



ENERGY

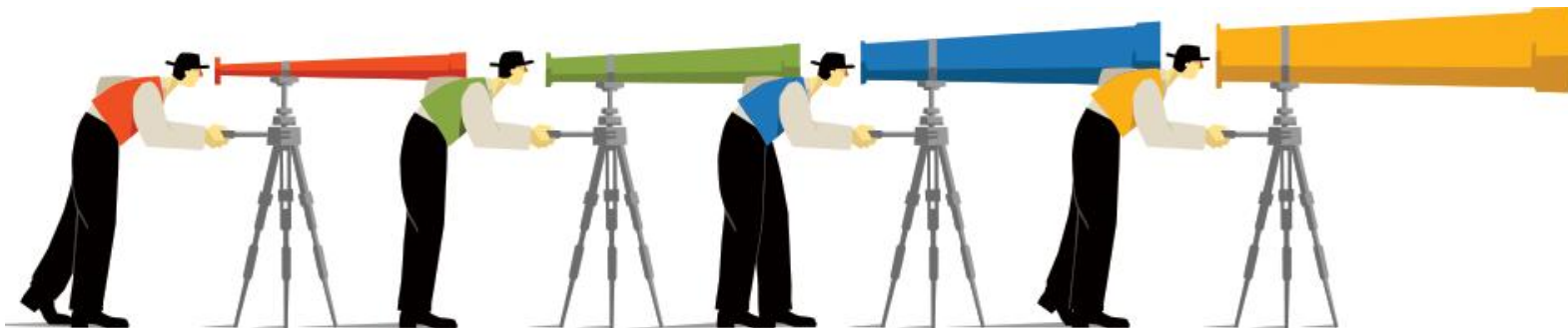
Modeling Behavior-based Saving Opportunities in Commercial Buildings

Estimates for Four U.S. Cities

October 19, 2015

Karen Ehrhardt-Martinez, Ph.D.

Associate Director



DISPUTES & INVESTIGATIONS • ECONOMICS • FINANCIAL ADVISORY • MANAGEMENT CONSULTING

Table of Contents



1 » Overview

2 » Estimation Approach

3 » A Set of City-Level Estimates

4 » City-to-City Comparisons

5 » Value

Overview: National Behavior Wedge Research

Summary of Residential Sector Findings

| | Dietz et al. (2009) | Laitner & Ehrhardt-Martinez (2009) | Gardner & Stern (2008) |
|---------------------------------------|-------------------------------------|------------------------------------|--------------------------------|
| Focus | Carbon Emissions Savings | Energy Savings Opportunities | Energy Savings Opportunities |
| Scope | 17 Household Actions | 110 Household Actions (Roughly) | 27 Household Actions (Roughly) |
| Potential Savings, Residential Sector | 20% (of Household Direct Emissions) | 22% | 30% |
| Potential Savings, National | 7.4% (of National Emissions) | 9% | 11% |

Note: Conservative estimates for Residential and Personal Transport only.

Overview: Goals and Strategy

- » Goal
 - Reduce citywide energy consumption
- » Strategy
 - Change behaviors in residential and commercial buildings
- » Resources
 - City funding (limited)
 - No city-wide data
- » Which behaviors to target?



» **Guiding Questions**

1. Can we generate low-cost, **city-level estimates** of achievable energy savings opportunities from occupant and operator behaviors in **commercial** buildings?
2. What could such estimates tell us about the scale of the savings opportunity and the specific behaviors that offer the most significant savings?
3. How much would the opportunities and behaviors vary between building types and between cities?

