

DOE BEHAVIORAL POTENTIAL ESTIMATES WORKSHOP

SAN FRANCISCO, CA

JUNE 13, 2016

NAVIGANT

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WORKSHOP AGENDA

- A. 12:15-1:00 Lunch and Introductions
- B. 1:00-1:45 Overview of Existing Studies
[**Break** 10-15 min] 1:45 – 2:00
- C. 2:00-3:00 Review of 3 Principal Estimation Methods
[**Break** 5-10 min] 3:00 -3:10
- D. 3:10-4:30 Small Group Discussion of Proposals
- E. 4:30-5:15 Report back and Discussion
- F. 5:15-5:45 Conclusion and Next Steps

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2. Overview of Existing Estimates and Methods

3. Review of 3 Principal Estimation Methods

4. Group Discussion

5. Conclusions and Next Steps

PURPOSE AND OBJECTIVES OF THE WORKSHOP

Purpose

Gather stakeholder feedback on the utility and credibility of existing methods of estimating behavior-based, energy efficiency potential.

Workshop Objectives

1. Review existing studies of behavior-based energy efficiency potential.
2. Understand prevalent methodologies used to estimate savings potential.
3. Evaluate the merits and disadvantages of selected estimation methods.
4. Determine preferences and reservations for particular estimation methods.
5. Recommend modifications to existing estimation methods.

DESIRED WORKSHOP OUTCOMES

- Stakeholder Insights about the utility and credibility of existing methods for estimating behavior-based energy-efficiency potential.
- Stakeholder preferences for particular estimation methods.
- Stakeholder suggestions for modifying existing methods.
- Viable method(s) for conducting behavior potential studies.

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STUDIES OF BEHAVIOR POTENTIAL

The Search for Behavior Potential Studies

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

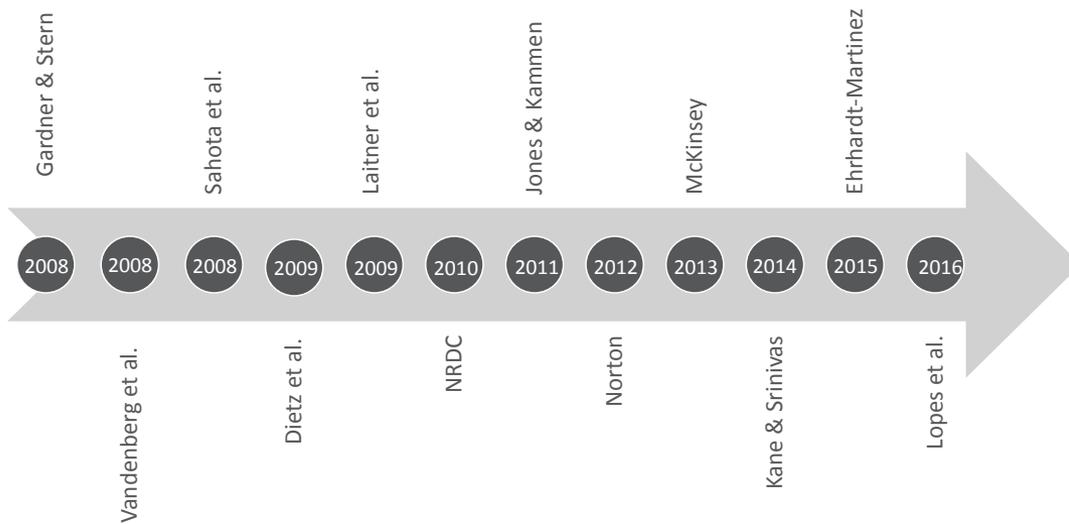
Potential Studies

- 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

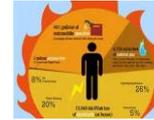


OVERVIEW OF STUDY CHARACTERISTICS

Publication dates: 2008 – 2016

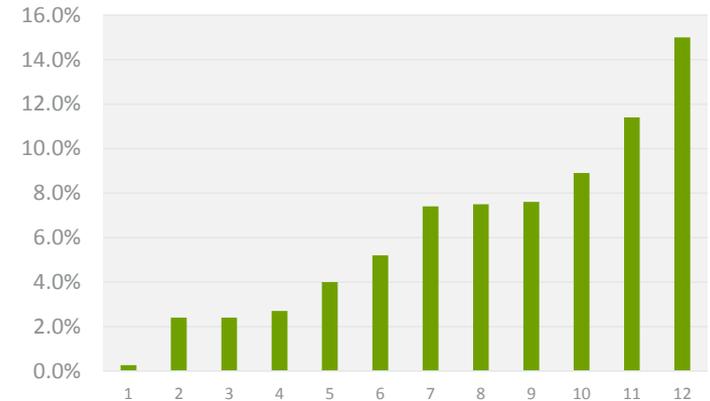


Number of Behaviors in Each Study: 7 to over 100



| # | Areas of Focus |
|---|------------------|
| 4 | Carbon Emissions |
| 6 | Energy |
| 2 | Electricity |

Estimates of Savings Potential:



From 0.26% to 15.0% of national consumption/emissions

MEASURES OF BEHAVIOR POTENTIAL

Need to define “Behavior” and “Potential”

What do we mean by *Potential* ?

