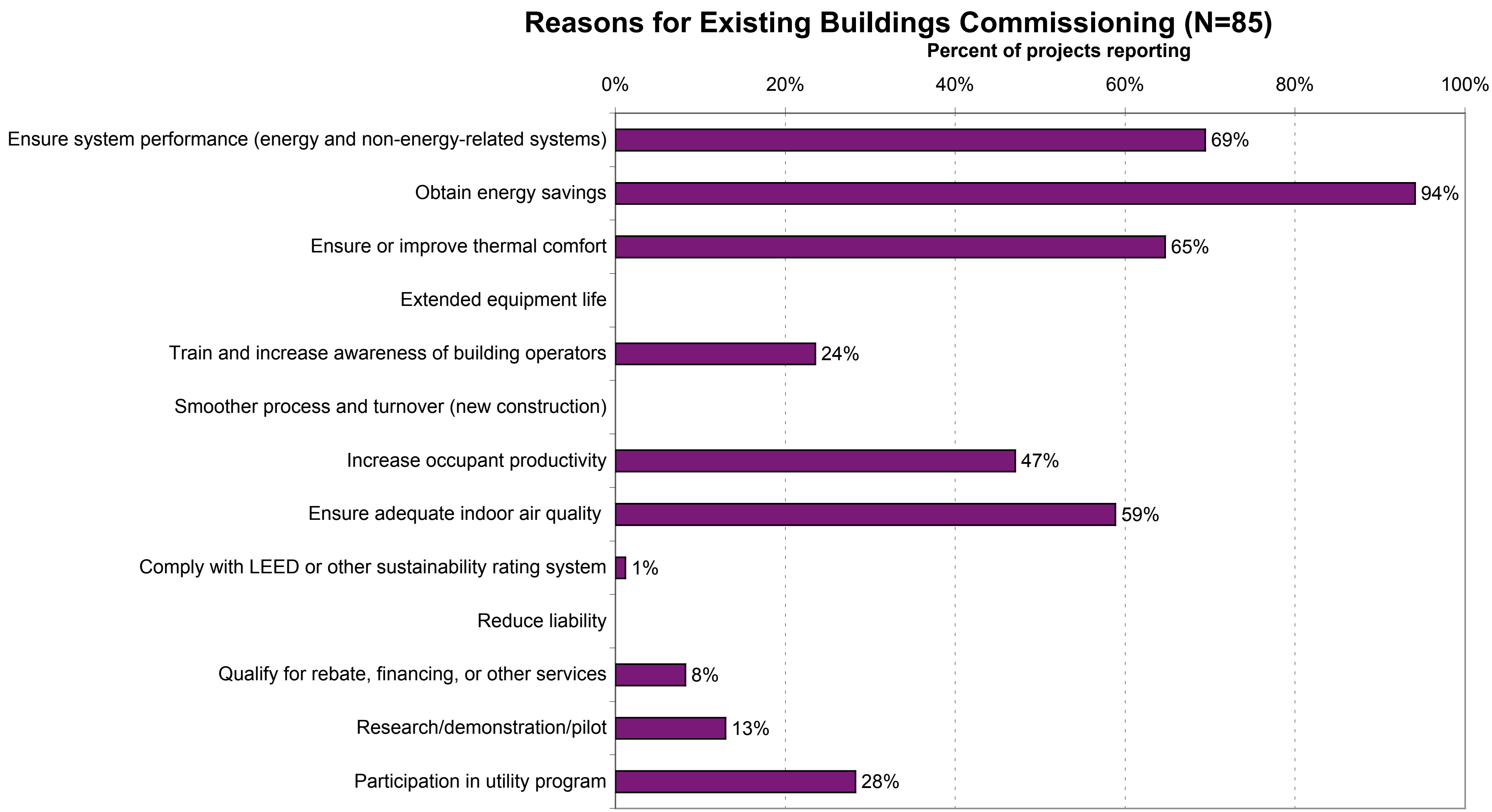
Commissioning Scope: New Construction

- Develop design intent documents
- Specifications
- Plan
- Design review
- Sequences of operation (if not already available)
- Review submittals
- Construction observation
- Verification checks
- Functional testing
- Issue resolution
- Training
- Review O&M manuals
- Systems manual/recommissioning manual
- Trend analysis; evaluate energy savings
- Report

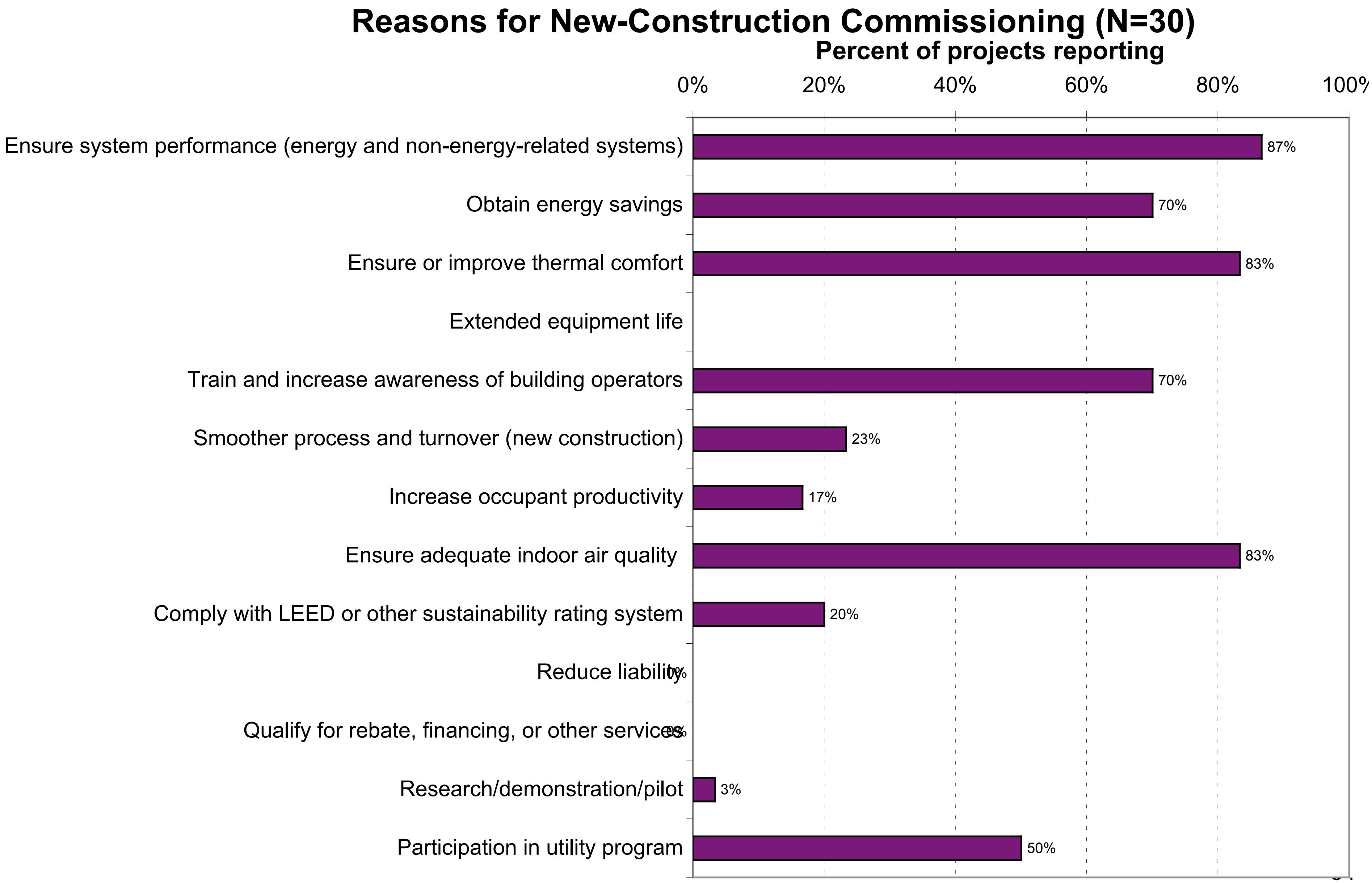
Scope


0%
20%
40%
60%
80%
100%
Commissioning provider development of design intent documents
Write specifications
Develop commissioning plan
Design review (indicate # of review cycles)
Develop sequences of operation (if not well-developed by mech or controls contractor)
Review submittals
Construction observation
Verification checks/prefunctional testing
Functional testing
Commissioning provider significantly involved in issue resolution
Oversee training
Review O&M manuals
Develop systems manual/recommissioning manual
Perform trend analysis
Evaluate energy cost savings
Final report

