

2018 Commissioning Cost/Benefit Study Findings

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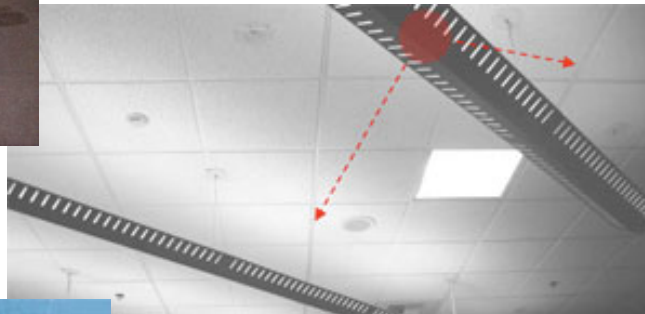
BACKGROUND

What is Cx? (New Construction, “NCCx”)

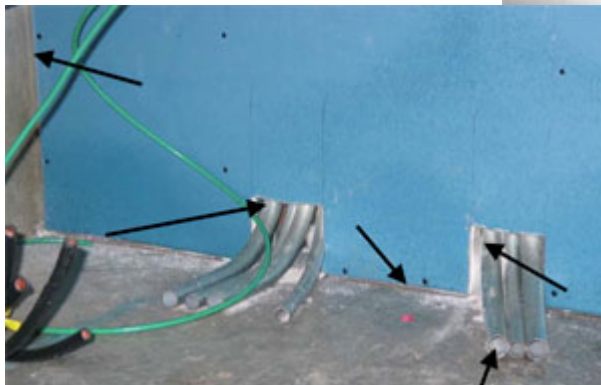
Example issues uncovered by NCCx



Piping design interferes with shut-off valve handle



Interior lighting shines directly on photosensor, interfering with daylighting controls



Pathways for conditioned air to escape

NCCx Process



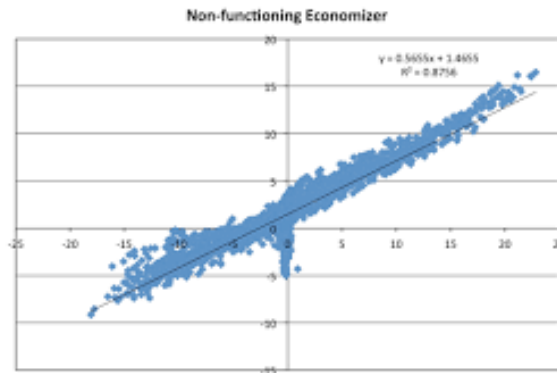
Source: California
Commissioning Collaborative

What is Cx? (Existing Buildings, “EBCx”)

Example issues uncovered by EBCx

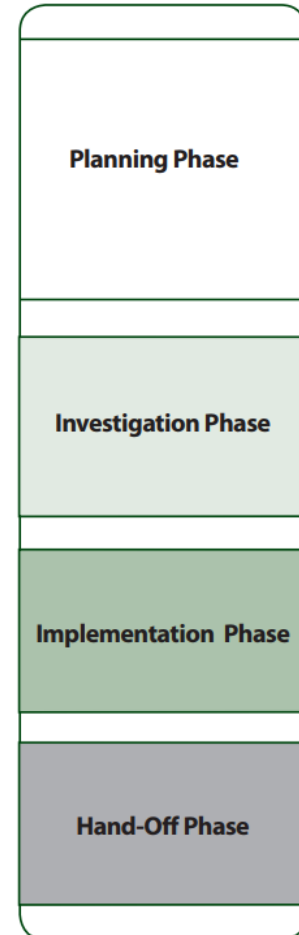


Interior lighting is often found to be on during unoccupied periods



Data analysis can uncover problems with economizer dampers

EBCx Process



Source: California Commissioning Collaborative

Prior Cx Cost Benefit Studies

Mills, E., H. Friedman, T. Powell, N. Bourassa, D. Claridge, T. Haasl, and M. A. Piette. 2004. *"The Cost-Effectiveness of Commercial-Buildings Commissioning: A Meta-Analysis of Energy and Non-Energy Impacts in Existing Buildings and New Construction in the United States."* Lawrence Berkeley National Laboratory.

Mills, E. 2009. *"Building Commissioning: A Golden Opportunity for Reducing Energy Costs and Greenhouse Gas Emissions."* Lawrence Berkeley National Laboratory.

THE COST-EFFECTIVENESS OF COMMERCIAL BUILDINGS COMMISSIONING A Meta-Analysis of Existing Buildings and New Construction in the United States

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¹Lawrence Berkeley National Laboratory
²Portland Energy Conservation Inc.
³Energy Systems Laboratory, Texas A&M University

November 23, 2004

LBNL - 56637

Acknowledgments: This work was sponsored by the Assistant Secretary for Energy Efficiency and Renewable Technologies Program, U.S. Department of Energy under Contract No. DE-AC03 76SF00098. In addition, project data, other useful case-study information and review were provided by (Consulting), Adam Benzuly (Affiliated with Lawrence Berkeley National Laboratory), John

Building Commissioning A Golden Opportunity for Reducing Energy Costs and Greenhouse Gas Emissions

Evan Mills, Ph.D.
Lawrence Berkeley National Laboratory
Berkeley, CA 94720 USA

Report Prepared for:
California Energy Commission
Public Interest Energy Research (PIER)

July 21, 2009

For a downloadable version of the report and supplementary information, visit:
<http://cx.lbl.gov/2009-assessment.html>

Key Research Questions for 2018 Study

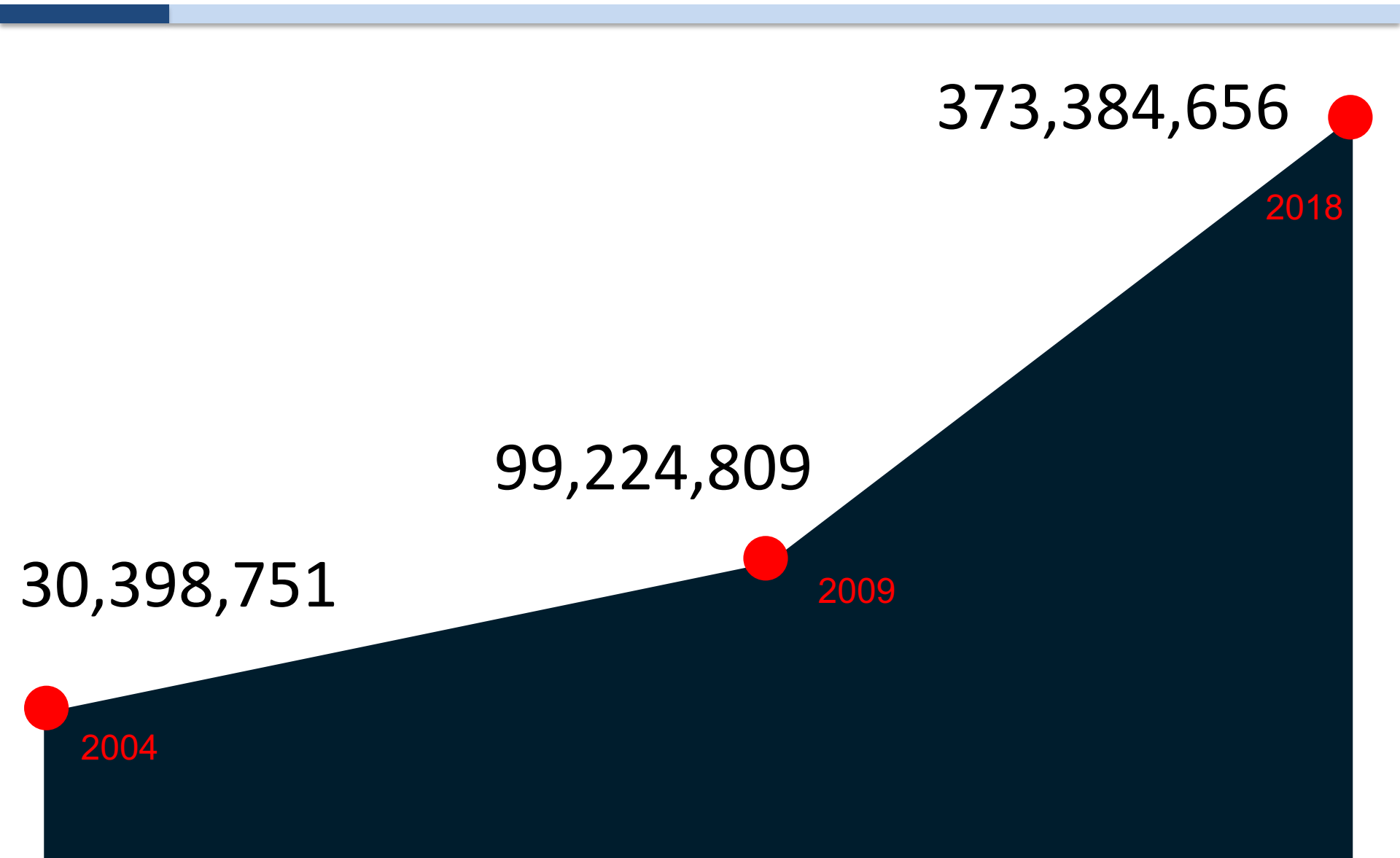
- Are key project metrics different compared to 2009? (savings, costs, payback)
- How do project results vary by region, building type, building size?
- How do EBCx costs/savings compare between utility-funded projects and non-utility projects?
- Have finding/measure types changed over time?
- Is there evidence that EBCx/NCCx has become commoditized? (eg. broader deployment, more consistent scope/results, less savings per project but remaining cost-effective, etc.)
- Has EBCx/NCCx shifted significantly beyond its historical focus on HVAC (lighting, particularly, but also envelope, refrigeration, etc.)
- Has there been a shift in market drivers for Cx (ie. what are the main reasons Cx is performed?)
- Has the emergence of analytics-based approaches (ongoing Cx, MBCx using EMIS) changed the savings or cost-benefit for EBCx?

Acknowledgements

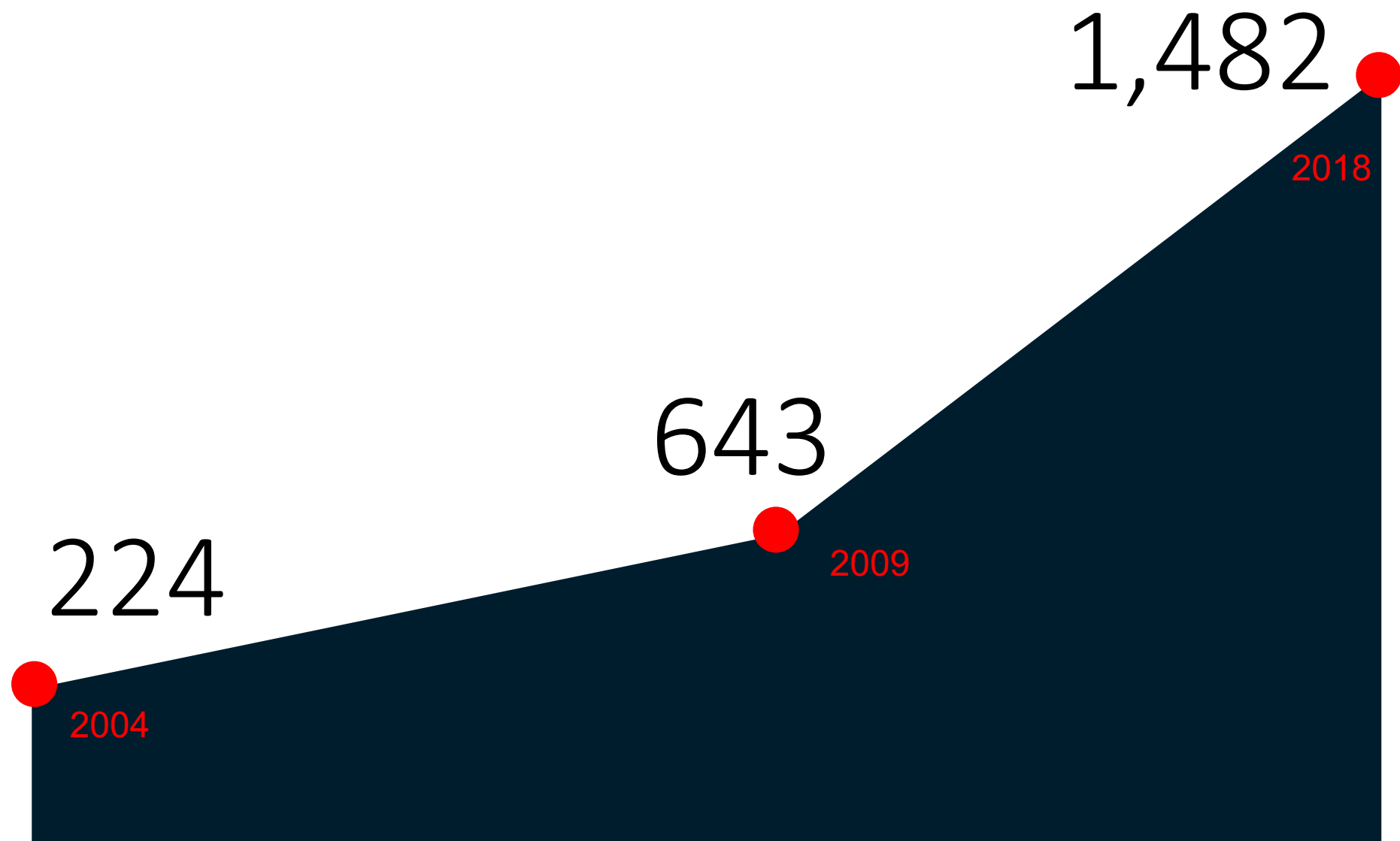
- Study funding
 - U.S. Department of Energy
- Data providers for the study include:
 - Building Commissioning Association
 - ComEd
 - BC Hydro
- Support for data analysis review
 - Building Commissioning Association
- Complementary market survey
 - Building Commissioning Association

STUDY COMPOSITION

Study Square Footage (cumulative)

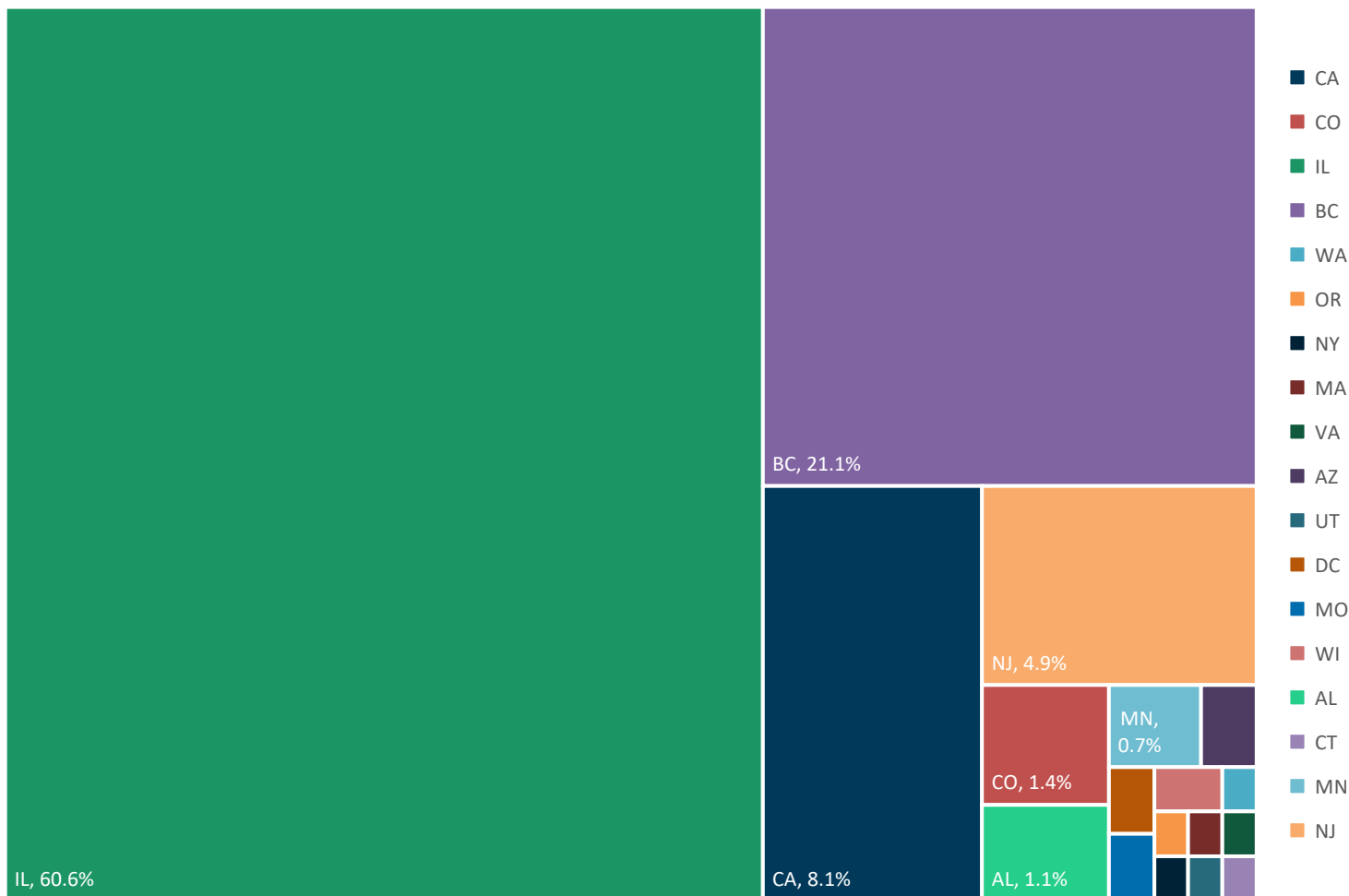


Number of Buildings in Study (cumulative)



Geographical Distribution: EBCx

Geographical Distribution, Percent of Total Buildings, 2018 (EBCx)

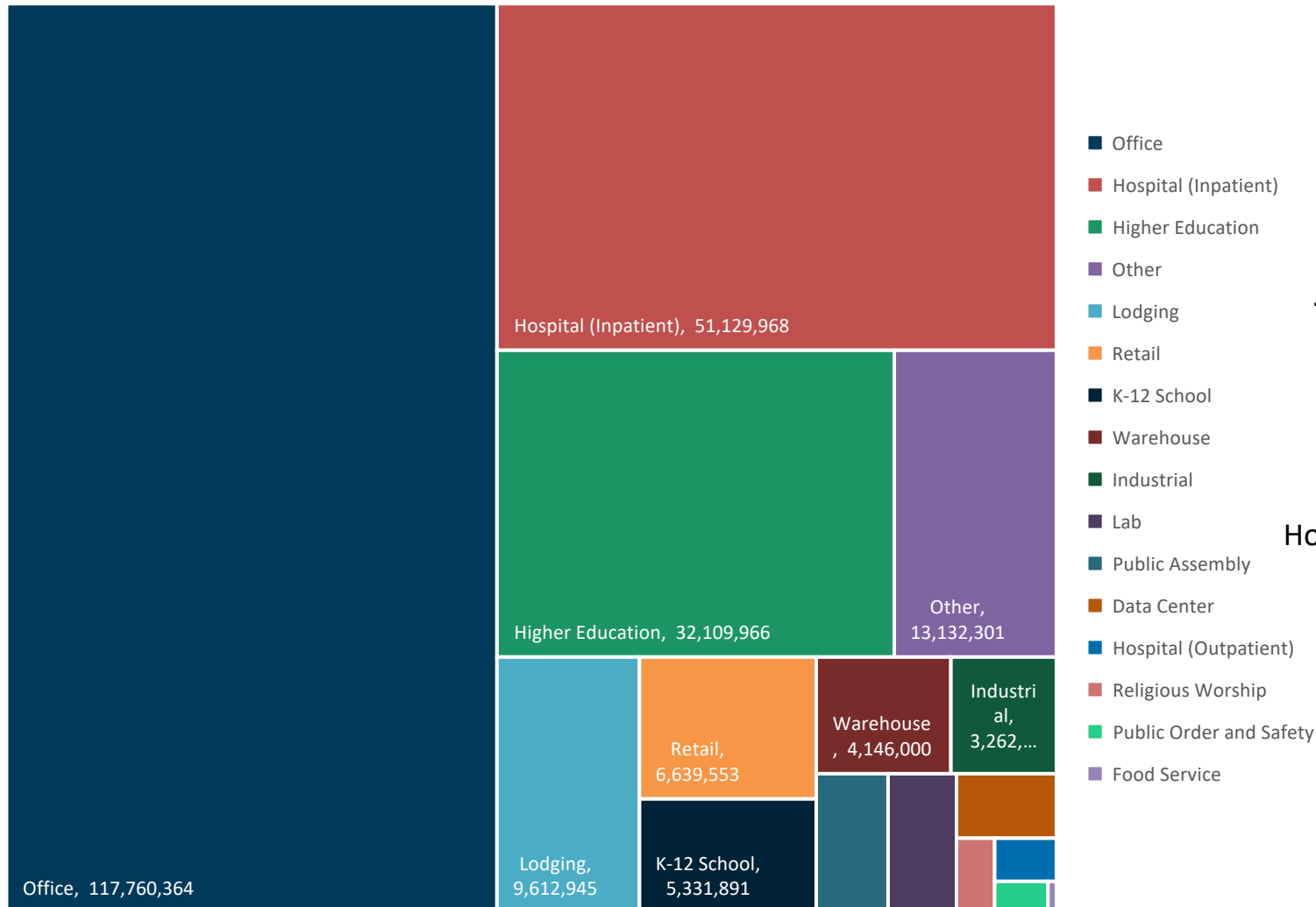


Top 4 states
in 2009

California	42%
Texas	25%
Colorado	17%
Minnesota	5%

Market Sector Distribution: EBCx

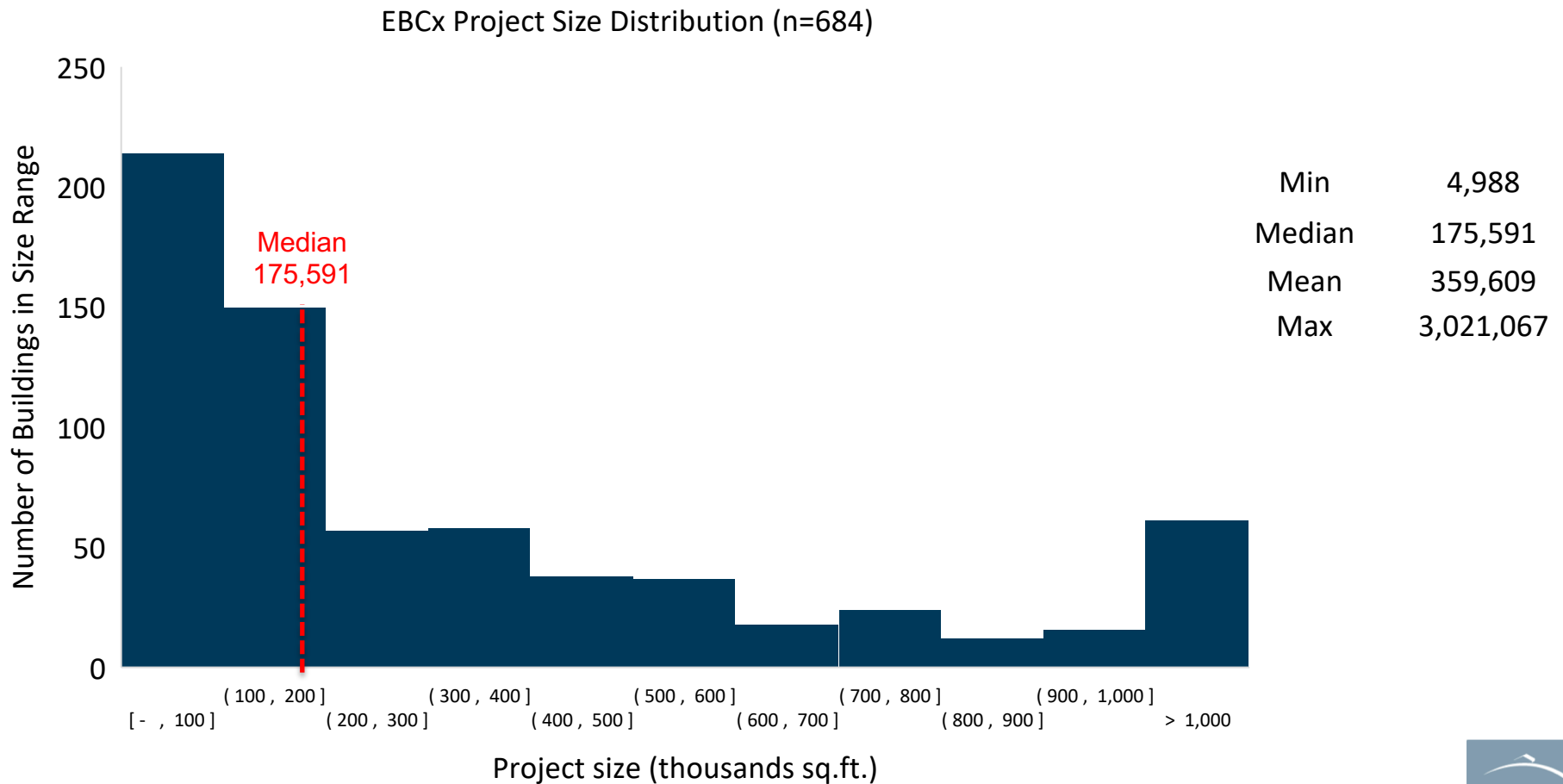
Market Segment, Square Footage, 2018 (EBCx)(Total 251,942,788sq.ft.)