Overview: Findings

- » Achievable savings \approx 7% of commercial building energy consumption (assuming a 25% participation rate)

Estimates of Achievable Energy Savings

| City | Savings Estimate |
|---------------|------------------|
| Baltimore, MD | 1.3 tBtu |
| Boston, MA | 1.4 tBtu |
| Charlotte, NC | 1.6 tBtu |
| Miami, FL | 1.9 tBtu |

Three Building Types Dominate

| Building type | % of City Savings |
|---------------|-------------------|
| Offices | 28%-33% |
| Education | 22%-24% |
| Retail | 16%-20% |
| SUM | 68%-75% |

Table of Contents

1 » Overview



2 » Estimation Approach

3 » A Set of City-Level Estimates

4 » City-to-City Comparisons

5 » Value

Data Sources and Inputs for Commercial Behavior Model

- 1** **CBECs DATA**
(Commercial Buildings Energy Consumption Survey)
 - Building Activities and Building Characteristics
 - Building Count per building type and census division
 - Building Area per building type and census division
 - Energy Intensity per building type and census division
- 2** **CENSUS DATA**
 - Population and demographic information
- 3** **LITERATURE REVIEW AND EXPERT INSIGHTS**
 - Technology Saturation
 - Energy consumption by end use and building type
 - Opportunities for energy savings by building type and energy end use



Estimation Approach

Model Development and Data Inputs

| | Model Development Process | Inputs/Resources |
|----|---|--|
| 1. | Estimation of current energy consumption patterns by building type and by end use for the city in question | National and regional CBECS data (floor space, energy intensity, end use data) |
| 2. | Identification of list of operator and tenant behaviors across building types (final list = 91 behaviors) | Review of commercial building literature (especially ASHRAE and NREL studies) |
| 3. | Creation of algorithms to estimate achievable savings opportunities for each behavior (eligibility x participation rate x savings rate) | Review of commercial building literature (especially ASHRAE and NREL studies) |
| 4. | Plug in Baltimore building stock data and run estimates | |

Achievable Savings =

Energy Consumption (Btu)

×

Eligibility to Participate

×

Likelihood of Participation

×

Action-Specific Energy Savings

Estimation Approach

Categories of Commercial Savings Estimates by Building Type and Energy End Use

| Energy End Uses | No. of Actions | Office | Retail | Educ. | Lodging | Healthcare | Service | Public Order | Food Sales | Food Serv. |
|-----------------|----------------|--------|--------|-------|---------|------------|---------|--------------|------------|------------|
| Space Heat | 15 | | | | | | | | | |
| Space Cooling | 10 | | | | | | | | | |
| Ventilation | 5 | | | | | | | | | |
| Water Heating | 8 | | | | | | | | | |
| Lighting | 12 | | | | | | | | | |
| Cooking | 3 | | | | | | | | | |
| Refrigeration | 11 | | | | | | | | | |
| Office Equip. | 8 | | | | | | | | | |
| Computers | 7 | | | | | | | | | |
| Other | 12 | | | | | | | | | |
| Total | 91 | | | | | | | | | |

