

# META-REVIEW OF BEHAVIOR- BASED ENERGY-SAVINGS POTENTIAL ESTIMATES FOR COMMERCIAL BUILDINGS

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NAVIGANT

# BEHAVIOR IN COMMERCIAL BUILDINGS

People as problem OR

People as solution?



*Buildings would work perfectly if it weren't for the people in them.*

*--Anonymous, ACEEE Conference, circa 1993*

# BEHAVIOR IN COMMERCIAL BUILDINGS

Simulations of occupant behavior  
in private offices

show that occupants who are proactive in saving energy....



...consume 50% less energy  
than average occupants.

-- Hong and Lin 2013

# BEHAVIOR-BASED SAVINGS POTENTIAL: RESIDENTIAL

	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 HH Actions (Roughly)	27 HH Actions (Roughly)
Potential Savings: Residential Sector	20% (of HH Direct Emissions)	22%	30%
Potential Savings: National	7.4% (of National Emissions)	9%	11%
Period to Achieve Max. Annual Savings	10 years	5 to 8 years	N/A

**Conservative estimates for Residential and Personal Transport only.**

# BEHAVIOR-BASED SAVINGS POTENTIAL: COMMERCIAL

But what do we know about the energy savings that could be achieved via changes in occupant and operator behaviors in commercial buildings?



## Meta-Review



# TABLE OF CONTENTS

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## **1. Overview of the Studies**

## 2. Comparisons and Insights

## 3. Take-Aways

# STUDIES OF BEHAVIORAL POTENTIAL

## Where we looked:

- Journal articles
- Conference proceedings: ACEEE, ECEEE
- Conference presentations: BECC



## The studies we found:

- 1 – Azar & Menassa 2014
- 2 – Ehrhardt-Martinez 2015, 2016
- 3 – Norton et al. 2013 / Burke & Baker 2008
- 4 – Wikler et al. 2016

## HIGH-LEVEL FINDINGS

4 - 91

Occupant & operator  
behaviors

12-21%

Technical  
Potential

<1-7%

Achievable  
Potential



# MEASURES OF BEHAVIOR POTENTIAL

## What do we mean by *Potential* ?

**Technical Potential:** The amount of energy savings that would be possible if ALL relevant opportunities to improve energy efficiency are taken immediately. **Accounts for eligibility**

**Achievable Potential:** The energy efficiency savings that could be expected in response to specific barriers, incentives, influences and other factors that determine participation.

**Accounts for eligibility and likely participation rates**

# AZAR AND MENASSA 2014

**“A comprehensive framework to quantify energy savings potential from improved operations of commercial building stocks”** *Energy Policy* 67 (2014)

**Method:** Commercial building energy modeling is used to emulate existing building conditions. Related studies in literature are used in the building energy modeling process to quantify the energy savings potential from improved building operations. Finally, sampling weights are used to generalize the obtained results to the entire stock of buildings under study.

Study	Scope	Behaviors		End Uses	Savings
		No.	Types		
Azar and Menassa 2014	Natl; Office Bldgs; Elec & N.Gas	4	Thermostat setpoints, unoccupied equip use & lighting	HVAC, equipment, lighting	Technical, 21%

## “Behavior-based Energy Savings Opportunities in Commercial Buildings: Estimates for Four U.S. Cities” *Proceedings of the ACEEE Summer Study (2016)*

- 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



# EHRHARDT-MARTINEZ 2015, 2016

End Use	No. of Behaviors
Space Heating	15
Space Cooling	10
Ventilation	5
Water Heating	8
Lighting	12

End Use	No. of Behaviors
Cooking	3
Refrigeration	11
Office Equipment	8
Computers	7
Other	12

Study	Scope	Behaviors		End Uses	Savings
		No.	Types		
Ehrhardt-Martinez 2015, 2016	5 U.S. cities; 9 bldg. types; Elec & N.Gas	91	A wide range: thermostat set points to computers	All	Achievable 7%

# NORTON 2013 (OPINION DYNAMICS)

**“ComEd Residential and C&I Saturation/End-Use, Market Penetration & Behavior Study.”** with Vermont Energy Investment Corp and Mad Dash Field Services.