Top 4 categories in 2009

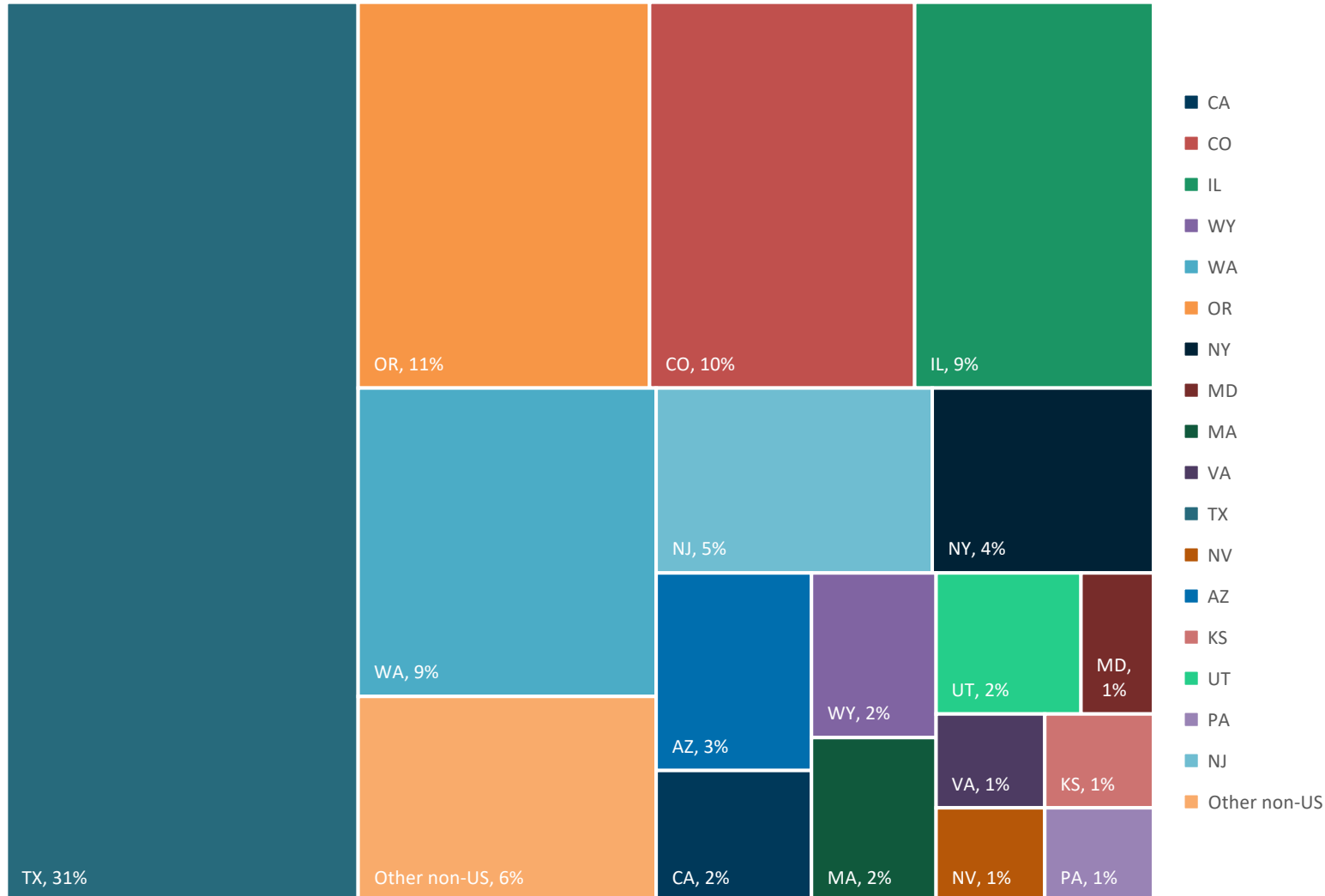
Office	44%
Higher Ed	13%
Lodging	11%
Hospital (Inpatient)	8%

Project Size Distribution: EBCx



Geographical Distribution: NCCx

Geographical Distribution, Percent of Total Buildings (NCCx)

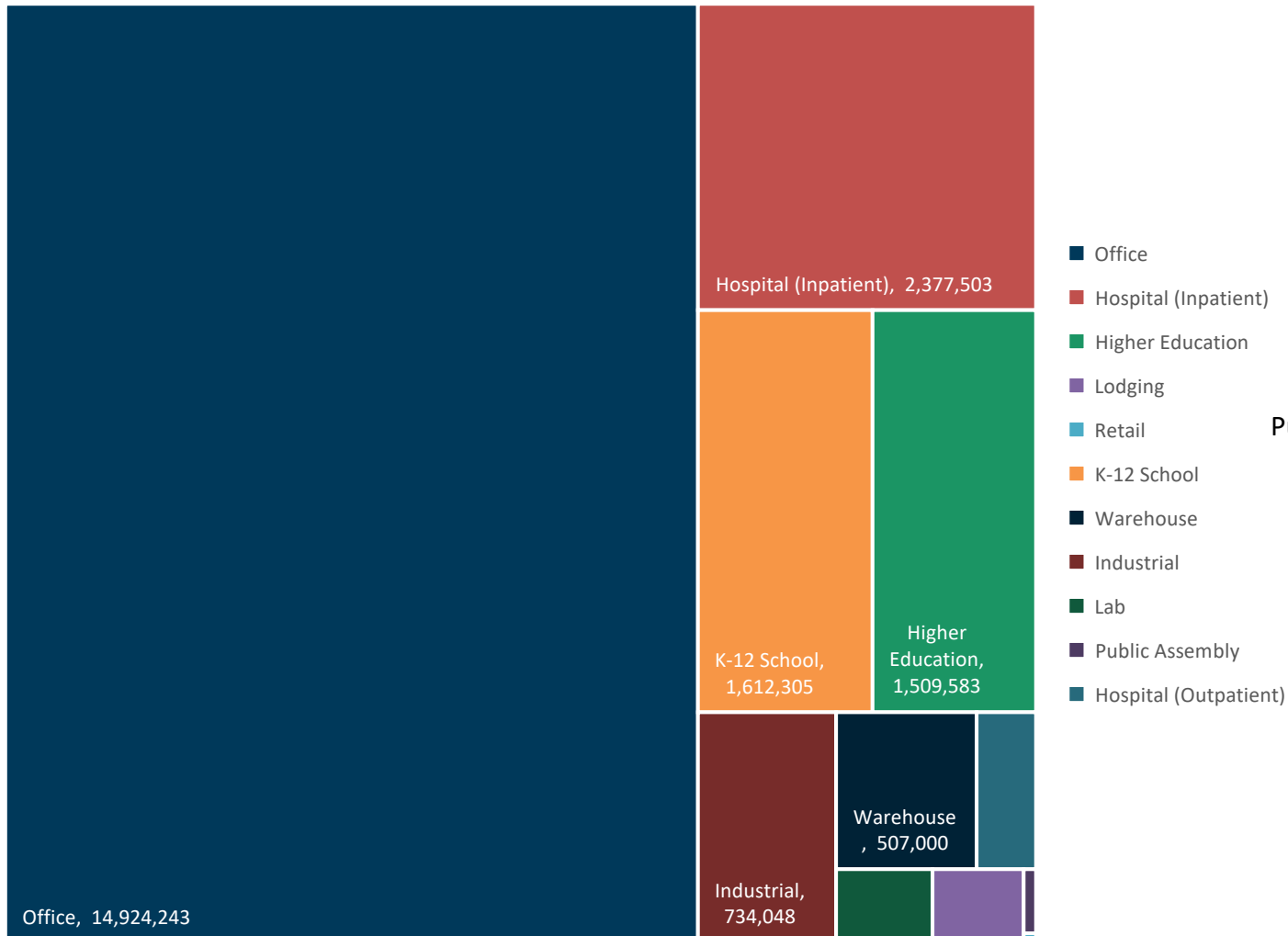


Top 3 states in 2009

Missouri	20%
Washington	19%
Oregon	16%

Market Sector Distribution: NCCx

Market Segment, Square Footage, 2018 (NCCx)(Total 22,217,059 sq.ft.)

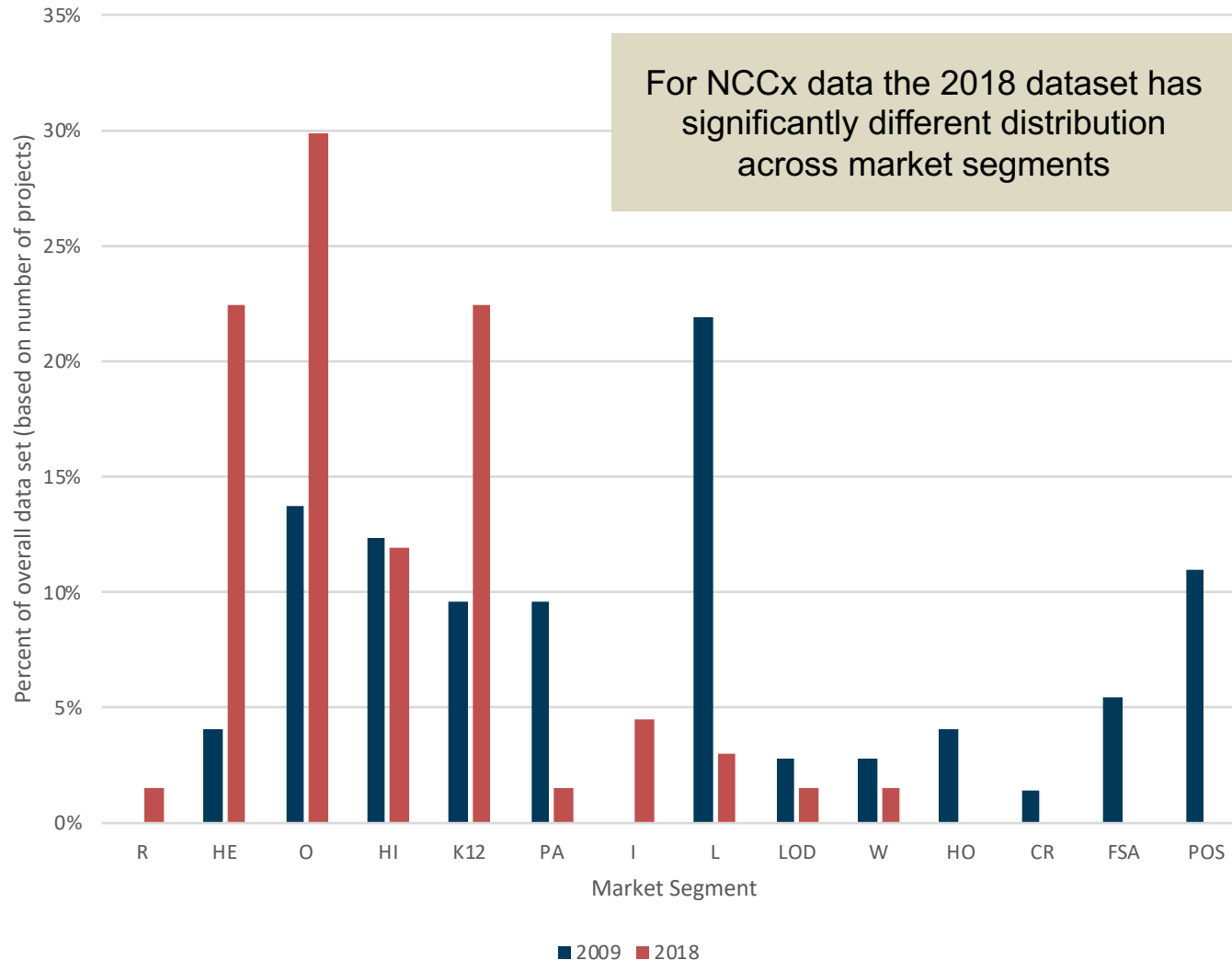


Top 3 categories in 2009

Public Order/Safety	26%
Laboratory	22%
Office	10%

NCCx sample composition

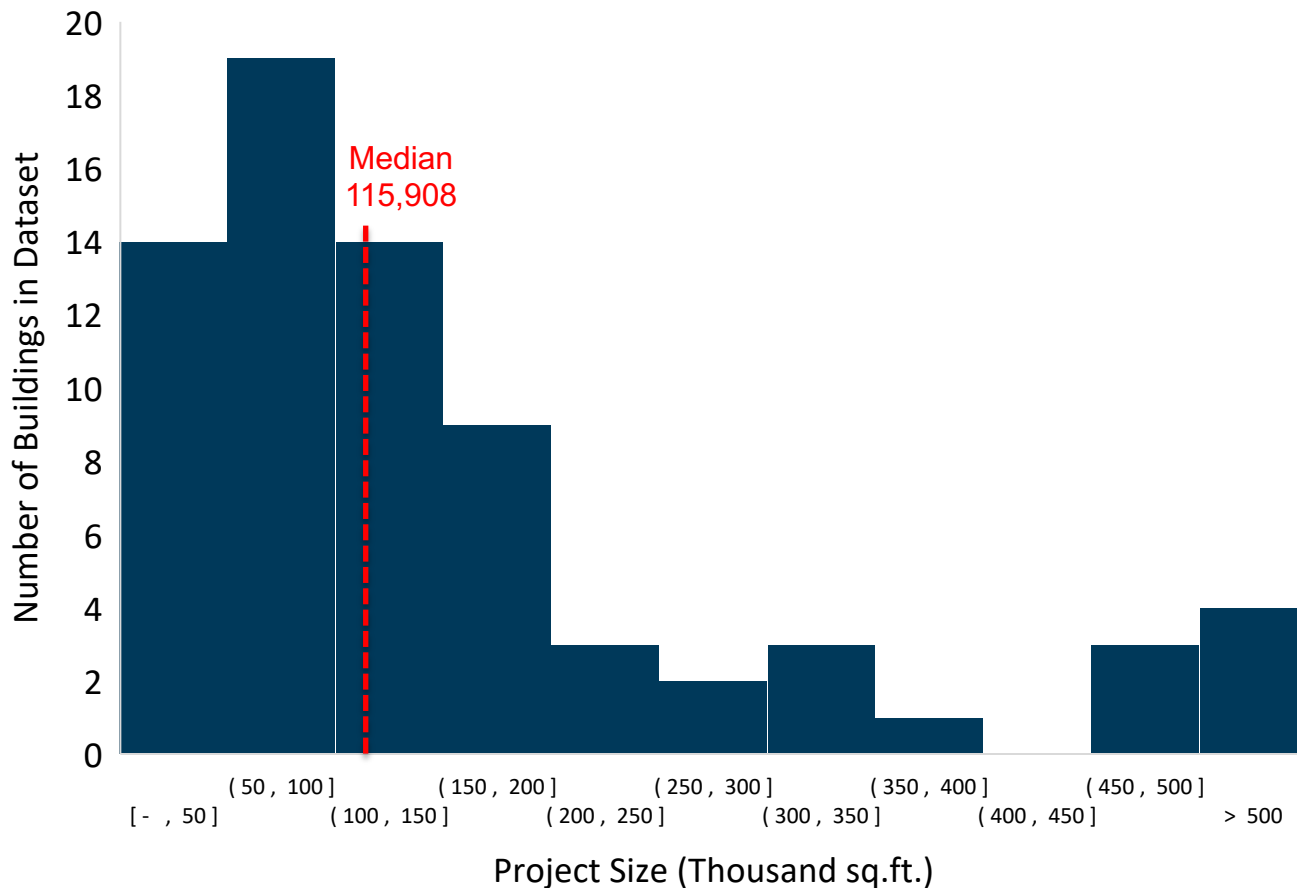
Market Segment Breakdown (Projects with Cost Data)



R	Retail
HE	Higher Ed.
O	Office
HI	Hospital (Inpatient)
K12	K-12 School
PA	Public Assembly
I	Industrial
L	Lab
LOD	Lodging
W	Warehouse
HO	Hospital (Outpatient)
CR	Cleanroom
FSA	Food Sales
POS	Public Order & Safety

Project Size Distribution: NCCx

NCCx Project Size Distribution (n=71)



Min	2,700
Median	115,908
Mean	232,409
Max	3,500,000

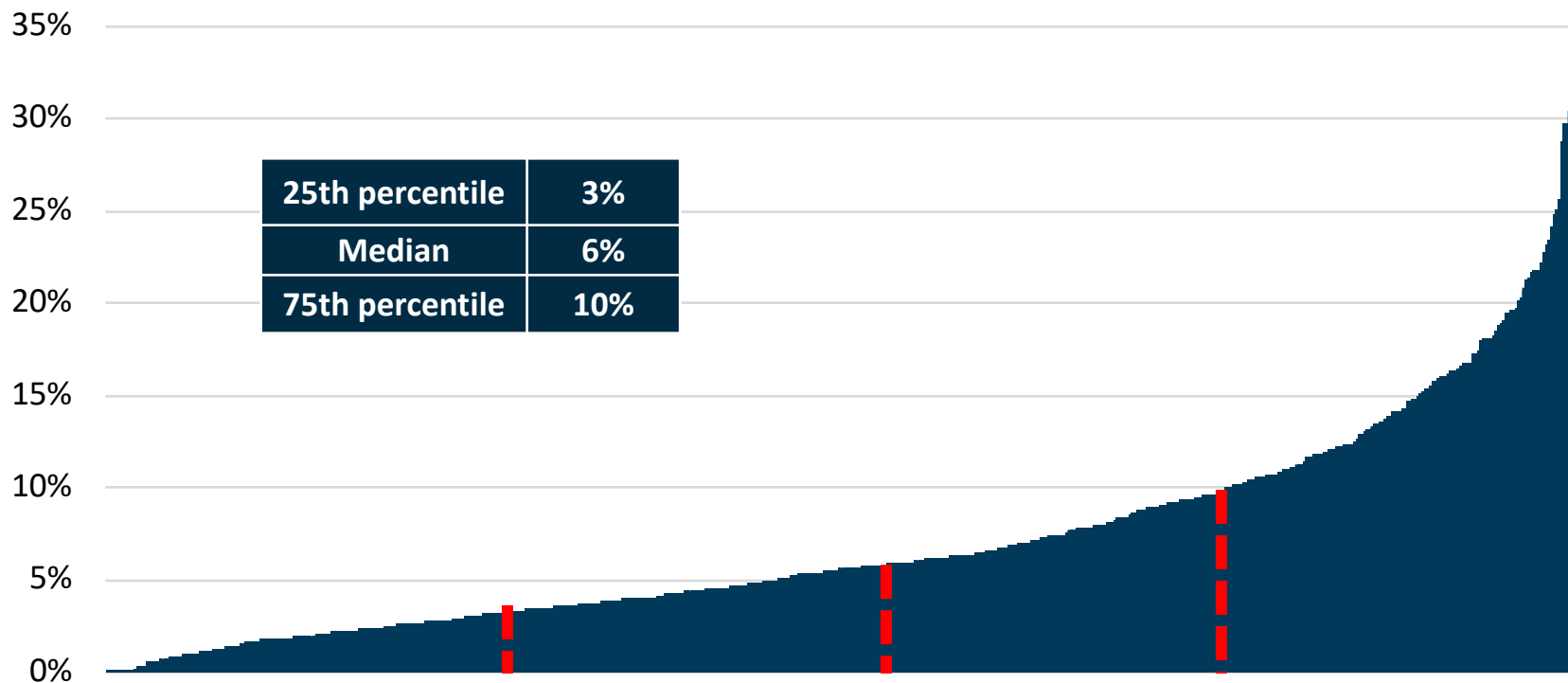
Sample Composition: Summary

- Significantly larger dataset compared to prior studies
- EBCx dataset largely drawn from 2 US states and British Columbia
- NCCx dataset spread more evenly across many states
- Office, hospital (inpatient), and education comprise the largest portions of both EBCx and NCCx datasets