Reasons for Commisisoning: Existing Buildings

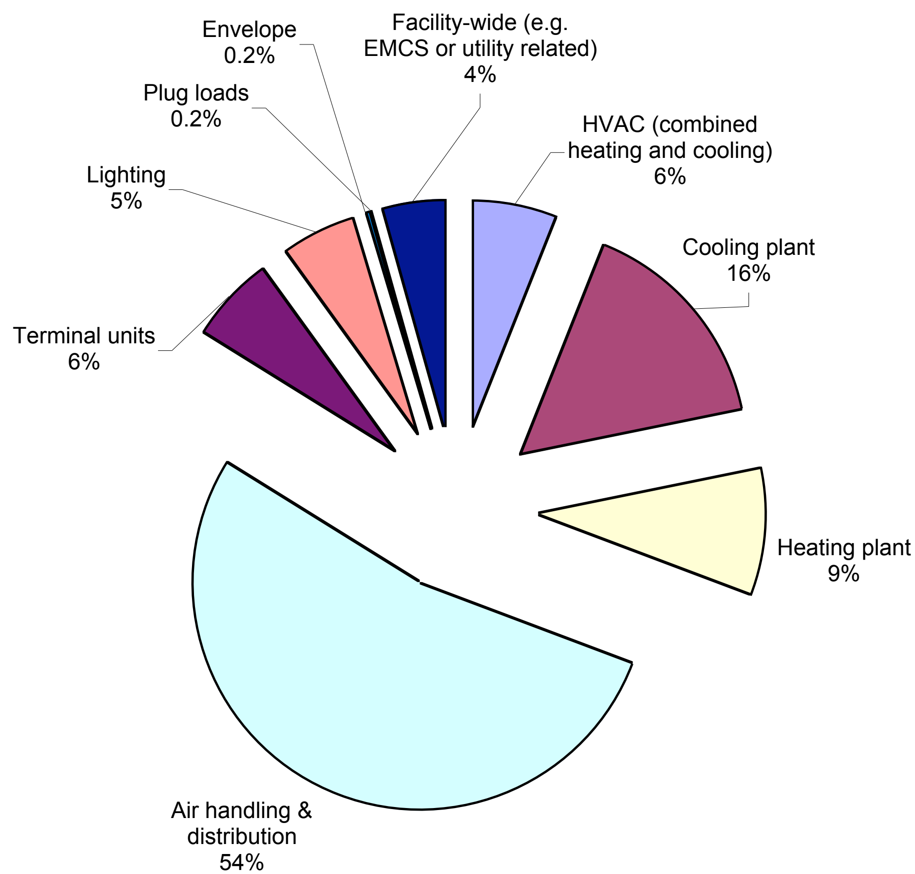


Reasons for Commissioning: New Construction

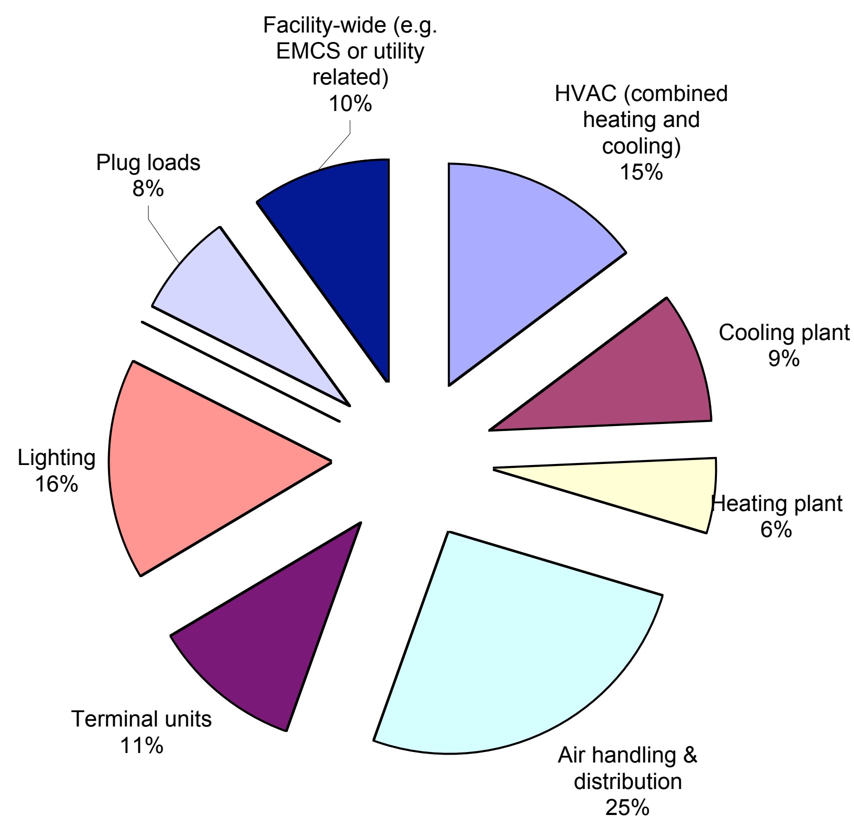


Types of Deficiencies Discovered

Existing (N=3500)



New (N=3300)



Measures Matrix

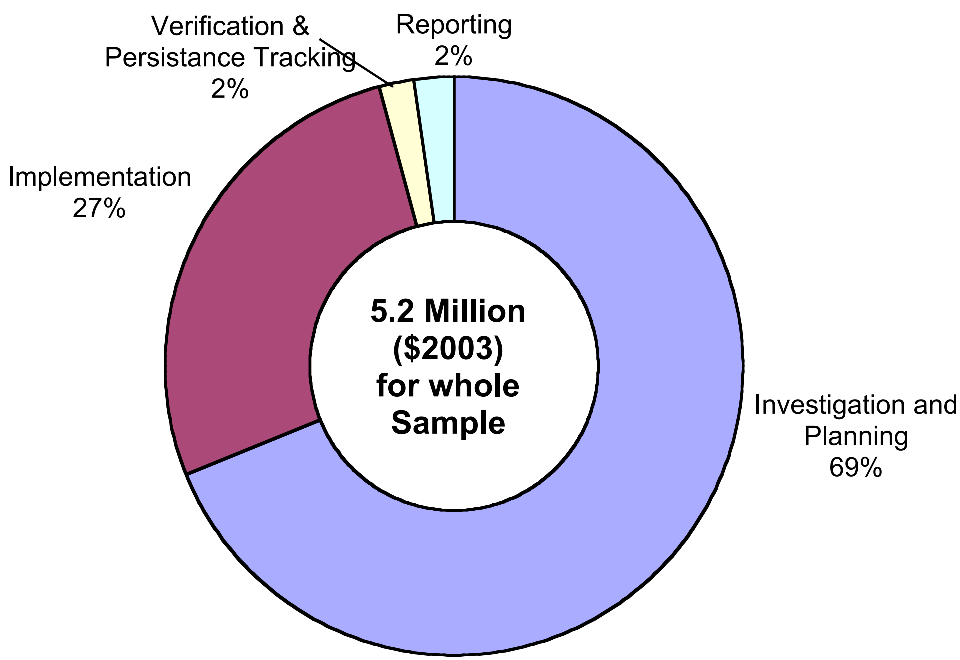
Results from Measures Matrices: Existing buildings (69 projects) [yellow highlights indicate most common measures, deficiencies, and combinations].

N (paired) = 702

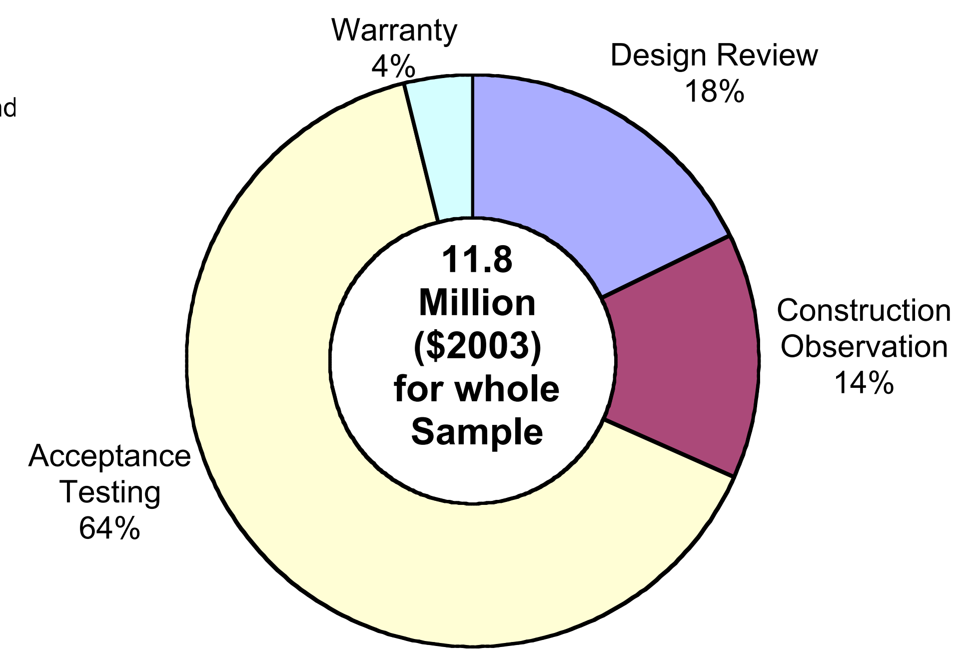
Deficiencies		Design, Installation, Retrofit, Replacement				Operations & Control									Maintenance					Deficiency unmatched to specific measure	Total
		Design change	Installation modifications	Retrofit/equipment replacement	Other	Implement advanced reset	Start/Stop (environmentally determined)	Scheduling (occupancy determined)	Modify setpoint	Equipment staging	Modify sequence of operations	Loop tuning	Behavior modification/manual changes to operations	Other	Calibration	Mechanical fix	Heat transfer maintenance	Filtration maintenance	Other		
		D1	D2	D3	D4	OC1	OC2	OC3	OC4	OC5	OC6	OC7	OC8	OC9	M1	M2	M3	M4	M5		
HVAC (combined heating and cooling)	V	0	2	8	1	1	1	5	3	1	5	0	0	2	5	7	1	5	2	12	61
Cooling plant	C	4	11	19	0	26	5	4	10	4	27	3	12	2	4	10	1	0	0	13	155
Heating plant	H	4	0	5	0	15	7	1	4	0	7	1	5	1	4	7	1	0	0	18	80
Air handling & distribution	A	15	9	19	3	80	9	21	25	4	24	12	14	6	40	27	3	4	2	40	357
Terminal units	T	1	3	2	1	4	0	3	14	0	4	1	2	1	7	10	0	0	0	8	61
Lighting	L	3	1	17	1	1	2	4	0	0	0	0	5	0	2	1	0	0	0	1	38
Envelope	E	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plug loads	P	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Facility-wide (e.g. EMCS or utility related)	F	2	3	2	0	1	0	7	0	0	1	1	7	2	2	2	1	0	0	3	34
Other	O	0	0	2	0	0	0	0	2	0	1	0	1	0	0	3	0	0	1	12	22
Deficiency unmatched to specific measure		10	9	7	0	2	2	1	29	2	7	2	4	1	12	10	0	0	0		809
Total		39	38	81	6	130	26	46	87	11	76	20	51	15	76	77	7	9	5	800	

Cost Allocation

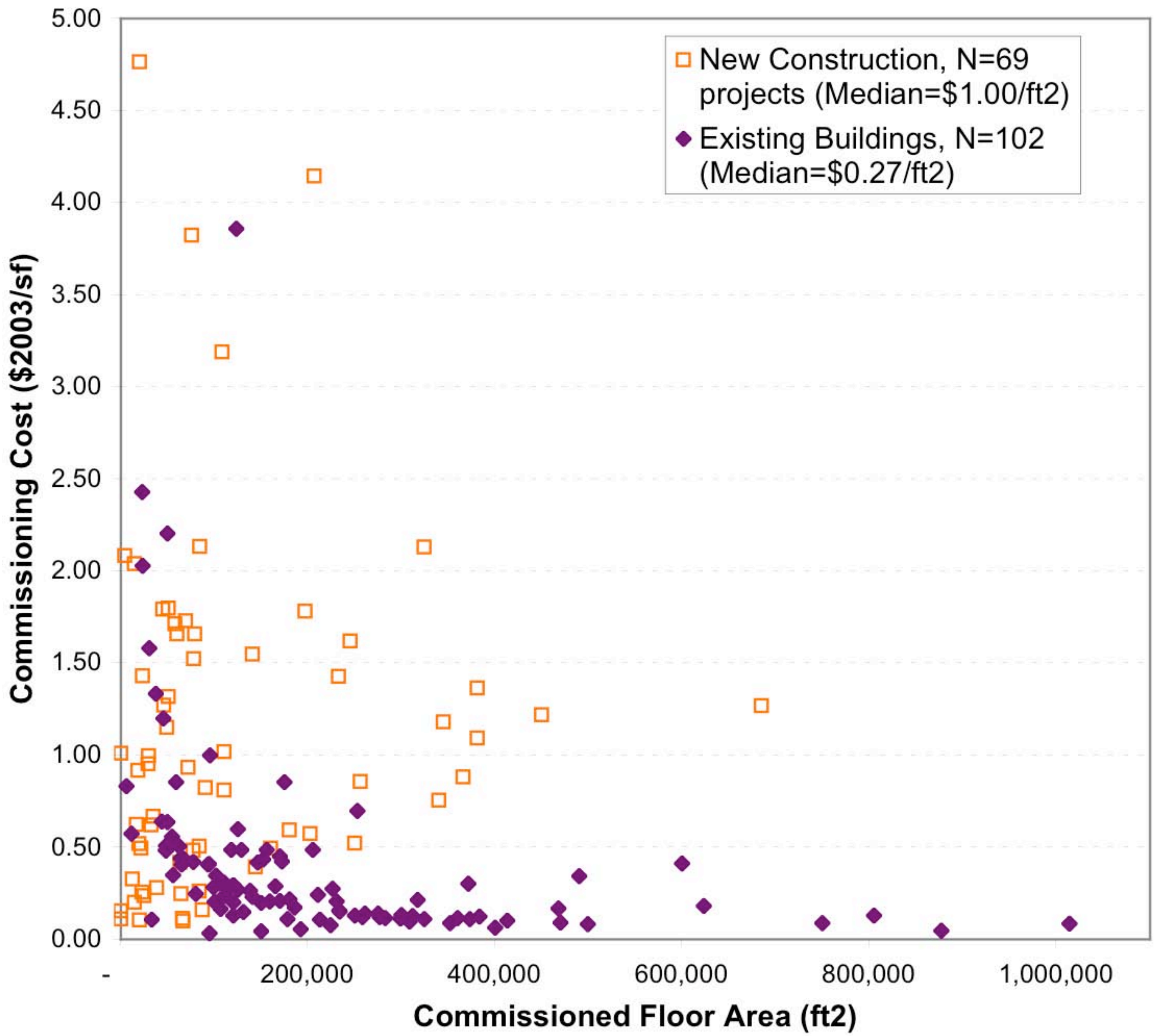
Existing Buildings (N=55)