Table of Contents

1 » Overview

2 » Estimation Approach



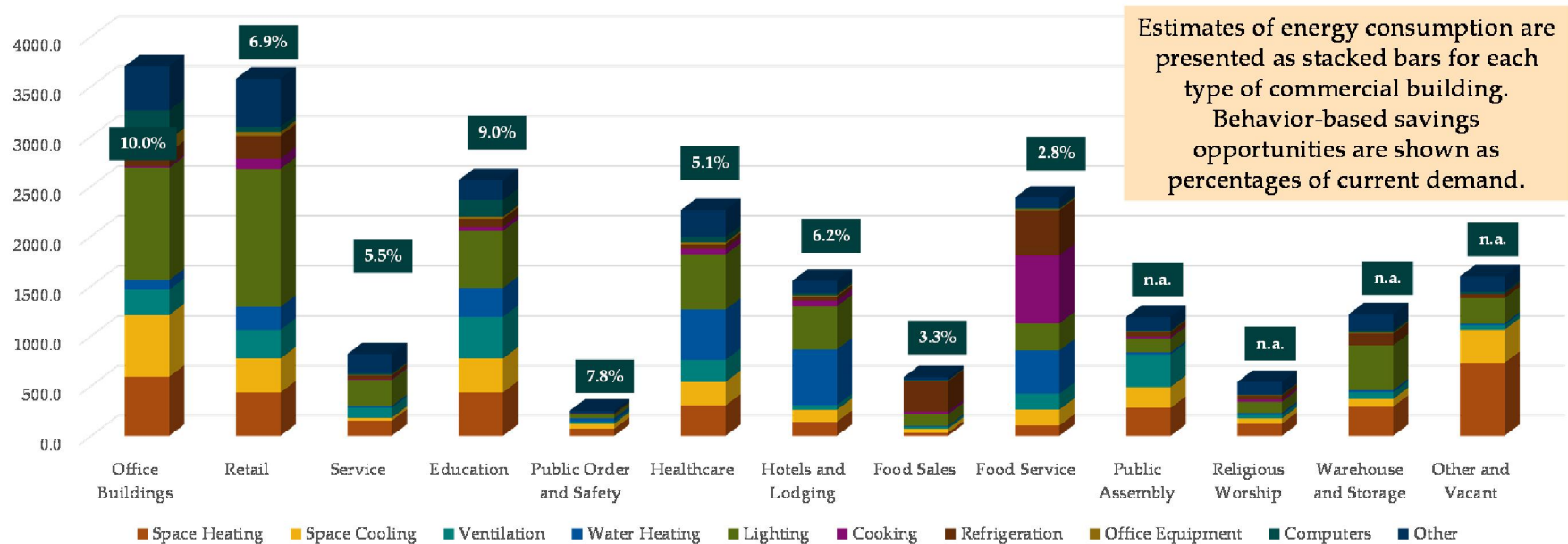
3 » A Set of City-Level Estimates

4 » City-to-City Comparisons

5 » Value

City-Level Estimates: Baltimore

Estimation Energy Use and Behavior-Based Savings Opportunities by Commercial Building Type and End Use: Baltimore

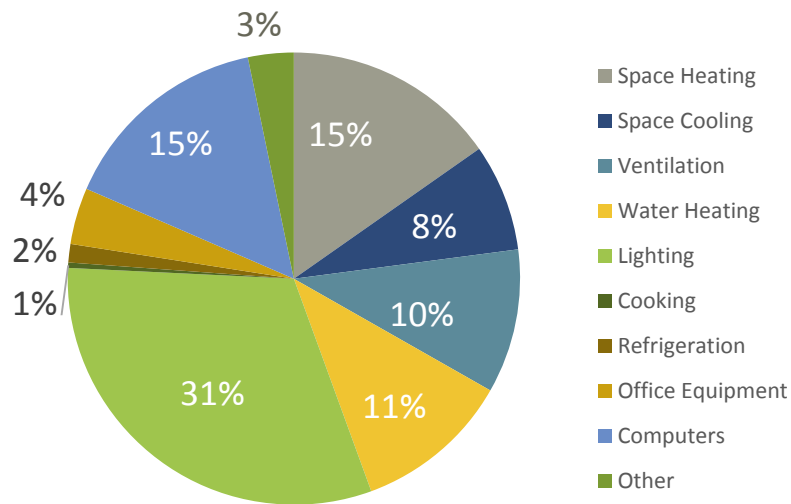


- » Includes estimates for 91 operator and tenant behaviors and 9 types of commercial buildings, which represent 62% of all commercial buildings in Baltimore, as well as 66.5% of square footage and 80% of energy use
- » Assumes a 25% participation rate
 - (Excludes Public Assembly, Religious, Warehouse and Storage and Other)

City-Level Estimates: Baltimore

- » Achievable savings \approx 7% of commercial building energy consumption, or 1.3 tBtu (assuming a 25% participation rate)

Key Findings



- » Lighting is the largest source of estimated savings (31%)
- » Other important sources of savings include:
 - Computers (15%)
 - Space heating (15%)
 - Water heating (11%)
 - Ventilation (10%)
 - Space cooling (8%)

City-Level Estimates: Baltimore



OFFICE BUILDINGS

4,133 bBtus
OF ENERGY

are used in office buildings annually. This is 19% of Baltimore's total commercial energy demand.