## **Method:**

1. Extensive primary data collection and metering.
2. Determination of efficient technologies and behaviors for each end use.
3. Enhanced engineering analysis to assess energy usage and waste.

		<b>Behaviors</b>			
Study	Scope	No.	Types	End Uses	Savings
Norton 2013	ComEd; C&I.; Elec.	16	Turn off, settings, maintenance, virtualization	Lighting, cooling, vent, motors, refrigeration, office equip.	Technical, 12-18%

## WIKLER ET AL. (NAVIGANT) 2016

### “A802 Technical Analysis: Potential Savings Analysis. Prepared for the California Public Utilities Commission. (2016)

**Method:** Estimate savings opportunity associated with particular types of behavioral interventions given the existing building stock and equipment stock. Representative programs modeled: building operator certification, lighting controls, building energy management systems, and tenant engagement

Study	Scope	Behaviors		End Uses	Savings
		No.	Types		
Wikler et al. 2016	CA IOUs; Most comm. bldgs.; Elec & N.Gas	?	Bldg. operations, lighting controls, tenant engagement	HVAC, lighting, equip., plug load	Achievable <1%



# TABLE OF CONTENTS

---

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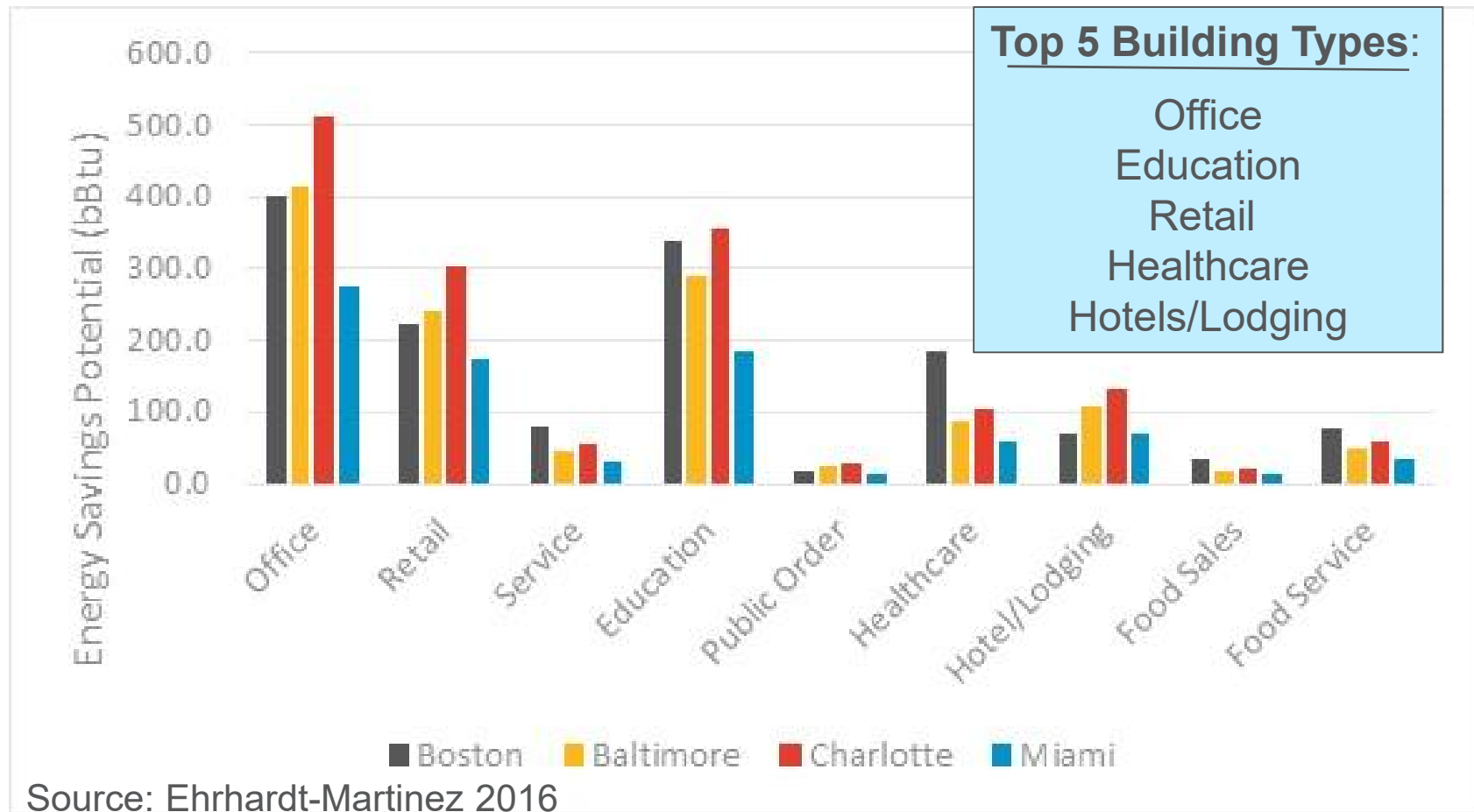
# LOOKING ACROSS STUDIES

