ENGAGING, ENABLING AND EMPOWERING PEOPLE

THE SAVINGS POTENTIAL OF BEHAVIORAL STRATEGIES & ENABLING TECHNOLOGIES

JUNE 26, 2017

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COMMON PERSPECTIVE ON THE ROLE OF PEOPLE

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

--Anonymous, ACEEE Conference, circa 1993

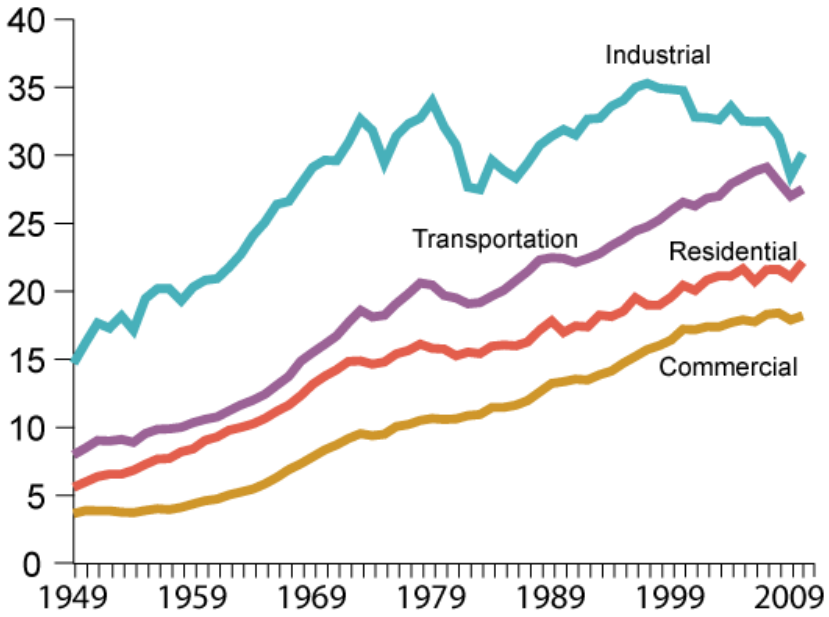
People as problem OR

People as solution?

TRENDS IN U.S. ENERGY CONSUMPTION

Energy Consumption by Sector, 1949-2010

Quadrillion Btu



Source: U.S. Energy Information Administration, *Annual Energy Review 2009*, Table 2.1a, and Monthly Energy Review (June 2011), preliminary 2010 data.

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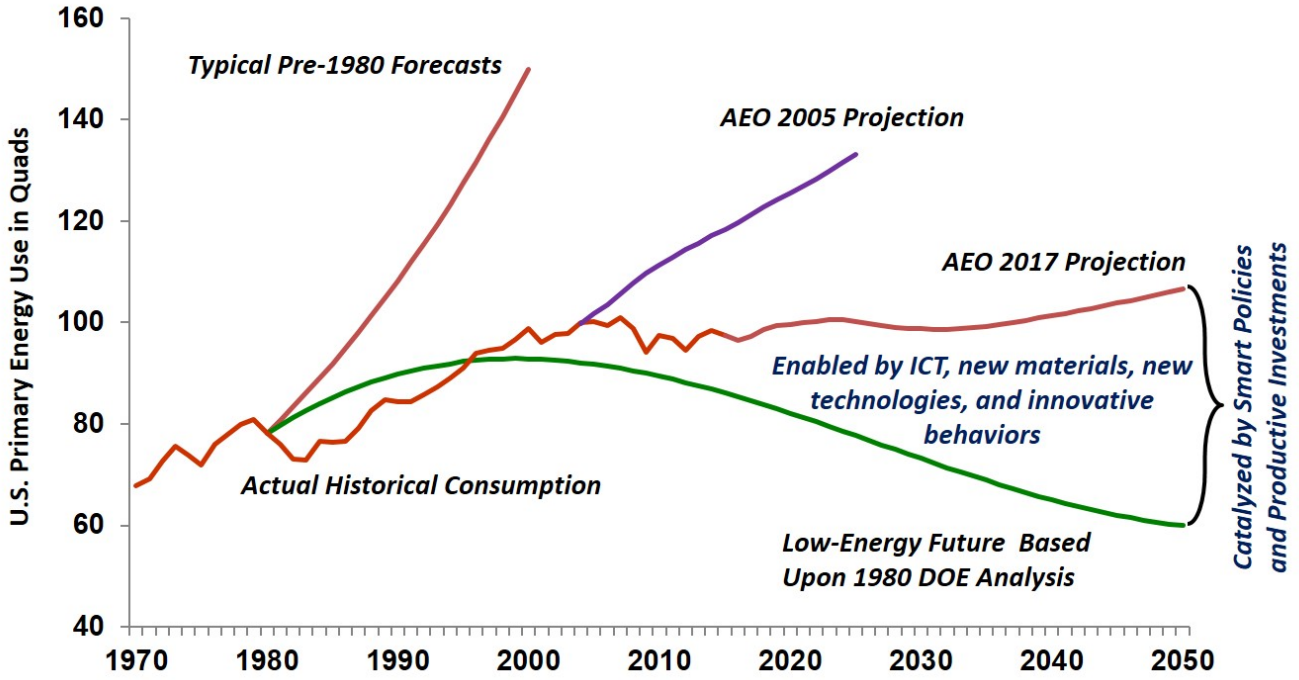
THE IMPACT OF ENERGY EFFICIENCY