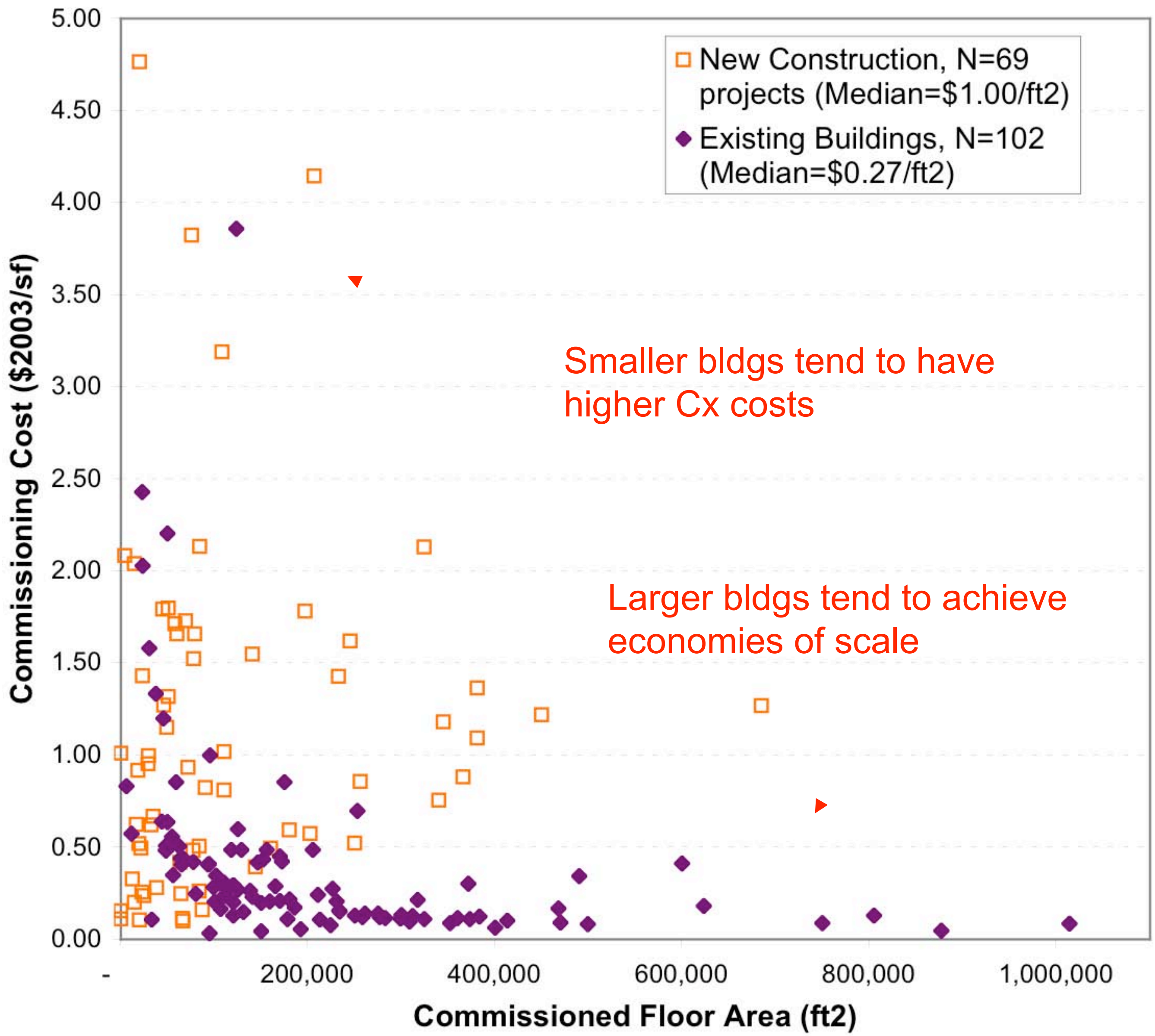
New Construction (N=5)



Normalized Costs

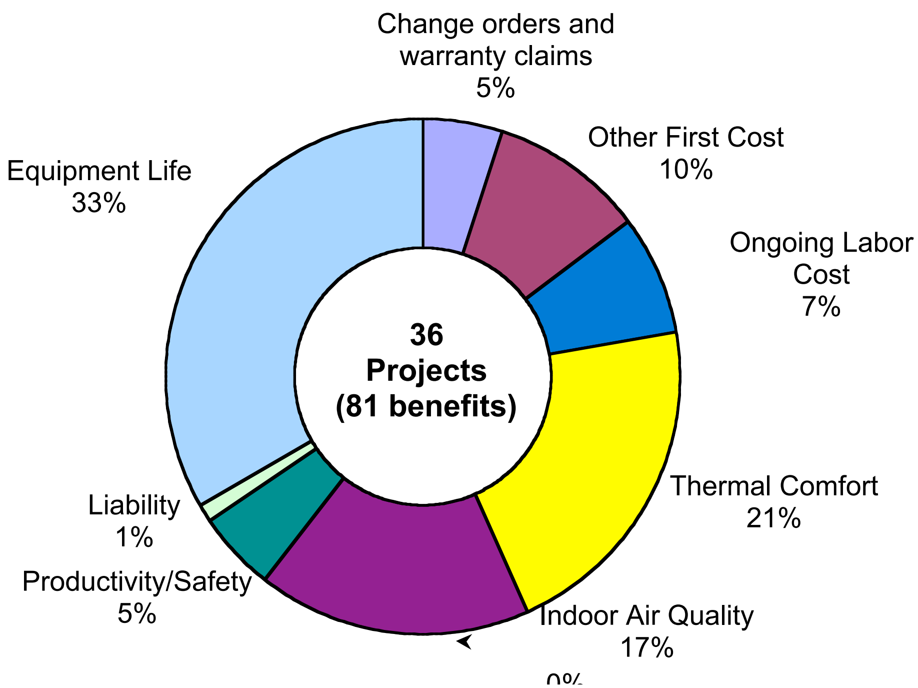


Outliers

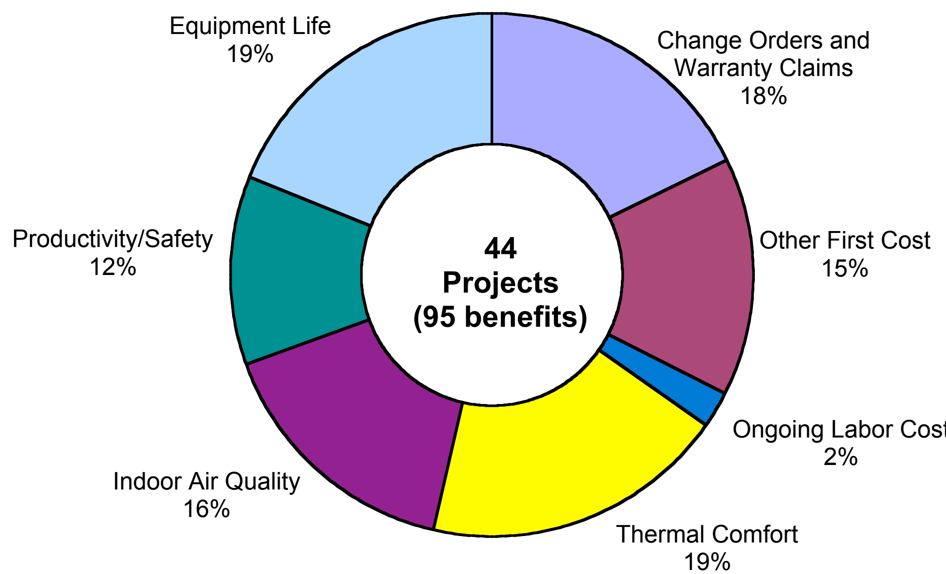

5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Commissioning Cost ($2003/sf)
-
200,000
400,000
600,000
800,000
1,000,000
Commissioned Floor Area (ft2)
New Construction, N=69 projects (Median=$1.00/ft2)
Existing Buildings, N=102 (Median=$0.27/ft2)
Smaller bldgs tend to have higher Cx costs
Larger bldgs tend to achieve economies of scale