Study	Scope	Behaviors		End Uses	Savings
		No.	Types		
Azar and Menassa 2014	Natl; Office Bldgs; Elec & N.Gas	4	Thermostat setpoints, unoccupied equip use & lighting	HVAC, equipment, lighting	Tech 21%
Norton 2013	ComEd; C&I.; Elec.	16	Turn off, settings, maintenance, virtualization	Lights, cooling, vent., motors, refrig., off. equip.	Tech 12-18%
Ehrhardt-Martinez 2015, 2016	5 U.S. cities; 9 bldg. types; Elec & N.Gas	91	A wide range: thermostat set points to computers	All	Achiev. 7%
Wikler et al. 2016	CA IOUs; Most comm. bldgs.; Elec & N.Gas	?	Bldg. operations, lighting controls, tenant engagement	HVAC, lighting, equip., plug load	Achiev. <1%



# INSIGHTS: OFFICES, EDUCATION, RETAIL ARE IMPORTANT

## BB Energy Savings Potential by Building Type and City



# INSIGHTS: OFFICES, RETAIL, AND EDUCATION BUILDINGS REPRESENT A LOT OF THE BEHAVIOR-BASED OPPORTUNITY\*

Building Type	% of City-level Savings
Offices	28%-33%
Education	22%-24%
Retail	16%-20%
<b>Sub-Total</b>	<b>68%-75%</b>
Remaining 6 Building Types	25%-32%
<b>Total</b>	<b>100%</b>