Key Insight: The Energy Efficiency Resource Is Larger than Generally Believed or Understood



Sources: DOE 1980 Policy Analysis, AEO 2005, AEO 2017, and Laitner estimates 2017.

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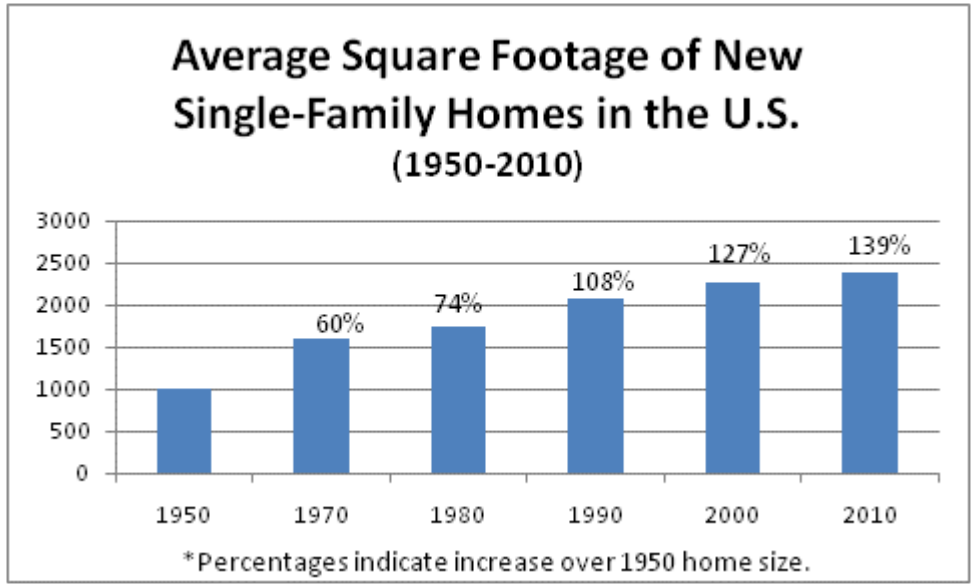
CULTURE AND COUNTERVAILING TRENDS



Patterns & Trends:

- Increased energy efficiency
- Invisible energy resources
- Culture of consumption

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THE INFLUENCE OF BEHAVIOR: THREE EXAMPLES

- Studies of nearly identical units , occupied by demographically similar families, have reported large (e .g. 200-300%) variations in energy use. (see Lutzenhiser 1993)
- Non-LEED schools have outperformed LEED buildings as a result of occupant behavior. (Schelly and Cross 2010)
- Standard military housing units used less energy than upgraded units. (Andres and Loudermilk 2010)

A STORY OF TWO SCHOOLS

Table 1. Annual Electricity Use (kWh/ft^2) and Percentage Decreases by High School and Fiscal Year[a]

	Rocky Mountain High School			Poudre High School			FCHS			Fossil Ridge High School LEED School[b]		
Fiscal Year	kWh/ft^2	Percentage Decrease Year-to-Year	Percentage Decrease from 2000	kWh/ft^2	Percentage Decrease Year-to-Year	Percentage Decrease from 2000	kWh/ft^2	Percentage Decrease Year to Year	Percentage Decrease from 2000	kWh/ft^2	Percentage Decrease Year to Year	Percentage Decrease from 2000
2000	9.62	—	—	11.15	—	-	10.85	—	—	—	—	—
2001	7.80	18.9[d]	18.9	8.76	21.4[d]	21.4	9.25	14.7[d]	14.7	—	—	—
2002	7.94	(1.7)	17.5	8.52	2.7	23.6	8.86	4.3	18.34	—	—	—
2003	7.86	1.0	18.3	7.99	6.3	28.4	8.45	4.5	22.1	—	—	—
2004	7.65	2.6	20.4	7.94	0.6	28.8	8.53	(0.8)	21.4	—	—	—
2005	7.11	7.1[e]	26.1	7.62	4.0	31.7	8.08	5.2	25.5	6.95	—	—
2006	6.58	7.6[e]	31.7	7.44	2.3	33.2	8.41	(4.1)	22.5	7.01	(0.9)	(0.9)[b]
2007	4.79	27.2[e]	50.2	7.36	1.1	34.0	7.82	7.0	27.9	6.24	12.4	10.2[b]

