Performance in the Commercial Sector 1980-2010

The long-term impact of codes and engineering practice

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Objectives

- Describe the commercial building performance in the PNW
  - Buildings built over ~50 years
  - Sampled at random using various sampling approaches
  - Compared to historic data
  - Focus on four building types
  - Assess current energy performance trends
- Performance based on EUI in Kbtu/sf
  - Conditioned floor area
  - Site energy based on complete utility bills
- Describe performance goals of the WA State Energy Code
  - Legislative mandate, 2009
  - Progress to date in the performance estimates
- Propose programs to significantly improve performance

Databases

- CBSA 2008 (2014 buildings, 1188 EUIs):
  - Developed from a series of commercial building audits from 1987 to 2008
    - About 9 separate stratified random samples
    - Sampled from various geographic areas across the regions.
  - Large new construction sample (2006-2007)
  - Complex sample designs make any weighting scheme very problematic
  - Utility energy use collected on 60% of the sample from 2008-9 utility records
- CBSA 2014 (1380 buildings, 593 EUIs):
  - A sample commercial buildings as available in 2012.
  - Sample corrupted by complexity and significant recruiting difficulties
  - Characteristics survey designed to be consistent with CBSA 2008
  - Utility energy use collected on about 43% of the sample

Comparison Datasets

- 2003 and 2012 CBECS:
  - National summary in two major data collection efforts,
  - About 5000 buildings each sample
  - Summaries mapped to CBSA building types.
- 1985 CAP Audits (~1700 buildings--Office, Retail, Groceries, Schools)
  - Sample of convenience drawn from utility sponsored audits
  - Database not available, data summaries from 1988
  - Energy bills and EUIs calculated for 1984-1985

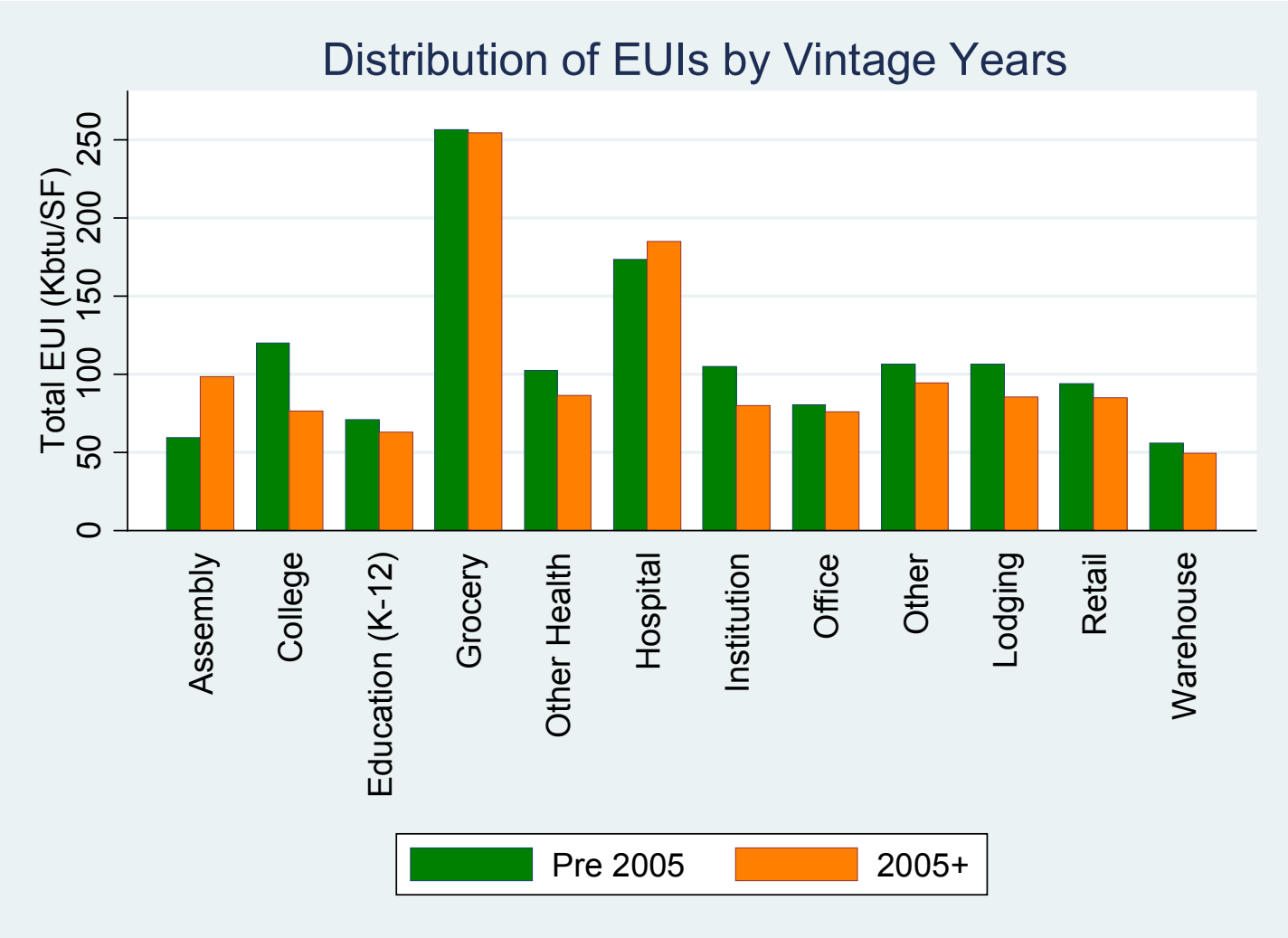
EUI Summary Development

- Combined CBSA samples with all available data
- Reviewed EUI information to assess the validity of the data entered
  - Buildings with modeled energy use removed (about 45% of the samples)
  - Building types reset to a single definition across all samples
- Sample weights and climates ignored (over 80% in Climate “4C”)
- Building type based on “use” when the audit was conducted
  - Updated in older samples with a phone survey
- Buildings categorized by vintage of initial occupancy
  - 2005 on is used as the modern building sample
  - Vintage cohorts in decade bins from 1980
  - Treated as stratified sample by building type and vintage.
  - No weightings applied