Observed Non-Energy Impacts

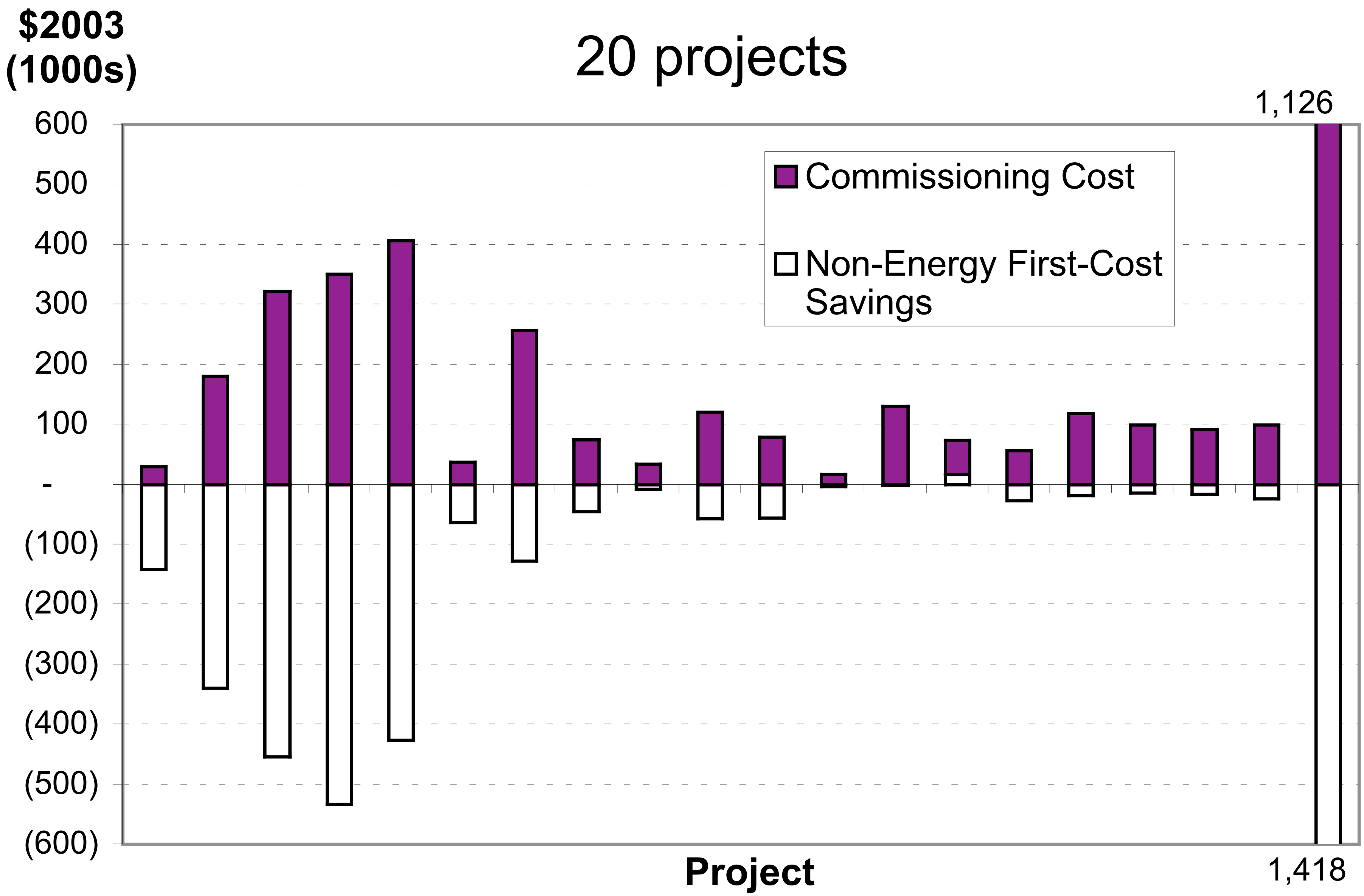
Existing Buildings



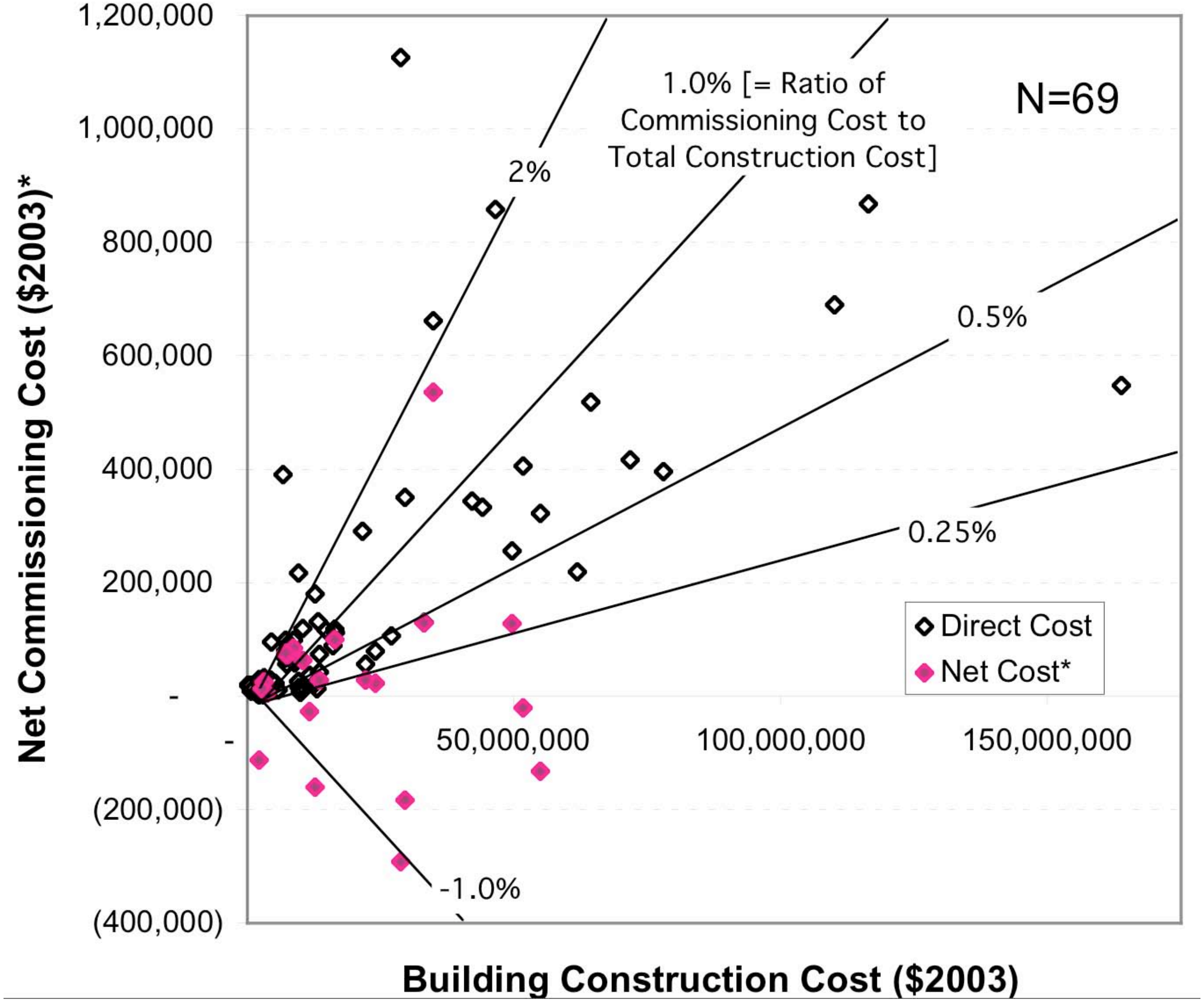
New Construction



Non-Energy Benefits Often Offset Cost of Commissioning

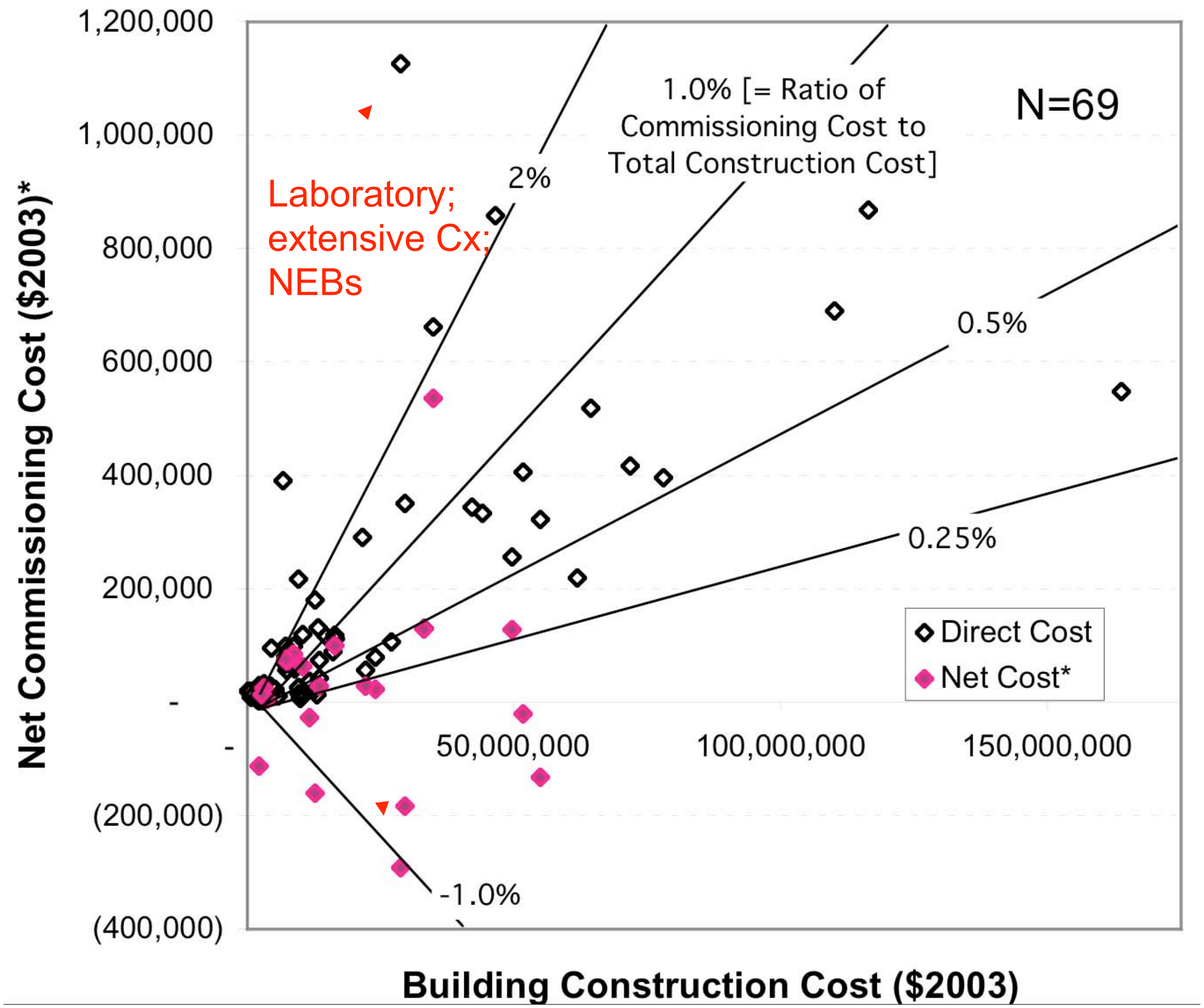


New Construction: Costs range from -1% to 2%+ of total construction cost



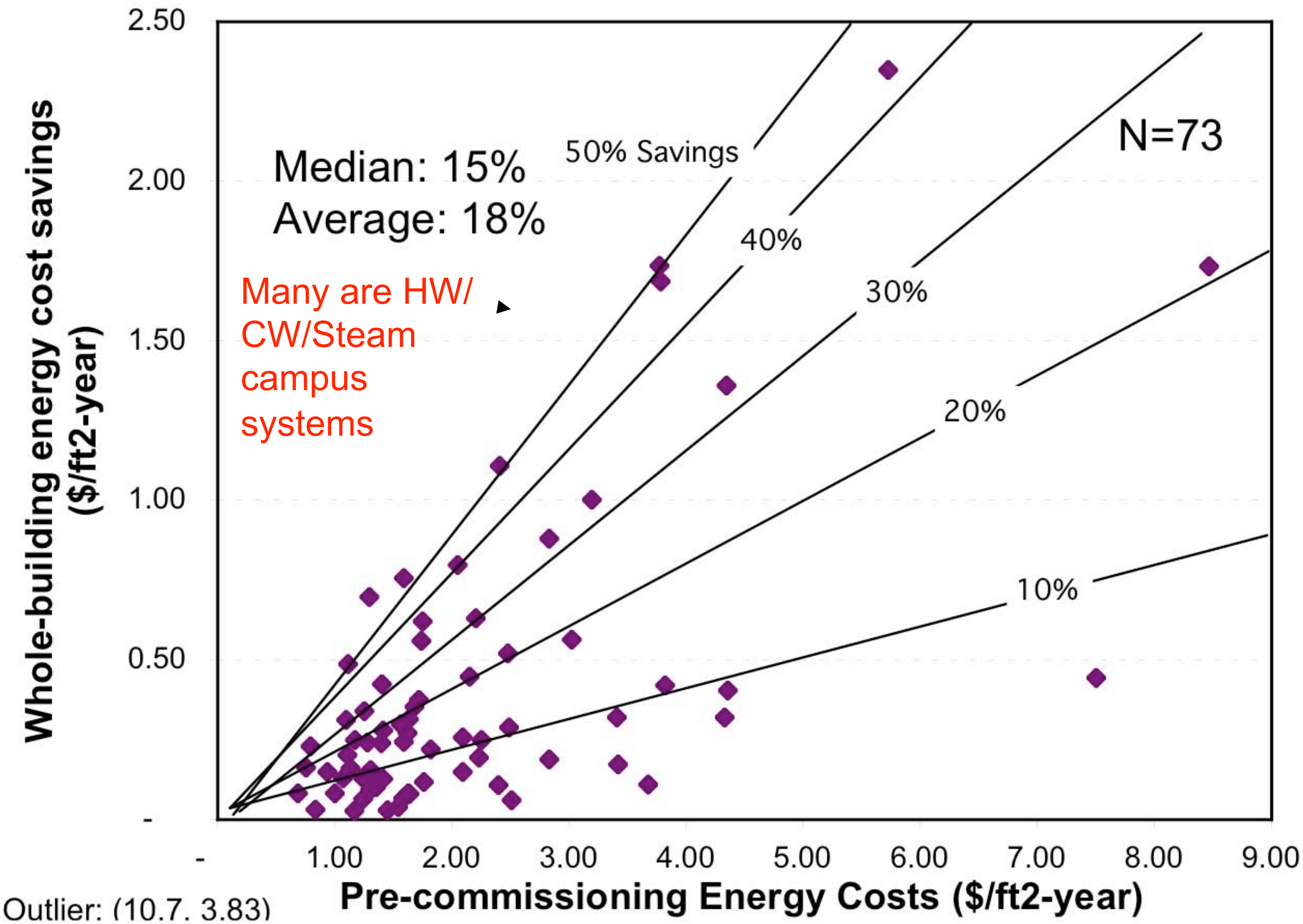
Inclusion of non-energy benefits (e.g. equipment downsizing, reduced callbacks, … significantly reduces costs