Note: FCHS = Fort Collins High School.

a. Fiscal years begin in July of the previous year and end in June of the stated year. (e.g., FY 2000 = July 1, 1999 through June 30, 2000)

b. FRHS not included in any regression tests because of missing data.

c. These data points are compared to first year of operation, fiscal year 2005.

d. Regression-based permutation for all schools tested that the average percentage decrease in 2001 is larger than the average decrease in all other years, $p < .001$ from a regression-based permutation coefficient (StataCorp. [2005]). Stata Statistical Software: Release 9. College Station, Texas: StataCorp. LP).

e. Regression-based permutation testing that the average percent decrease after 2004 at Rocky was larger than the average percent decrease at FCHS and Poudre, $p < .001$ from a regression-based permutation coefficient (ibid.).

A STORY OF TWO SCHOOLS

Rocky Mountain High School created a new organizational culture of conservation through:

- The work of charismatic leaders,
- By communicating expectations and successes,
- An enhanced sense of personal and group efficacy.
- By engaging the facilities manager, the administration, the teachers and the students.

A STORY OF A MILITARY DEMONSTRATION PROJECT

Project: Demonstrate the energy-saving capacity of various energy-efficient technologies.

Approach: Four houses, each built with varying degrees of energy-efficient technologies.

Results: the control house was the ***most*** energy efficient and the Cadillac fourth house was the ***least*** energy efficient.

Insights: The couple living in the control house turned off lights when they left rooms, opened windows instead of running the A/C, rarely ran their dishwasher and engaged in other energy-saving behaviors.