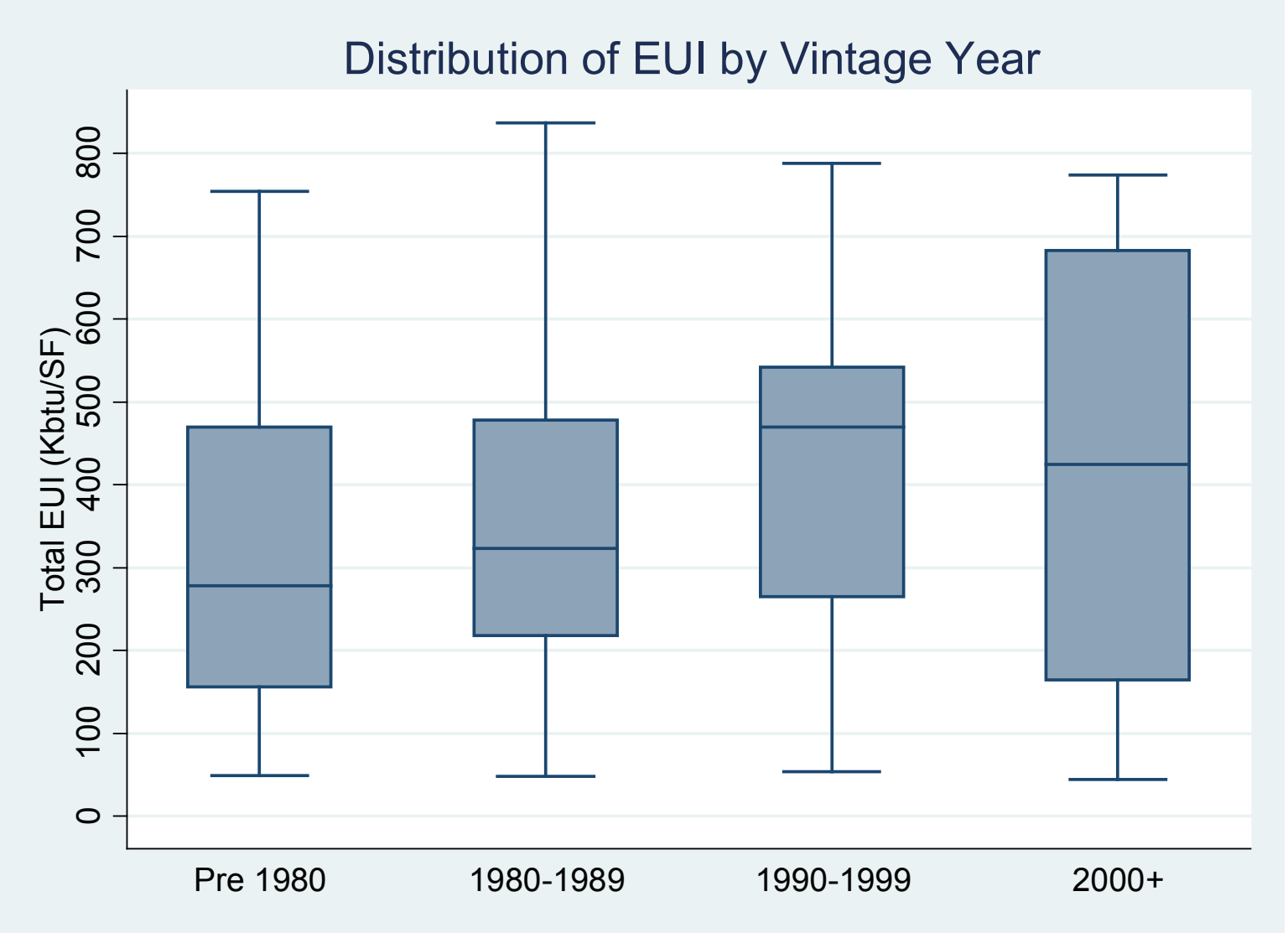
CBSAs Building Type Sample Sizes

Building Type	Audits	EUI sample	%
Assembly	177	84	47
College	119	22	17
Education (K-12)	343	161	47
Grocery	289	155	54
Other Health	217	137	63
Hospital	131	45	32
Institution	134	75	56
Office	533	342	64
Other	149	74	50
Lodging	173	100	57
Restaurant/Bar	296	140	47
Retail	521	287	55
Warehouse	292	172	59
Total	3374	1794	53

Comparison of EUI Averages



…and Restaurants



Energy Use Trends

- In some building types comparisons across buildings are less meaningful
  - Process loads depend on occupancy not on building construction
    - Hospitals/Labs
    - Warehouse becomes manufacturing
    - Restaurants: EUI dominated by food prep not building characteristics
  - Master metered and district steam
    - Colleges/Universities
  - Diverse categories with building that are not comparable
    - Assembly and Other: Catch all categories with very diverse building types

EUI analysis

- Building type “case studies”: Office, Retail/Grocery, Schools
  - About 55% of the buildings in the sample
  - About 60% of the total conditioned area
- Benchmarks
  - CBECS (2003, 2012):
    - Nationwide sample, almost 5000 buildings each survey
    - Traceable sample design and weights
  - BPA (CAP), SCL (~1985 Audits)
    - Region-wide audits with EUIs
    - Most comprehensive survey of 1980s baseline
    - Most building types represented, compiled from secondary sources
    - Original data not available
  - Energy code requirements (lighting power)
    - WSEC, 1986-2006
    - OSEC, 1989-2000

Determinants of EUI

- For most building types: new buildings like old buildings
- Size?
  - Overall size *doesn't* matter for EUI comparison
  - In the target buildings the EUI relation to size has an $R^2<0.02$
- LPD Improvement?
  - Utility programs over 30 years have reduced the LPD comparably with Codes
  - Balanced by other building characteristics
    - Increased ventilation,
    - Simultaneous heating and cooling (especially VAV)
- Heat loss rates, Reduced UA
  - 30 to 50 percent reduction in envelope heat loss rate
  - Little evidence of an impact on EUIs in most building types
- Sloppy engineering,
  - Oversized and expensive systems,
  - Consistent whining about someone else's issues.

Building Types

Office

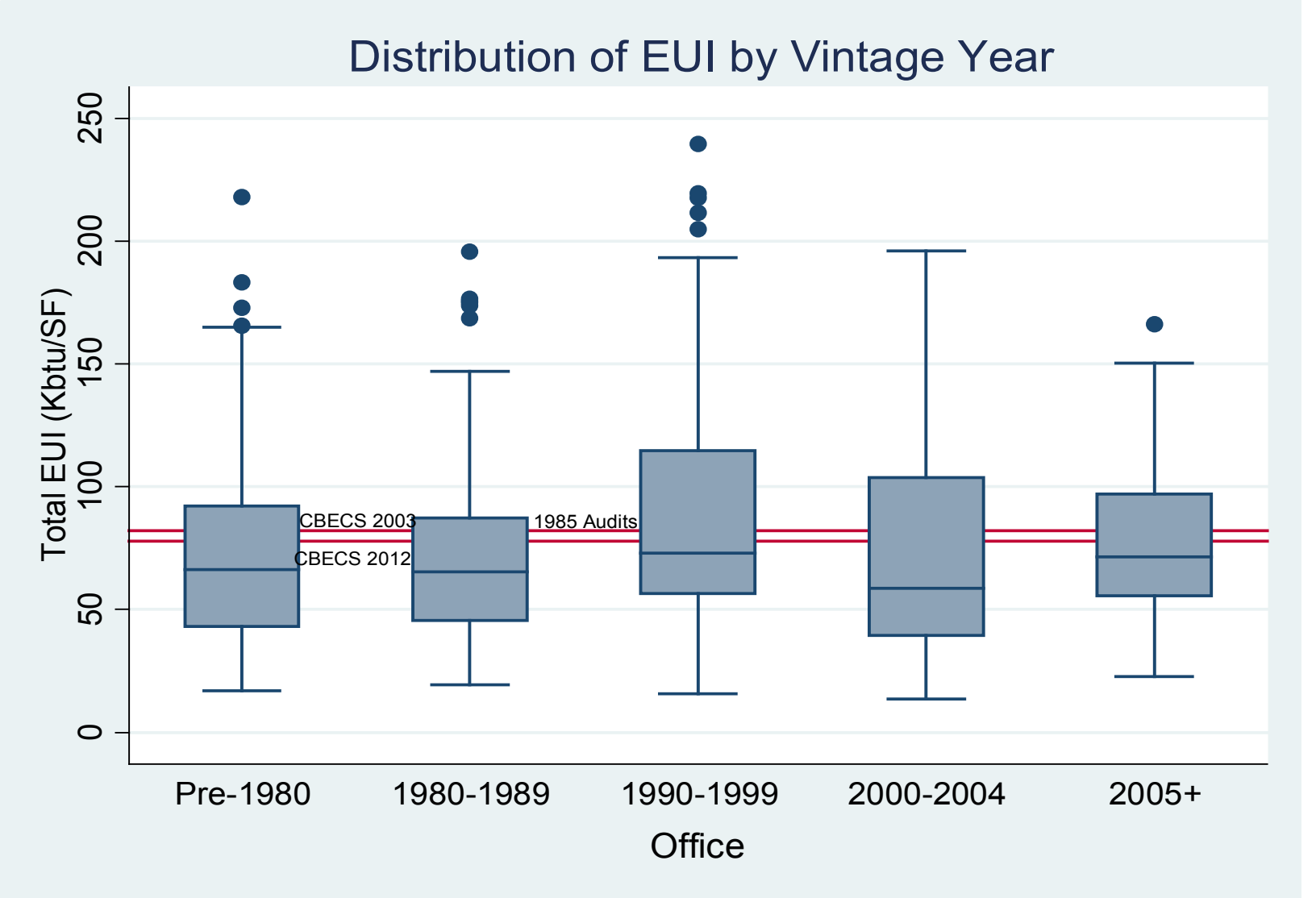
Retail/Grocery

Schools (K-12)