10.0%
REDUCTION

of current energy use in office buildings is possible through the behavior related actions and choices identified in the following pages.

| | Annual Energy Demand by Energy End Use | | Annual Savings Opportunity by Energy End Use | |
|------------------|---|---------------|---|---------------|
| | (bBtu) | (%) | (bBtu) | (%) |
| Space Heating | 878 | 21.3% | 58 | 13.9% |
| Space Cooling | 427 | 10.3% | 30 | 7.3% |
| Ventilation | 287 | 6.9% | 40 | 9.7% |
| Water Heating | 110 | 2.7% | 11 | 2.6% |
| Lighting | 1,276 | 30.9% | 130 | 31.2% |
| Cooking | 17 | 0.4% | 2 | 0.5% |
| Refrigeration | 160 | 3.9% | 2 | 0.5% |
| Office Equipment | 144 | 3.5% | 26 | 6.2% |
| Computers | 337 | 8.2% | 108 | 26.0% |
| Other | 497 | 12.0% | 8 | 2.0% |
| Total | 4,133 | 100.0% | 415 | 100.0% |

City-Level Estimates: Baltimore



TOP 24 BEHAVIORS

Office Buildings

| | | % of End Use Savings | % of Total Savings Opportunity | Estimated Annual Savings (mmBtu) |
|--------------|---|----------------------|--------------------------------|----------------------------------|
| 1 | Replace desktops with laptops | 26.2% | 6.8% | 28.2 |
| 2 | Employ lighting "sweeps" at closing to ensure lights are off at night and on weekends | 19.4% | 6.1% | 25.1 |
| 3 | Ensure proper maintenance and operation of heating system | 41.7% | 5.8% | 24.0 |
| 4 | Ensure proper operation of Air-side Economizer | 51.3% | 5.0% | 20.6 |
| 5 | Turn off computers (evenings and weekends) and use EE computer settings | 18.6% | 4.8% | 20.1 |
| 6 | Purchase EE computers | 17.1% | 4.4% | 18.4 |
| 7 | Use EE task lighting and reduce ambient lighting | 14.2% | 4.4% | 18.4 |
| 8 | Turn off monitors and use EE monitor settings | 16.3% | 4.2% | 17.5 |
| | | | | |
| 24 | Minimize exterior lighting | 4.2% | 1.3% | 5.4 |
| TOTAL | | | 82.4% | 341.6 |

City-Level Estimates: Baltimore

Estimated Savings by Building Type

| # | Building Type | bBtu Savings | As % of Use | Top 3 Areas of Savings Opportunities |
|---|----------------|--------------|-------------|--|
| 1 | Office | 415 | 10.0% | Lighting, computers, air conditioning |
| 2 | Retail | 288 | 6.9% | Lighting, air conditioning, ventilation |
| 3 | Education | 238 | 9.2% | Lighting, computers, space heating |
| 4 | Hotels/Lodging | 108 | 6.2% | Water heating, lighting, space heating |
| 5 | Healthcare | 86 | 5.1% | Water heating, lighting, space heating |
| 6 | Food Service | 47 | 2.8% | Water heating, lighting, other |
| 7 | Service | 45 | 5.5% | Lighting, space heating, ventilation |
| 8 | Public Order | 24 | 7.8% | Space heating, lighting, ventilation |
| 9 | Food Sales | 17 | 3.3% | Lighting, refrigeration |
| | Total | 1,278 | 7.1% | (5.7% of commercial building energy demand) |

City-Level Estimates: Baltimore

Estimated Savings by End Use

| # | End Use | Office | Education | Retail |
|----|-------------------|------------|------------|------------|
| 1 | Space Heating | 13.9% | 17.6% | 11.8% |
| 2 | Space Cooling | 7.3% | 7.3% | 10.2% |
| 3 | Ventilation | 9.7% | 12.6% | 10.9% |
| 4 | Water Heating | 2.6% | 9.1% | 9.2% |
| | Subtotal | 33.5% | 46.6% | 42.1% |
| 5 | Lighting | 31.2% | 28.9% | 41.9% |
| | | | | |
| 8 | Office Equipment | 6.2% | 4.1% | 3.7% |
| 9 | Computers | 26.0% | 16.2% | 5.3% |
| 10 | Other | 2.0% | 3.6% | 6.2% |
| | Subtotal | 34.2% | 23.9% | 15.2% |
| | Total bBtu | 415 | 289 | 241 |