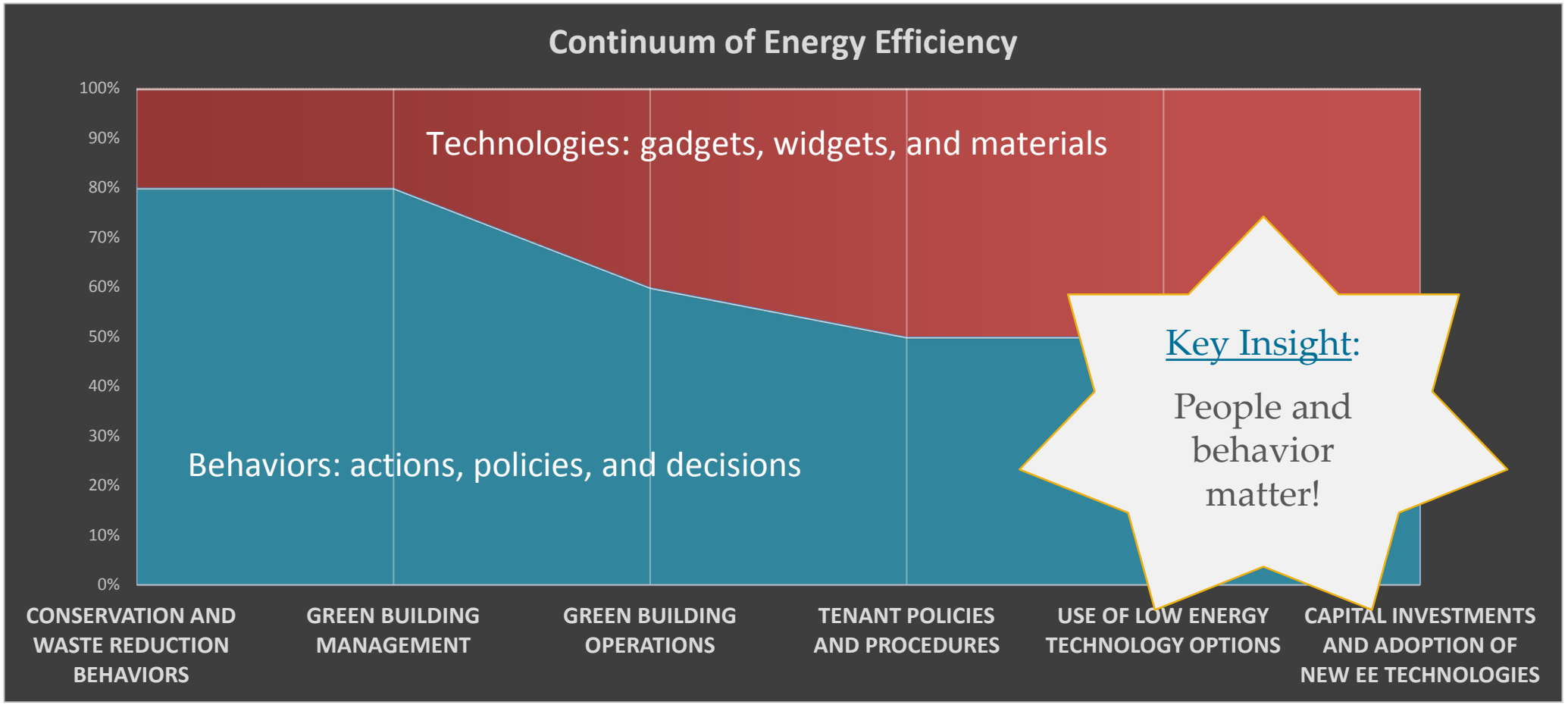
A NEW WAY OF THINKING

"A revolution doesn't happen when society adopts new tools, it happens when society adopts new behaviors."

Clay Shirky

Digital Guru and NYU Professor of Telecommunications.

THE BEHAVIOR / TECHNOLOGY CONTINUUM



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BEHAVIOR-BASED ENERGY SAVINGS POTENTIAL:

RESIDENTIAL SECTOR

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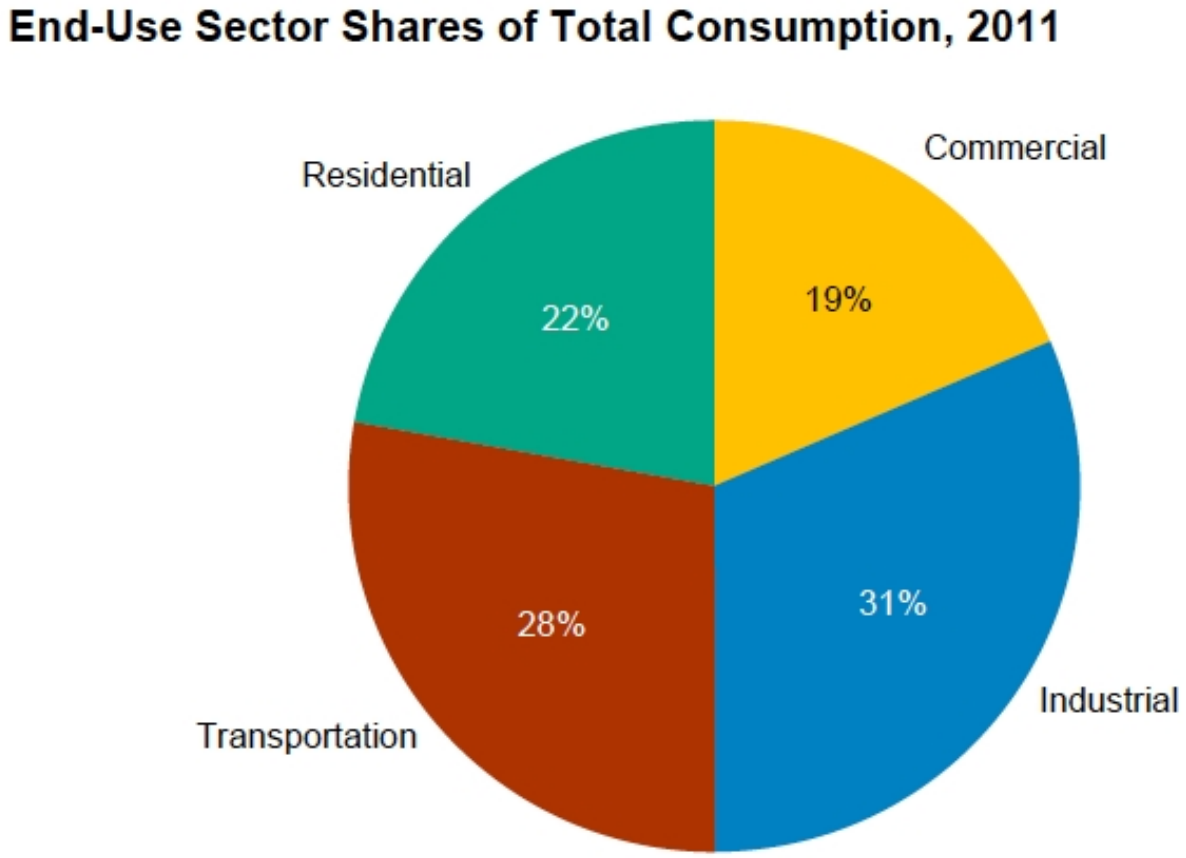
ENERGY CONSUMPTION BY END USE