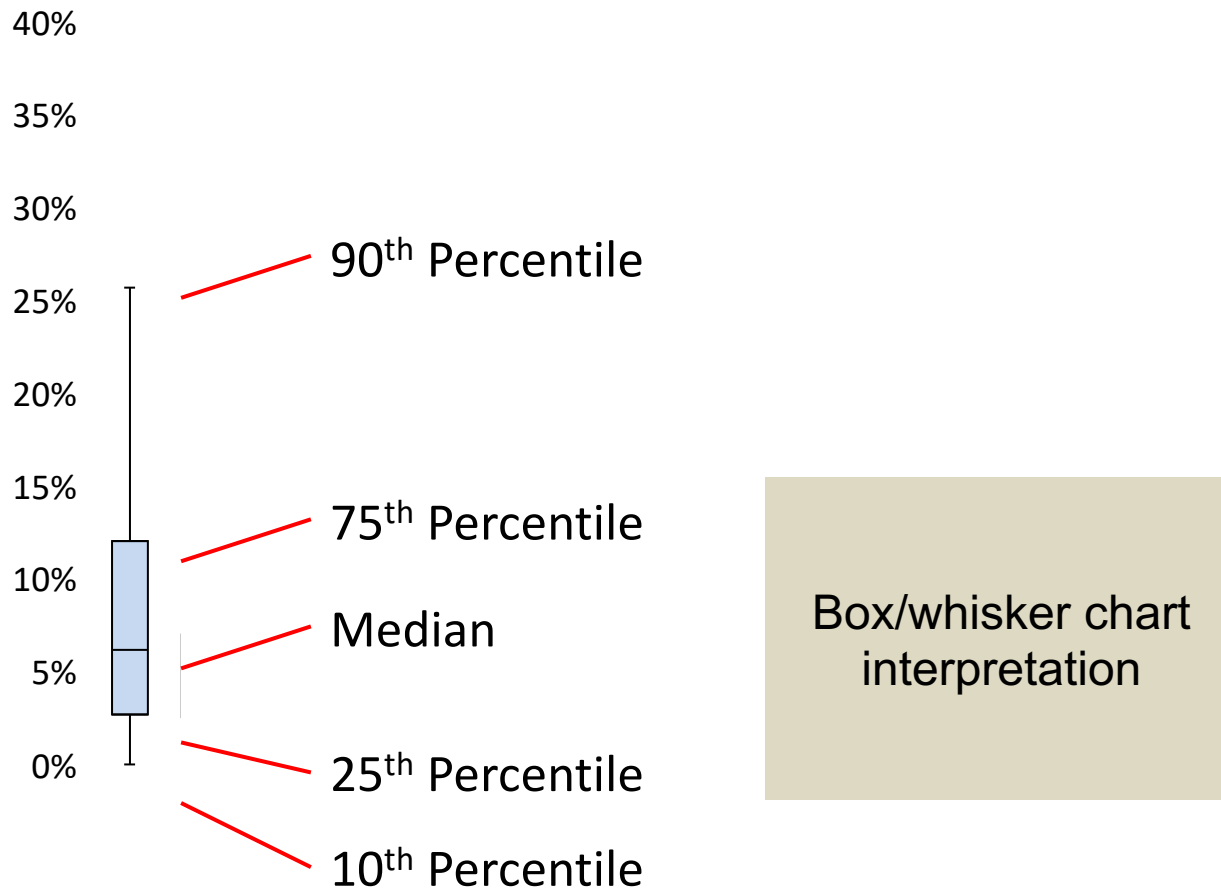
EBCX COSTS, SAVINGS, AND PAYBACK

EBCx Percent Savings

EBCx Percent Savings (Source Energy)(n=604)

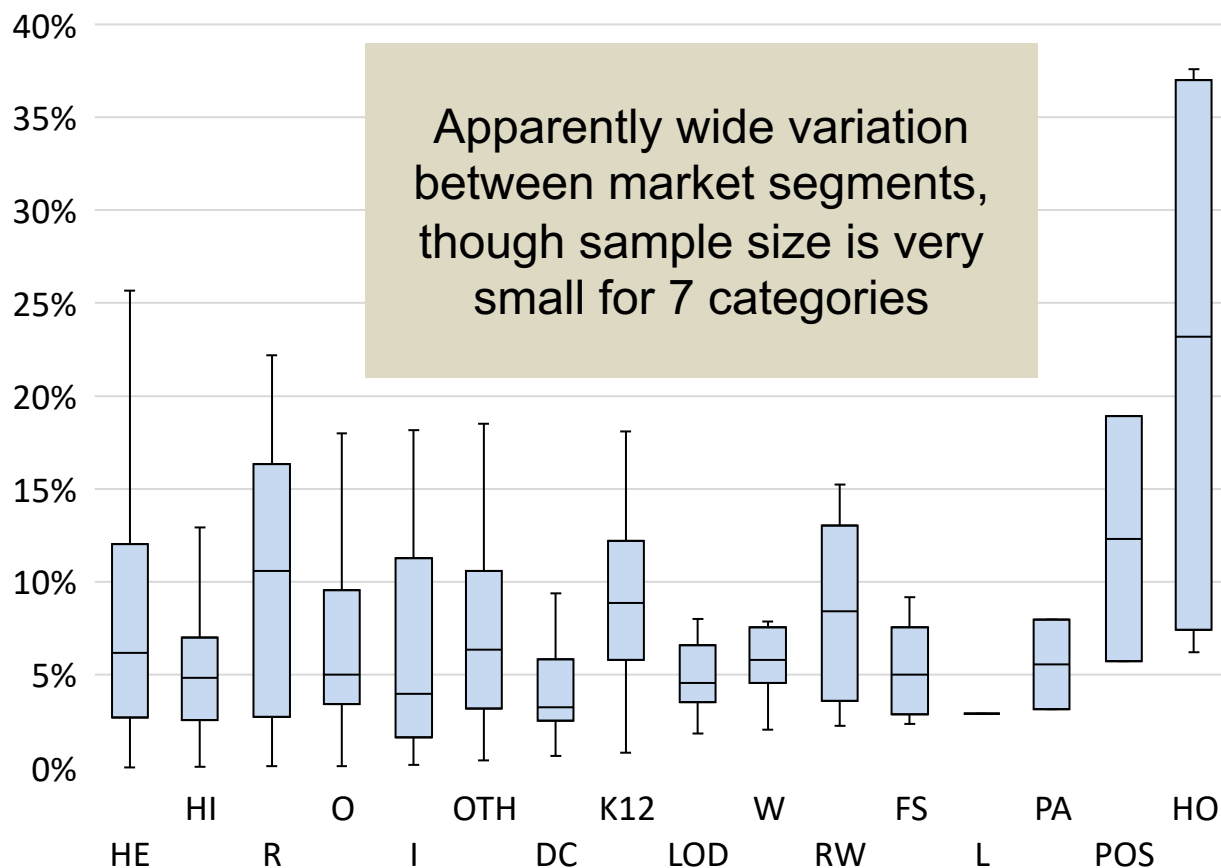


EBCx Percent Savings by Market Segment



EBCx Percent Savings by Market Segment

EBCx Percent Savings by Building Type (Source Energy)(n=604)

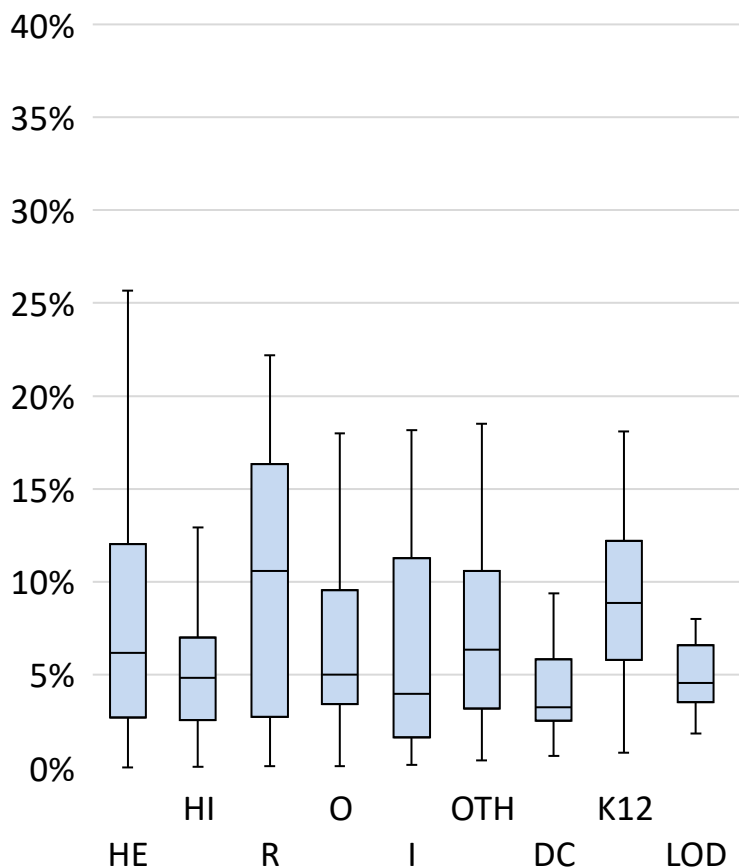


Sample Size

HE	Higher Ed.	112
HI	Hospital (Inpatient)	115
R	Retail	30
O	Office	194
I	Industrial	10
OTH	Other	42
DC	Data Center	15
K12	K-12 School	42
LOD	Lodging	17
W	Warehouse	6
RW	Religious Worship	6
FS	Food Service	6
L	Lab	1
PA	Public Assembly	2
POS	Public Order & Safety	2
HO	Hospital (Outpatient)	4
		604

EBCx Percent Savings by Market Segment

EBCx Percent Savings by Building Type (Source Energy)(n=604)



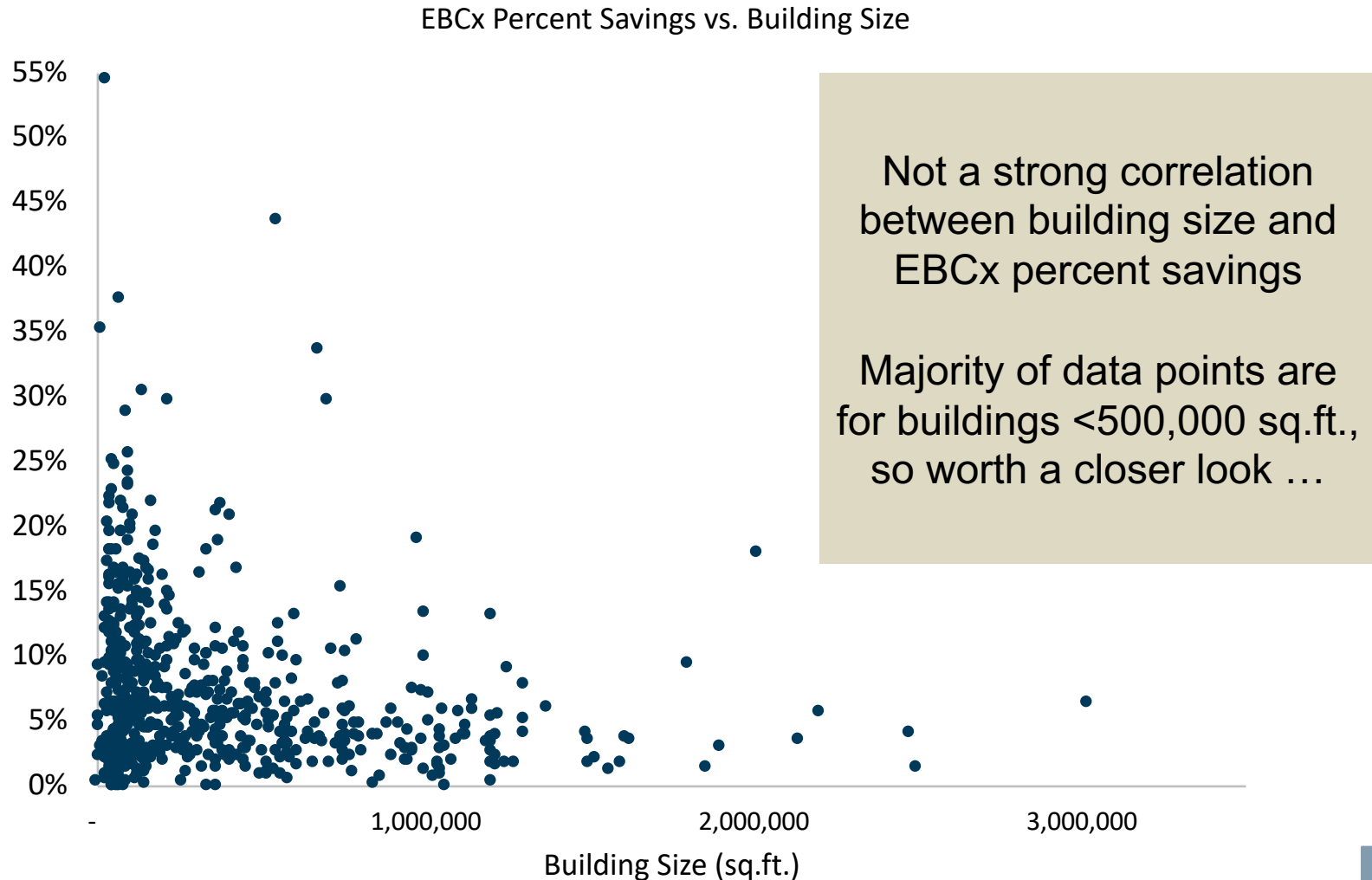
Removed market segments with sample size of 6 or less.

Median values range from 3%-10%

Sample Size

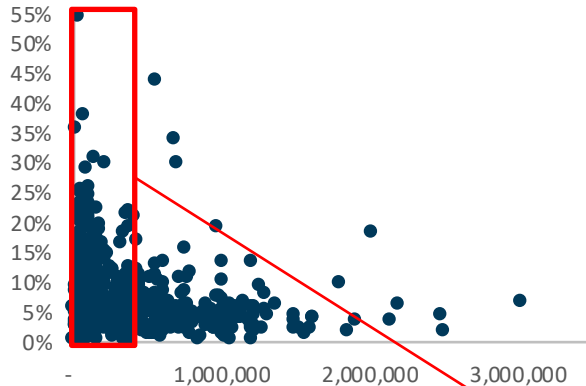
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EBCx Percent Savings by Building Size

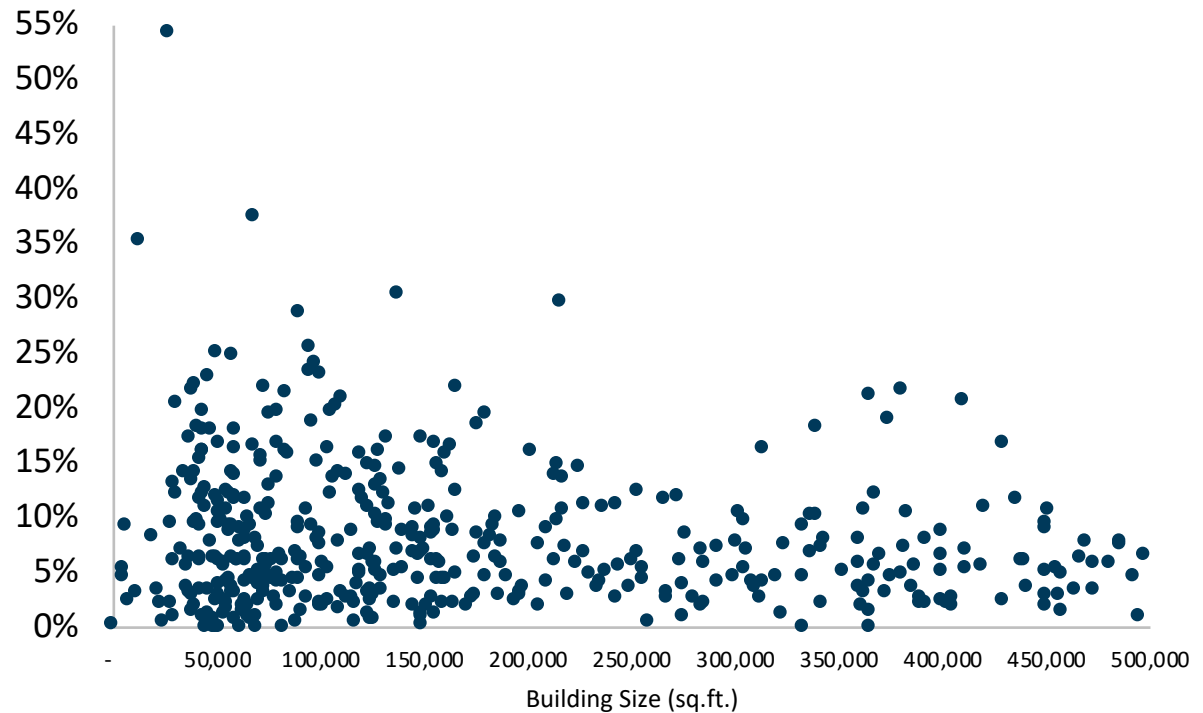


EBCx Percent Savings by Building Size

EBCx Percent Savings vs. Building Size



EBCx Percent Savings vs. Building Size (<500,000sq.ft)



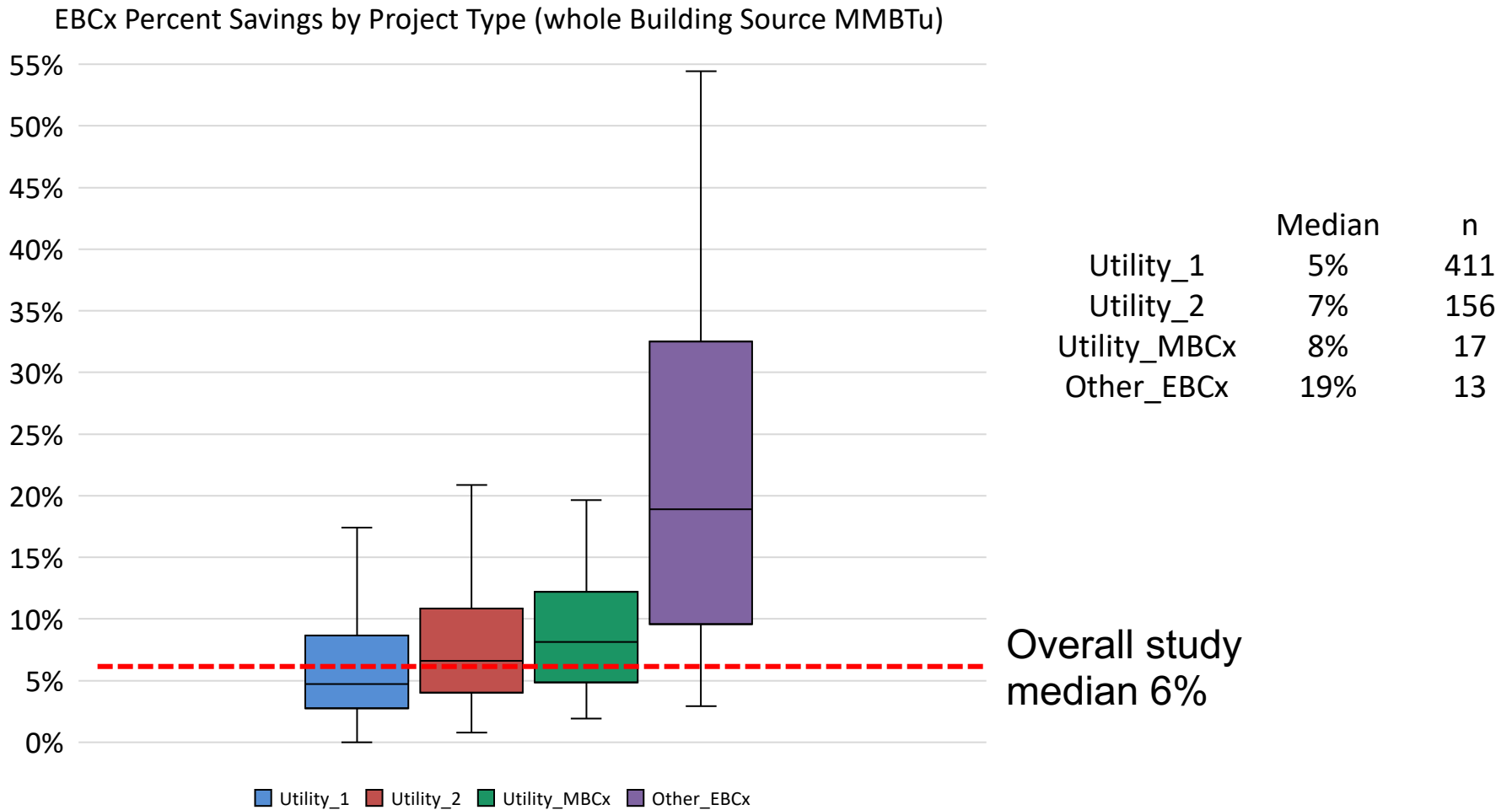
Zooming in to buildings
<500,000 sq.ft., still no
strong correlation
between EBCx percent
savings and building size

EBCx Percent Savings by Project Type

Project Type Characteristics

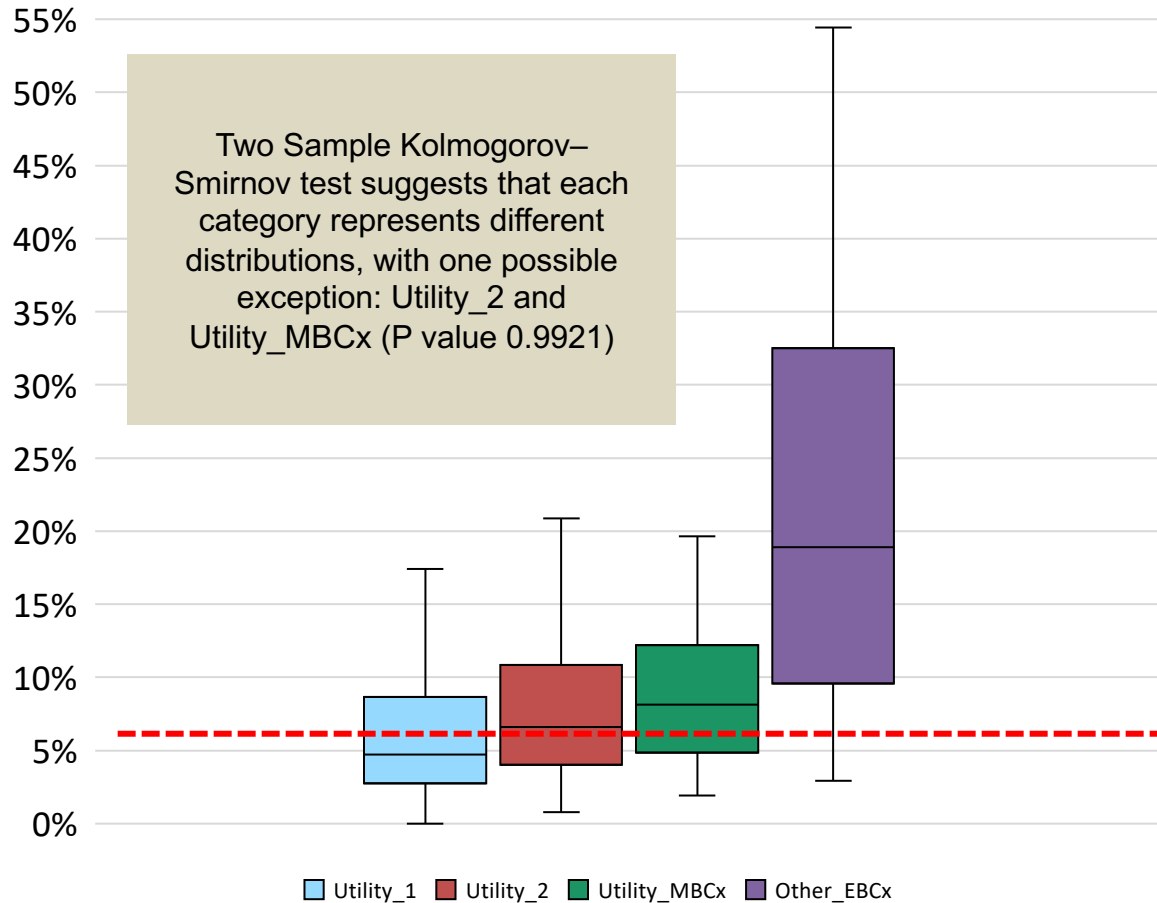
- **Utility EBCx Projects:**
 - Standardized scope, focused on energy savings
 - High rigor applied to review of savings estimates
 - Typically restricted budgets, but customer may have cash incentive to install measures
- **Utility MBCx Projects:**
 - Similar to Utility EBCx, but with additional budget/effort to install metering, and possibly a longer engagement period to uncover more measures
- **“Other”:**
 - Services offered direct to customers by commissioning firms. May target outcomes beyond energy savings (e.g. comfort). Scrutiny on savings calculations varies. Budget determined on a case-by-case basis.