Source: Ehrhardt-Martinez 2016



Office



Retail



Education



Lodging



Healthcare



Services



Public  
Order



Food  
Sales

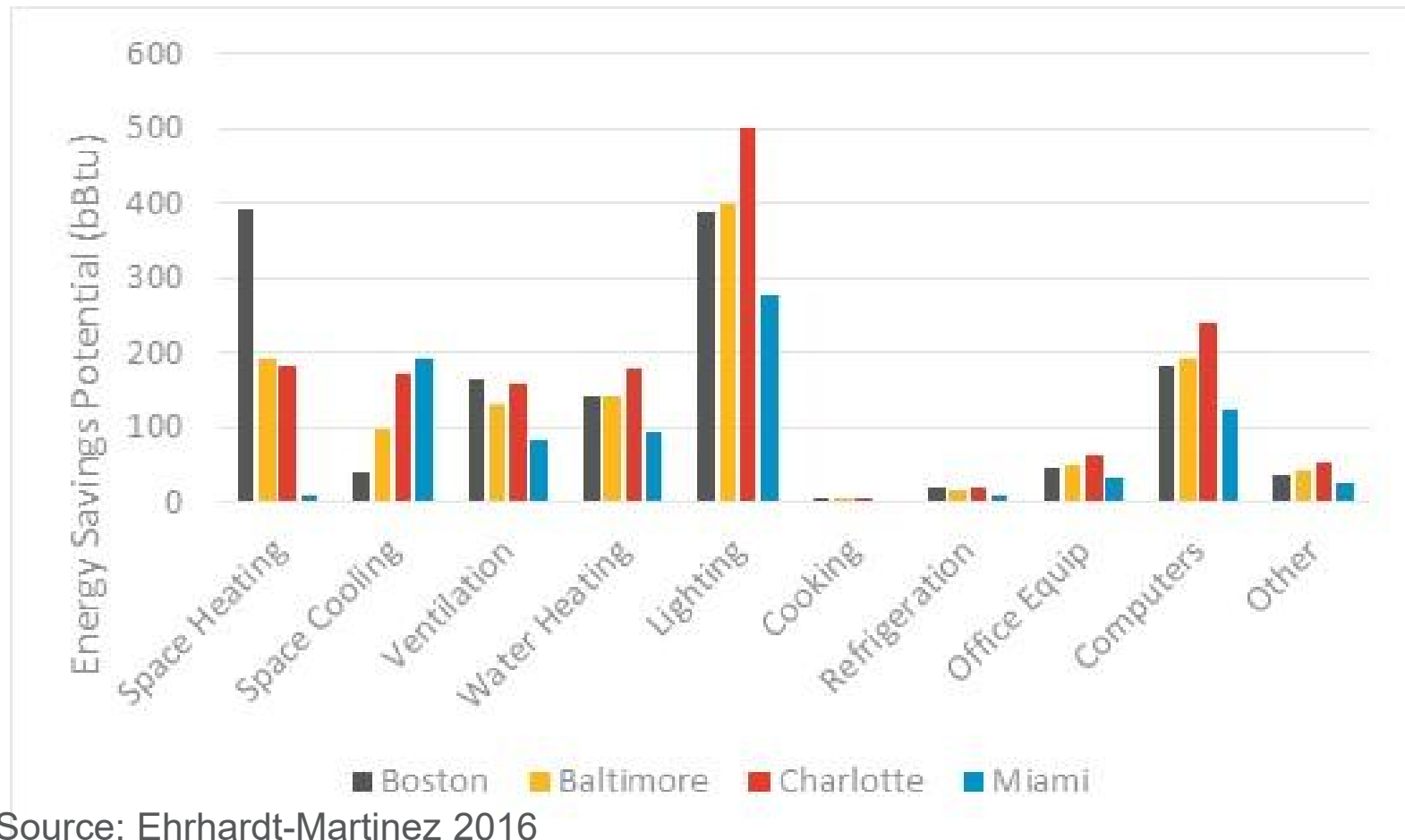


Food  
Service

\*Of the 9 commercial building types included in the study.

