ENGAGING, ENABLING AND EMPOWERING PEOPLE

THE SAVINGS POTENTIAL OF BEHAVIORAL STRATEGIES & ENABLING TECHNOLOGIES

JUNE 26, 2017
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

THE IMPACT OF ENERGY EFFICIENCY

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

CULTURE AND COUNTERVAILING TRENDS

Patterns & Trends:
- Increased energy efficiency
- Invisible energy resources
- Culture of consumption

Average Square Footage of New Single-Family Homes in the U.S. (1950-2010)

*Percentages indicate increase over 1950 home size.
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/ft²) and Percentage Decreases by High School and Fiscal Year

<table>
<thead>
<tr>
<th>Fiscal Year</th>
<th>Rocky Mountain High School</th>
<th>Poudre High School</th>
<th>FCHS</th>
<th>Fossil Ridge High School LEED School</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>kWh/ft²</td>
<td>Year-to-Year</td>
<td>Percentage Decrease from 2000</td>
<td>kWh/ft²</td>
</tr>
<tr>
<td>2000</td>
<td>9.62</td>
<td>11.15</td>
<td>-</td>
<td>10.85</td>
</tr>
<tr>
<td>2001</td>
<td>7.80</td>
<td>8.76</td>
<td>21.4d</td>
<td>9.25</td>
</tr>
<tr>
<td>2002</td>
<td>7.94</td>
<td>8.52</td>
<td>2.7</td>
<td>8.86</td>
</tr>
<tr>
<td>2003</td>
<td>7.86</td>
<td>7.99</td>
<td>6.3</td>
<td>8.45</td>
</tr>
<tr>
<td>2004</td>
<td>7.65</td>
<td>7.94</td>
<td>0.6</td>
<td>8.53</td>
</tr>
<tr>
<td>2005</td>
<td>7.11</td>
<td>7.62</td>
<td>4.0</td>
<td>8.08</td>
</tr>
<tr>
<td>2006</td>
<td>6.58</td>
<td>7.44</td>
<td>2.3</td>
<td>8.41</td>
</tr>
<tr>
<td>2007</td>
<td>4.79</td>
<td>7.36</td>
<td>1.1</td>
<td>7.82</td>
</tr>
</tbody>
</table>

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 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

Key Insight:
People and behavior matter!

Continuum of Energy Efficiency
- Technologies: gadgets, widgets, and materials
- Behaviors: actions, policies, and decisions

Categories:
- Conservation and Waste Reduction Behaviors
- Green Building Management
- Green Building Operations
- Tenant Policies and Procedures
- Use of Low Energy Technology Options
- Capital Investments and Adoption of New EE Technologies
BEHAVIOR-BASED ENERGY SAVINGS POTENTIAL:

RESIDENTIAL SECTOR
End-Use Sector Shares of Total Consumption, 2011

- Residential: 22%
- Commercial: 19%
- Transportation: 28%
- Industrial: 31%
## BEHAVIOR-BASED SAVINGS POTENTIAL: RESIDENTIAL

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Focus:</strong></td>
<td>Carbon Emissions Savings</td>
<td>Energy Savings Opportunities</td>
<td>Energy Savings Opportunities</td>
</tr>
<tr>
<td><strong>Scope:</strong></td>
<td>17 Household Actions</td>
<td>110 HH Actions (Roughly)</td>
<td>27 HH Actions (Roughly)</td>
</tr>
<tr>
<td><strong>Potential Savings:</strong></td>
<td>Residential Sector: 20% (of HH Direct Emissions)</td>
<td>22%</td>
<td>30%</td>
</tr>
<tr>
<td></td>
<td>National: 7.4% (of National Emissions)</td>
<td>9%</td>
<td>11%</td>
</tr>
<tr>
<td><strong>Period to Achieve Max. Annual Savings</strong></td>
<td>10 years</td>
<td>5 to 8 years</td>
<td>N/A</td>
</tr>
</tbody>
</table>

*Conservative estimates for Residential and Personal Transport only.*
OVERVIEW OF STUDY CHARACTERISTICS


# Areas of Focus
4 Carbon Emissions
6 Energy
2 Electricity

Number of Behaviors in Each Study: 7 to over 100
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
10 - Ehrhardt-Martinez, 2015
11 - Kane and Srinivas, 2014
12 - Lopes et al., 2016

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.
MEASURES OF BEHAVIOR POTENTIAL

Savings Estimates as Percent of National Consumption or Emissions by Estimate Type and Scope

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

Pattern Key
- Household
- Household + Transport
- Household, Transport + Embedded

*Number above each bar indicate the number of behaviors
BEHAVIOR-BASED ENERGY SAVINGS POTENTIAL:

COMMERCIAL SECTOR
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
### Meta-review

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

Source: Ehrhardt-Martinez 2016
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*

<table>
<thead>
<tr>
<th>Building Type</th>
<th>% of City-level Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offices</td>
<td>28%-33%</td>
</tr>
<tr>
<td>Education</td>
<td>22%-24%</td>
</tr>
<tr>
<td>Retail</td>
<td>16%-20%</td>
</tr>
<tr>
<td><strong>Sub-Total</strong></td>
<td><strong>68%-75%</strong></td>
</tr>
<tr>
<td>Remaining 6 Building Types</td>
<td>25%-32%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

Source: Ehrhardt-Martinez 2016

*Of the 9 commercial building types included in the study.
SAVINGS OPPORTUNITY BY BUILDING SIZE

Estimates of Savings Potential by Building Size and Vintage

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

Source: Azar and Menassa 2014
## Behavior-based Savings Ranking by End Use

<table>
<thead>
<tr>
<th>Study</th>
<th>HVAC</th>
<th>Lighting</th>
<th>Office Computers &amp; Equip.</th>
<th>Hot Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Azar &amp; Menassa (offices) 2014</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>?</td>
</tr>
<tr>
<td>Norton (C&amp;I) 2013</td>
<td>2</td>
<td>1</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Ehrhardt-Martinez (Comm.) 2015</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Ehrhardt-Martinez (offices) 2015</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>
## SUMMARY: RESIDENTIAL AND COMMERCIAL SAVINGS OPPORTUNITY

<table>
<thead>
<tr>
<th></th>
<th>Residential</th>
<th>Commercial</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Technical</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sectoral</td>
<td>20-30%</td>
<td>12-21%</td>
<td></td>
</tr>
<tr>
<td>National</td>
<td>4-6.5%</td>
<td>2.3-4%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>→ 6.5 quads</td>
<td>→ 4 quads</td>
<td>→ 10.5 quads</td>
</tr>
<tr>
<td><strong>Achievable</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sectoral</td>
<td>2.5-11%</td>
<td>0.5-7%</td>
<td></td>
</tr>
<tr>
<td>National</td>
<td>0.5-2.5%</td>
<td>.01-1.3%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>→ 2.5 quads</td>
<td>→ 1.3 quads</td>
<td>→ 3.8 quads</td>
</tr>
</tbody>
</table>
Enable and Empower:
• Teach: Increase understanding
• Enable: Make it easy
• Engage: Interesting, fun, & worthwhile
CONTACTS

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