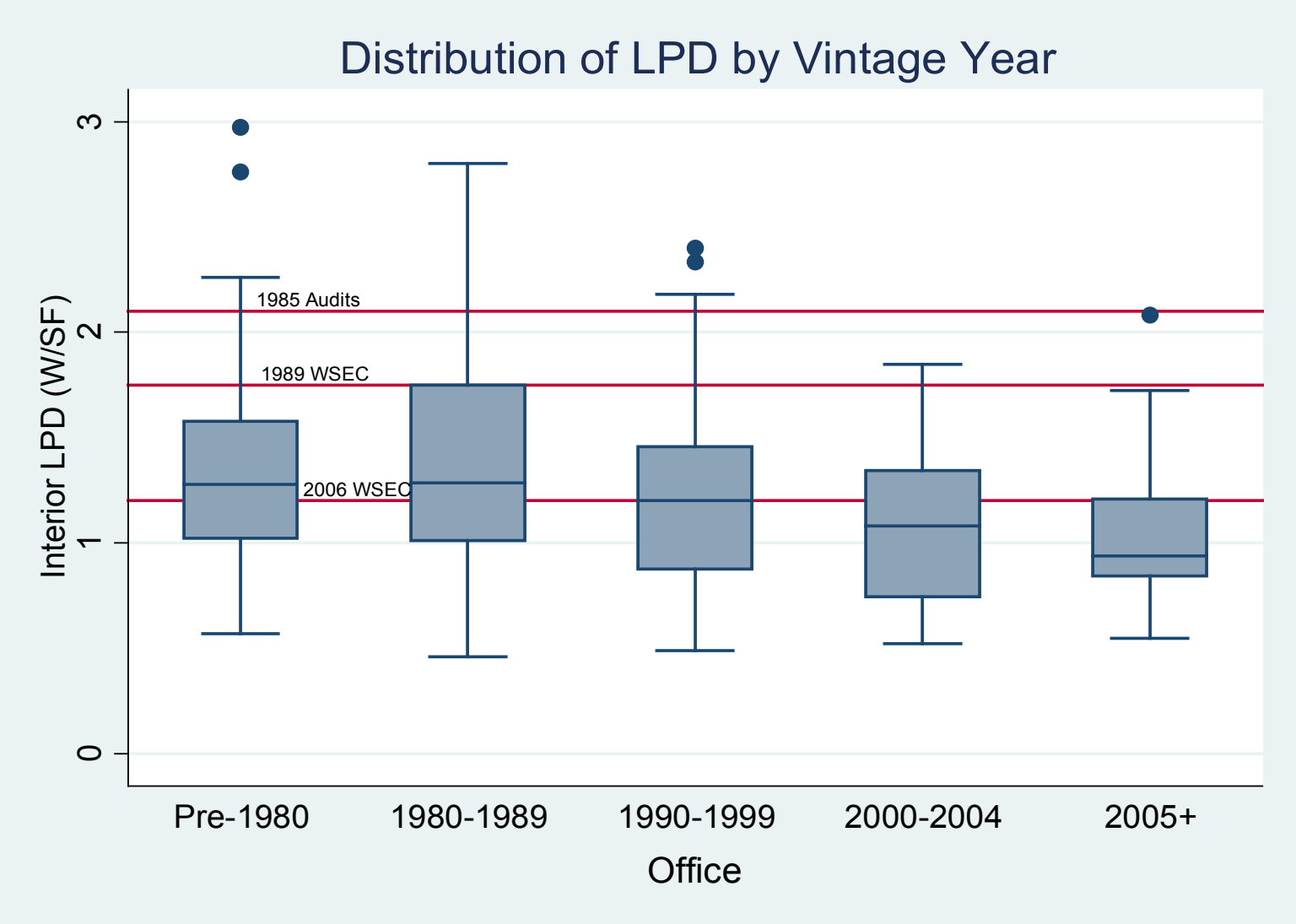
Office

- Similar HVAC systems across the sector
- EUIs uncorrelated to building size (R^2<0.02)
- Similar lighting throughout the sector
  - Substantial lighting change outs over time (T12 to T8)
  - Consistent LPD in all vintages
  - LPDs will be further reduced by LEDs
- Heat loss rate (UA/sf) reduced almost 50% from the pre 1980 buildings
  - Mostly in the first decade of code enforcement
- About an 8% site energy reduction from historic averages (pre 1980) in the 2005+ buildings

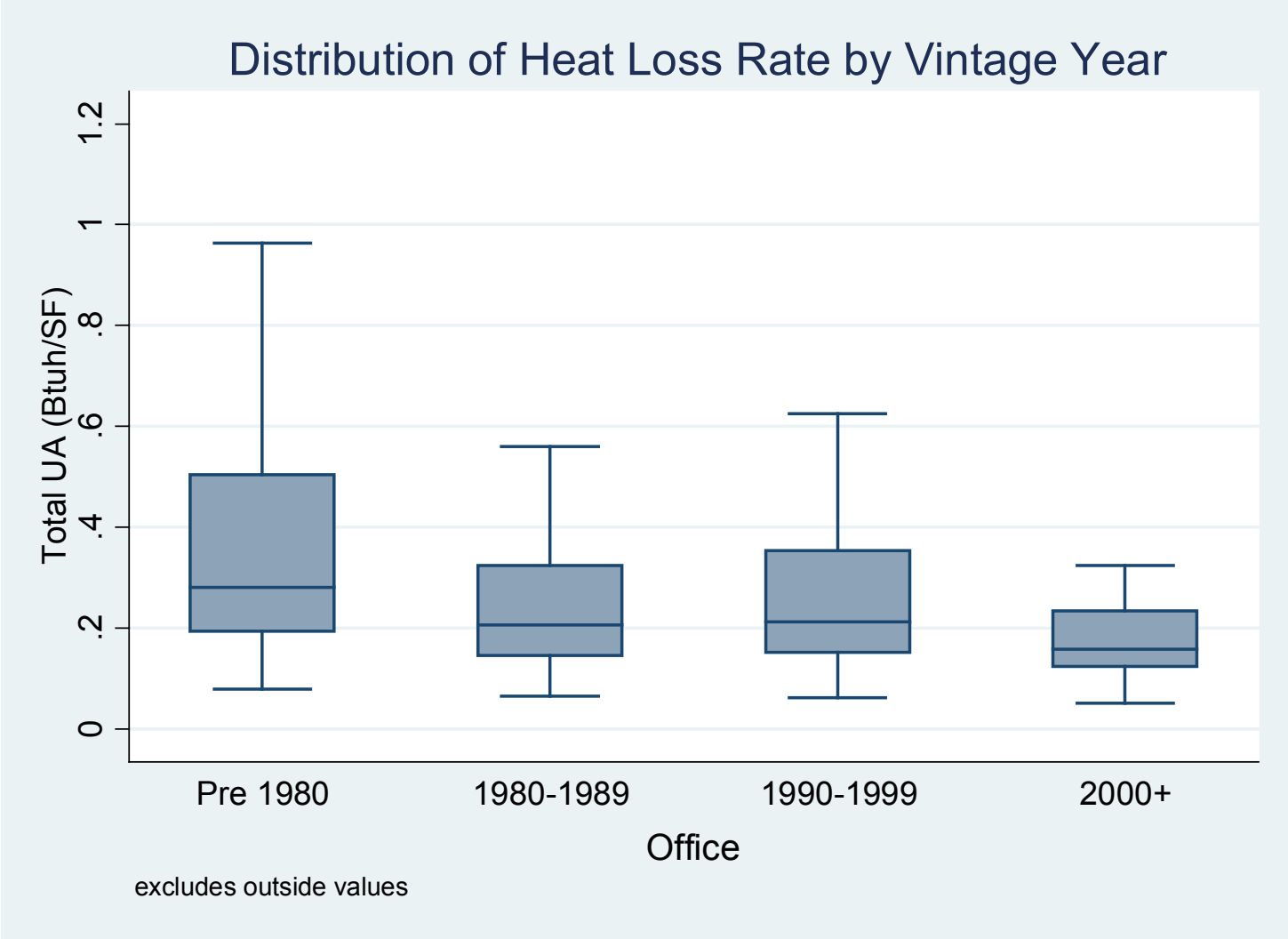
Office EUIs, 1980 to 2010



Office LPDs, 1980-2010



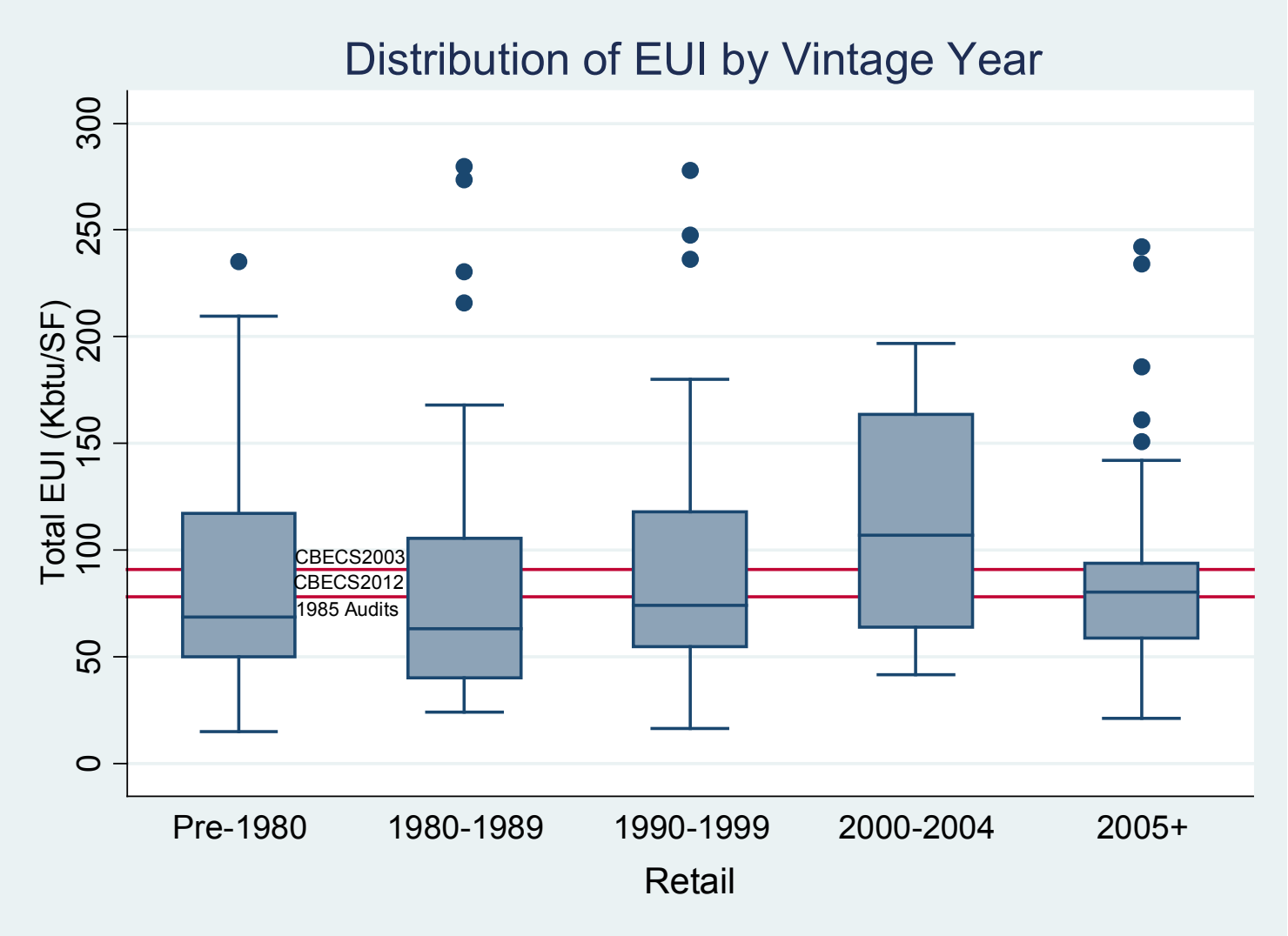
Office: Heat Loss Rate (UA/sf)