# INSIGHTS: LIGHTING, HVAC, AND COMPUTERS ARE GOOD TARGETS

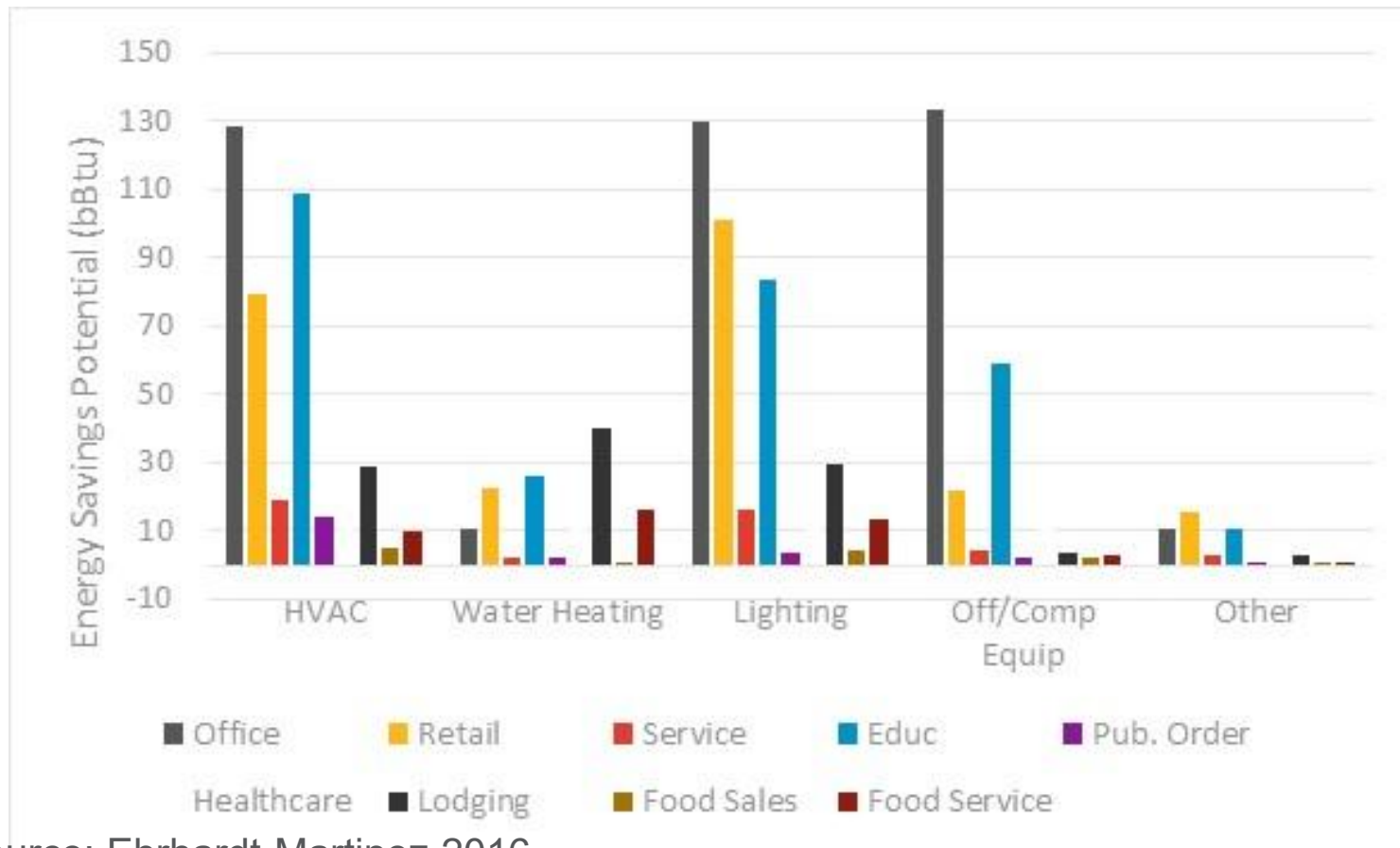
## BB Energy Savings Potential by End Use and City