New Construction: Costs range from -1% to 2%+ of total construction cost



Inclusion of non-energy benefits (e.g. equipment downsizing, reduced callbacks, … significantly reduces costs

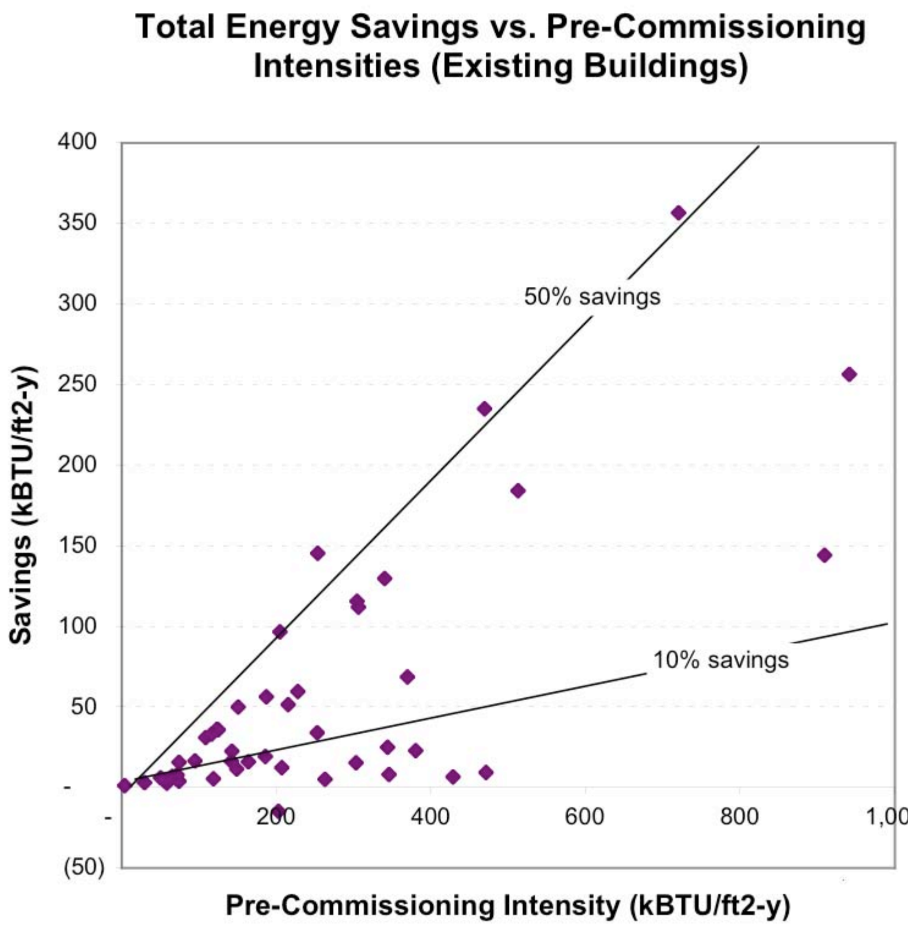
Up to 50% Whole-Building Energy Savings

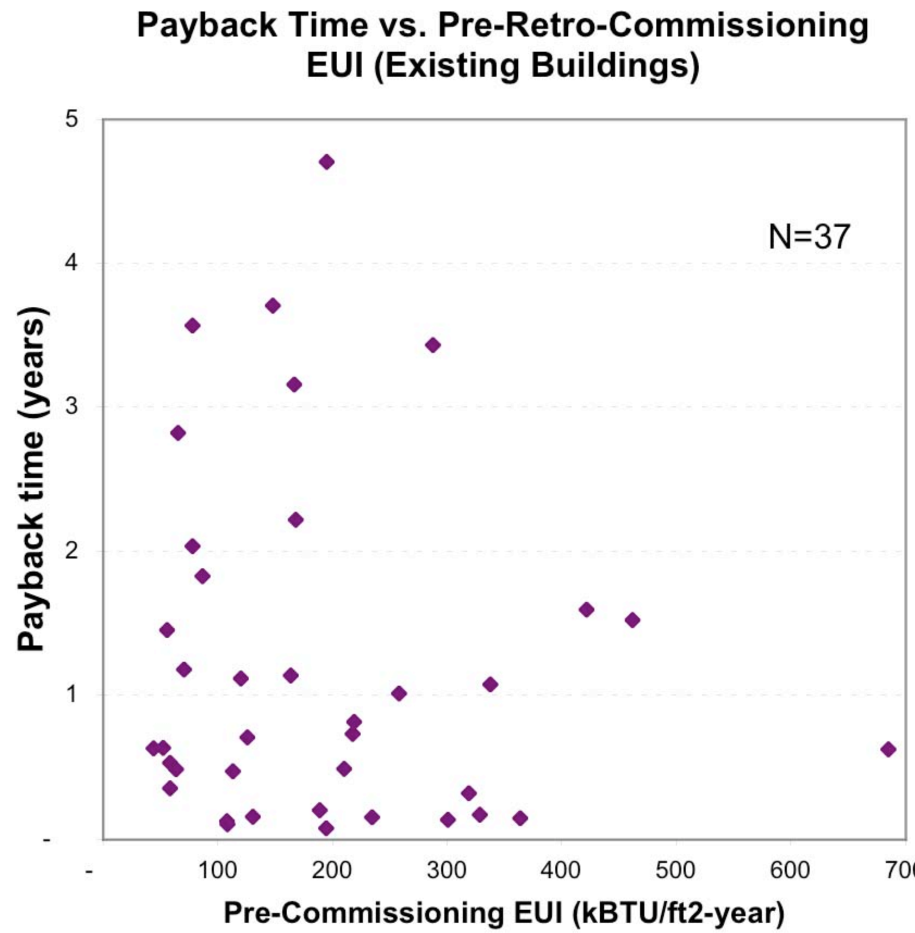


Outlier: (10.7, 3.83)

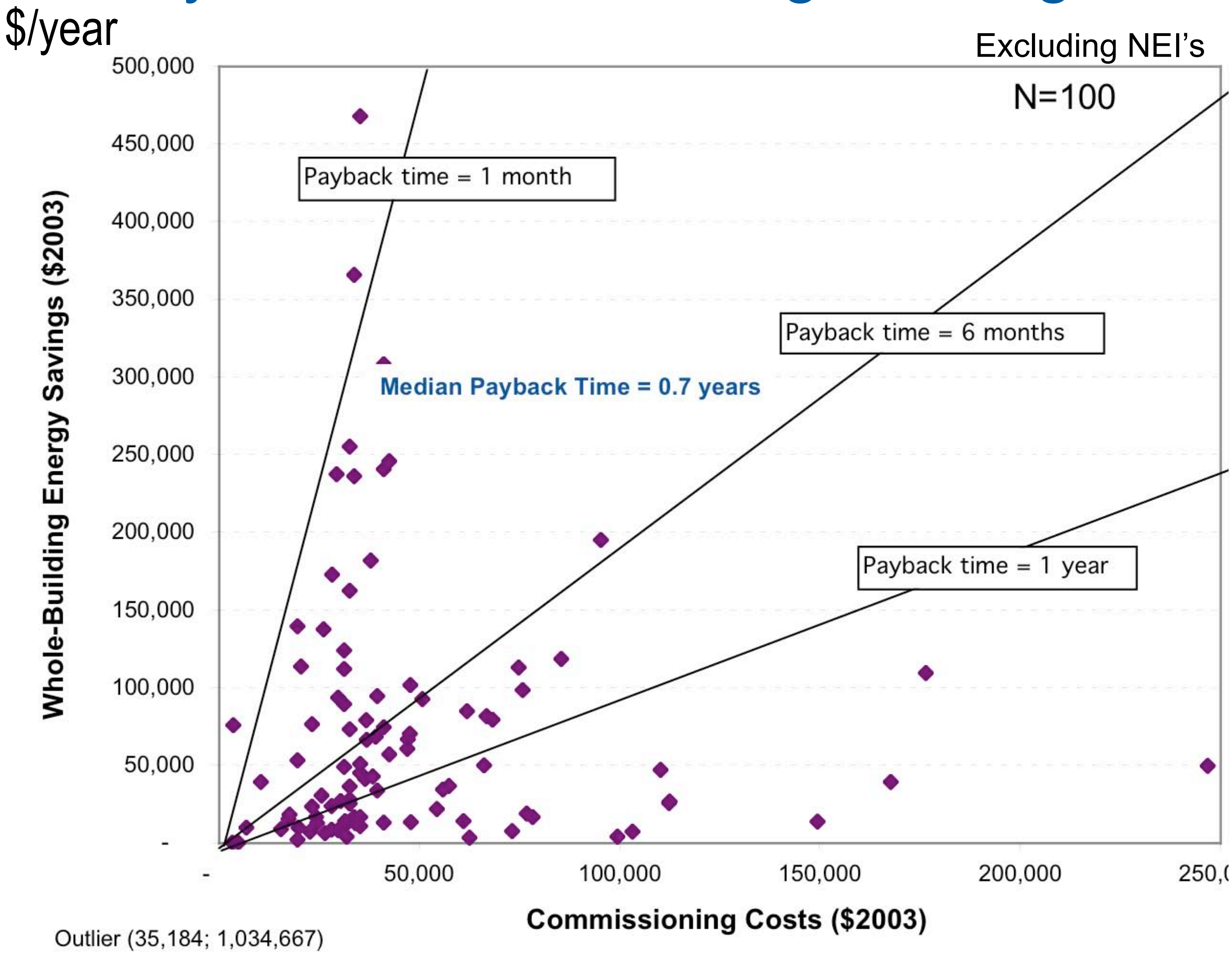
High savings even for non-energy-intensive buildings