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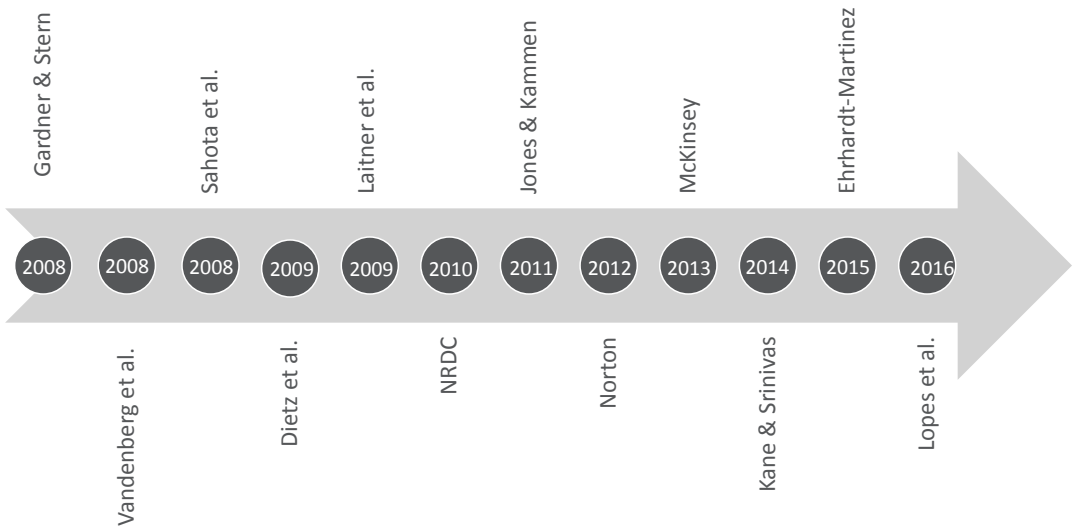
BEHAVIOR-BASED SAVINGS POTENTIAL: RESIDENTIAL

	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.

OVERVIEW OF STUDY CHARACTERISTICS

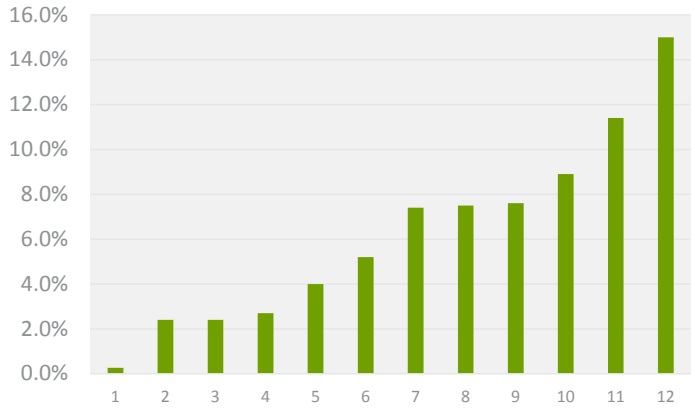
Publication dates: 2008 – 2016



Number of Behaviors in Each Study: 7 to over 100

#	Areas of Focus
4	Carbon Emissions
6	Energy
2	Electricity

Estimates of Savings Potential:



From 0.26% to 15.0% of national consumption/emissions

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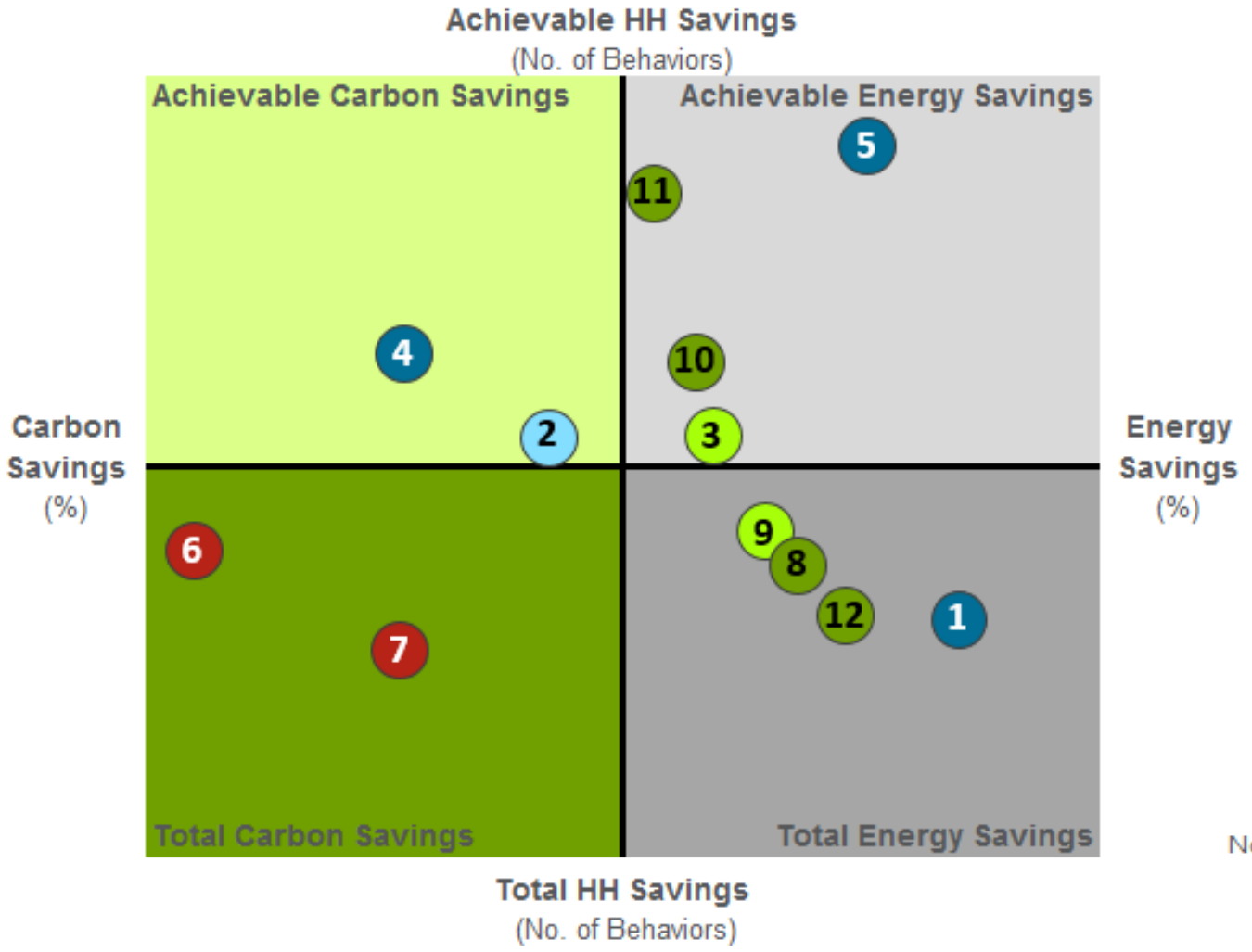
MEASURES OF BEHAVIOR POTENTIAL



Potential Studies

1 - Gardner and Stern, 2008
2 - Vandenberg et al., 2008
3 - Sahota et al., 2008
4 - Dietz et al., 2009
5 - Laitner et al., 2009
6 - NRDC & The Garrison Institute, 2010
7 - Jones and Kammen, 2011
8 - Norton, 2012
9 - McKinsey, 2013
10 - Ehrhardt-Martinez, 2015
11 - Kane and Srinivas, 2014
12 - Lopes et al., 2016

- Res. conservation + no/low cost actions
- Res. actions + EE investment
- Any res. actions & invest. + personal transport actions
- Any res. actions & invest. + personal transport investments
- Any res. actions & invest. + personal transport + embedded energy/carbon

Notes: Circle colors indicate range of behaviors. Number (1-12) indicates study. Location indicates whether focus is on energy or carbon, technical or achievable savings, the number of behaviors examined and the size of the savings.