Source: Ehrhardt-Martinez 2016

# INSIGHTS: END USE SAVINGS POTENTIAL VARIES DRAMATICALLY BY BUILDING TYPE

## BB Energy Savings Potential by End Use and Building Type

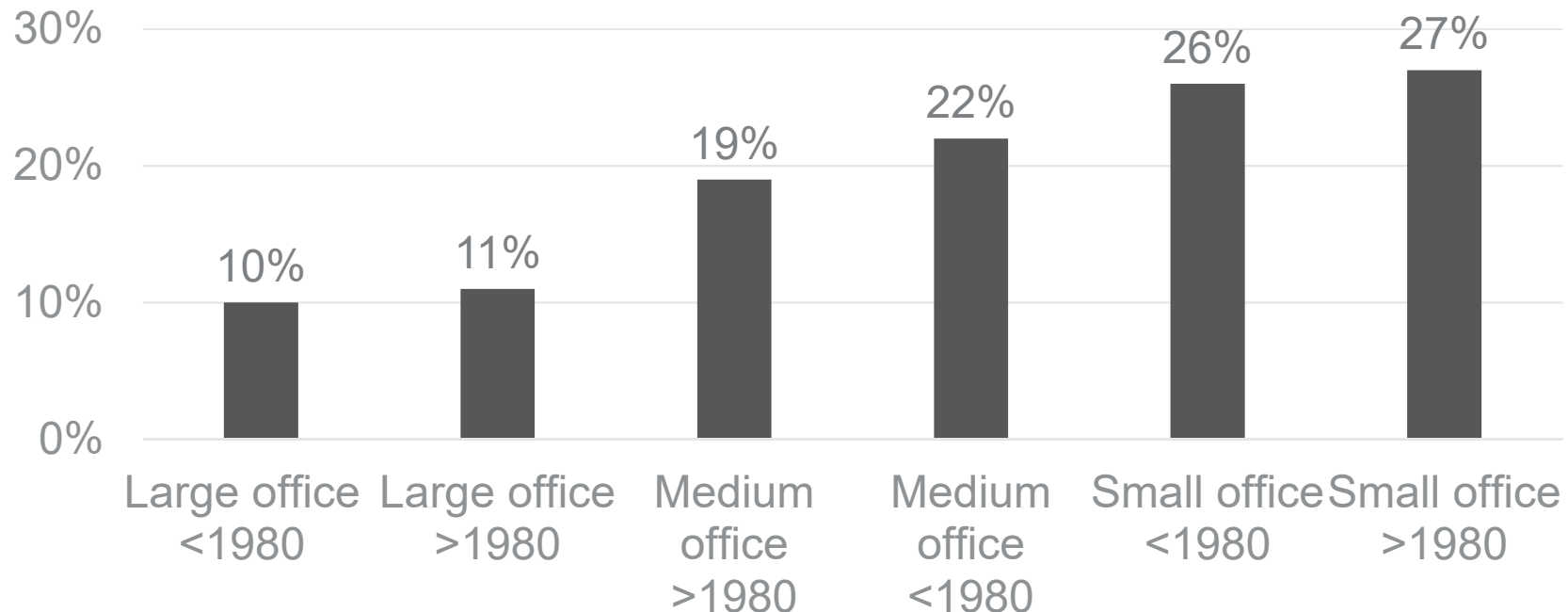


Source: Ehrhardt-Martinez 2016