Retail/Grocery

- Changes with the advent of Big Box stores.
  - Dominated by RTUs in all size ranges
  - Grocery (refrigeration) removed as much as possible for “Retail” Classification
- Retail includes dry goods retail as well as “super stores” which appeared mostly since 2000.
- Grocery: Food Store with Deli
  - Comparable to historic definitions
- Grocery EUIs are more than double retail even with the expanded definition
- Lighting retrofit and modernization typical in across this sector
  - Groceries and retail are comparable but presented separately
  - Consistent pattern across the sector and across vintages
- Lighting power in modern buildings influenced by increasing LEDs
- Retail/Grocery: Heat loss reduced by over 50% between 1980 and present
  - Most of the reduction was between 1980 and the mid 1990s.

Retail EUIs, 1980-2010



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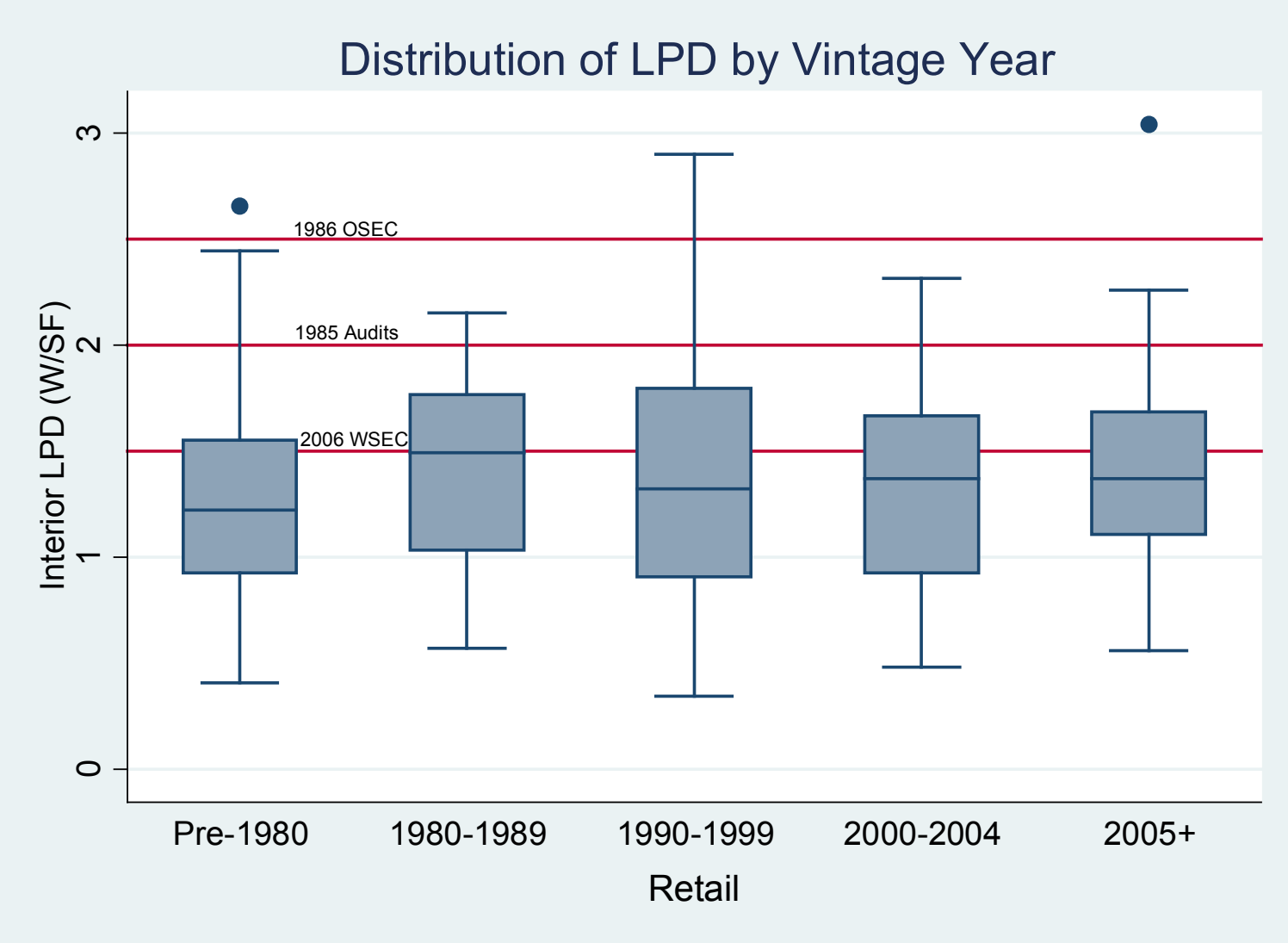
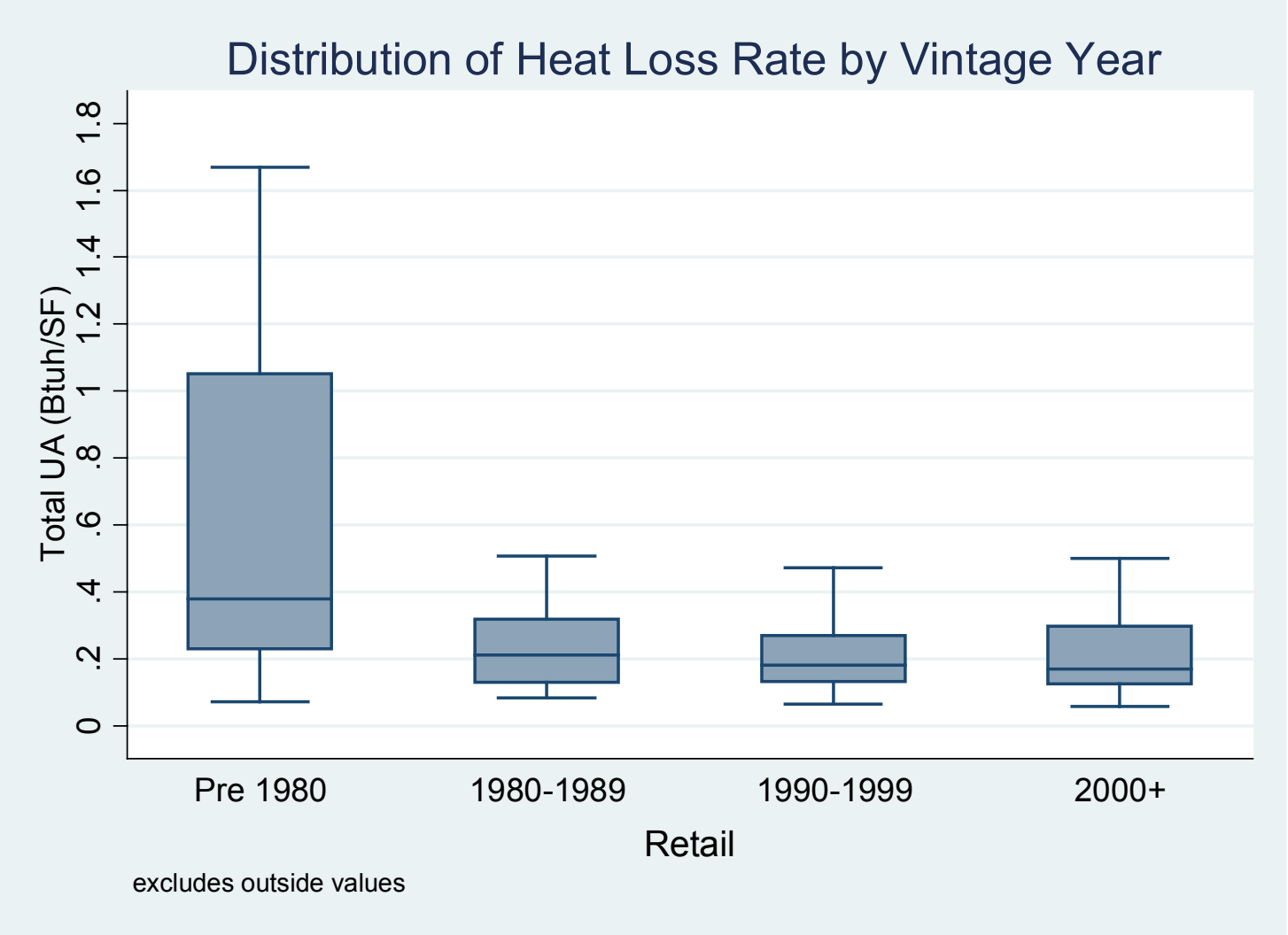
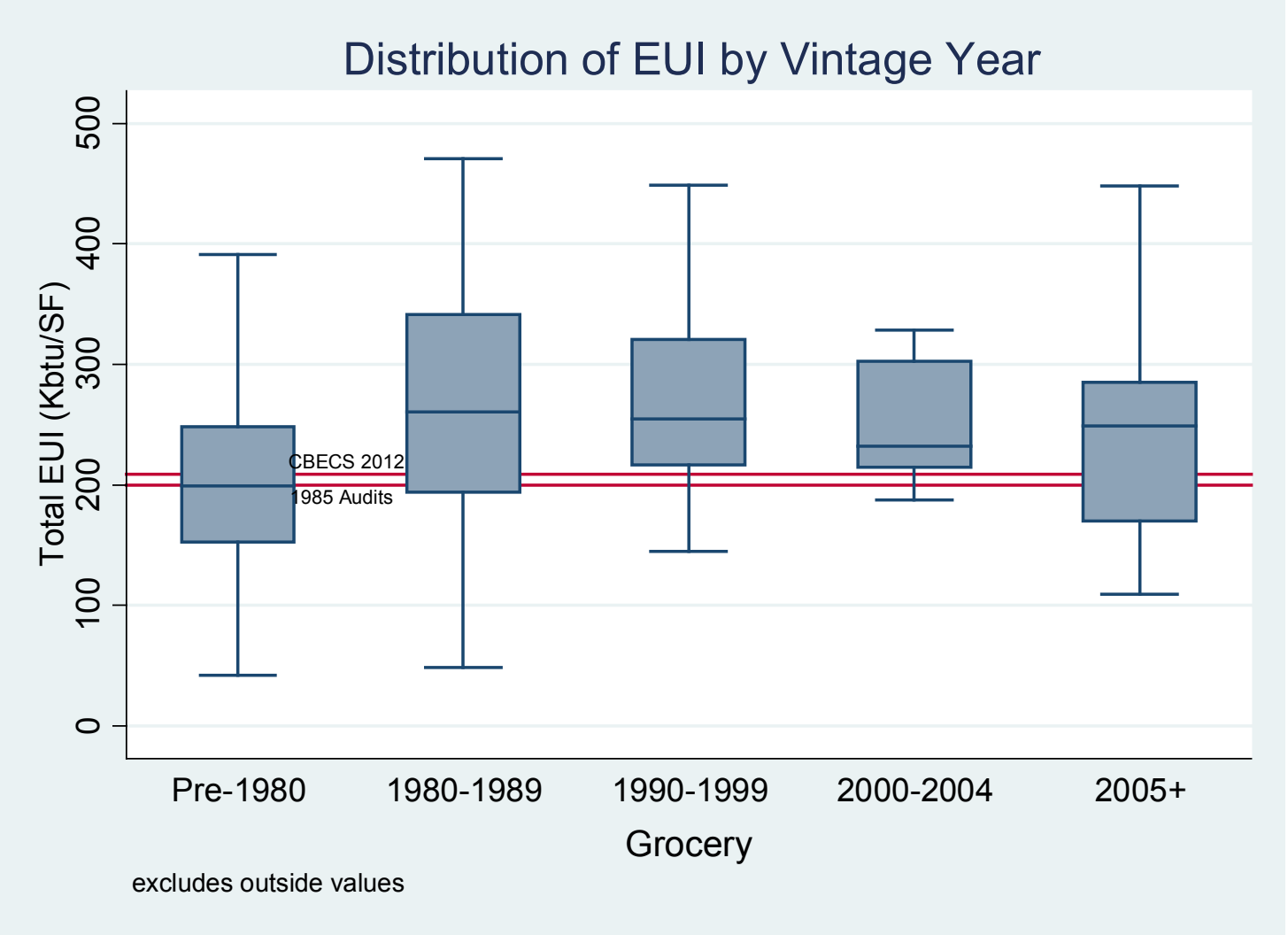