EBCx Percent Savings: 2018



EBCx Percent Savings: 2018

EBCx Percent Savings by Project Type (whole Building Source MMBTu)



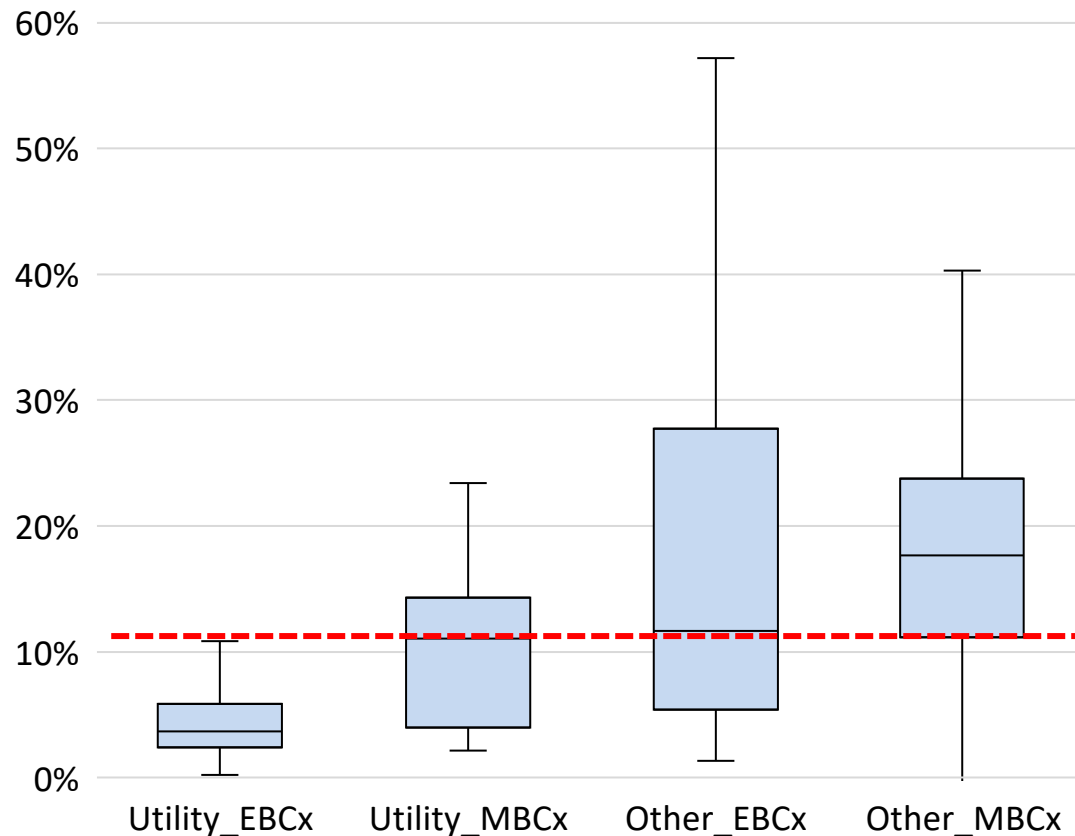
	Median	n
Utility_1	5%	411
Utility_2	7%	156
Utility_MBCx	8%	17
Other_EBCx	19%	13

Note: relatively small sample size for MBCx and Other

Median 6%

EBCx Percent Savings: 2009

EBCx Percent Savings by Program Type (2009 data)(n=162)



2009 median for Utility_EBCx is similar to 2018 data (5% and 7%).

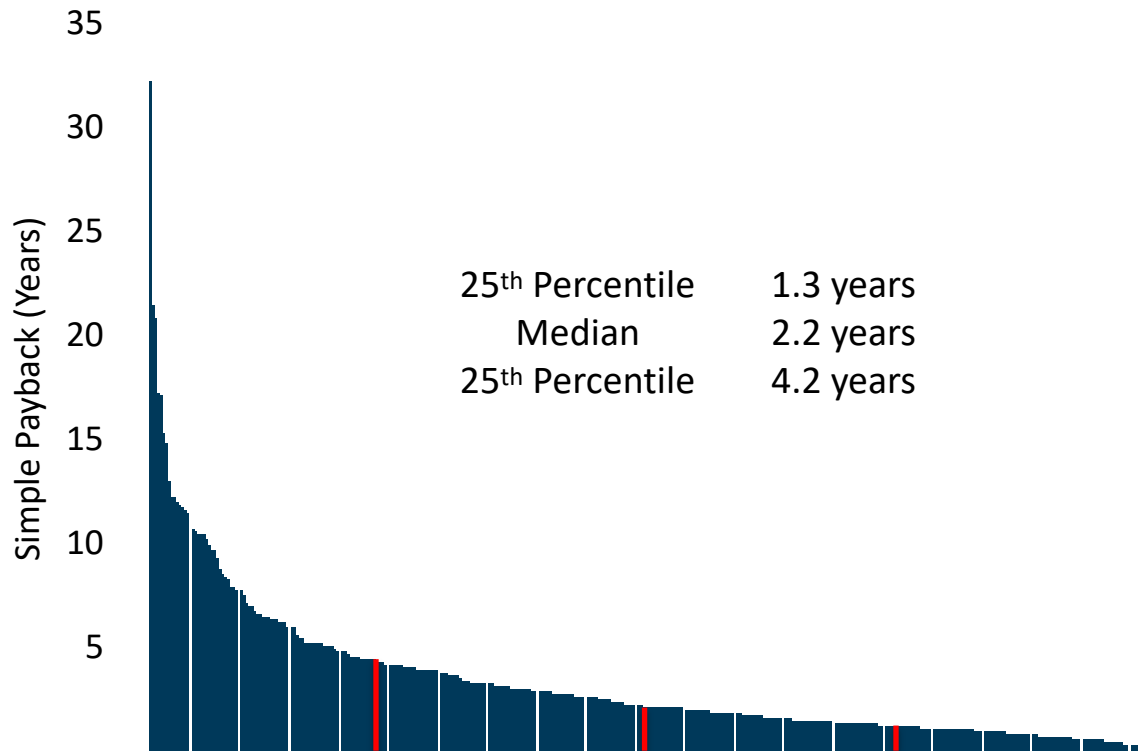
Wider variation between median values for different project types in 2009 data set, and very wide distribution for "Other" category projects

	Median	n
Utility_EBCx	4%	47
Utility_MBCx	11%	21
Other_EBCx	12%	54
Other_MBCx	18%	40

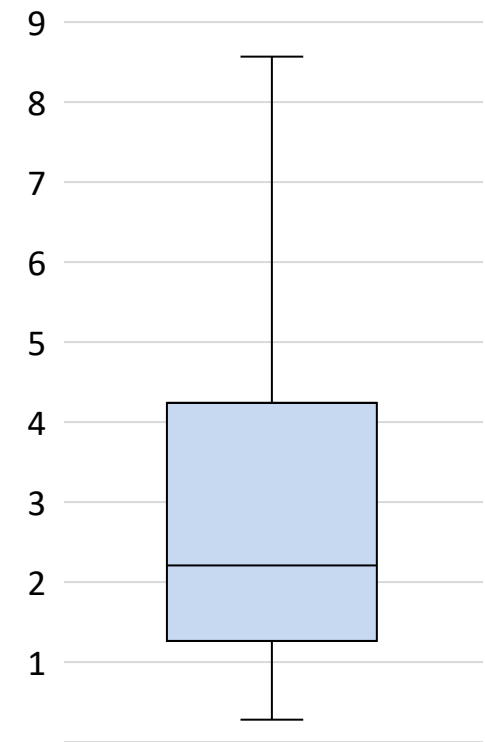
Median 10%

EBCx Simple Payback

EBCx Simple Payback (Years)(n=356)

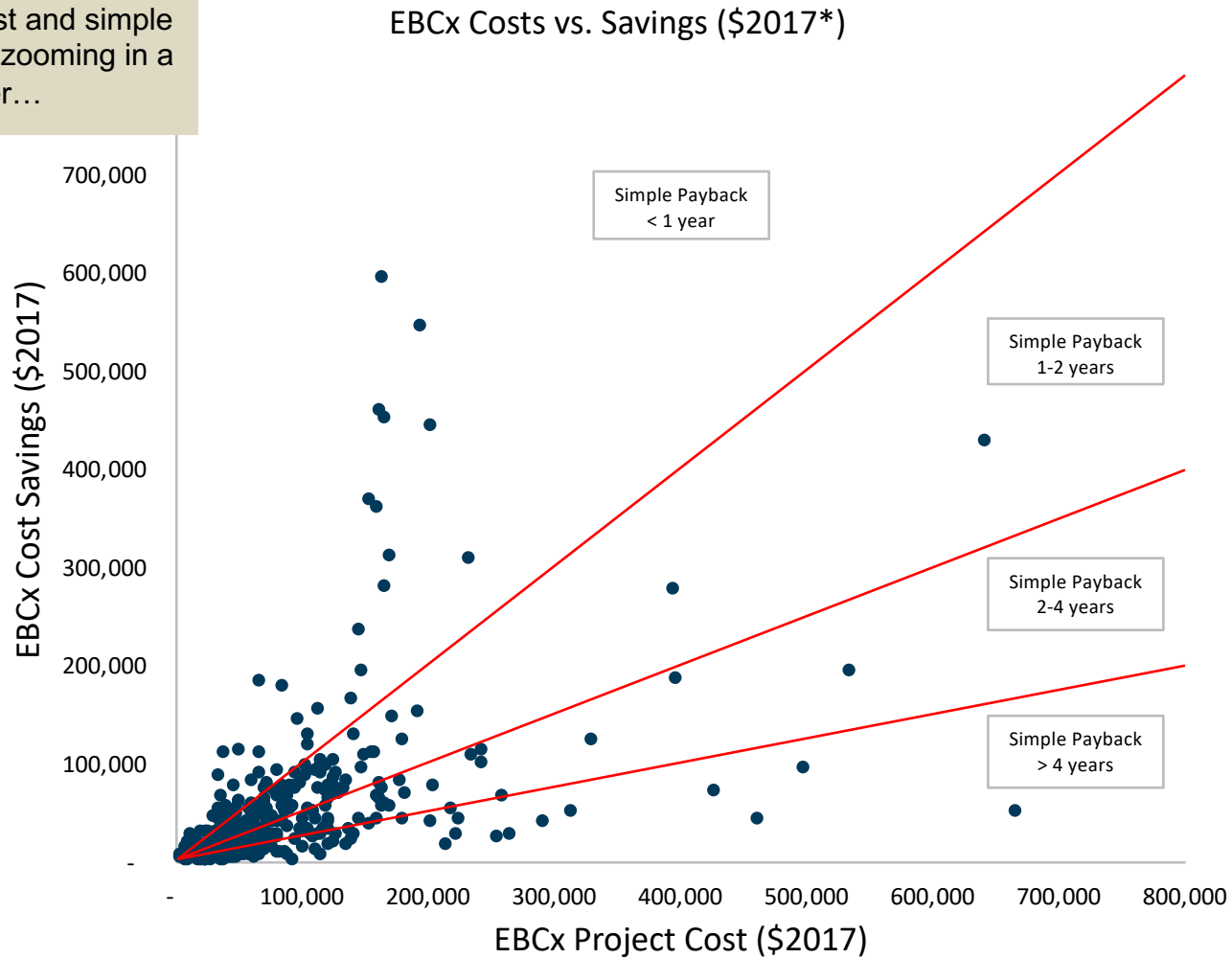


EBCx Simple Payback (Years)
(n=356)



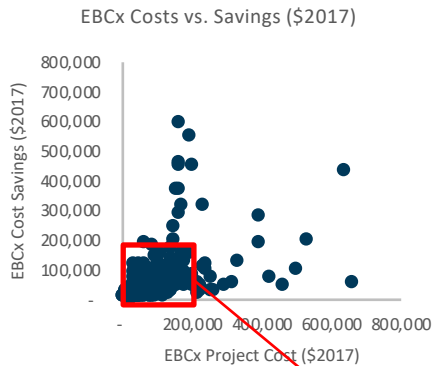
EBCx Simple Payback

No apparent relationship between project cost and simple payback, but worth zooming in a little closer...

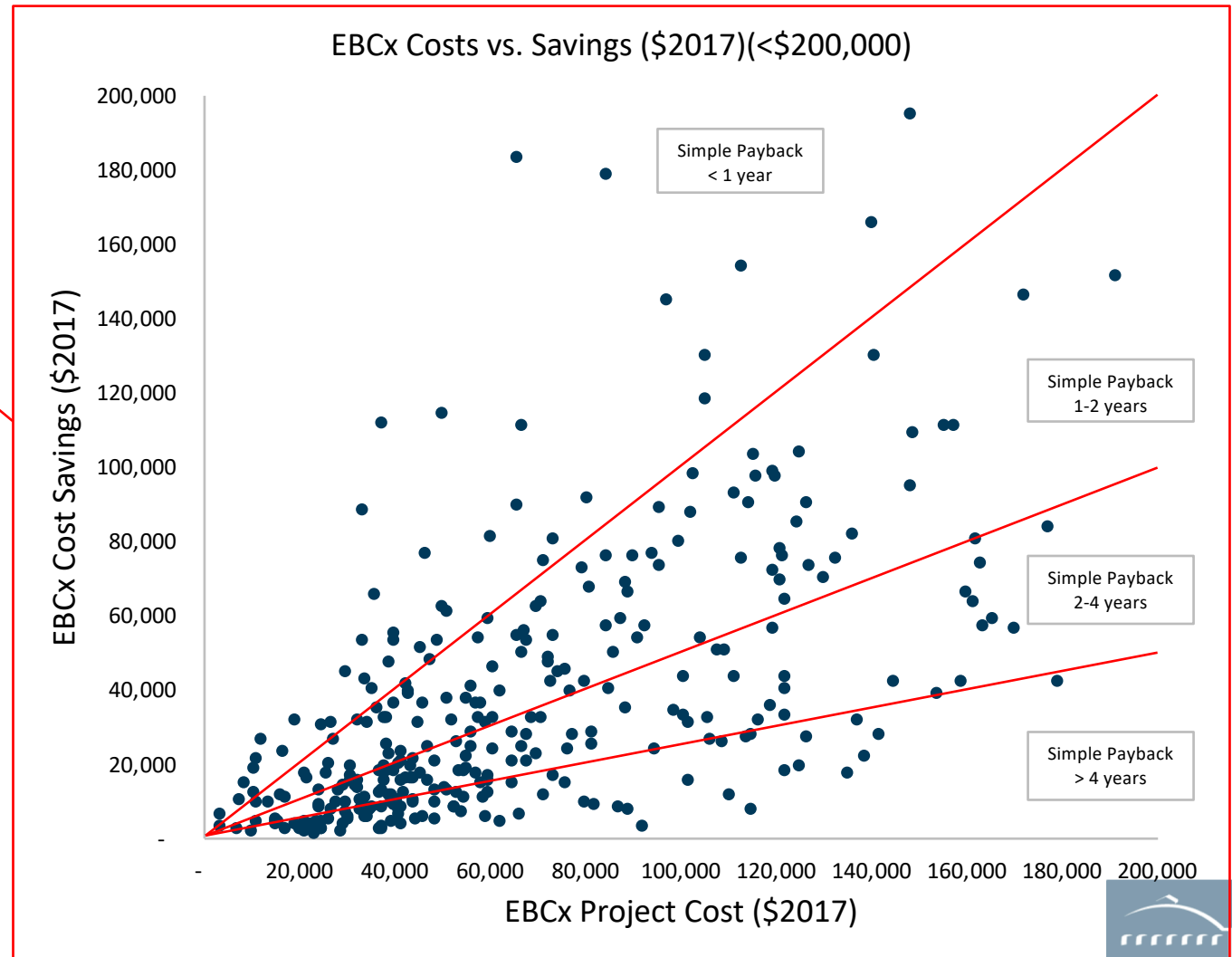


* Data in 2018 study normalized to 2017 dollars

EBCx Simple Payback

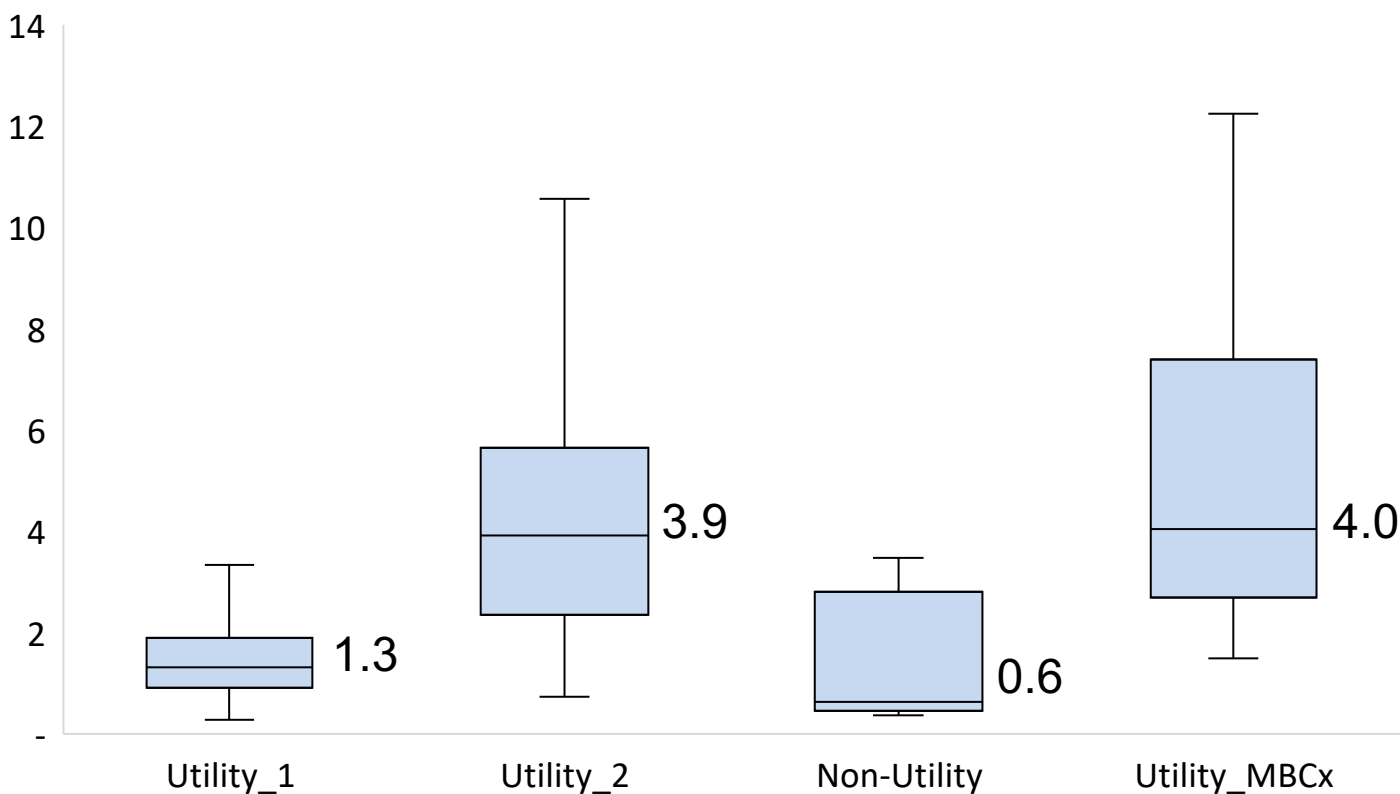


Looking only at projects costing <\$200,000, there is still a high degree of scatter



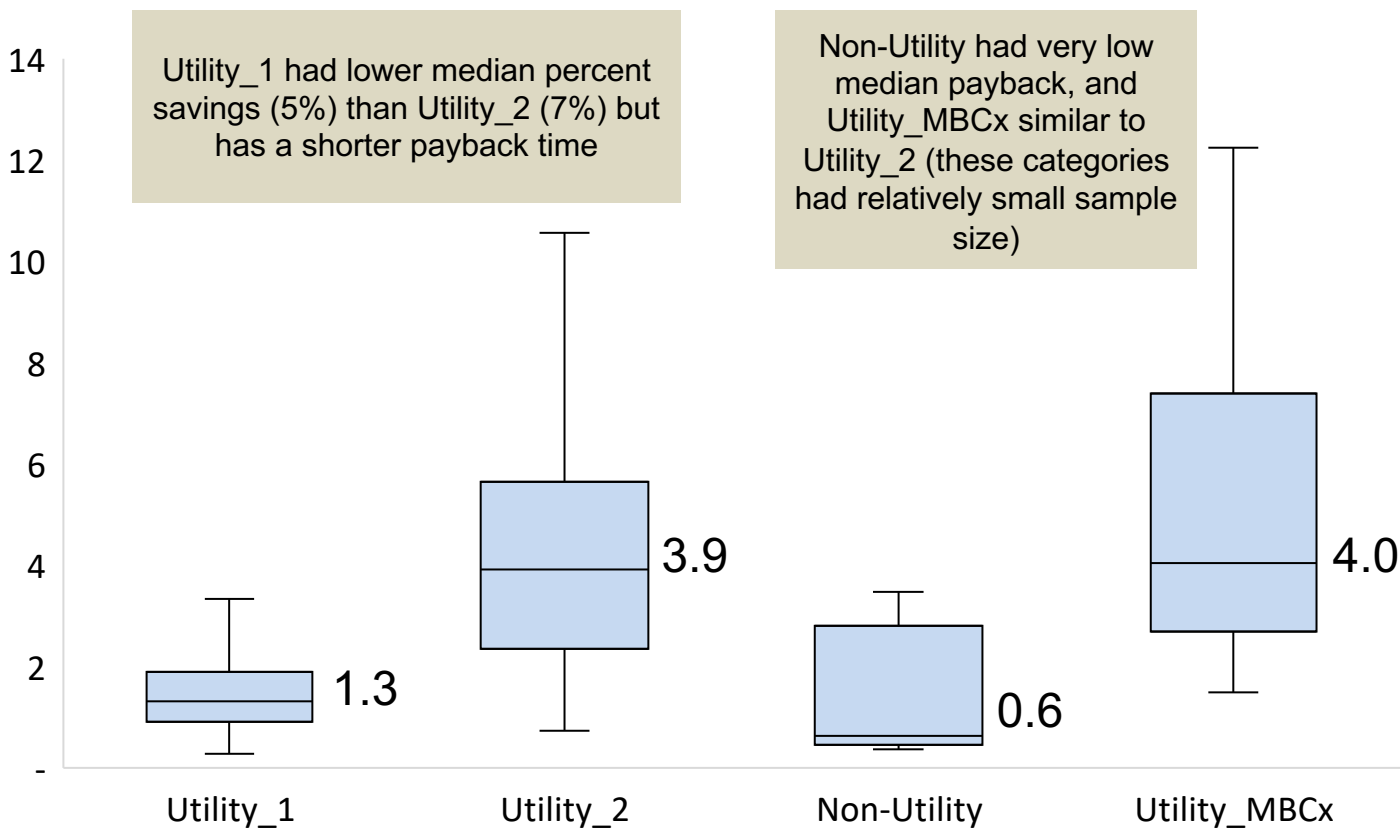
EBCx Simple Payback by Project Type

EBCx Simple Payback (years) by Data Source (Adjusted to 2017, using Standard Energy Prices)(n=355)