# INSIGHTS: OPERATOR-BASED SAVINGS OPPORTUNITY PROPORTIONALLY BIGGER IN SMALLER BUILDINGS

## Savings Estimates by Building Size and Vintage

Average savings  
across all U.S. Office  
Buildings = 21%



Source: Azar and Menassa 2014

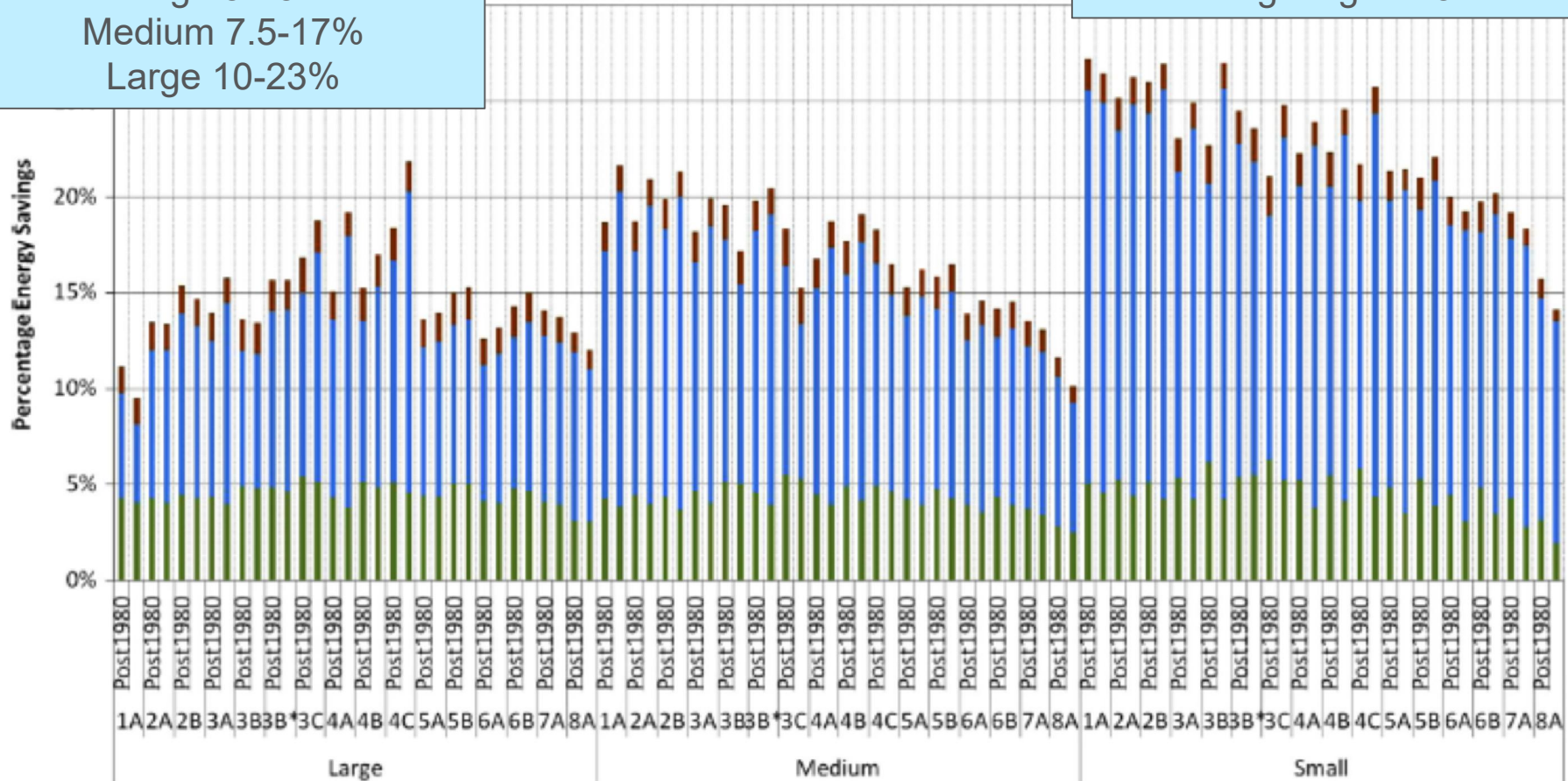
# INSIGHTS: HVAC-RELATED POTENTIAL IS THE LARGEST