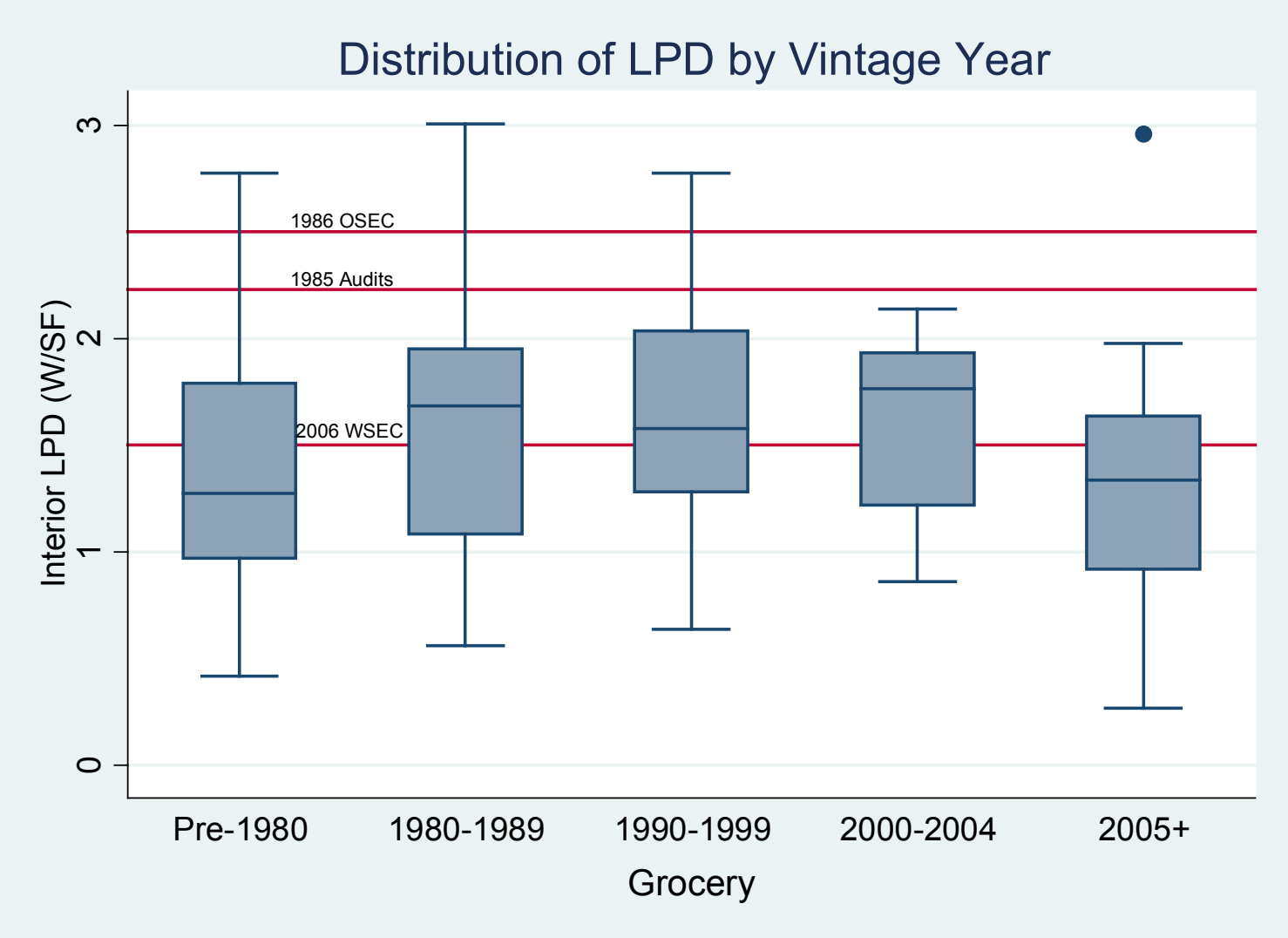
Retail: Heat Loss Rate (UA/sf)