Table of Contents

1 » Overview

2 » Estimation Approach

3 » A Set of City-Level Estimates



4 » City-to-City Comparisons

5 » Value

City-to-City Comparisons

Energy Use and Energy Savings by City

| | Baltimore, MD | Boston, MA | Charlotte, NC | Miami, FL |
|--|-------------------|-------------------|-------------------|-------------------|
| No. of Buildings | 10,659 | 11,095 | 13,218 | 6,900 |
| Square Feet (million) | 183 | 168 | 227 | 119 |
| Energy Use (bBtu) | 17,580 | 20,140 | 21,800 | 11,710 |
| Estimated Savings Opportunity (bBtu) | 1,272 | 1,423 | 1,575 | 1,913 |
| Savings Equiv. | 32,000 HHs | 35,575 HHs | 39,375 HHs | 47,825 HHs |
| HDD | 3745 | 5412 | 3262 | 224 |
| CDD | 2046 | 903 | 1886 | 6900 |

Note: Savings equivalent represents the annual electricity consumption for specified number of households

City-to-City Comparisons

Comparison of Savings Opportunities by Building Type

| | Baltimore, MD | Boston, MA | Charlotte, NC | Miami, FL |
|---|-------------------------|-------------------------|-------------------------|-------------------------|
| 1 | Office | Office | Office | Office |
| 2 | Education | Education | Education | Education |
| 3 | Retail | Retail | Retail | Retail |
| 4 | Lodging | Healthcare | Lodging | Lodging |
| 5 | Healthcare | Service | Healthcare | Healthcare |
| 6 | Food Service | Food Service | Food Service | Service |
| 7 | Service | Lodging | Service | Food Service |
| 8 | Public Order and Safety | Food Sales | Public Order and Safety | Public Order and Safety |
| 9 | Food Sales | Public Order and Safety | Food Sales | Food Sales |

City-to-City Comparisons

Comparison of OFFICE Building Energy Savings by City and End Use

| End Use | Baltimore, MD | Boston, MA | Charlotte, NC | Miami, FL |
|------------------|---------------|-------------|---------------|-------------|
| Space Heating | 13.9% | 6.3% | 10.6% | -- |
| Space Cooling | 7.3% | 1.8% | 10.4% | 17.8% |
| Ventilation | 9.7% | 8.9% | 9.5% | 8.3% |
| Water Heating | 2.6% | 3.0% | 2.6% | 2.6% |
| Lighting | 31.2% | 37.0% | 31.6% | 35.9% |
| Cooking | 0.5% | 0.5% | 0.5% | 0.5% |
| Refrigeration | 0.5% | 0.5% | 0.5% | 0.5% |
| Office Equipment | 6.2% | 5.8% | 6.2% | 6.1% |
| Computers | 26.0% | 24.3% | 26.0% | 25.5% |
| Other | 2.0% | 1.9% | 2.1% | 2.0% |
| Total | 100% | 100% | 100% | 100% |
| Energy Savings | 415 bBtu | 400 bBtu | 514 bBtu | 274 bBtu |

Table of Contents

- 1 » Overview
- 2 » Estimation Approach
- 3 » A Set of City-Level Estimates
- 4 » City-to-City Comparisons



- 5 » Value

» **Model Accomplishments**

1. Quantifying the scale of behavior-based savings opportunities at the city level

2. Identifies and quantifies behavior-based savings opportunities
 - Across 9 commercial building types
 - Across specific energy end uses
 - Associated with specific behaviors

» **Enhanced Ability to ...**

1. Assess where behavior-based efforts might fit within larger sustainability efforts or carbon action plans
2. Thoughtfully select between behavioral approaches and more technology-focused approaches
3. Determine which types of buildings, end uses, and behaviors should be targeted
4. Make the case to funders, collaborators, and other stakeholders

Key CONTACTS



©2015 Navigant Consulting, Inc.
Confidential and proprietary. Do not distribute or copy.

Karen Ehrhardt-Martinez,
Associate Director
Customers and Markets
Navigant Consulting
Boulder, CO 80302
+1.303.942.1094
Karen.Ehrhardt.Martinez@Navigant.com

Behaviors and Technologies