Energy Savings & Payback Times Independent of Pre-Cx Energy Intensities



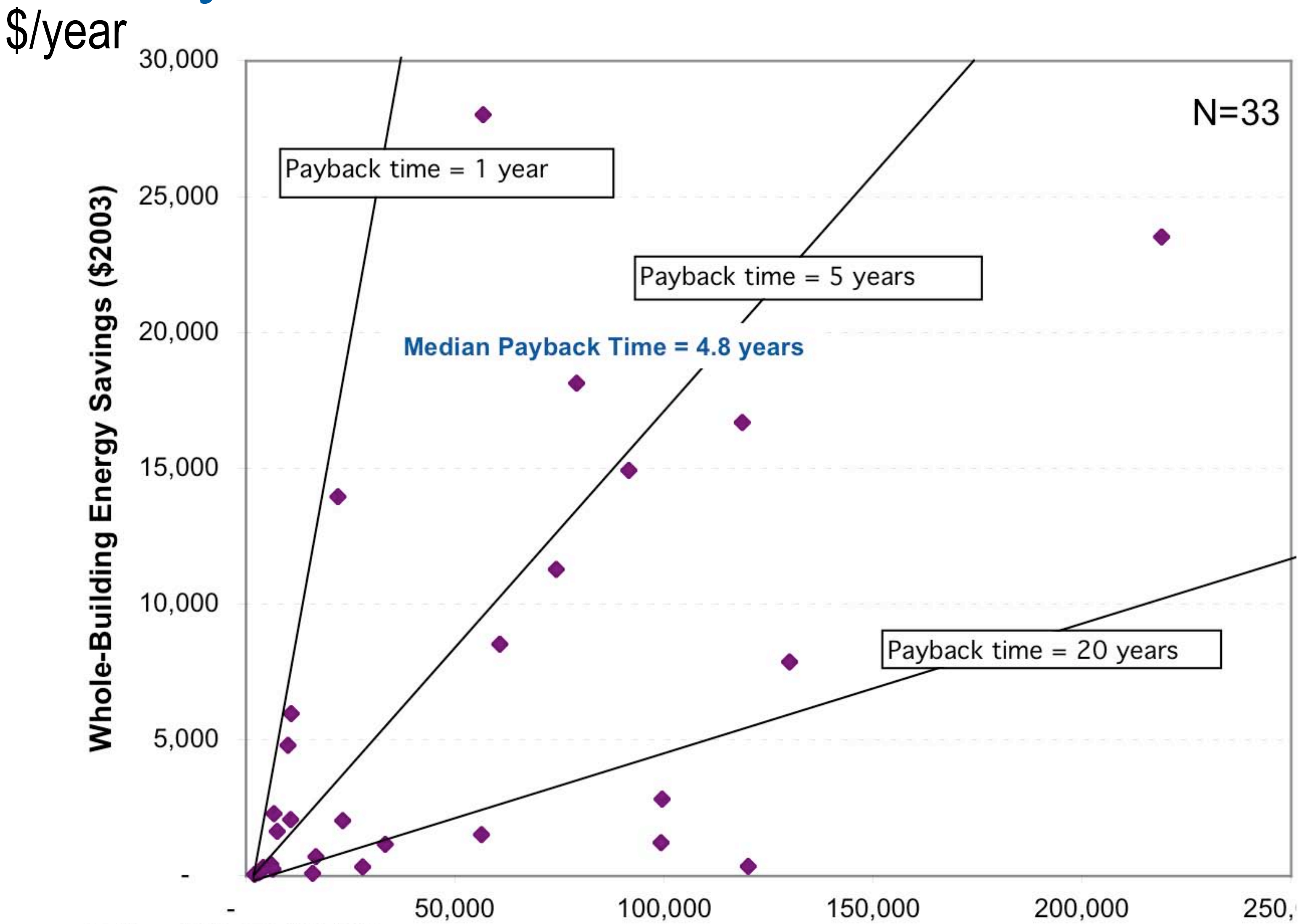


Payback Times: Existing Buildings



Attractive payback times across a range of Cx costs

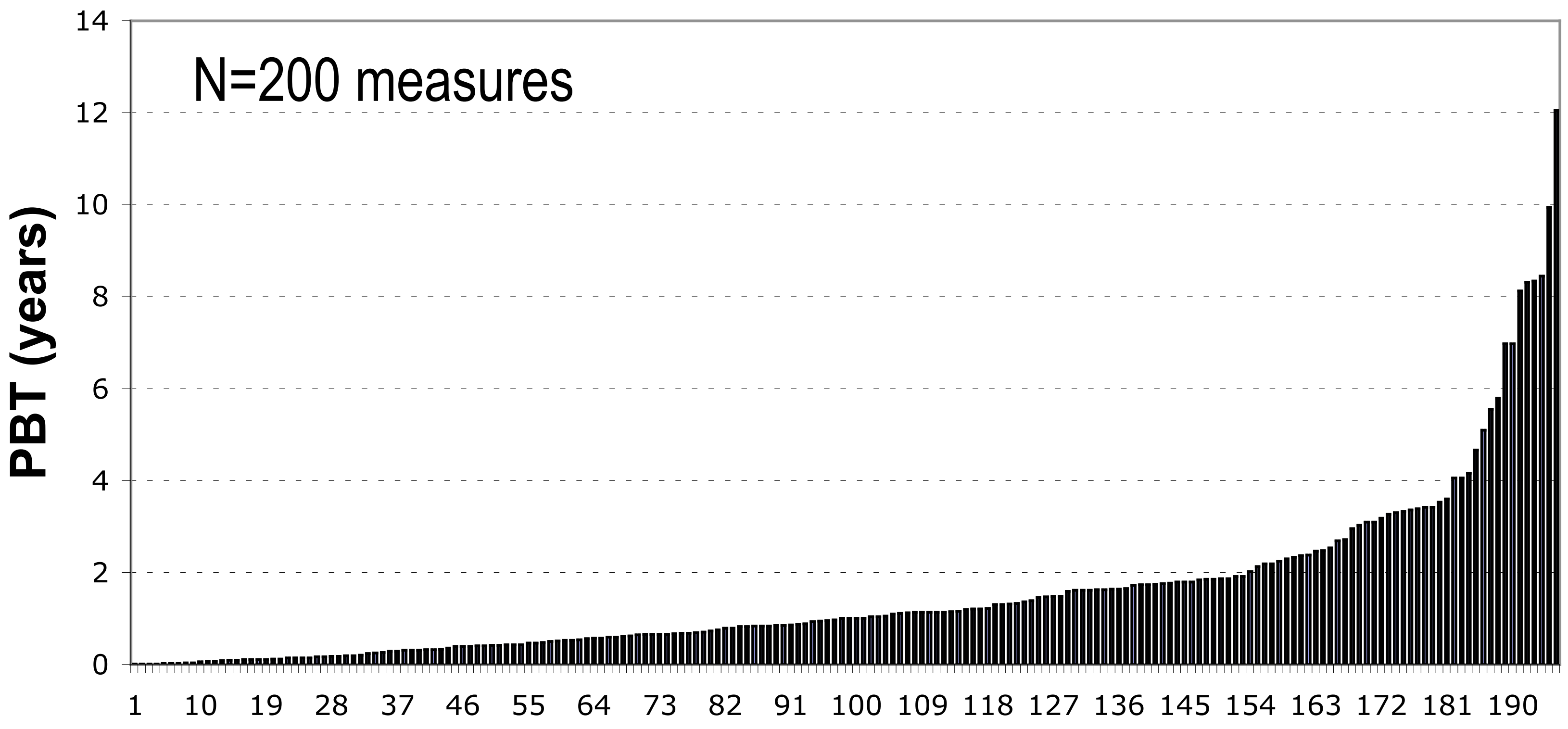
Payback Times: New Construction



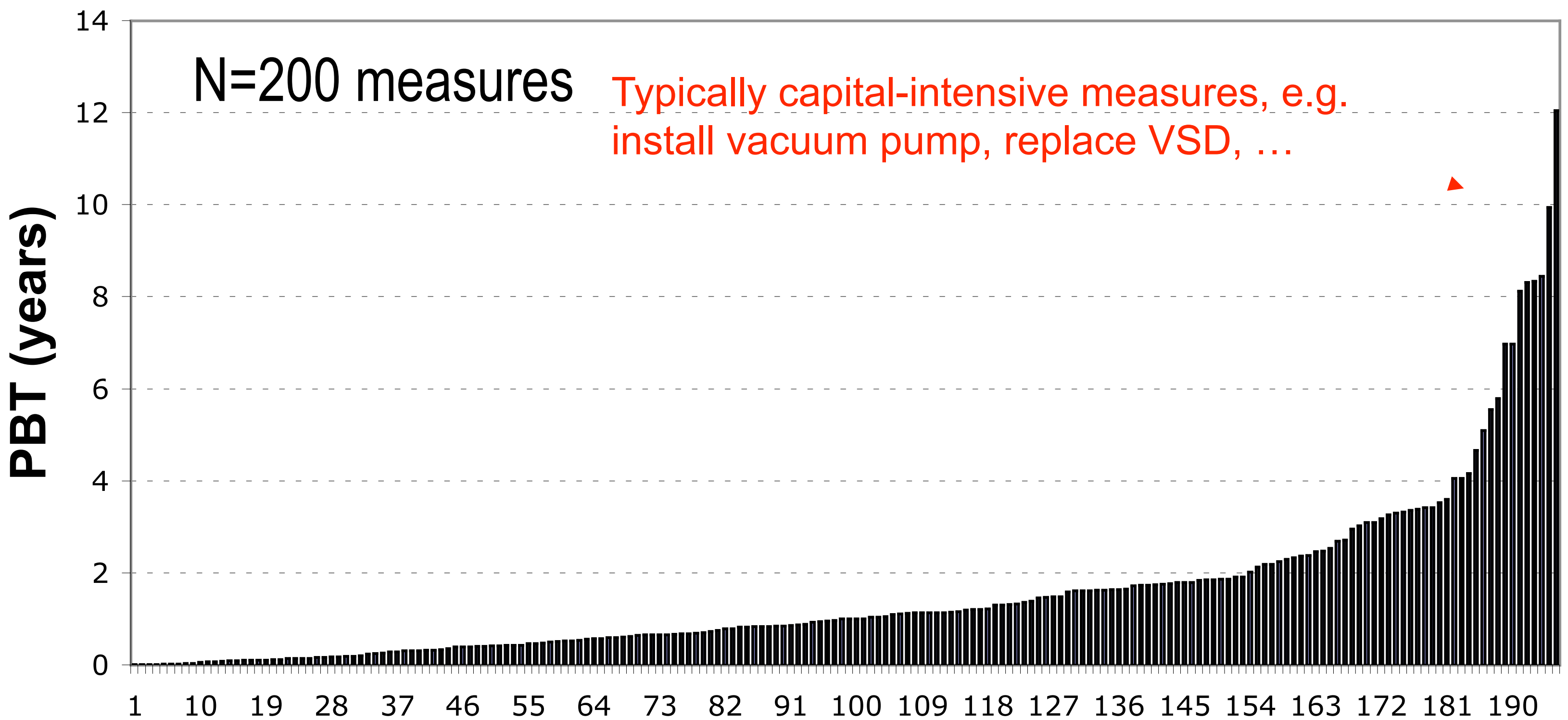
Outliers: (390,575;165,130), (661,752; 149,513), (1,126,000; 306.344)

Payback times not always attractive (if NEBs excluded)