Grocery EUIs, 1980-2010



Grocery LPDs, 1980-2010



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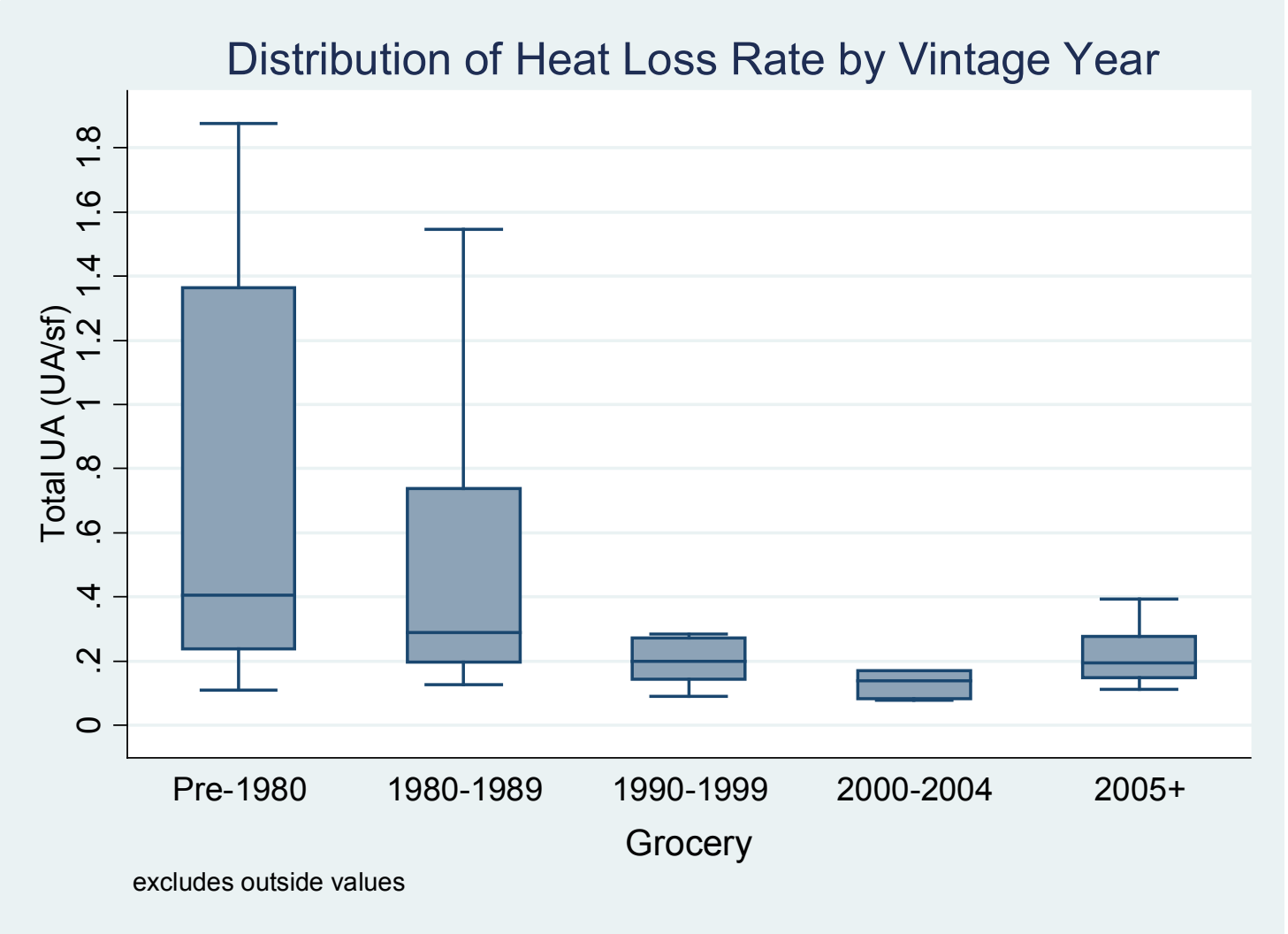
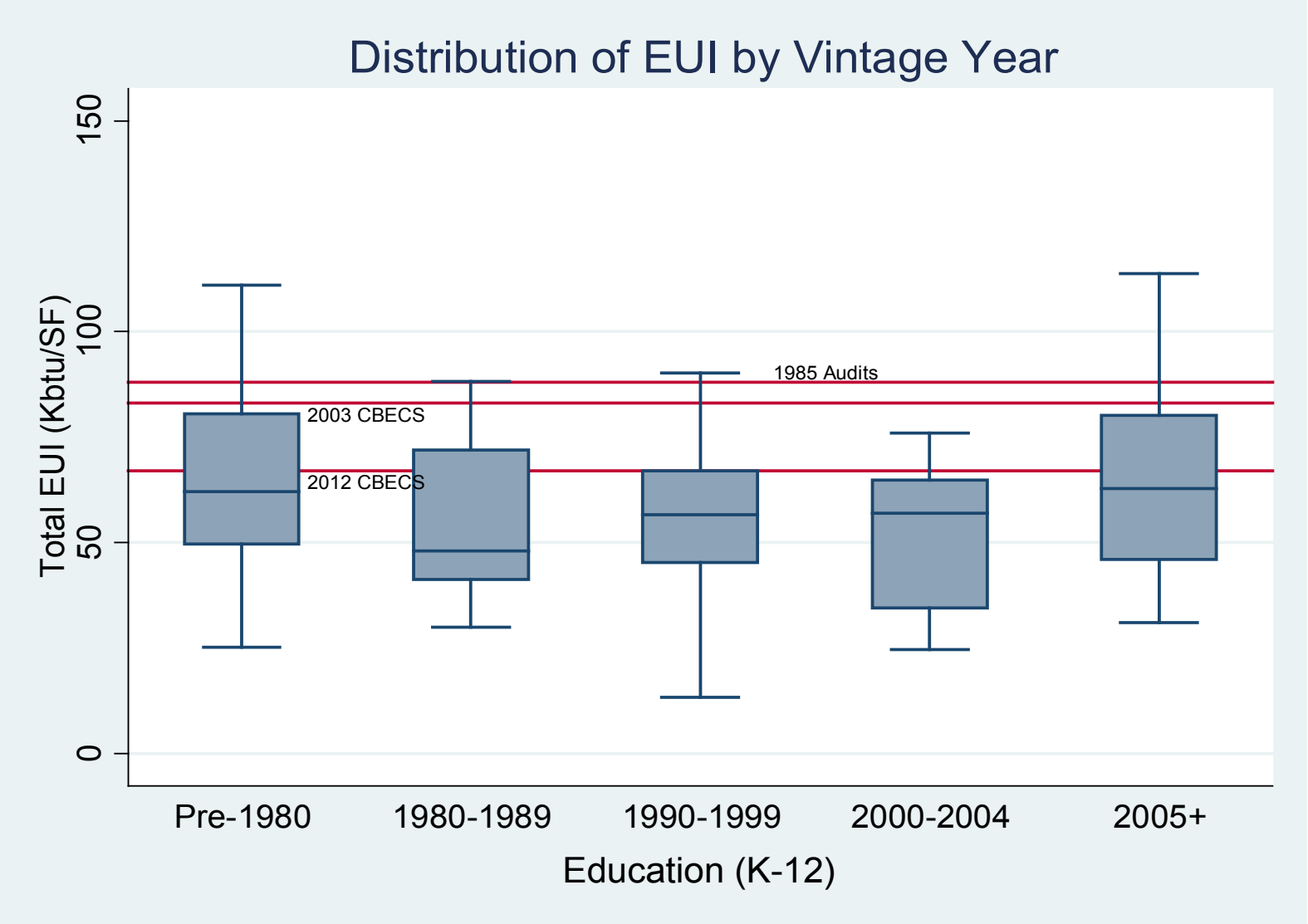