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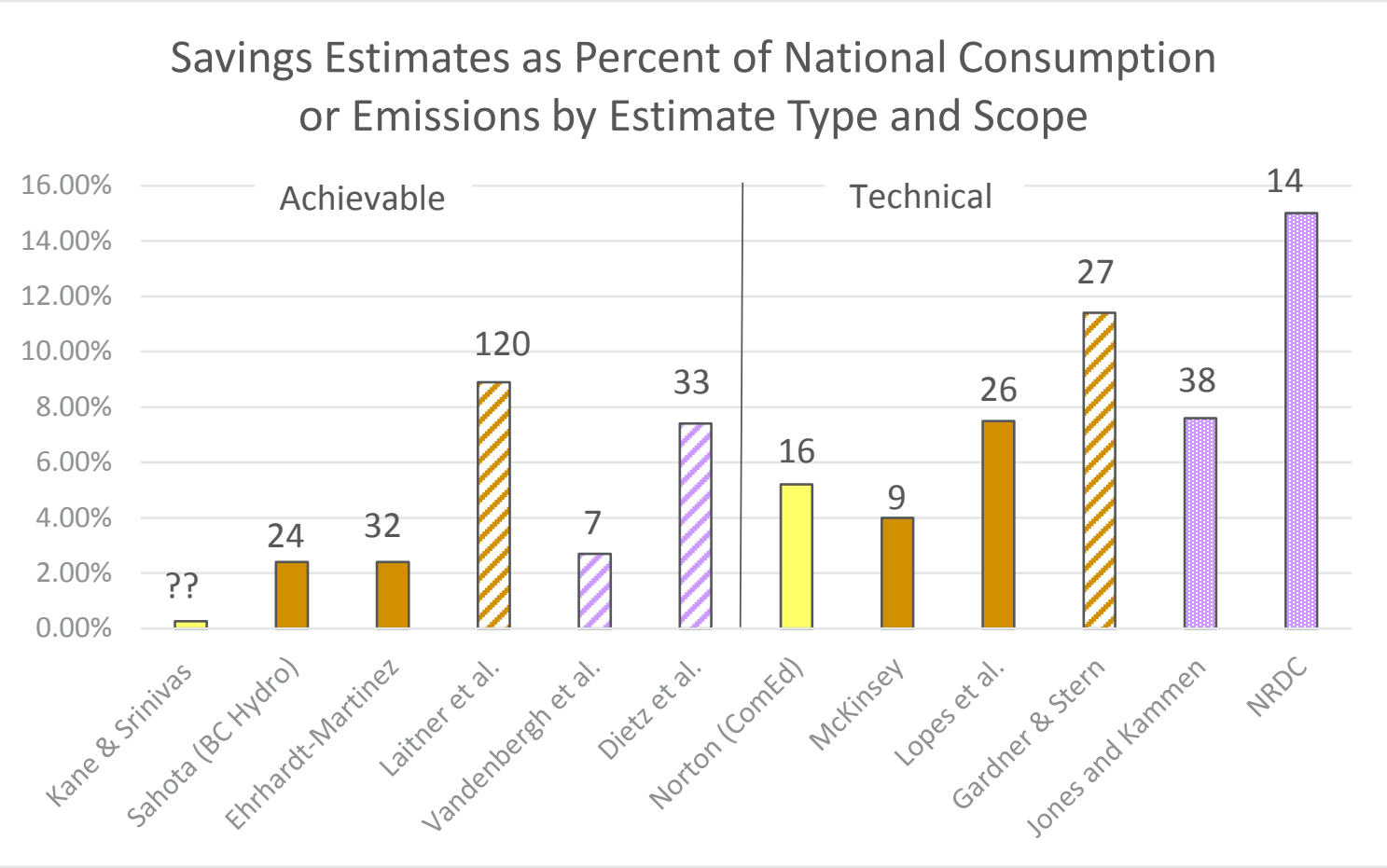
MEASURES OF BEHAVIOR POTENTIAL



*Number above each bar indicate the number of behaviors

Electricity
Energy
Carbon

Pattern Key

Household
Household + Transport
Household, Transport + Embedded

Technical Potential:
20-30% of residential consumption
4 - 6.5% of total nat'l consumption
→ 6.5 quadrillion Btus

Achievable Potential:
2.5-11% of residential consumption
0.5 - 2.5% of total nat'l consumption
→ 2.5 quadrillion Btus

BEHAVIOR-BASED ENERGY SAVINGS POTENTIAL:

COMMERCIAL SECTOR

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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

LOOKING ACROSS 4 POTENTIAL STUDIES

Meta-review

		Behaviors			
Study	Scope	No.	Types	End Uses	Savings
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%

Source: Ehrhardt-Martinez 2016

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HIGH-LEVEL FINDINGS ACROSS 4 STUDIES

Estimates of behavior-based savings potential across all commercial buildings

Technical Potential:
12-21% of com. consumption
2.3-4% of total nat'l consumption
→ 4 quadrillion Btus

Achievable Potential:
0.5-7% of com. consumption
.01-1.3% of total nat'l consumption
→ 1.3 quadrillion Btus

BEHAVIOR-BASED OPPORTUNITY BY BUILDING TYPE*

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

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.