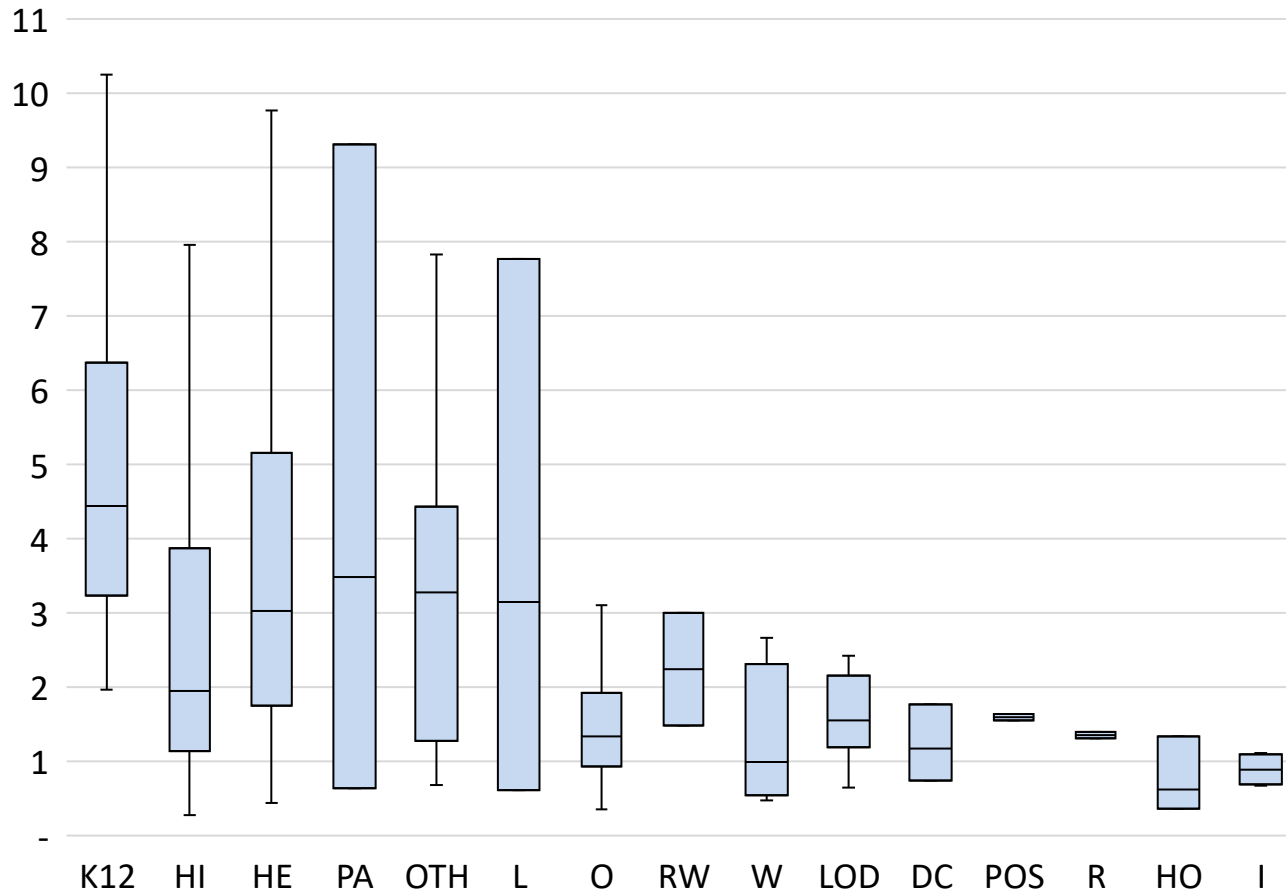
EBCx Simple Payback by Project Type

EBCx Simple Payback (years) by Data Source (Adjusted to 2017, using Standard Energy Prices)(n=355)



EBCx Simple Payback by Market Segment

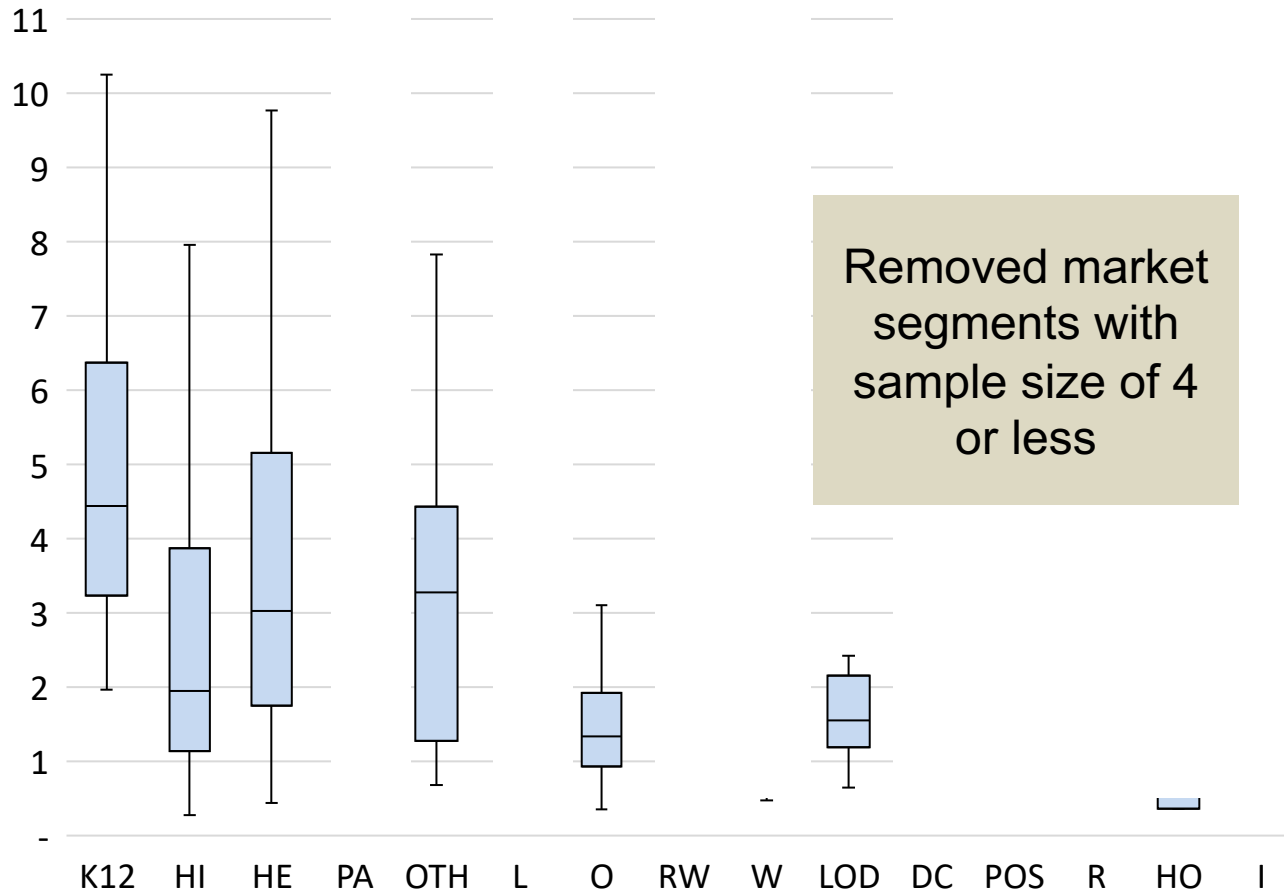
EBCx Simple Payback (years) by Building Type (n=356)



		n =
K12	K-12 School	39
HI	Hospital (Inpatient)	100
HE	Higher Ed.	111
PA	Public Assembly	3
OTH	Other	20
L	Lab	3
O	Office	48
RW	Religious Worship	2
W	Warehouse	4
LOD	Lodging	12
DC	Data Center	3
POS	Public Order & Safety	2
R	Retail	2
HO	Hospital (Outpatient)	3
I	Industrial	4
		356

EBCx Simple Payback by Market Segment

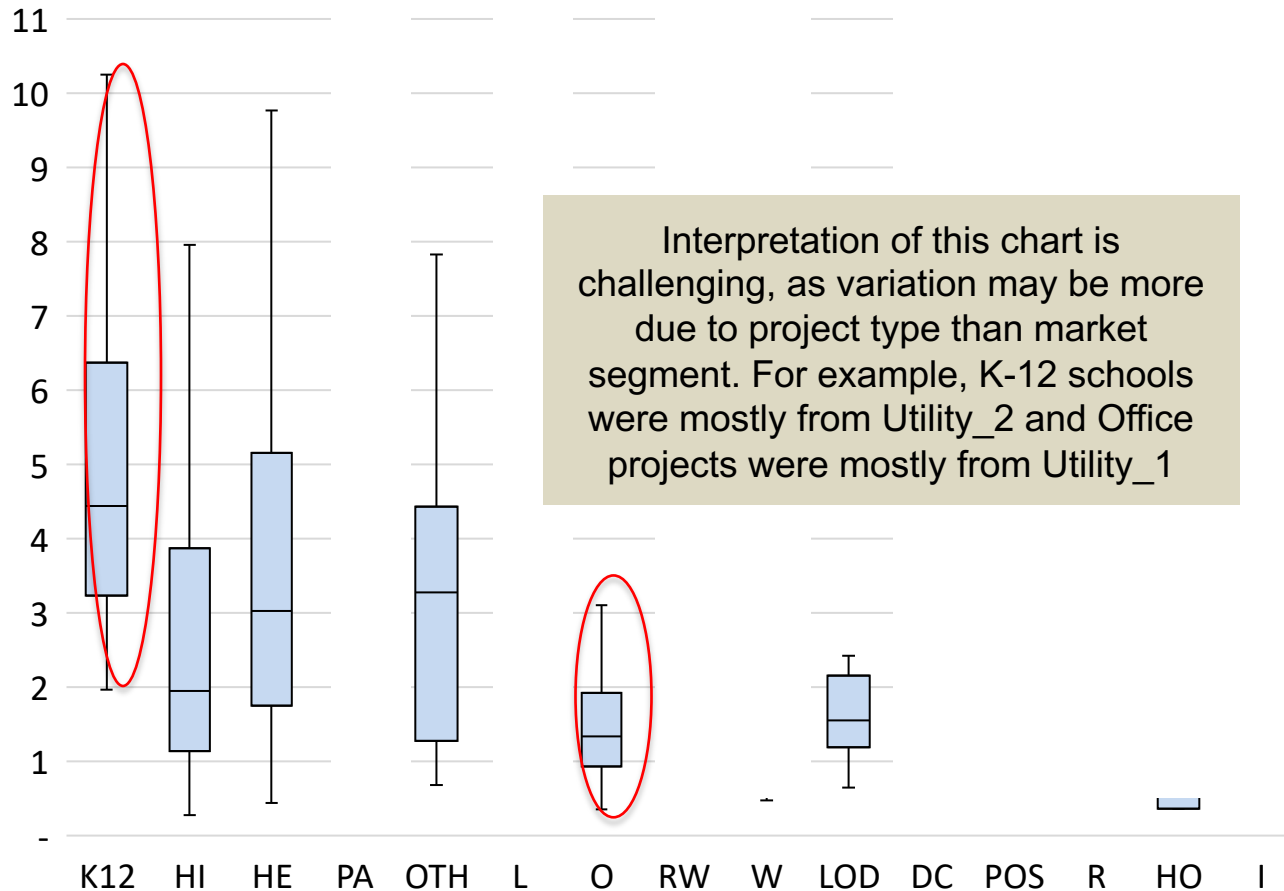
EBCx Simple Payback (years) by Building Type (n=356)



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EBCx Simple Payback by Market Segment

EBCx Simple Payback (years) by Building Type (n=356)

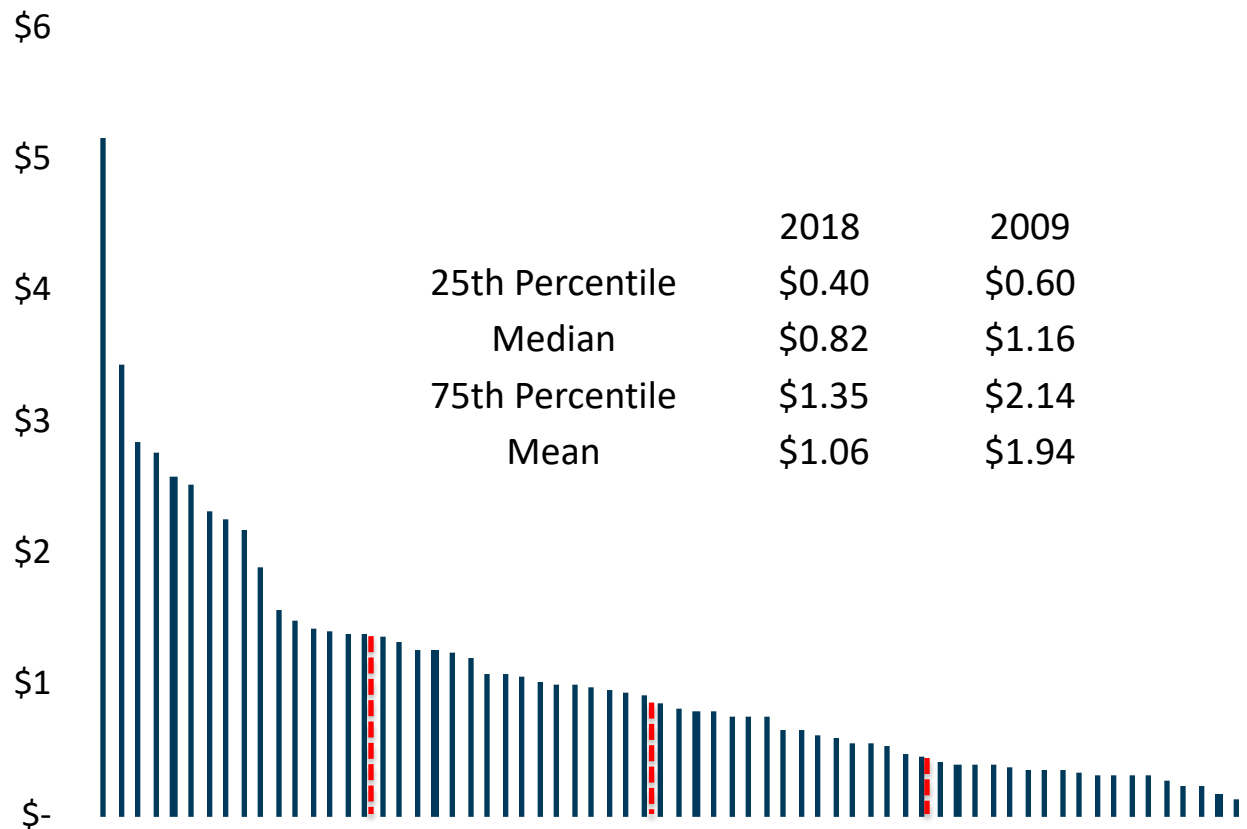


K12	K-12 School	n = 39
HI	Hospital (Inpatient)	100
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NCCX COSTS

NCCx Cost per Square Foot

New Construction Commissioning Cost
(\$2017/sq.ft.)(n=67)

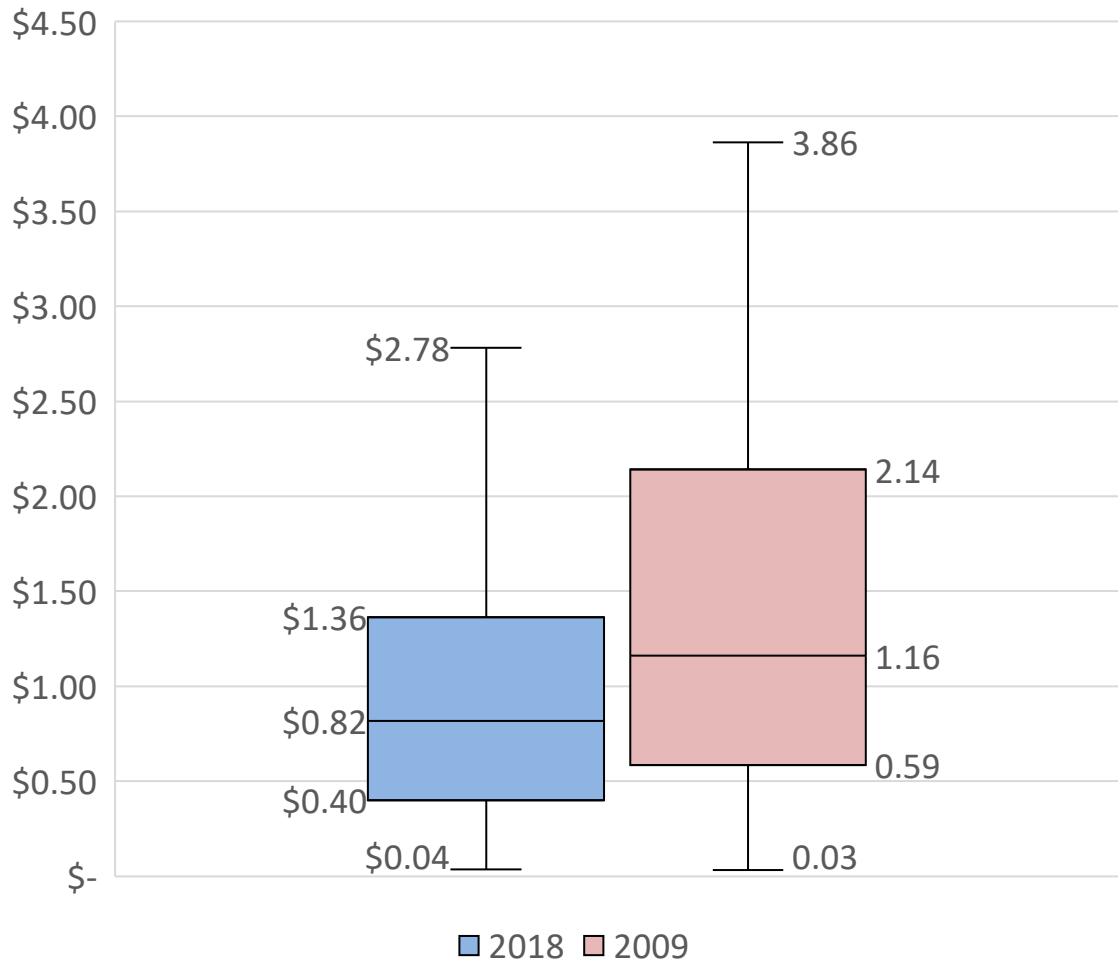


New Construction
Commissioning Cost
(\$2017/sq.ft.)



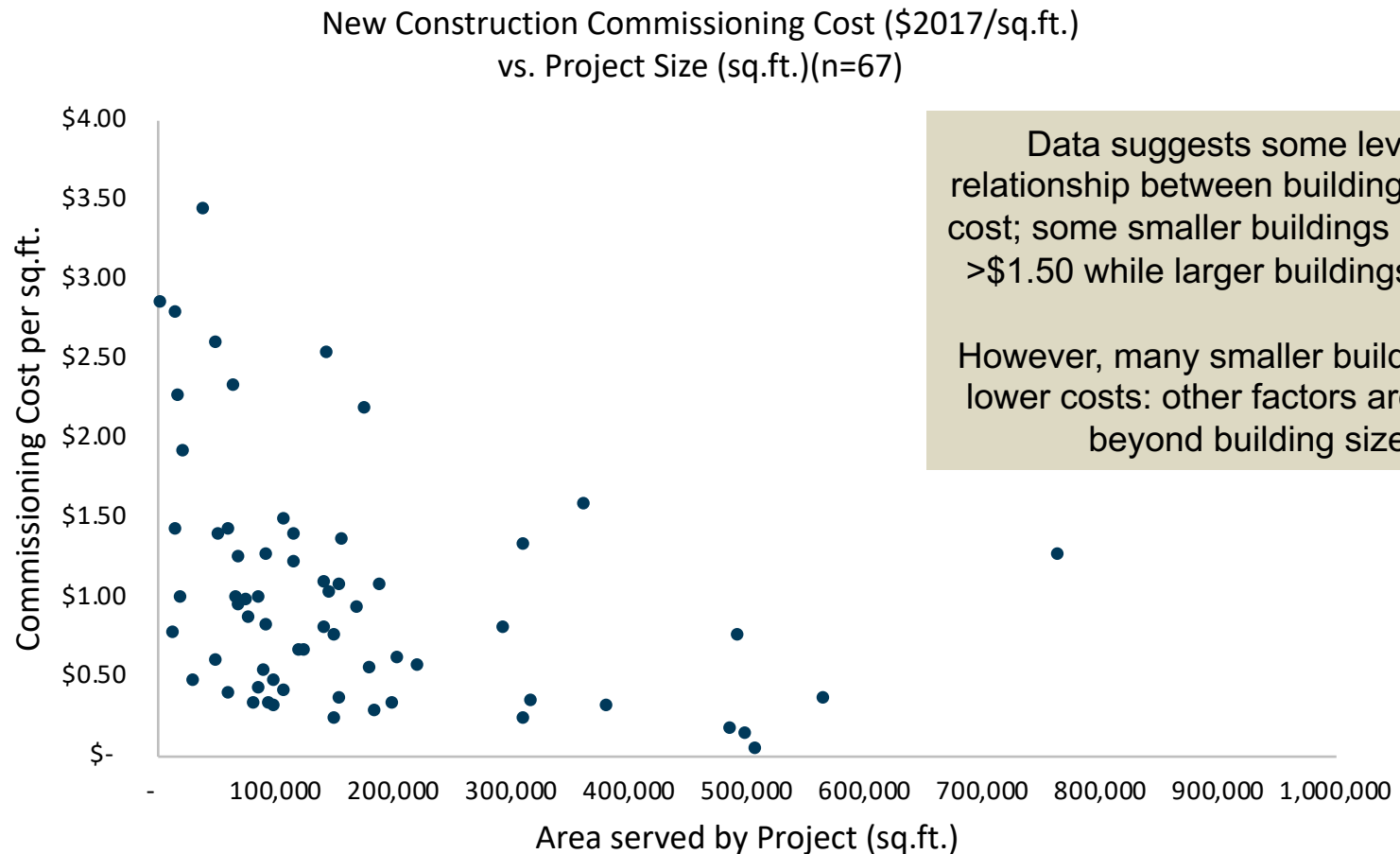
NCCx Cost per sq.ft., 2009 vs 2018

New Construction Commissioning Cost (\$/sq.ft.)