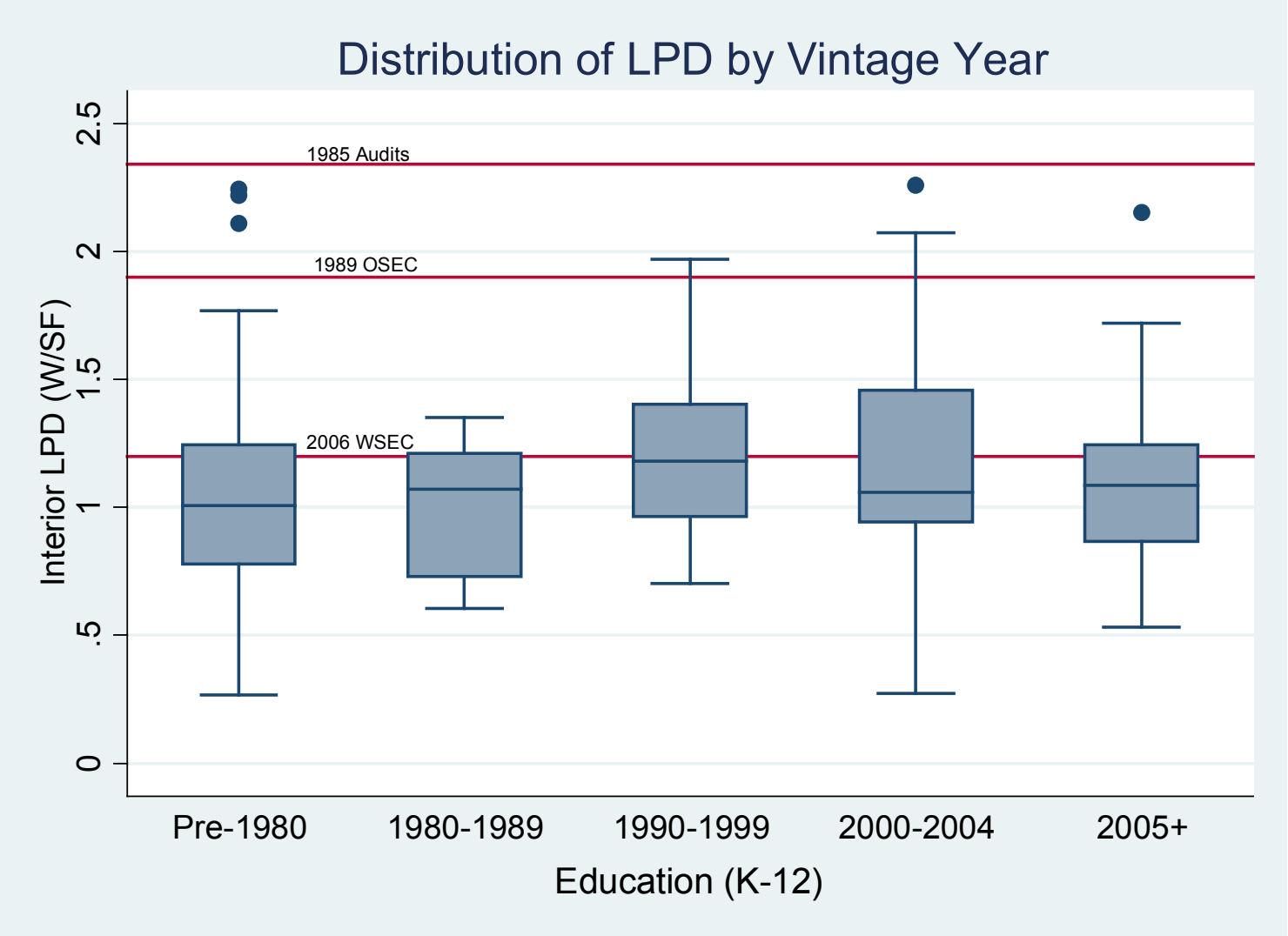
School (K-12)

- Consistent improvement until 2005
  - Advent of cooling in HVAC design
  - More summer programs
- Overall a 25% reduction from historic averages in the 2005+ building
- Lighting upgraded modern standards over time
  - Consistent target of utility and public retrofit programs
  - Lighting power cut in half from historic averages in all vintages
- Small “improvements” beyond lighting
  - Increased ventilation
  - Better insulation and glazing
  - Reduced WWR especially in early vintages
  - Lighting control
- Heat loss rates reduced by 60% since 1980.

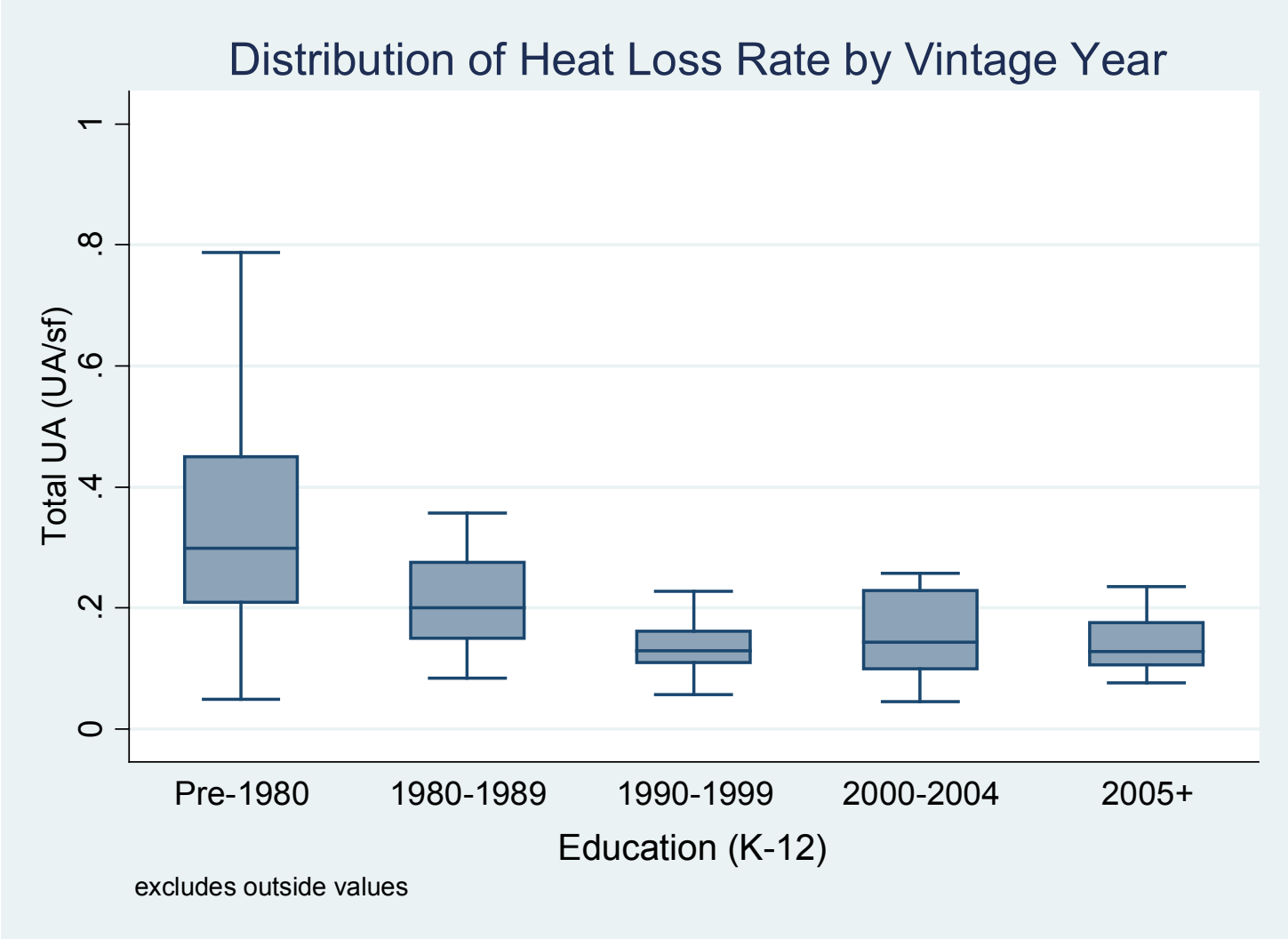
School (K-12) EUIs, 1980-2010



School (K-12) LPDs, 1980-2010



School (K-12) Heat Loss Rates (UA/sf)



Commercial Sector Results

- Reduced LPD by a factor of 2 since 1985 across building types.
- Improved Building Envelope Components by 50%
- Improved Controls
  - Lighting
  - HVAC scheduling
- Stable energy use across buildings despite improvements
  - Reduced mechanical system (HVAC) efficiency
  - Careless applications of ventilation standards
  - Oversized equipment
  - Simultaneous heating and cooling
  - Large quantifies of outdoor air beyond ventilation requirements (pressurization)
- Minimal impact on energy use from 30 years of energy codes and utility programs
- No real impact from jawboning in the Architecture and Engineering professions

Washington State Performance Goals (2009)

- Designed to help achieve carbon reduction agreements
  - Energy reduction of 70% over 2006 code by the 2031 code cycle
  - Legislative mandate to code writing agency
  - Delivers a near net zero building stock
- This analysis uses the 2005+ sample as a baseline
- Some code initiatives since 2011
  - DOAS
  - Zone definition
  - Equipment sizing initiative
  - 25% reduction in LPD (with the advent of LEDs)
  - Building leakage testing
  - Back sliding on building shell
- Probably a reduction of 25% to date

Performance Goals for 2031 (WSEC)

Building Type	Base	70% Reduction
	KBTU/sf	KBTU/sf
Education	67	20
Other Health	89	27
Institution	79	24
Office	80	24
Lodging	86	26
Retail	86	26
Grocery	260	80
Warehouse	23	7

Outcome Code targets

- Major improvements in building performance is required
- Primary target should be the HVAC system
  - Eliminate simultaneous heating and cooling (VAV)
  - Improve zone separations
  - Reduce substantially building pressurization with outdoor air
  - Size equipment to reflect the calculated loads (believe your calcs)
  - Separate required ventilation air from heating and cooling delivery (DOAS)
    - Heat recovery, demand control
- Reduce lighting 30% from 2015 WSEC code
  - LED provides a path for this goal
- Improve envelope
  - Decrease allowable envelope leakage (.25 CFM/sf)
  - Decrease component heat loss by 30%
  - Improve window performance
- 60% to 70% reduction over the 2005+ cohort
  - Roughly equivalent to WSEC legislative goals for 2031

Outcome Based Program (utilities):