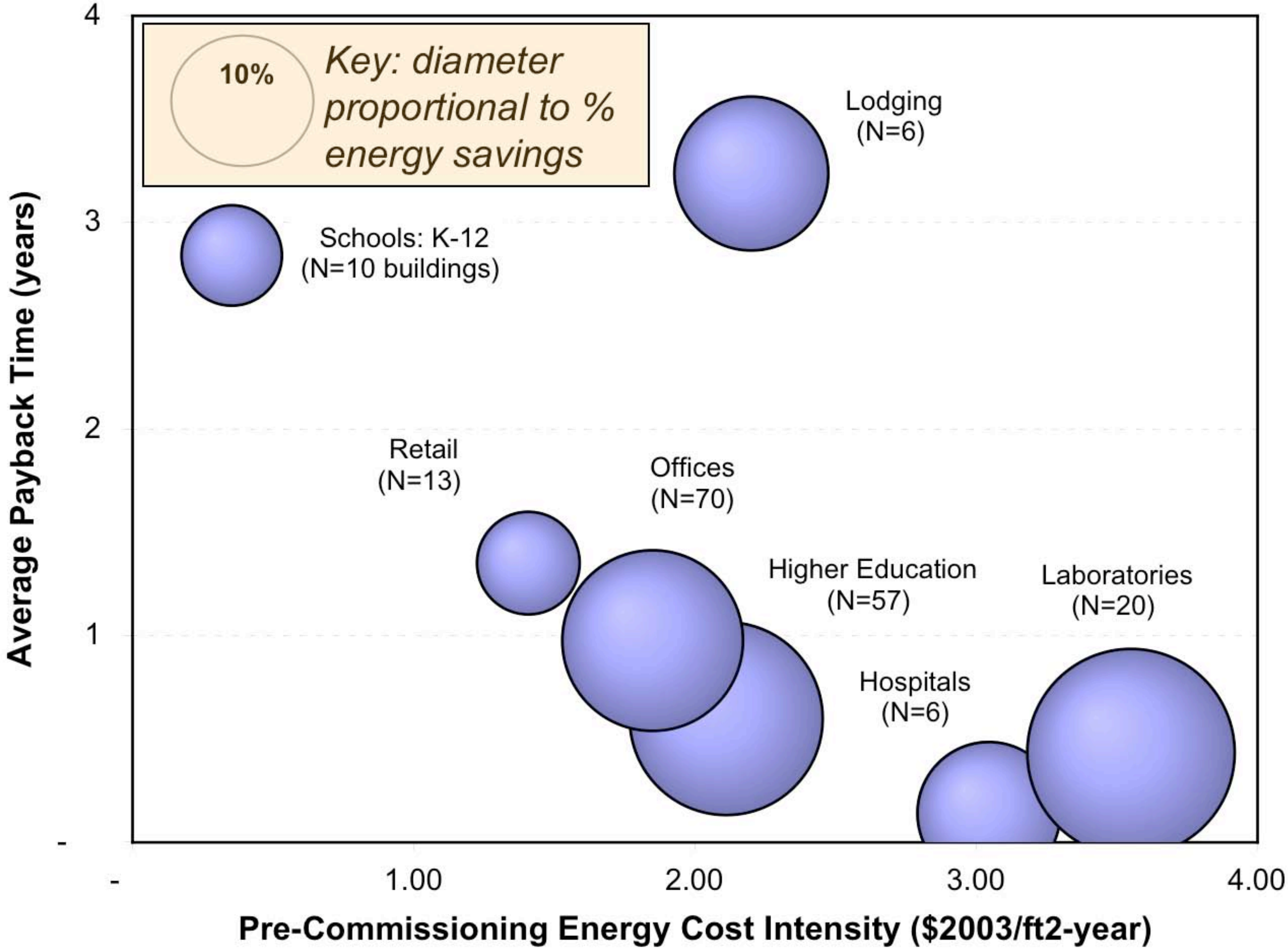
Payback Time Distribution by Measure



Payback Time Distribution by Measure

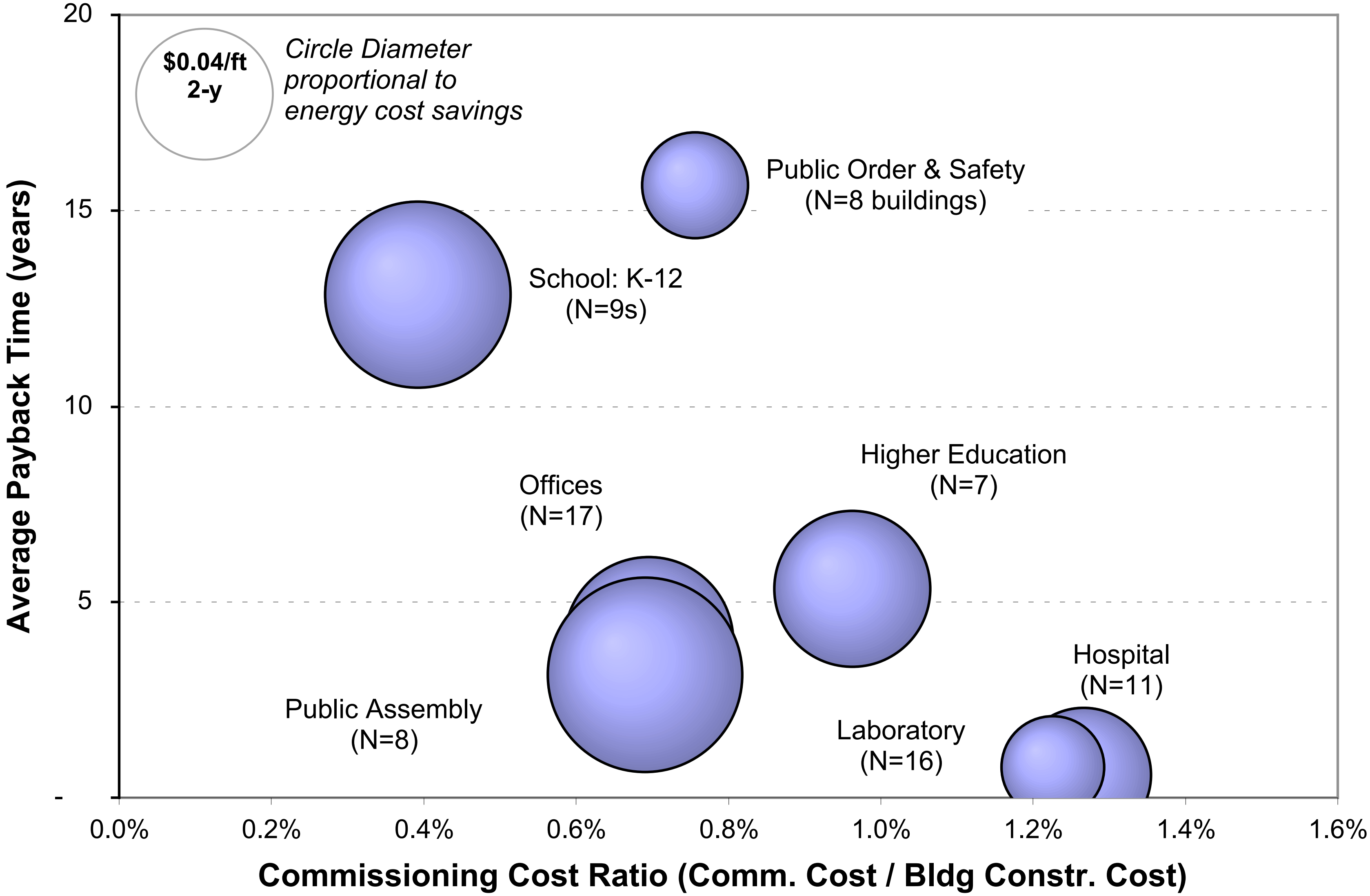


Results vary by building type: Existing Bldgs.



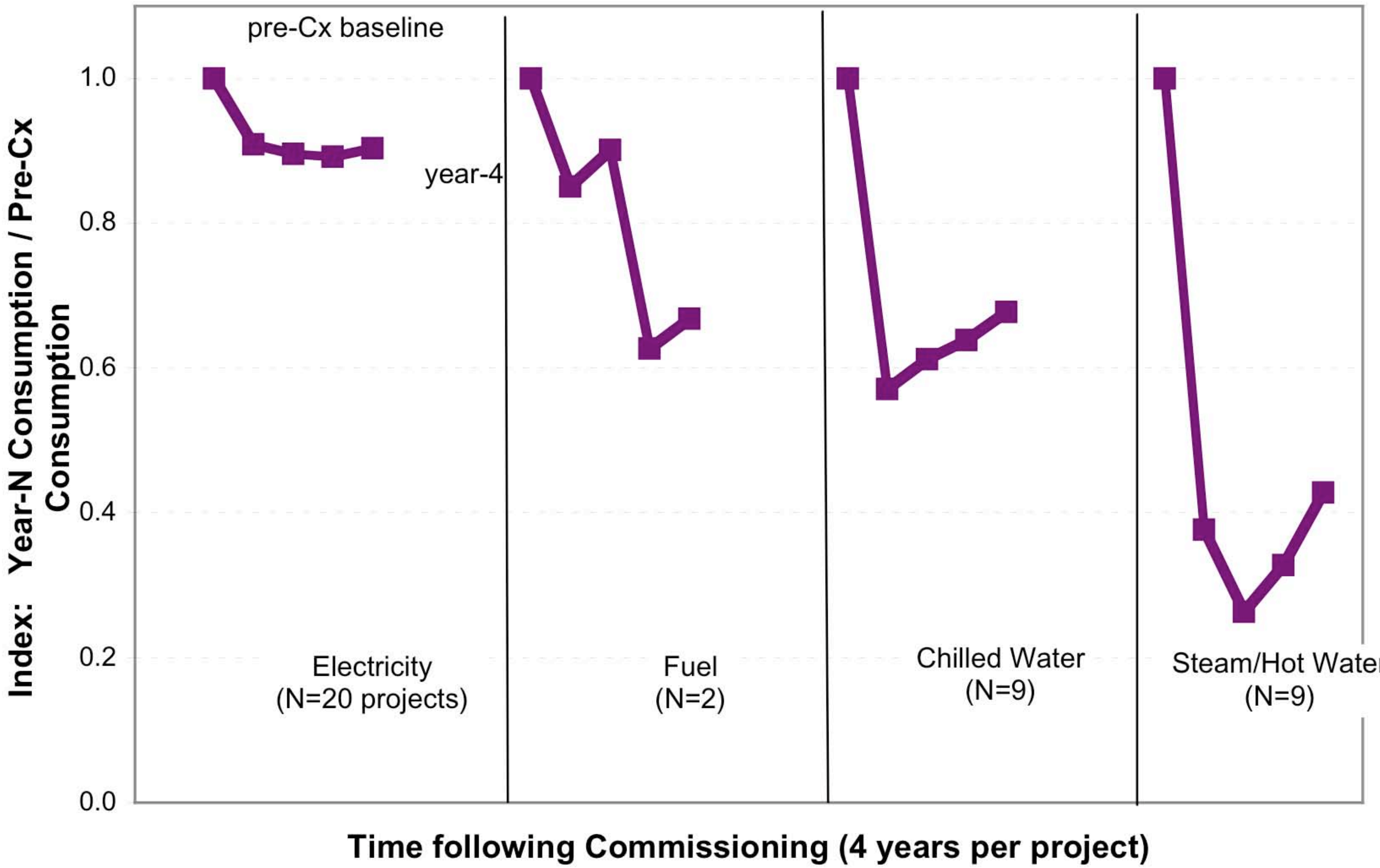
Excluding non-energy impacts

Results vary by building type: New const.