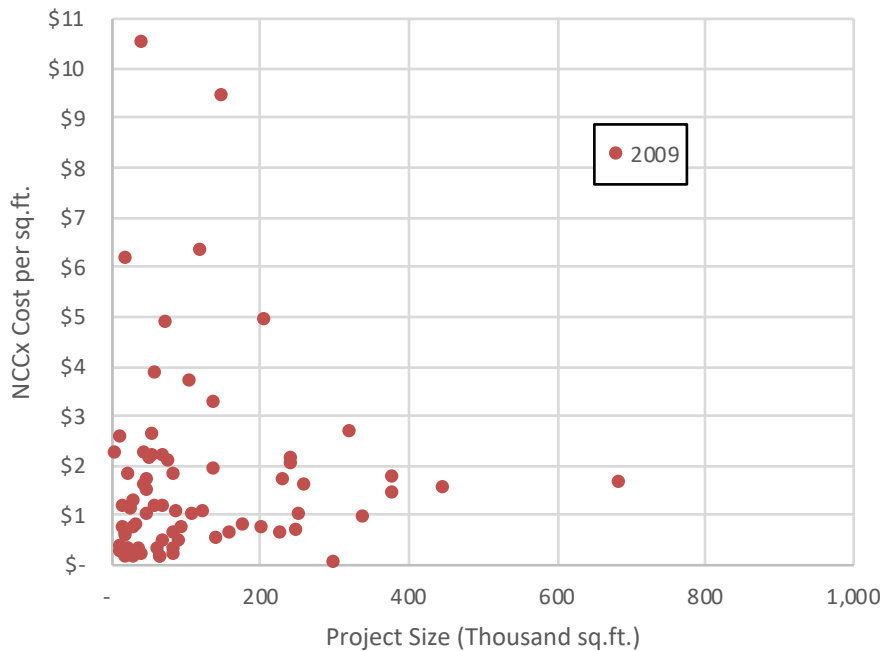
2018 data shows lower cost per sq.ft. than 2009 data set. Need to look deeper to understand if this is a true shift in market costs or possibly due to sample composition

NCCx Cost vs. Project Size

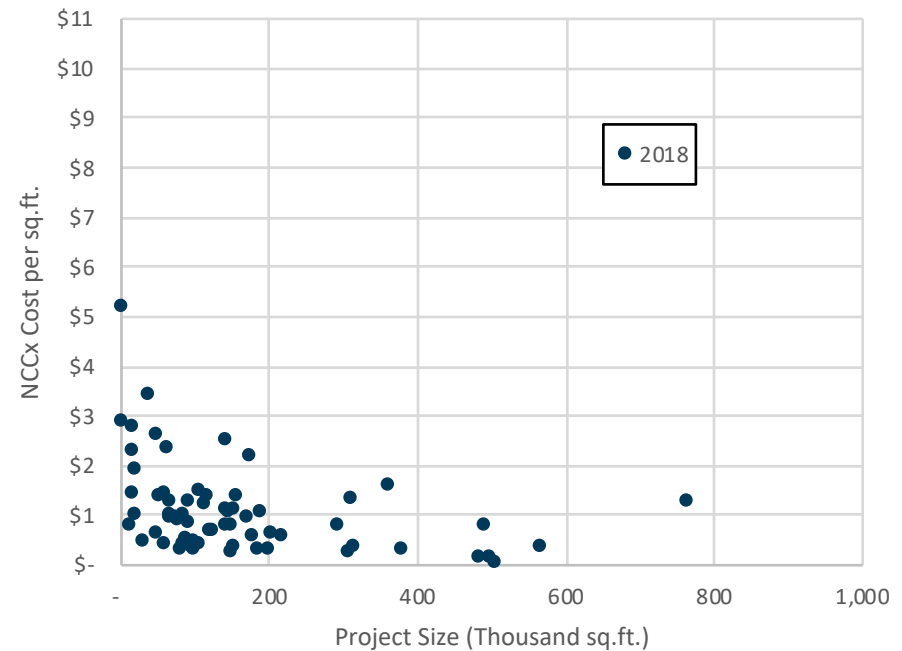


NCCx Cost vs. Project Size

NCCx Cost per sq.ft. vs. Project Size



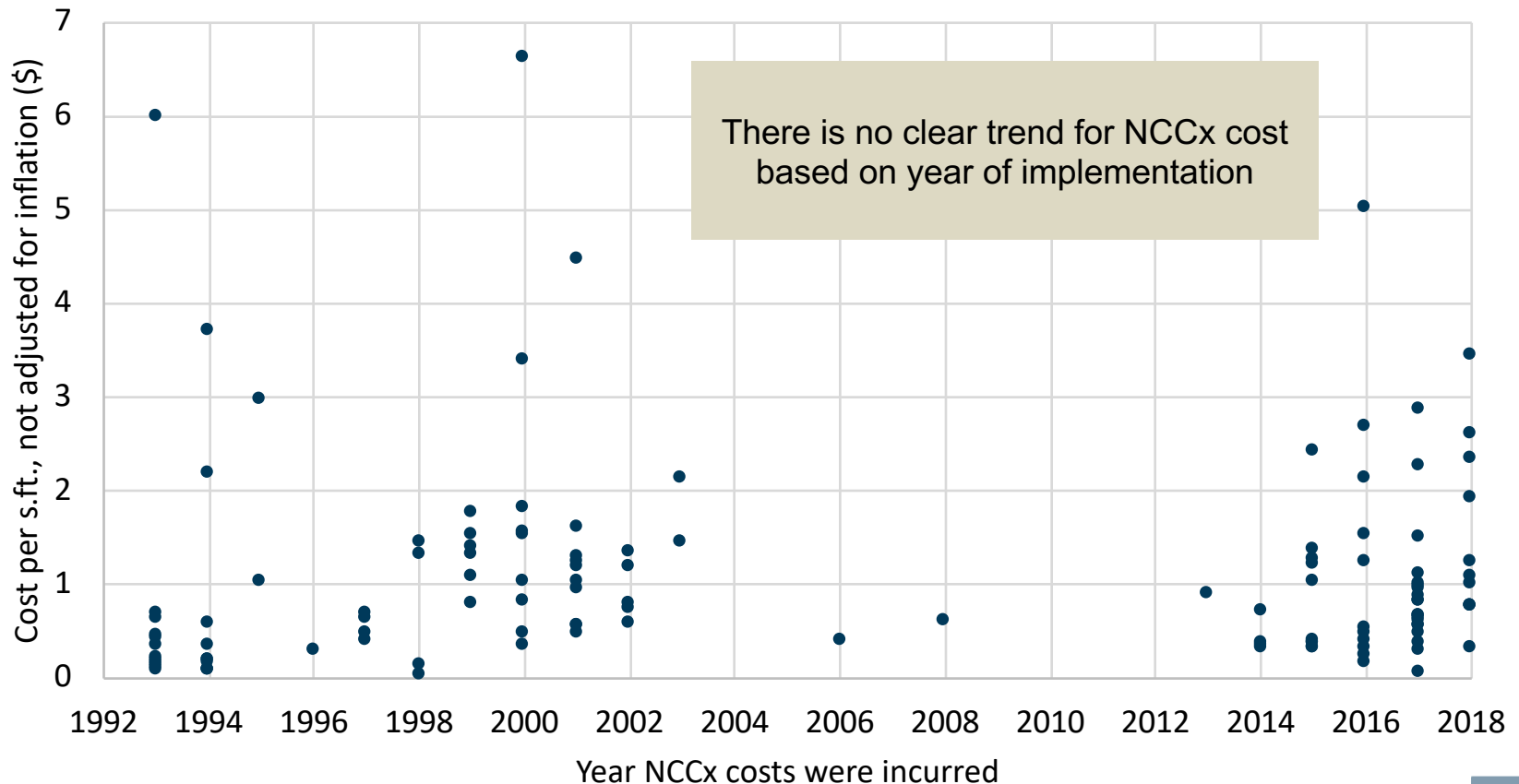
NCCx Cost per sq.ft. vs. Project Size



Looking at 2009 vs. 2018 data sets,
neither shows a strong relationship
between building size and NCCx cost

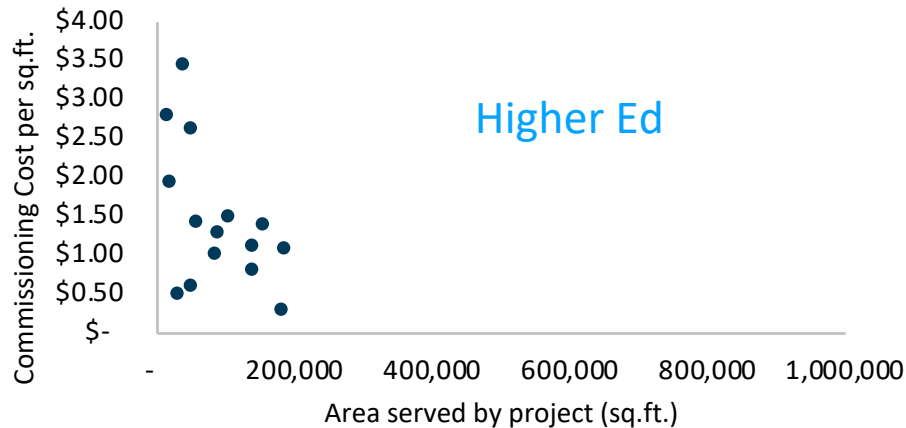
Category	Percentage
Category 1	10%
Category 2	20%
Category 3	30%
Category 4	40%
Category 5	50%
Category 6	60%
Category 7	70%
Category 8	80%
Category 9	90%
Category 10	100%

NCCx Project Cost by year (Actual \$ paid at time of project completion)

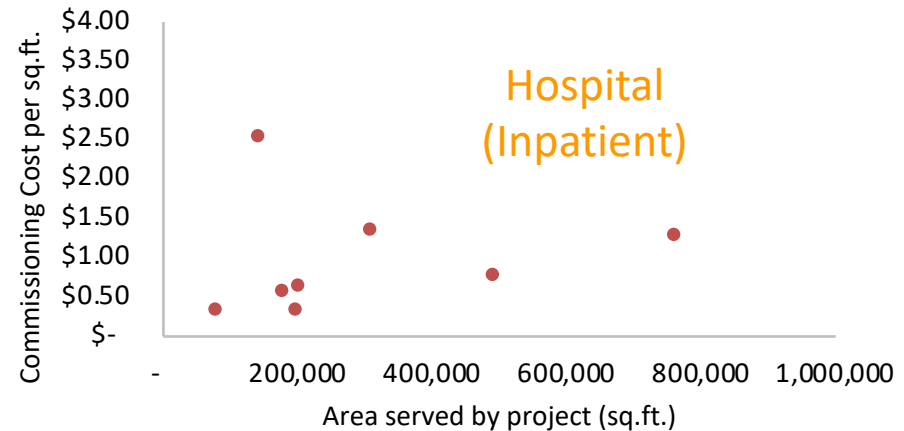


NCCx Cost vs. Project Size

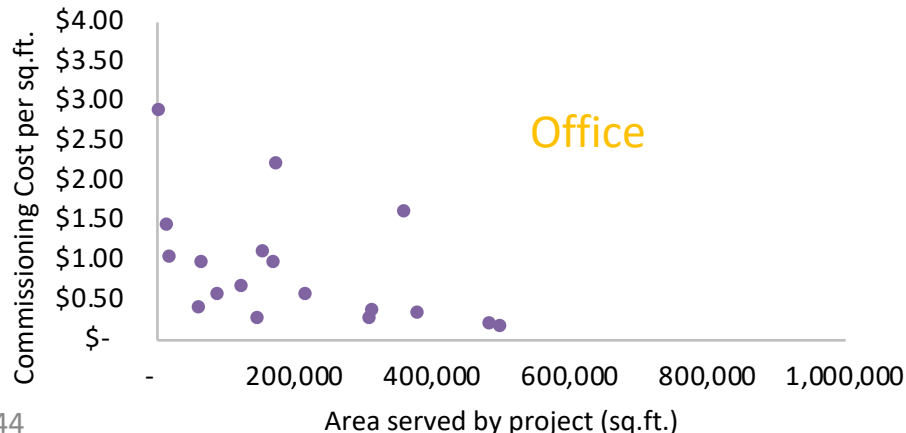
New Construction Commissioning Cost (\$2017/sq.ft.) vs. Project Size (sq.ft.)



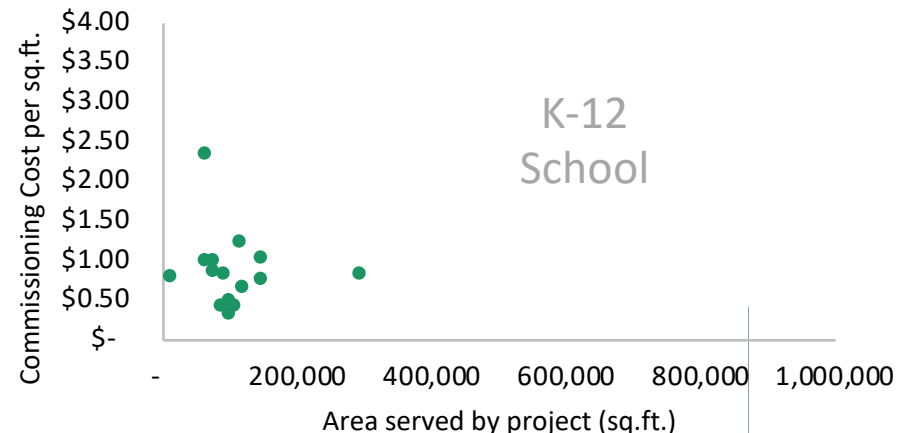
New Construction Commissioning Cost (\$2017/sq.ft.) vs. Project Size (sq.ft.)



New Construction Commissioning Cost (\$2017/sq.ft.) vs. Project Size (sq.ft.)

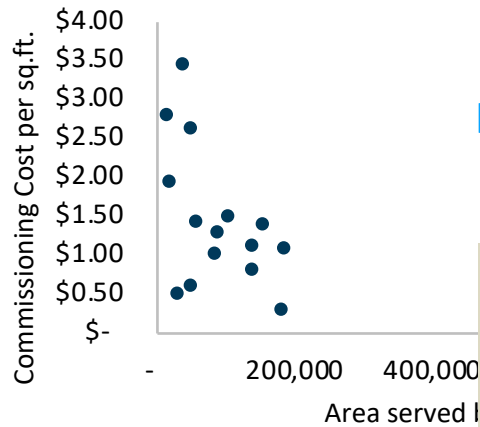


New Construction Commissioning Cost (\$2017/sq.ft.) vs. Project Size (sq.ft.)



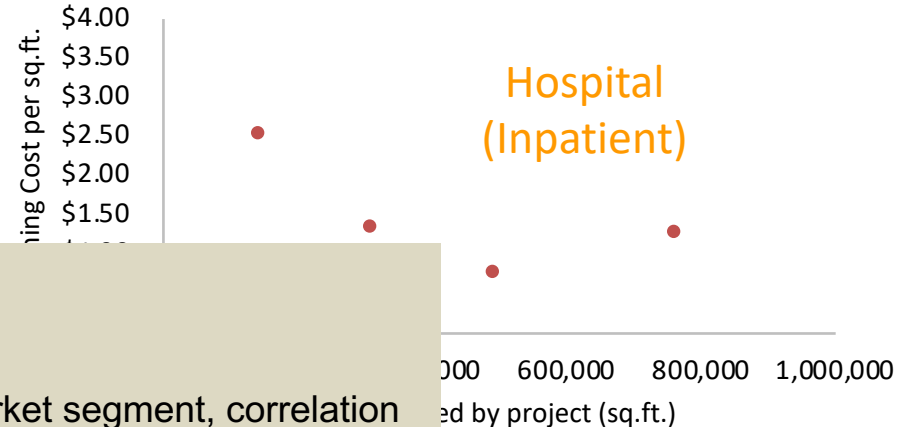
NCCx Cost vs. Project Size

New Construction Commissioning Cost
(\$2017/sq.ft.) vs. Project Size (sq.ft.)



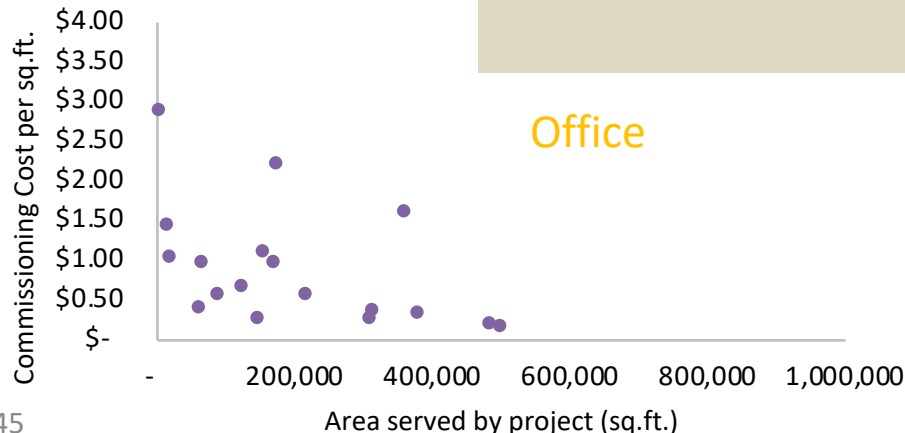
Higher Ed

New Construction Commissioning Cost
(\$2017/sq.ft.) vs. Project Size (sq.ft.)



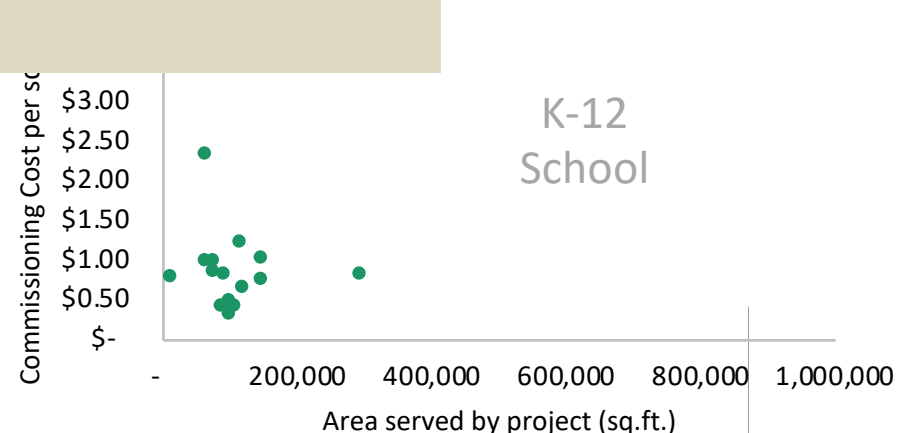
Hospital
(Inpatient)

New Construction Commissioning Cost
(\$2017/sq.ft.) vs. Project Size (sq.ft.)



Office

New Construction Commissioning Cost
(\$2017/sq.ft.) vs. Project Size (sq.ft.)



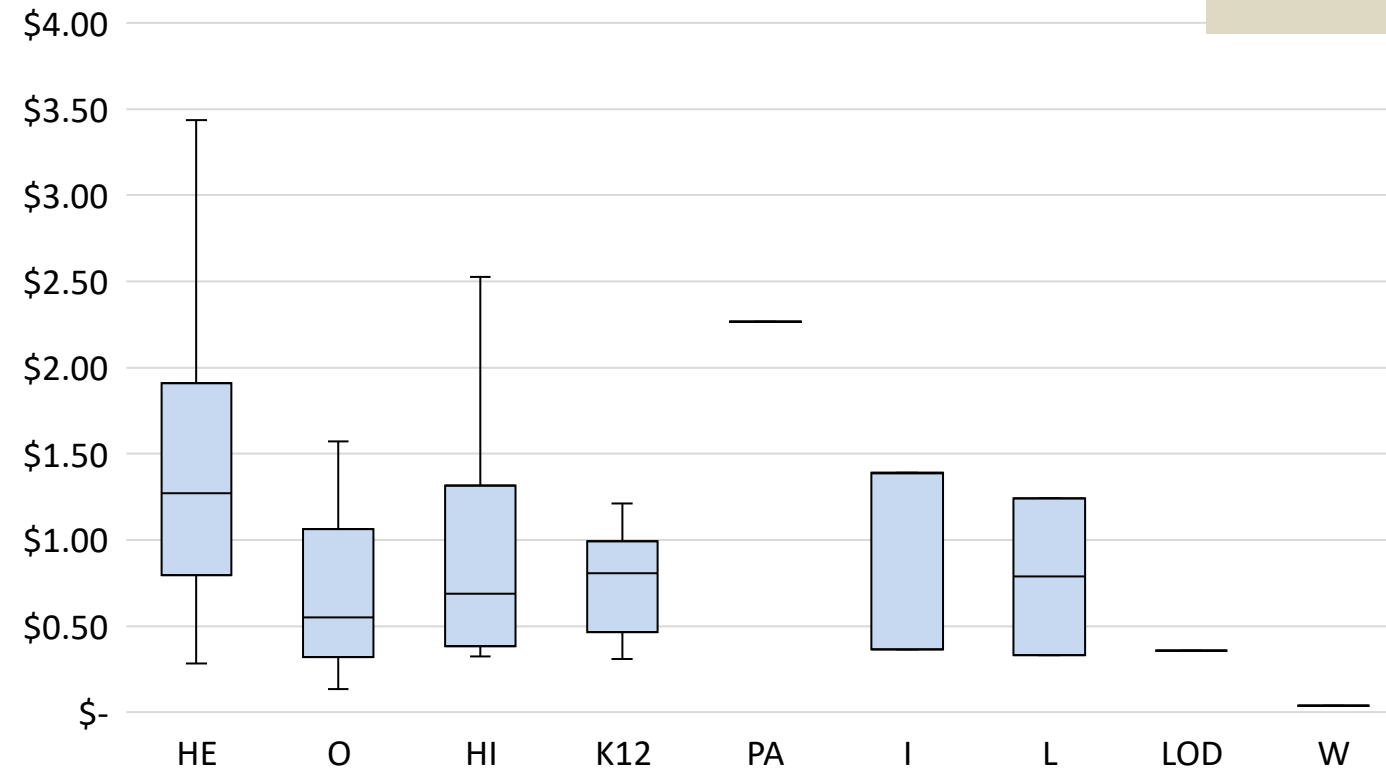
K-12
School

When broken down by market segment, correlation between building size and NCCx cost is still not clear (small sample size)

NCCx Cost by Building Type

New Construction Commissioning Cost (\$2017/sq.ft.)