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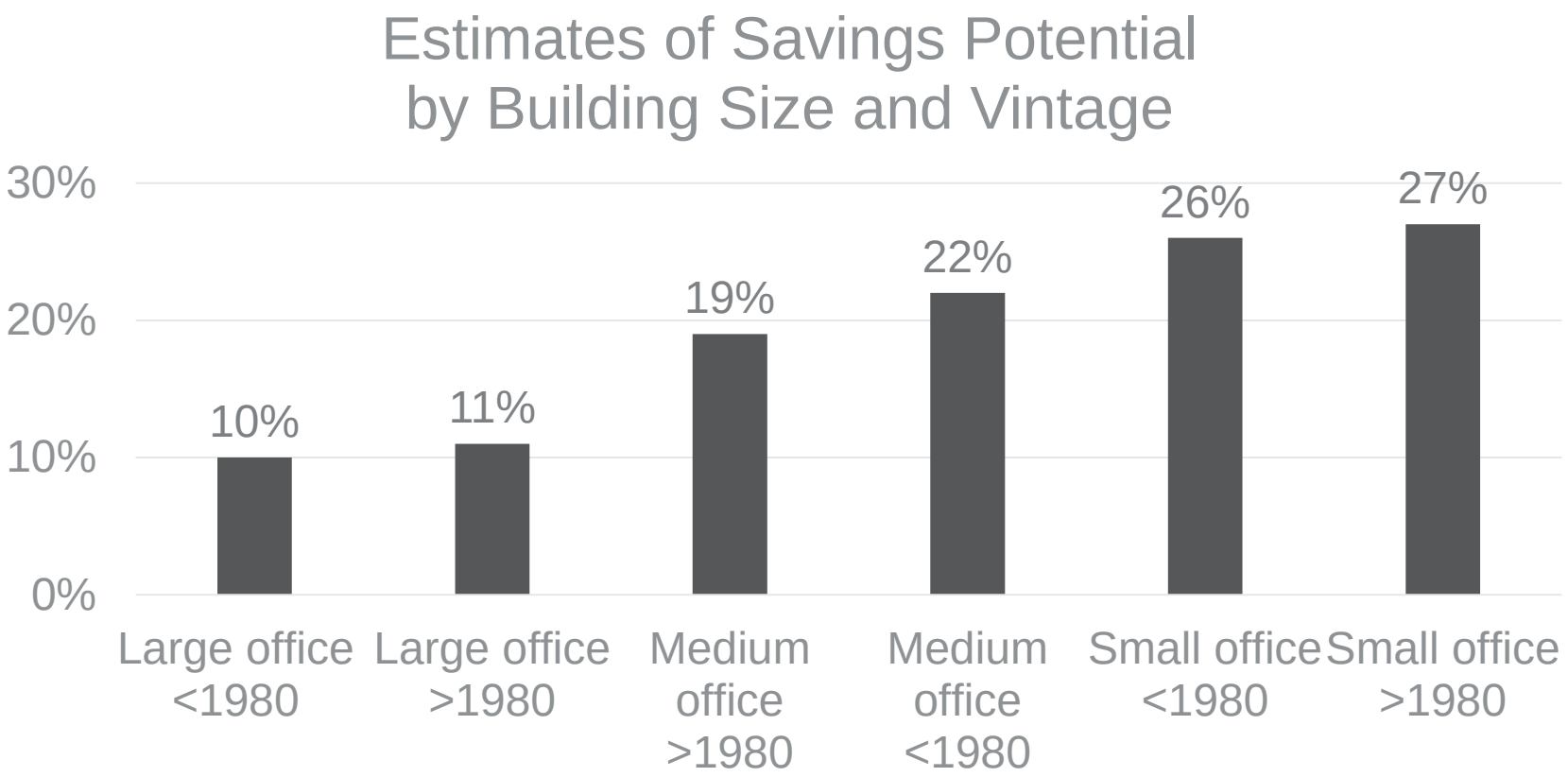
SAVINGS OPPORTUNITY BY BUILDING SIZE



Source: Azar and Menassa 2014

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

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SAVINGS BY END USE ACROSS STUDIES

Behavior-based 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

SUMMARY: RESIDENTIAL AND COMMERCIAL SAVINGS OPPORTUNITY

		Residential	Commercial	TOTAL
Technical				
	Sectoral	20-30%	12-21%	
	National	4-6.5%	2.3-4%	
		→ 6.5 quads	→ 4 quads	→ 10.5 quads
Achievable				
	Sectoral	2.5-11%	0.5-7%	
	National	0.5-2.5%	.01-1.3%	
		→ 2.5 quads	→ 1.3 quads	→ 3.8 quads

ENABLING TECHNOLOGIES & BEHAVIOR

Enable and Empower:

- Teach: Increase understanding
- Enable: Make it easy
- Engage: Interesting, fun, & worthwhile

Energy Feedback Displays

Thermostat technologies

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