Excluding non-energy impacts

Emergence & Persistence of Energy Savings



Existing Buildings vs. New Construction

- Existing buildings
  - larger
  - greater normalized energy savings
  - more cost-effective (excluding NEBs)
- New construction
  - less comprehensive
  - normalized costs higher
  - larger non-energy benefits
  - NEBs are a more important motivation for embarking on commissioning, and can go farther in offsetting the cost of commissioning
  - more deficiencies found

National Potential; National Need

- $18 billion <u>annual</u> energy savings potential (US-wide) -- *plus* non-energy benefits

- Without commissioning, many energy-efficiency projects, programs, and policies will often fall short of their goals

Best Practices

Best Practices for Value Maximization

- Be thorough in the Cx process (savings likely to be higher)
- Catch problems at time of design (pre-construction)
- Fix problems as you go (to the extent possible)
- Do not get “dinged” for O&M, TAB, hardware upgrades, warranty-related work,…
- Emphasize NEBS (valued and unvalued – value not necessarily expressed in $)
- Meter for a reason; don’t skimp, but don’t pay for excessive accuracy. Temporary versus permanent loggers/meters
- Persistence enablers: design review, benchmarking, trending, system diagnostics, document sequences of operations, training
- Sampling (e.g. check 1 in 10 fan boxes)
- Quick tests: shut down bldg; wait one hour and restart (or come in AM) – you’ve step-changed almost every process [test for power recovery]
- Obtain and review complaint logs
- Limited budget: design review, design for lowest-cost O&M and future RCx, functionally test critical items, trend analysis

Recommendations

No energy management program is complete without commissioning (in-house or outsourced)

- Invest in commissioning (existing buildings and new construction)
- Institutionalize the process
- Benchmark, track outcomes, ensure persistence, refine process

Evaluation Tool

Cx Project Evaluation Tool

- A simple spreadsheet tool for cataloging, comparing, and evaluating commissioning project information
- Pre/post energy use, costs, savings, payback times
- Project characteristics
- Non-energy impacts

Download: http://eetd.lbl.gov/emills/PUBS/Cx-Costs-Benefits.html

Cx Project Evaluation Tool

- TABS
  - Instructions
  - Main Data Sheet
  - Measures
  - Measures Key
  - Building Type Key
  - M&V Key
  - Cost Rules
  - Non-Energy Impacts

Cx Project Evaluation Tool

Cx_CB_Template.xls

Cost-Effectiveness of Commercial Buildings Commissioning

Lawrence Berkeley National Laboratory

Version: November 20, 2005

The overall goal of this project is to gather real-world data on the costs and energy savings of new- and existing-buildings commissioning. We welcome contributions of data where preferably both energy savings and/or commissioning cost data are available. Address comments/questions to Evan Mills, 510-486-6784 or emills@lbl.gov.

It is not expected that all data will be available for all projects. Enter data only in color-shaded cells (other cells will be calculated or should not otherwise be altered).

1. THIS WORKBOOK

This workbook has six tabs, as described below. There are two tabs in which to enter data, and the rest are informational: 1. The "Main Data Sheet" (primary database) and "Measures" (details on measures). The other tabs provide background information. **As the worksheets will be ultimately be merged, do not alter the structure (except as noted below), I.e. do not insert/delete rows or columns or change labels. PLEASE enter information in the exact units shown; adding extraneous information will confound our efforts to tabulate and otherwise analyze the results. Use Excel's "Comments" feature to attach clarifying information, notes, or questions.**

Main Data Sheet

The design is intended to collect the results in a single column ("record") per project. Do not insert or delete rows; do not modify row labels. **Please group the columns for existing-buildings projects and new-construction projects. Where data are available at a finer level of detail (by measure), complete a table on the "Measures" tab, with one row per measure (including associated energy savings, where available).**

Cx Project Evaluation Tool

Cx_CB_Template.xls

	A	B	C	D
1	**Data Collection Instrument for LBNL Commissioning Cost-Benefits Analysis**			
3	Version: November 20, 2005	Units	Notes	EXAMPLE
6	PROJECT DESCRIPTION			
7	Name of person completing this entry	text		John Doe
8	Case Identifier	PECI-#, TAMU-#, LBNL-#, etc.	For internal tracking	Project 1-Rx
9	Commissioning provider			Commissioners Inc (Seattle, WA)
10	Existing building (RCx); New construction (Cx)	Cx; RCx	new	RCx
11	Was the building previously commissioned?	Y; N	existing	N
12	Commissioning project leader's level of experience	number of projects previously completed (number only; no text)	Applies to project leader, not firm. Do not include general "energy efficiency experience"; R/Cx only	75
13	Building name and street address (if PUBLIC INFORMATION)	text	Data will be included in final report	Courthouse
14	Building name and street address (if CONFIDENTIAL)	text	Data will be kept confidential, I.e. not included in final report	
15	Location - City	text		Boise
16	Location - State	Postal Abbreviation		ID
17	Building Ownership	Public; Private		Public

Cx Project Evaluation Tool

Cx_CB_Template.xls

Use this matrix to enter measures for which itemized costs and energy savings estimates are available.

INSTRUCTIONS: Check (only) one Components box and one Strategies box per row with an "x". Two checks per row only. Multiple checks per category will not be recognized. Limit number of measures (rows) to 19, and conclude with a 20th row labeled "Other" which should include the sum total of any residual values not itemized in the preceding rows. Priority for itemized measures should be given to items that combine high energy savings and attractive payback times. See "Measures Key" tab for definitions, and "M&V Options Tab for key to M&V Code.

Recommended measures known to have been rejected should be collected in the last (21st) row (and aggregated into a numerical value for each column). Costs and energy savings estimates should not be included for these items.

Note: Unshaded columns and rows will automatically calculate; do not alter formulas

SAMPLE

Project ID Number: (e.g. PECI-4)

Components (locus of fault)										Measures																				
										Design, Installation, Retrofit, Replacement				Operations & Control									Maintenance							
HVAC (combined heating and cooling)	Cooling plant	Heating plant	Air handling & distribution	Terminal units	Lighting	Envelope	Plug loads	Facility-wide (e.g. EMCS or utility related)	Other	Design change	Installation modifications	Retrofit/equipment replacement	Other	Implement advanced reset	Start/Stop (environmentally determined)	Scheduling (occupancy determined	Modify setpoint	Equipment staging	Modify sequence of operations	Loop tuning	Behavior modification/manual changes to operations	Other	Calibration	Mechanical fix	Heat transfer maintenance	Filtration maintenance	Other			Savings Estimation Approach
V	C	H	A	T	L	E	P	F	O	D1	D2	D3	D4	OC1	OC2	OC3	OC4	OC5	OC6	OC7	OC8	OC9	M1	M2	M3	M4	M5	Measure Code	Implemented [Y; Unknown; Rejected]	(IPMVP A;B;C;D or Estimated)
							x												x									P-OC6	Y	B
			x														x											A-OC4	U	E
			x												x													A-OC2	Y	C
			x													x												A-OC3	Y	D
			x													x												A-OC3	etc.	etc.

Cx Project Evaluation Tool

Cx_CB_Template.xls

	A	B
1	**KEY TO MEASURE DEFINITIONS**	
2		
3	**Design, Installation, Retrofit, Replacement**	
4		**Code**
5	**Design, Installation, Retrofit, Replacement**	**D1**
6	Design problems found and corrected during design review of a new building (Cx), a design problem physically corrected or circumvented (during Cx or RCx). [Problems with the design of control sequences are accounted for under "Control".]	
7		
8	**Installation modifications**	**D2**
9	To address improper installation of equipment, sensors, distribution systems, etc.	
10		
11	**Retrofit/equipment replacement**	**D3**
12	RCx strategies to improve the performance of a system, as distinct from a change in design [treated above].	
13		
14	**Other**	**D4**
15	Other design, installation, retrofit, or replacement measures.	
16		
17	**Operations & Control**	
18		
19	**Implement advanced reset**	**OC1**
20	Recommended modifications to reset schedules of HVAC processes. E.g., Supply Air Temperature reset based on Outside Air Temperature.	
21		
22	**Start/Stop (environmentally determined)**	**OC2**
23	Recommendations that affect environmentally determined equipment control settings (e.g., chiller or boiler lockouts that based on out side air dry bulb temperature or seasonally determined equipment operation).	

Cx Project Evaluation Tool

Cx_CB_Template.xls

A

BUILDING TYPE DEFINITIONS (From DOE CBECS)

Description of Building Types Used in the MSE Energy Calculator

In the Commercial Buildings Energy Consumption Survey (CBECS), upon which our calculator is based, buildings were classified according to principal activity, which was the primary business, commerce, or function carried on within each building. Buildings that were used for more than one of the activities described below were assigned to the activity occupying the most floorspace at the time of the interview. Thus, a building assigned to a particular principal activity category may have been used for other activities in a portion of its space or at some time during the year.

Each of the principal activity categories is listed alphabetically and described below. Lists of specific types of buildings included in each category are presented for clarification but are not intended to be exhaustive.

1. **Agricultural:** See Other.

2. **Education:** refers to buildings used for academic or technical classroom instruction. This category includes the following:

Schools:
- Preschool
- Elementary
- Junior high
- Senior high
- College or university classroom/Laboratories
- Vocational school.

Other activities that occur on school campuses are reported separately:
- Administration (see Office)
- Auditorium (see Public Assembly)
- Dormitory (see Lodging)
- Gymnasium (see Public Assembly)
- Infirmary (see Health Care)
- Library (see Public Assembly)
- Museum (see Public Assembly)
- School for the Mentally Retarded (see Health Care)
- Stadium (see Public Assembly)
- Student Union (see Public Assembly).

Cx Project Evaluation Tool

Cx_CB_Template.xls

Table 1: Overview of M&V Options

M&V Option	How Savings Are Calculated	Typical Applications
A. Partially Measured Retrofit Isolation Savings are determined by partial field measurement of the energy use of the system(s) to which an ECM was applied, separate from the energy use of the rest of the facility. Measurements may be either short-term or continuous. Partial measurement means that some but not all parameter(s) may be stipulated, if the total impact of possible stipulation error(s) is not significant to the resultant savings. Careful review of ECM design and installation will ensure that stipulated values fairly represent the probable actual value. Stipulations should be shown in the M&V Plan along with analysis of the significance of the error they may introduce.	Engineering calculations using short term or continuous post-retrofit measurements and stipulations.	Lighting retrofit where power draw is measured periodically. Operating hours of the lights are assumed to be one half hour per day longer than store open hours.
B. Retrofit Isolation Savings are determined by field measurement of the energy use of the systems to which the ECM was applied, separate from the energy use of the rest of the facility. Short-term or continuous measurements are taken throughout the post-retrofit period.	Engineering calculations using short term or continuous measurements	Application of controls to vary the load on a constant speed pump using a variable speed drive. Electricity use is measured by a kWh meter installed on the electrical supply to the pump motor. In the base year this meter is in place for a week to verify constant loading. The meter is in place

Resources

- PECI
  http://www.peci.org
- CA Commissioning Collaborative online library
  http://resources.cacx.org/library/
- LBNL cost-benefit study
  (and spreadsheet download)
  http://eetd.lbl.gov/emills/PUBS/Cx-Costs-Benefits.html
- Commissioning Functional Test Guide
  http://buildings.lbl.gov/hpcbs/FTG
- Design Intent Tool
  http://ateam.lbl.gov/DesignIntent/home.html
- Energy Design Resources
  http://energydesignresources.com
- Pacific Energy Center Cx workshops!

Participate in our Research
Contribute Data

Evan Mills

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510-486-6784 • emills@lbl.gov

http://eetd.lbl.gov/emills/PUBS/Cx-Costs-Benefits.html