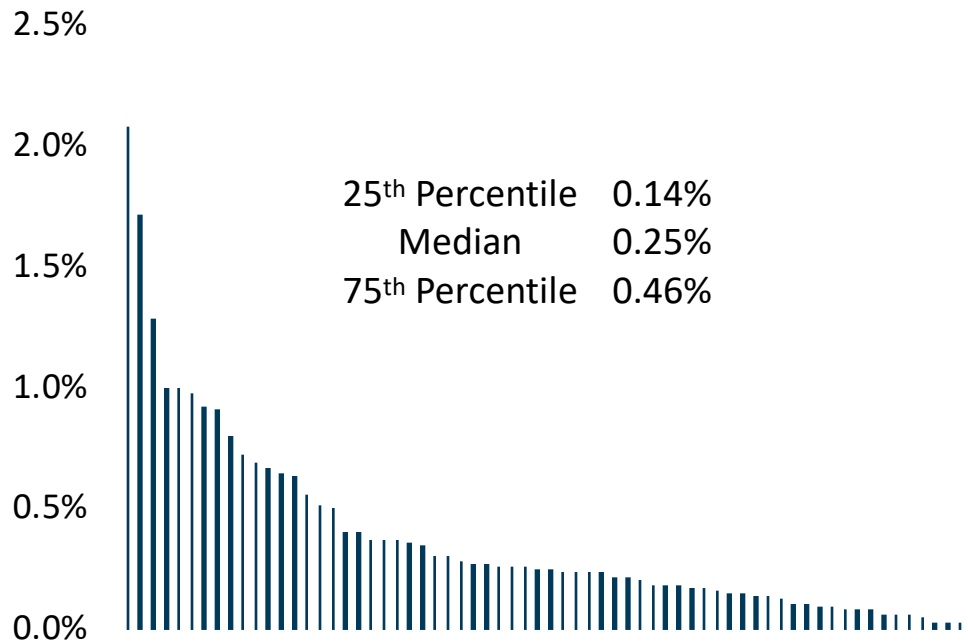
Reviewed NCCx costs by market segment, but datasets too small to draw firm conclusions



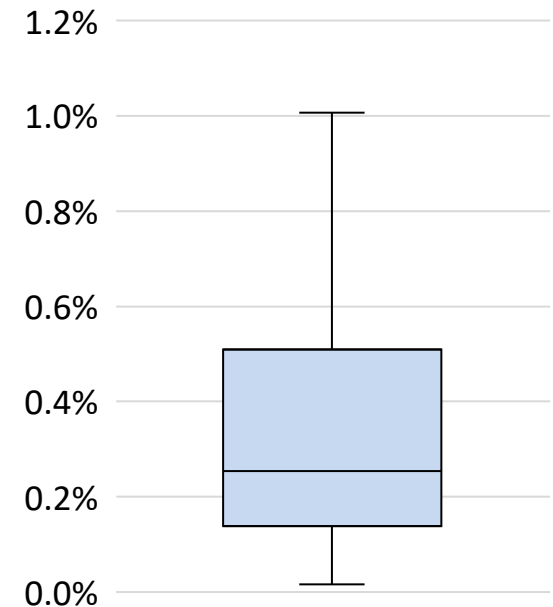
	n=
R	1
HE	15
O	20
HI	8
K12	15
PA	1
I	3
L	2
LOD	1
W	1
	67

NCCx Cost as Percent of Construction

New Construction Commissioning Cost as a
Percentage of Overall Construction Cost
(\$2017)(n=67)

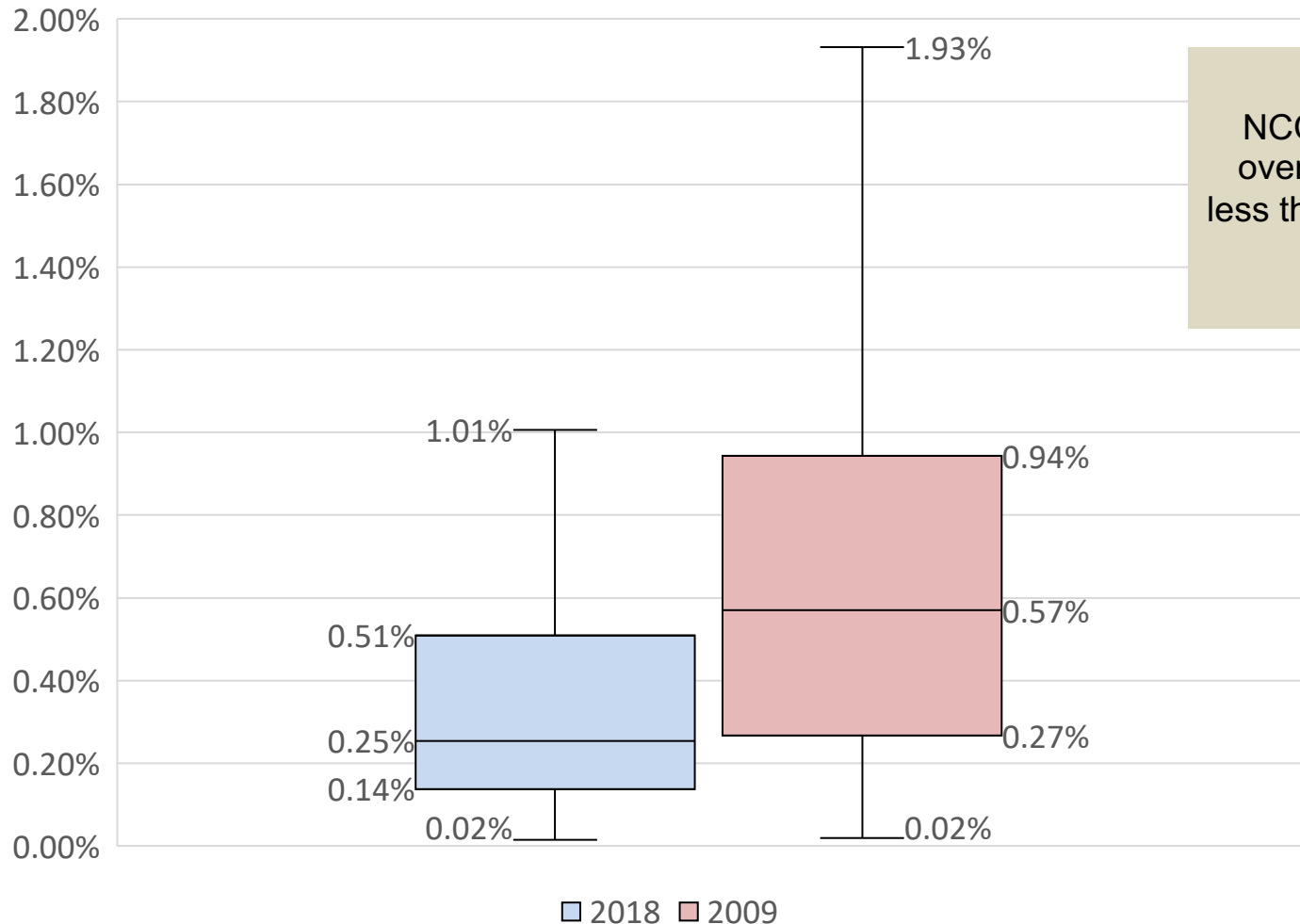


New Construction
Commissioning Cost as a
Percentage of Overall
Construction Cost (\$2017)



NCCx Cost as Percent of Construction

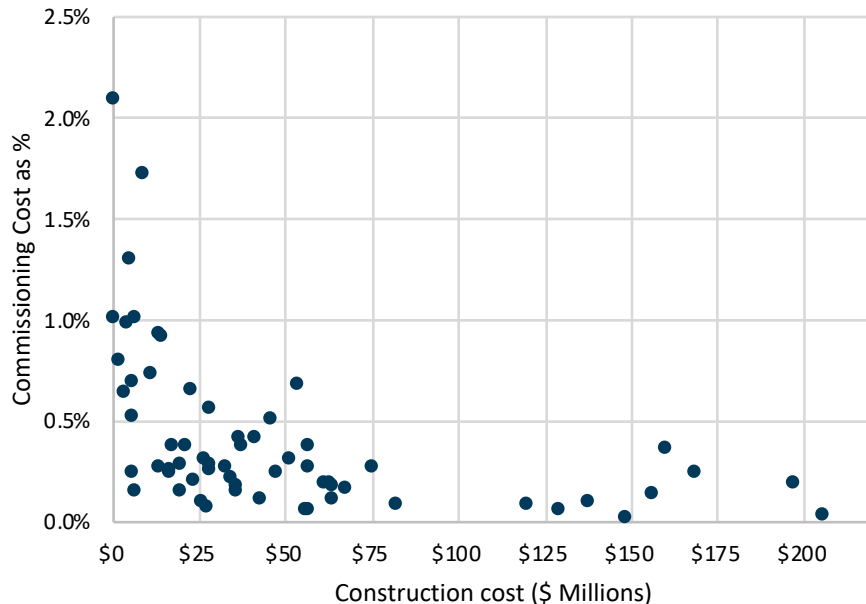
New Construction Commissioning Cost as a Percentage of Overall Construction Cost



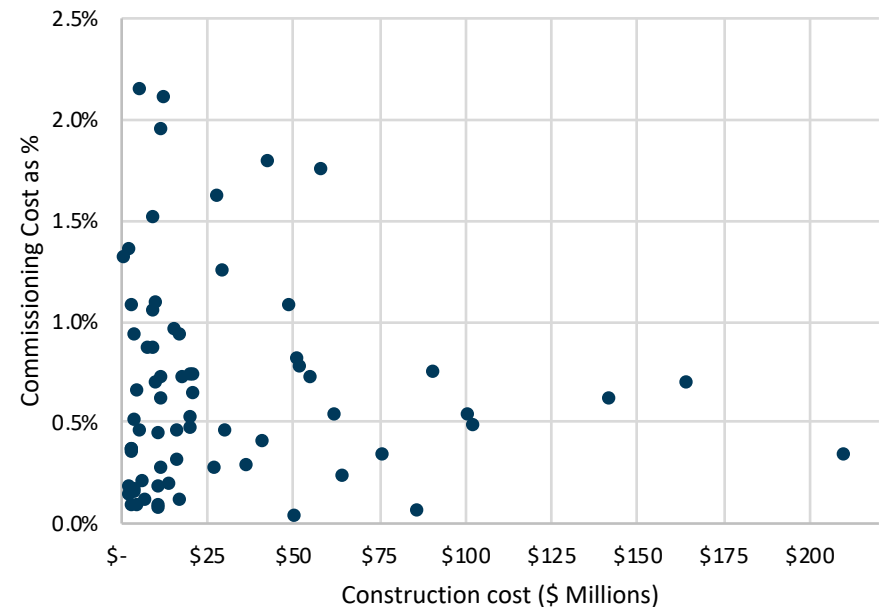
NCCx costs as a percent of overall construction cost are less than half compared to 2009 data set

NCCx Cost as Percent of Construction

Commissioning Cost as a Percent of Overall Construction Cost (2018)(n=67)



Commissioning Cost as a Percent of Overall Construction Cost (2009)(n=72)



2018 data shows clearer relationship between construction cost and commissioning cost percentage (higher construction cost related to lower percentage). 2009 appears more scattered

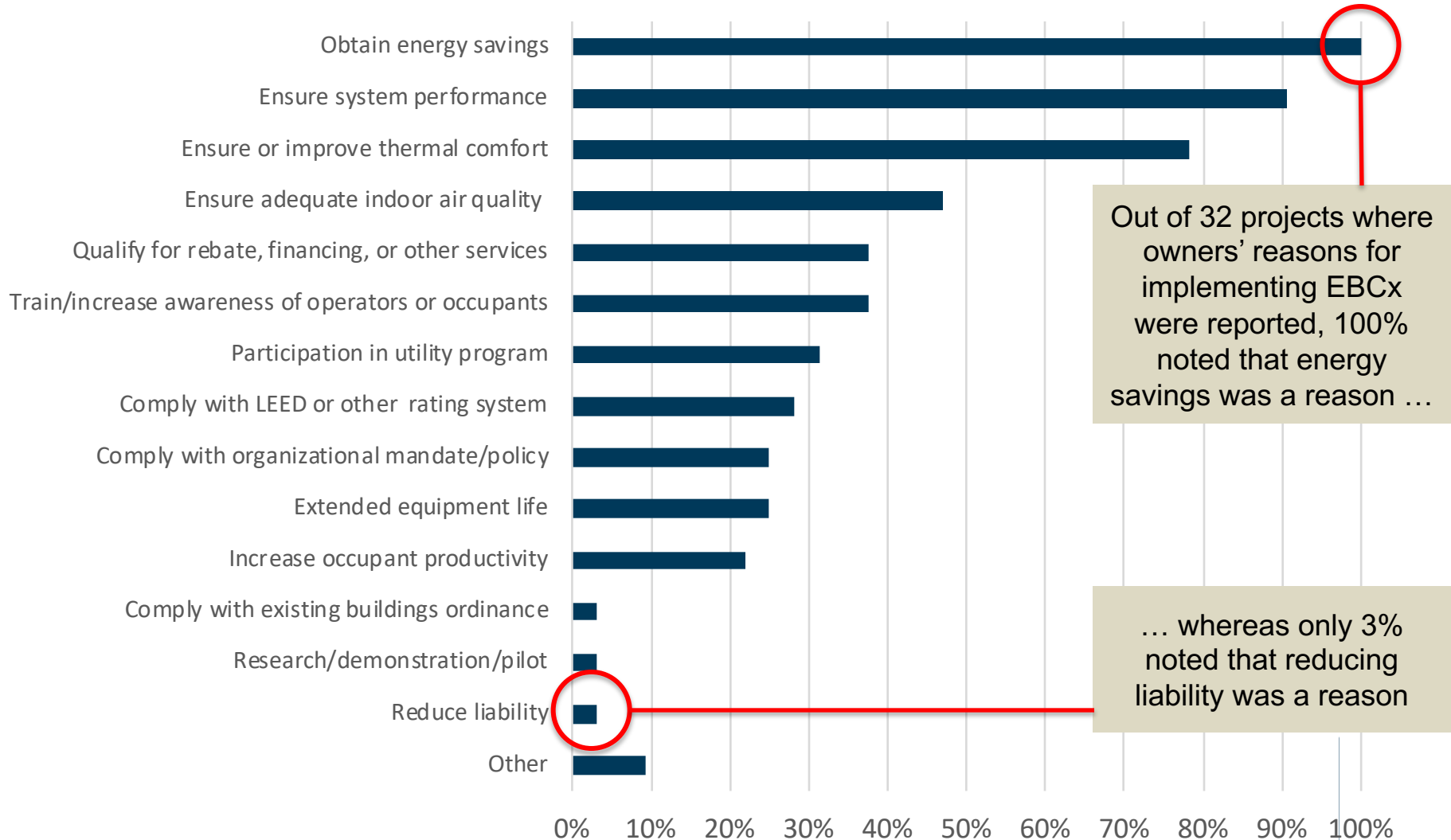
THE WHAT AND WHY

Reasons for Implementing Cx

- Data survey included questions relating to owner motivation for implementing Cx
- 15 possible reasons; respondents (Cx Providers) could choose multiple
- Results determined as: percent of projects where reason 'X' was one of owner's motivations

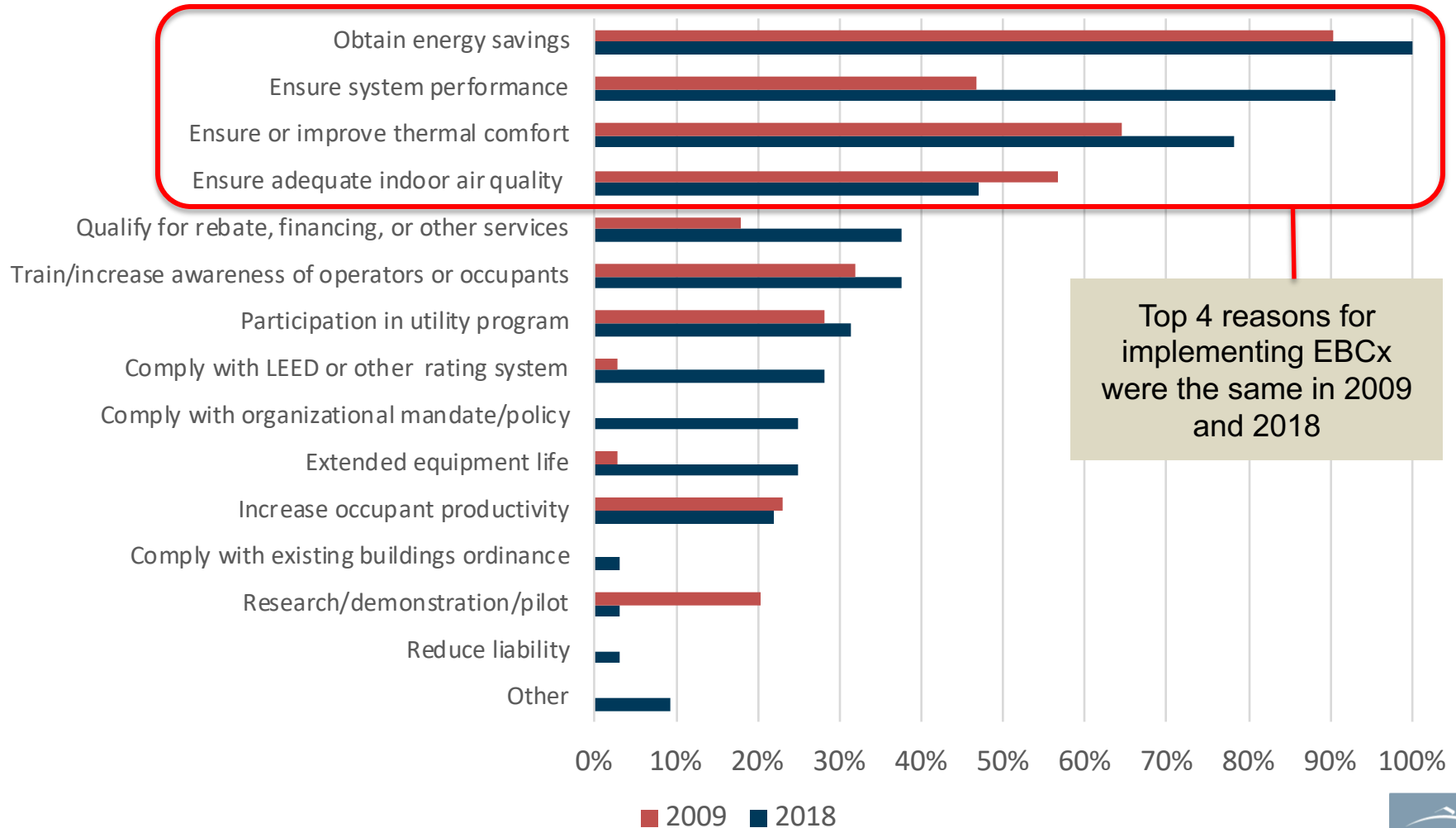
Reasons for Implementing EBCx

Fraction of reporting projects with reason (EBCx), 2018



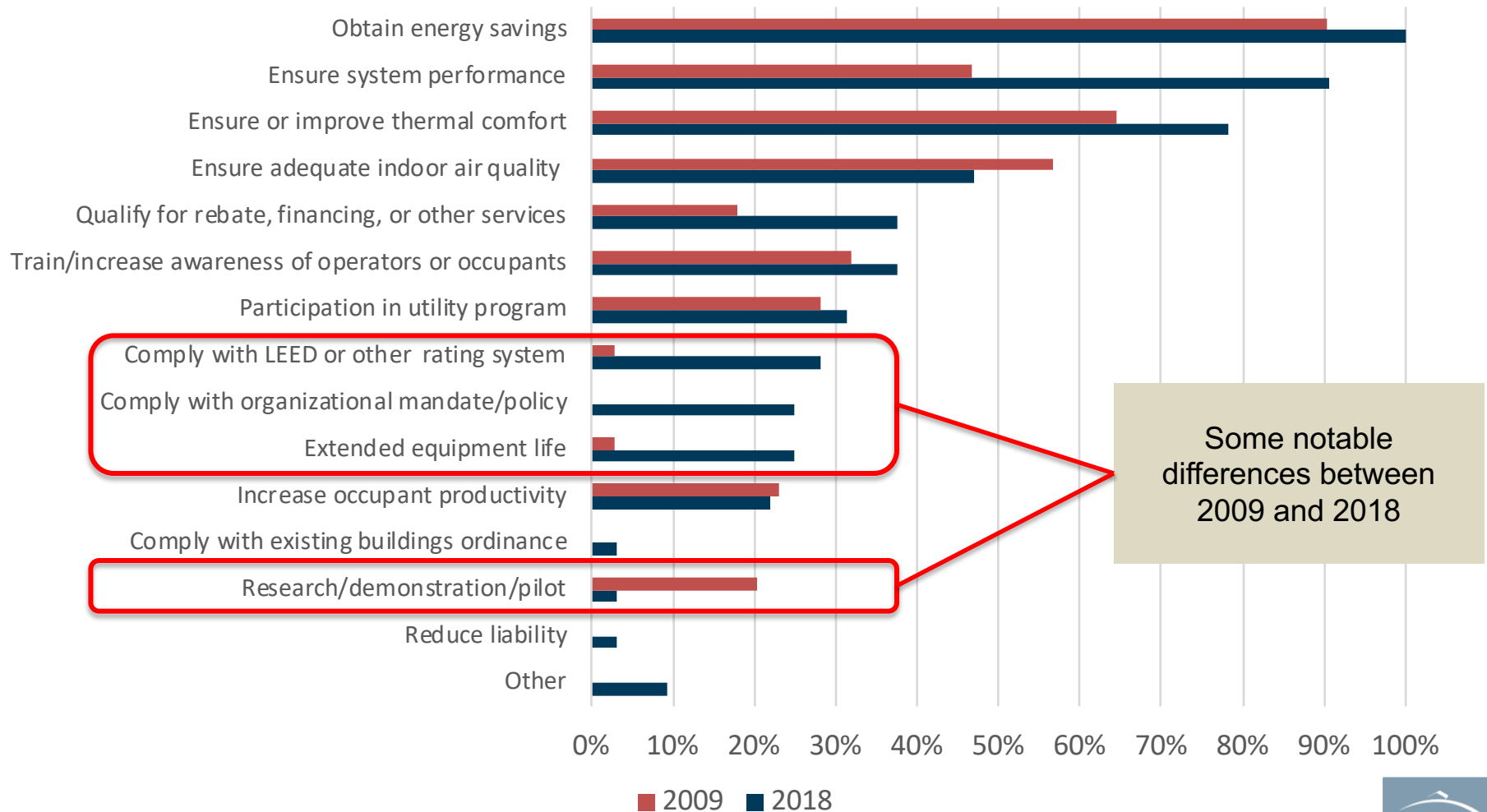
Reasons for Implementing EBCx: 2009 vs. 2018

Fraction of reporting projects with reason (EBCx), 2009 vs. 2018



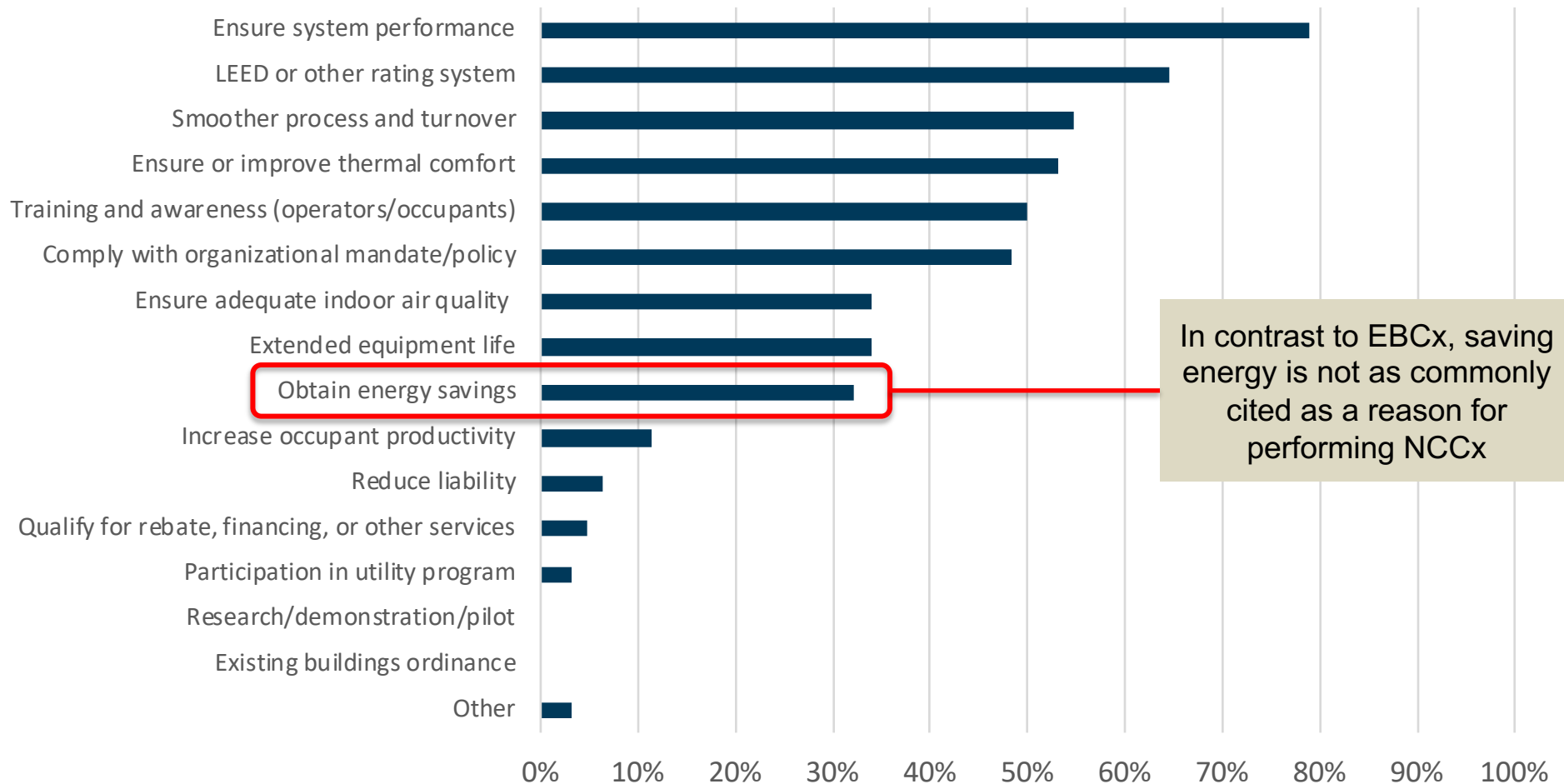
Reasons for Implementing EBCx: 2009 vs. 2018