HVAC Savings by End Use:  
 Large 5-15%  
 Medium 7.5-17%  
 Large 10-23%

## Energy Savings Potential by End-Use

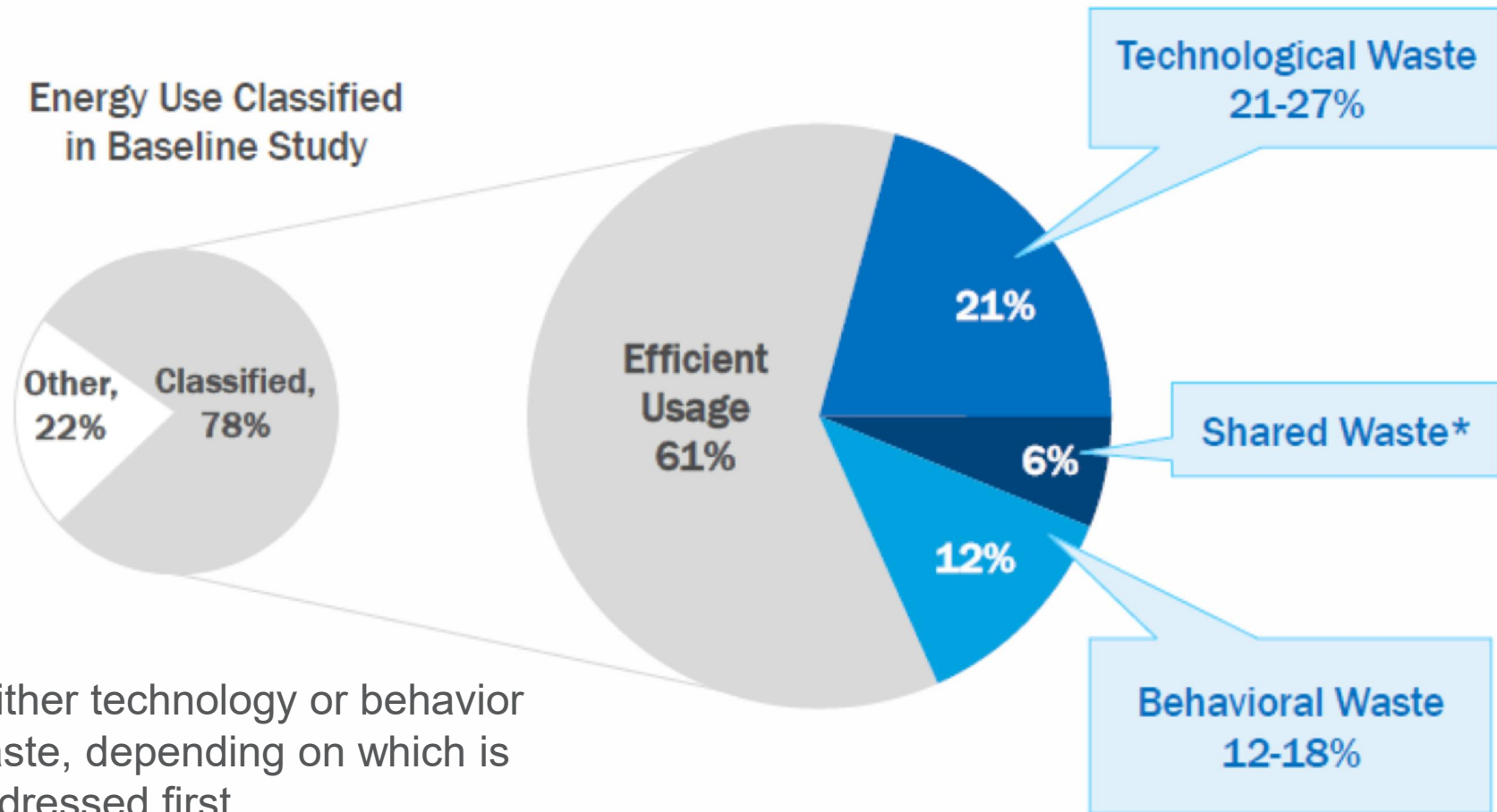
■ Equipment ■ HVAC ■ Lighting

Equipment Savings ≈ 5-15%  
 Lighting ≈ 2-3%



Source: Azar and Menassa 2014

# INSIGHTS: BEHAVIOR AND TECHNOLOGY-BASED OPPORTUNITIES OVERLAP



\*Either technology or behavior waste, depending on which is addressed first.

Source: Norton (Opinion Dynamics) 2013

# SAVINGS BY END USE ACROSS STUDIES

## BB Savings Ranking by End Use

Study	HVAC	Lighting	Office Computers & Equip.	Hot Water
Azar & Menassa (offices) 2014	1	3	2	?
Norton (C&I) 2013	2	1	?	?
Ehrhardt-Martinez (Comm.) 2015	1	1	1	2
Ehrhardt-Martinez (offices) 2015	1	2	3	4





# TABLE OF CONTENTS

---

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## TAKE AWAYS

### ***Technical BB Savings Potential =***

- 21% in office buildings; 4 behaviors (Azar & Menassa 2014)
- 12-18% in C&I; 16 behaviors (Norton 2013)

### ***Achievable BB Savings Potential =***

- 7% in commercial buildings; up to 91 behaviors (Ehrhardt-Martinez 2015)
- 10% in office buildings: up to 91 behaviors (Ehrhardt-Martinez 2015)
- <1% in commercial buildings; 4 program interventions (Wikler 2016)

### **Variation in Size and Source of Savings:**

- Savings estimates vary by building type, geography, size and vintage.
- Most important building types: offices, schools, retail – healthcare, lodging
- Most important end uses: vary by building type and geography.

## REFERENCES

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