- Set an operating EUI target and base the incentives on this target.
  - Track EUI performance over time
- Set the target consistent with Energy code goals
  - Low enough so you get good engineering design
  - About 25 KBTU/sf/yr or about 7 kWh/sf/yr
  - Schools with partial occupancy periods about 16 KBTU/sf/yr or about 5 kWh/sf/yr
  - Develop custom targets for building types with specific process loads or occupancy loads
    - Restaurants
    - Hospitals
    - Assembly (Casinos, Churches, Community Centers)
    - Etc.
- Incentives based on performance after full occupancy and sufficient billing history

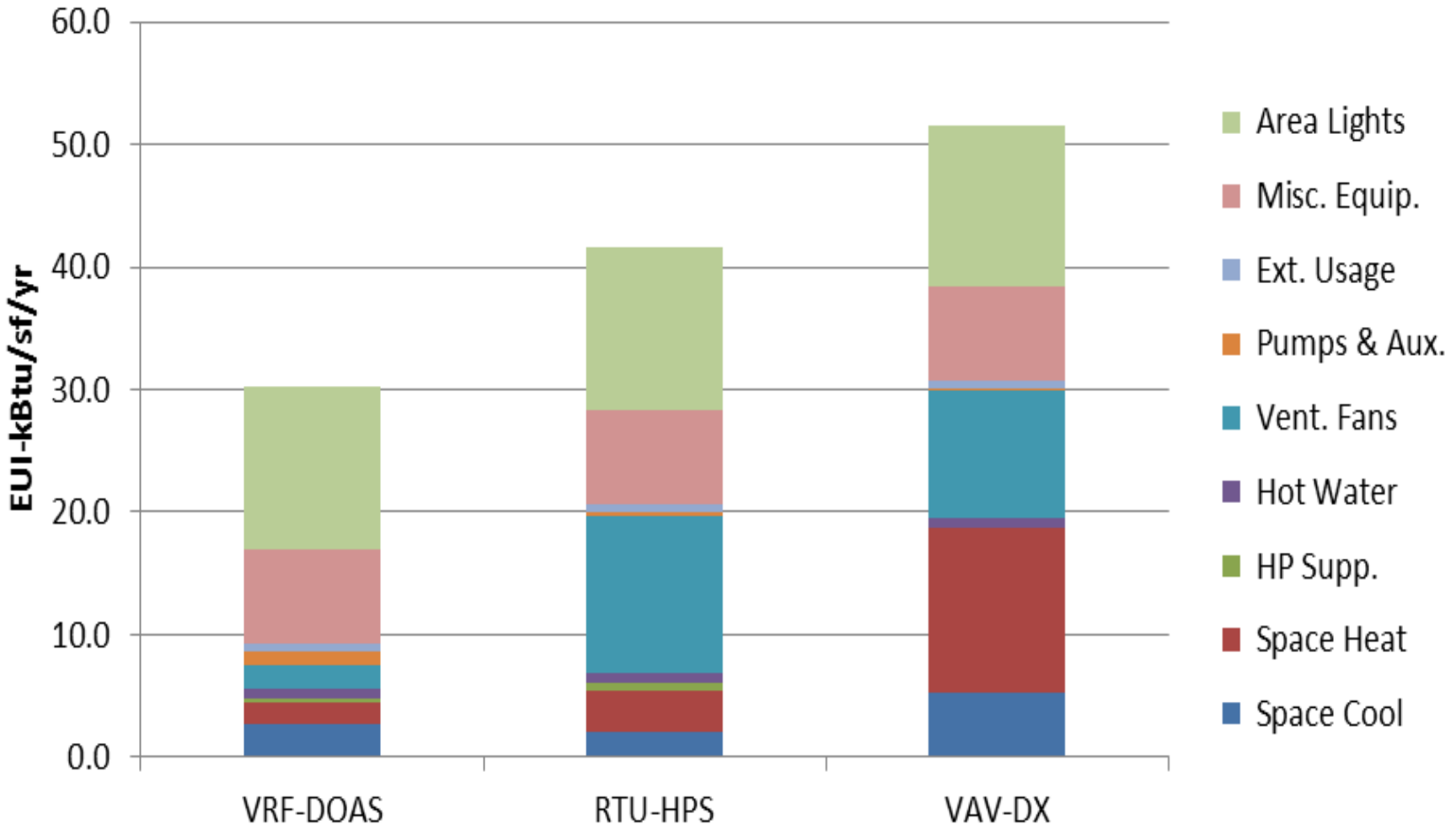
Outcome Based Program (code)

- Code based performance codes can be developed based on utility experience
  - Performance modeling inadequate by itself
  - Engineered gaming typical
  - EUI performance requirement would “focus the mind”
- Develop public “benchmarking” for new buildings
  - Public tracking of building performance
  - Key code metrics such as building size and equipment type
- Ongoing code development focused on design to achieve performance goals.

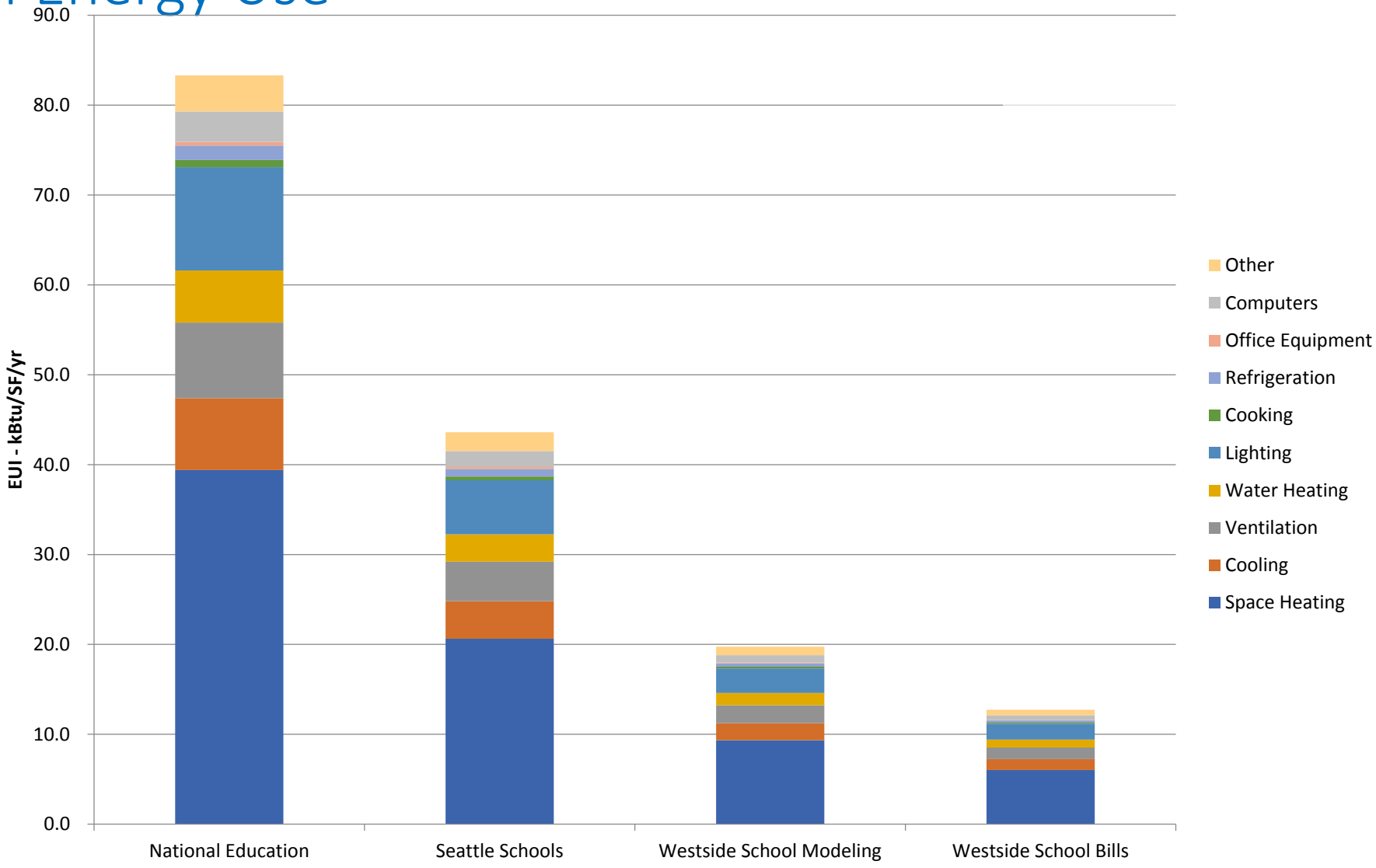
Questions, Comments

Other Slides

System Comparison (KCHA)



School Energy Use



Is it possible? Yes

- Engineering the mechanical systems for efficiency reduces the predicted EUI by a factor of three:
  - 27 Kbtu/sf/yr for KCHA Office building
  - 22 Kbtu/sf/yr for RFM office building
  - 29 Kbtu/sf/yr for Issaquah fire station
  - 14 Kbtu/sf/yr for Westside school