Fraction of reporting projects with reason (EBCx), 2009 vs. 2018



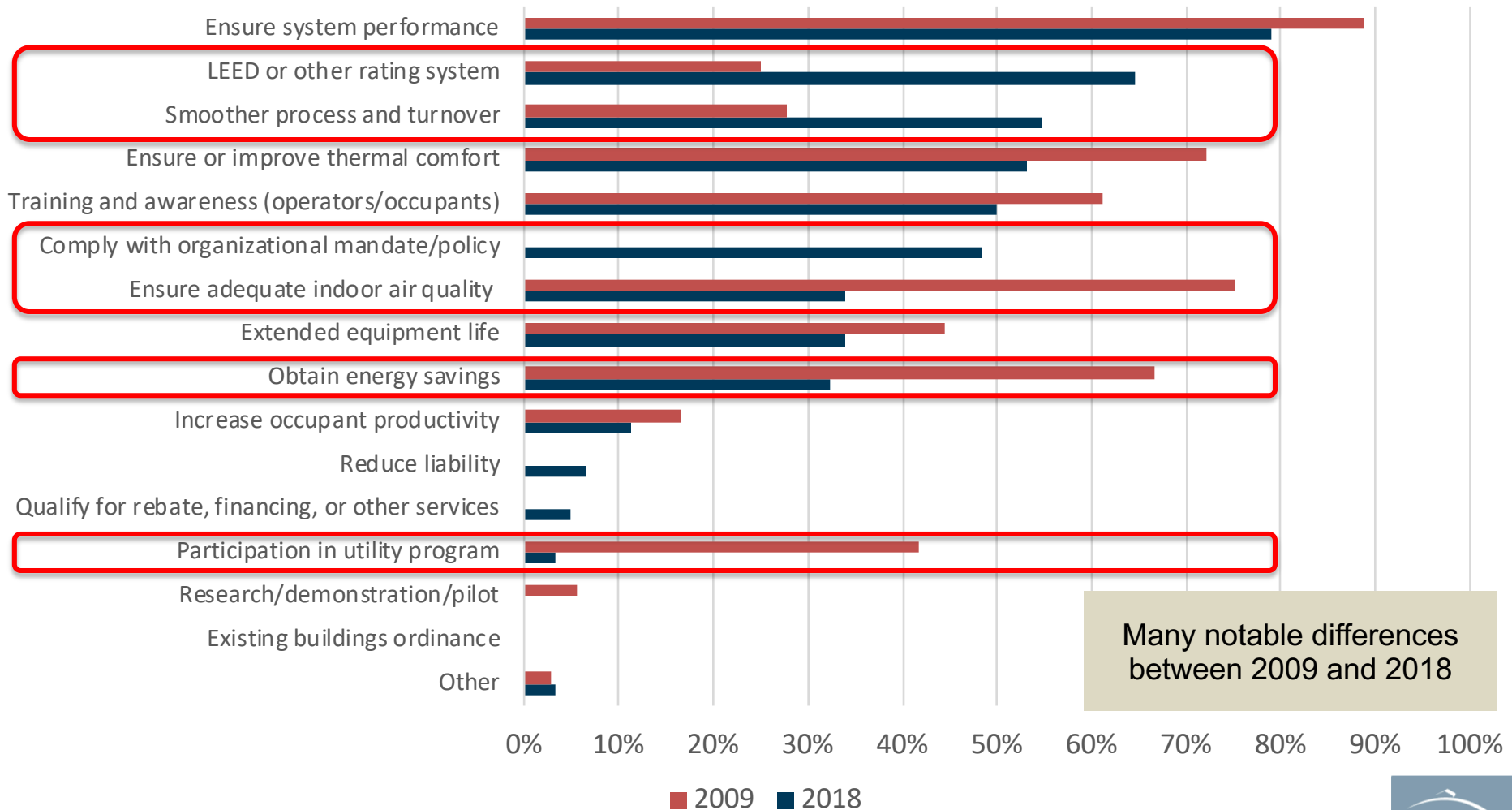
Reasons for implementing NCCx

Fraction of reporting projects with reason (New Construction), 2018 (n = 62)



Reasons for implementing NCCx

Fraction of reporting projects with reason (New Construction), 2009 vs. 2018

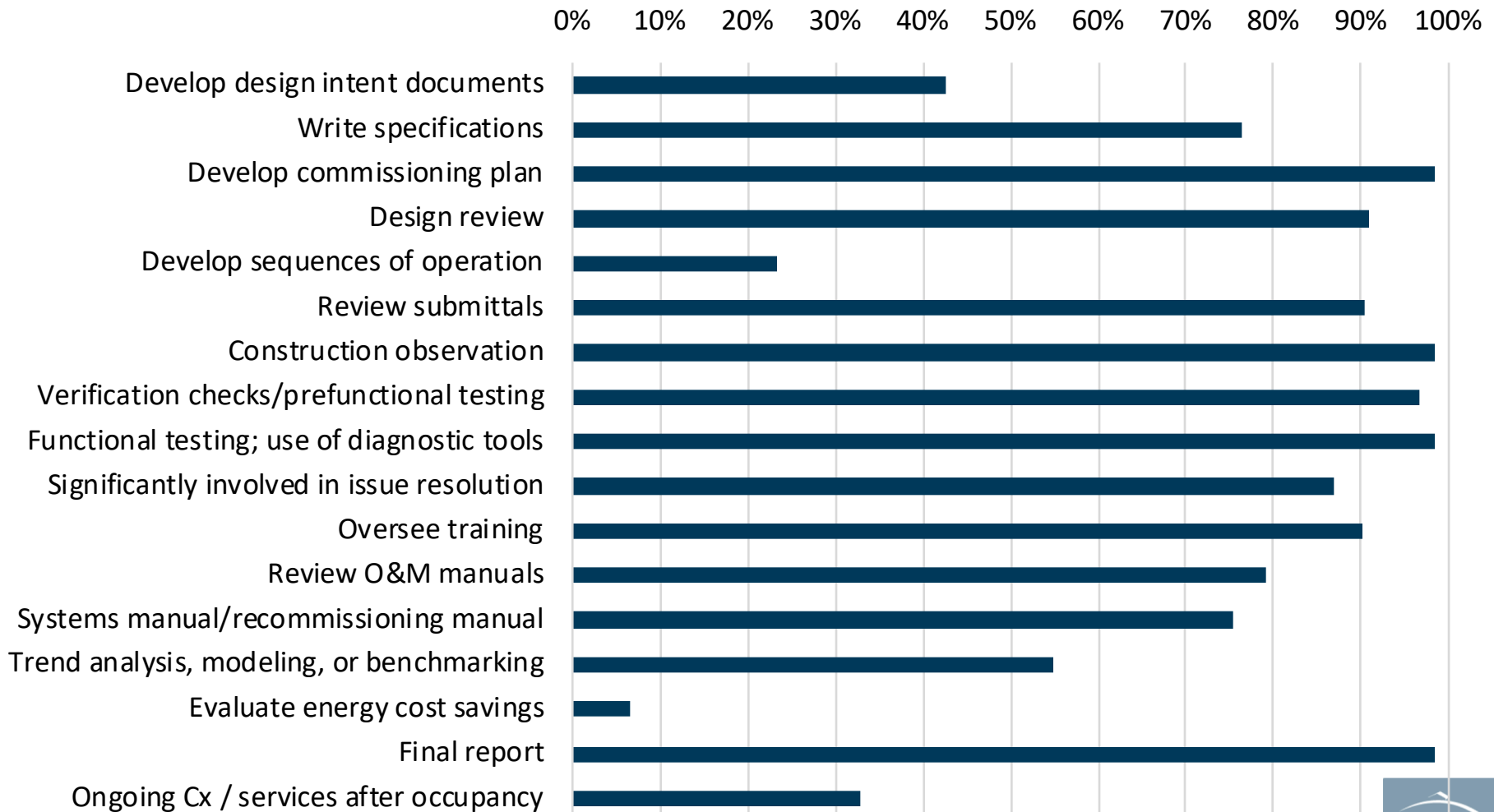


NCCx Scope of Work

- NCCx best practice calls for Cx Provider involvement from pre-design stage through to occupancy
- Implied linkage between quality of Cx, Cx cost, and the comprehensiveness of Cx scope
- Data survey asked or list of items included in NCCx scope

NCCx Scope of Work

Activities included in New Construction Commissioning Scope (n=62)

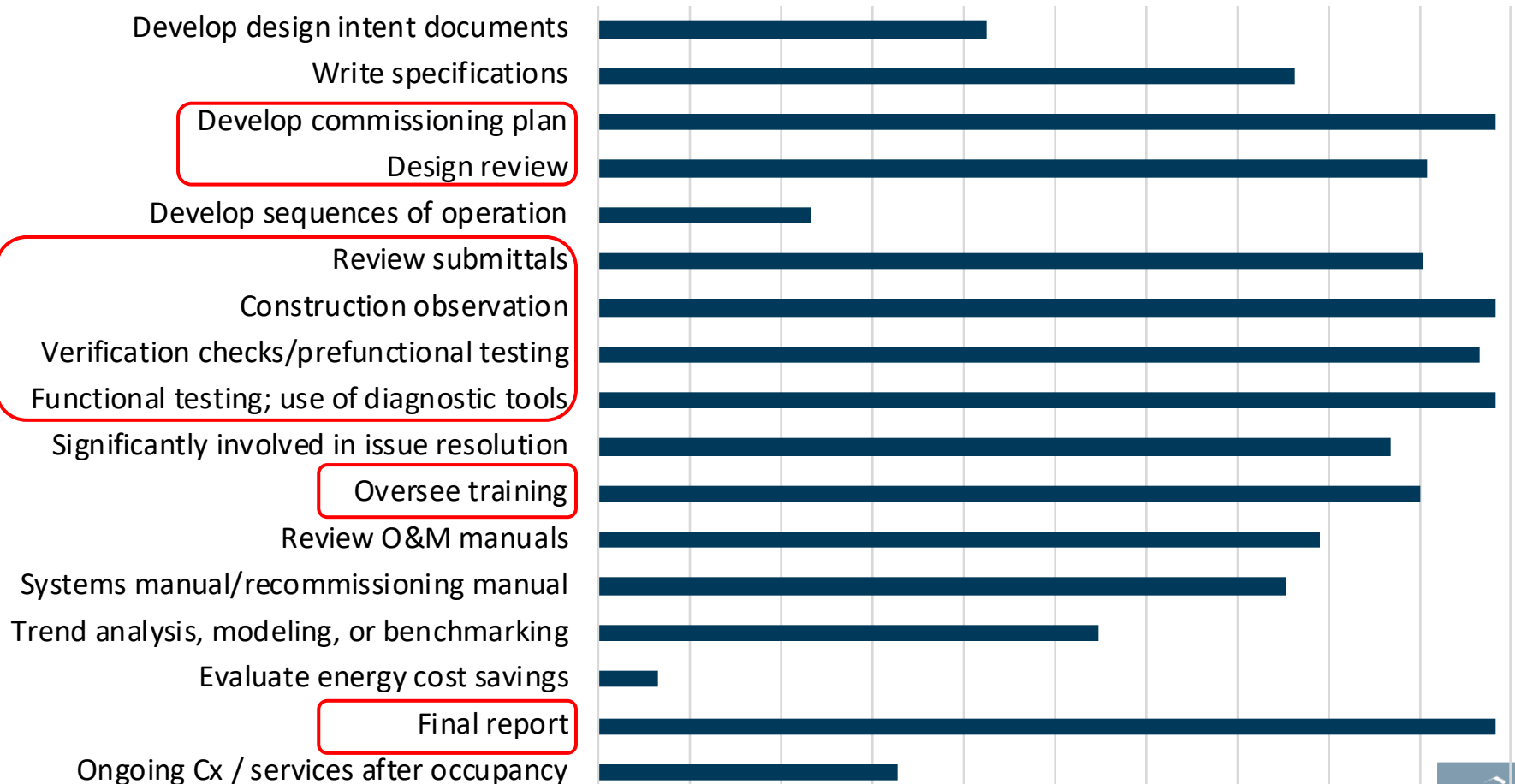


NCCx Scope of Work

Activities included in New Construction Commissioning Scope (n=62)

> 80%

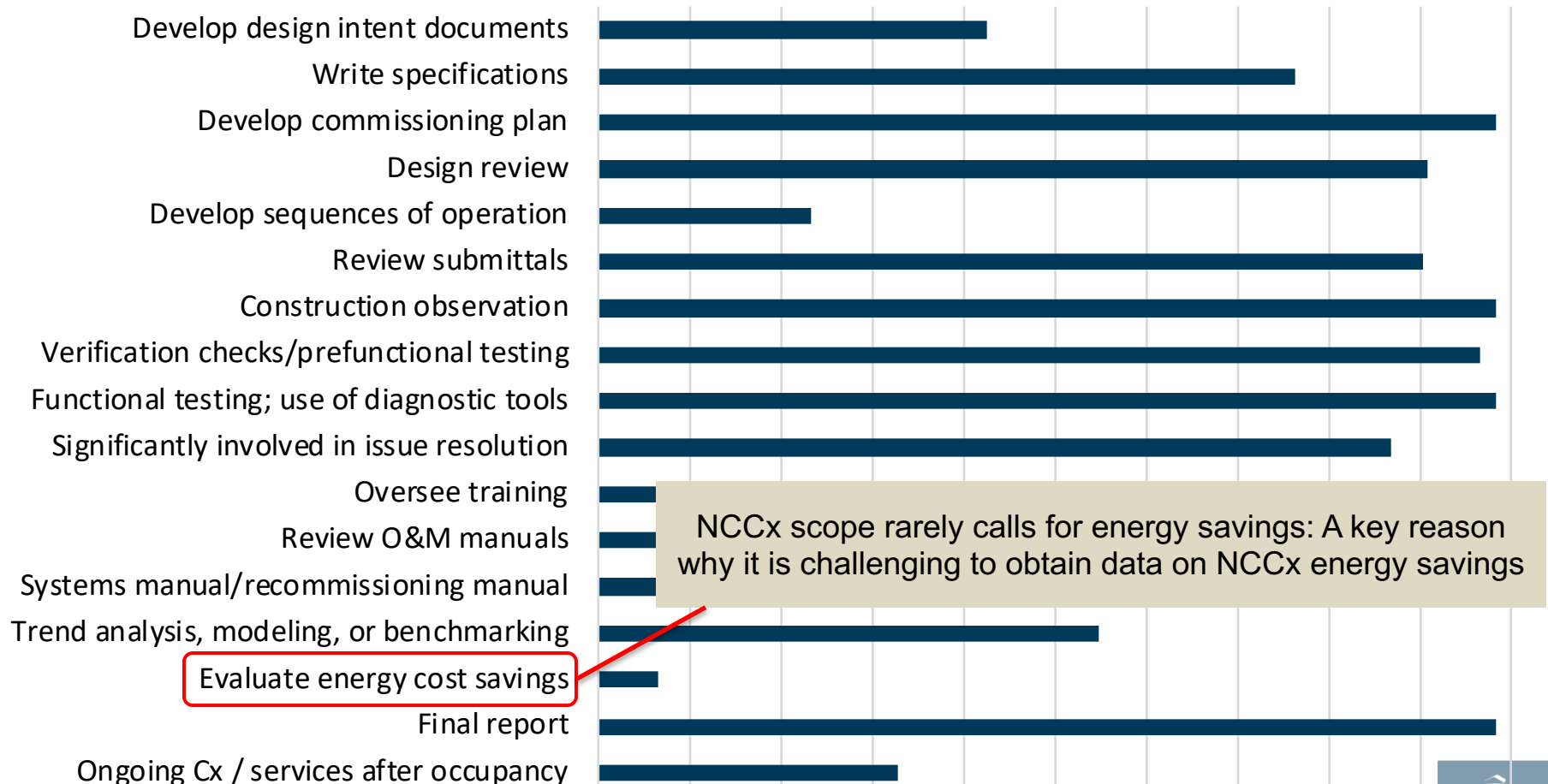
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%



NCCx Scope of Work

Activities included in New Construction Commissioning Scope (n=62)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%



Non-Energy Benefits of NCCx

Percent of Projects Reporting Non-energy Benefits (New Construction)(n=39)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

FIRST COST SAVINGS

On schedule, problems detected/corrected earlier

Occupied on schedule

System design improved, right-size equipment

Improve team coordination

Occupied sooner, reduced call-backs / TAB costs

Fewer change orders; warranty claims

Other or unspecified first-cost

ONGOING (RECURRING) IMPROVEMENTS

Thermal Comfort

Maintenance

Improved O&M

Training; education

Indoor Air Quality

Equipment Life

Liability

Tenant retention; turnover

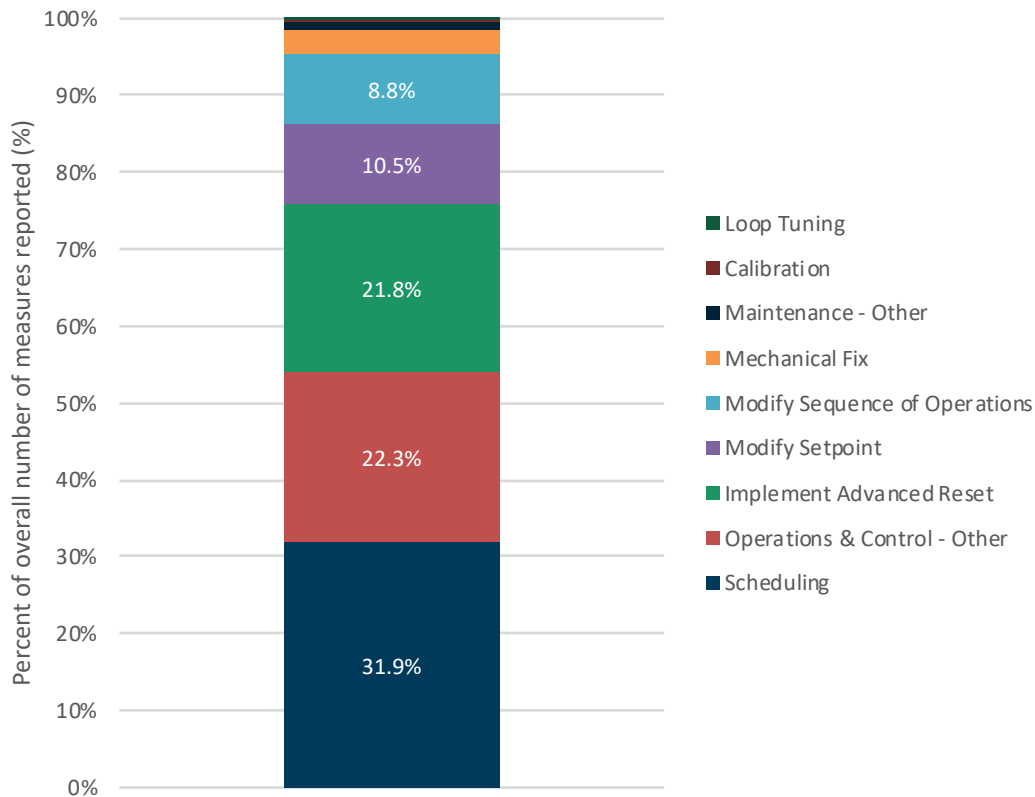
Productivity/Safety

Other (or combination of above)

10 high-value non-energy benefits reported on over two thirds of projects, impacting construction project first costs and ongoing benefits

EBCx Measures Implemented

Utility Program EBCx Measure Types (n = 3,695 measures, 503 projects)



- A total of 3,695 installed EBCx measures were reported, across 503 projects: 7.3 measures per projects
- Top 5 measure types account for 95% of the reported measures
- Detailed data on measures not available for NCCx

Key Findings: EBCx

1. Utility EBCx programs shown to reliably offer cost effective savings in the 3%-10% range, at scale
2. Energy Savings
 - a. Median 6%, typical range 3%-10%
 - b. MBCx or EBCx outside utility programs could hit 10%-20% range (but data is limited)
 - c. 2018 median down from 2009, though looking at project type suggests no major market shift (changes more likely due to sample composition)
3. Simple Payback
 - a. Median 2.2 years. Range generally 1 and 4 years payback
 - b. Median \$0.25 project cost per sq.ft., with a typical range \$0.13-\$0.48
 - c. Projects at lower percent savings can still be highly cost-effective
4. Owners' reasons for implementing EBCx: Top 4 are unchanged from 2009 study
5. EBCx Measures
 - a. Top 5 measure types (out of 9) account for 95% of all EBCx measures
 - b. Top measures focused on control improvements not mechanical repairs

Key Findings: NCCx

1. NCCx Cost

- a. \$0.82 per sq.ft., typical range \$0.40-\$1.35, compared with median \$1.16 in 2009 study
- b. 0.25% of overall construction cost, compared with median 0.57% in 2009 study
- c. Difference in 2018 and 2009 sample composition makes it difficult to conclude true shift in market costs for NCCx, though there is anecdotal evidence costs have reduced
- d. Larger projects tend to have lower cost per sq.ft., and market segment also has an impact on cost

2. Savings and Payback: insufficient data for updating 2009 results

- a. Survey responses report that only 6% of projects include scope item to evaluate energy savings

3. NCCx Scope of Work

- a. For projects in 2018 dataset, >90% of Cx Providers were involved at the design review stage
- b. Engagement of Cx provider for post-occupancy services is still low

4. Non-Energy Benefits

- a. 10 high-value non-energy benefits reported on over two thirds of projects, impacting construction project first costs and ongoing benefits

Key Contacts

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