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

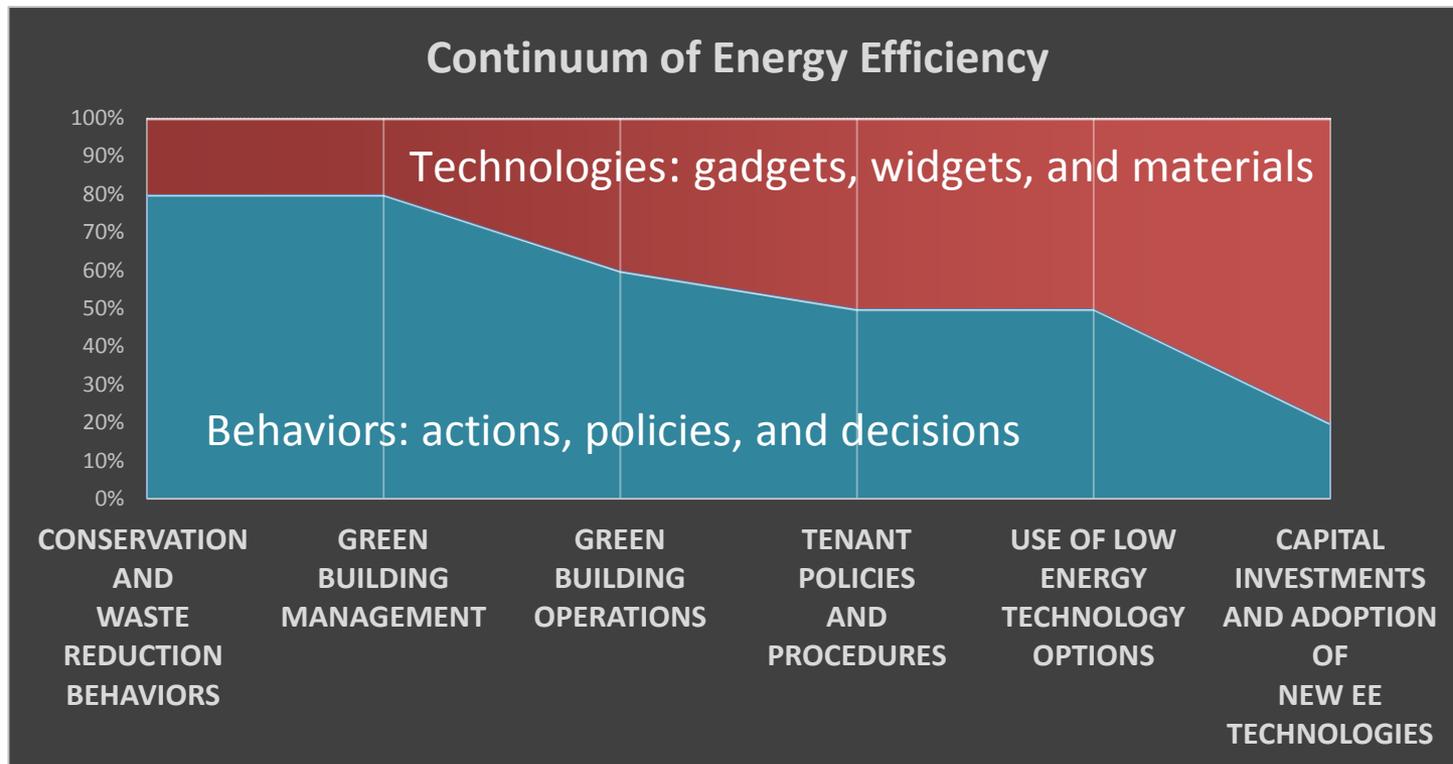
Achievable Potential: The energy efficiency savings that could be expected in response to specific levels of incentives and assumptions about policies, market influences, and barriers. Some studies also refer to this as “achievable potential.”

Accounts for eligibility and likely participation rates

MEASURES OF BEHAVIOR POTENTIAL

Need to define “Behavior” and “Potential”

What do we mean by *Behavior* ?



MEASURES OF BEHAVIORAL POTENTIAL

Energy Efficiency Programs as delivery mechanisms...

| Categories | Definition | Subcategories | Examples |
|--------------------|---|---|--|
| Cognition | Intrinsic psychological processes are foremost. Focus on unidirectional delivery of information. | Communication (mass media & targeted), Social media, Education & training | <i>Flex Your Power</i> <i>Local on the 8s</i> <i>Opower HERs</i> <i>ASE PowerSave Schools</i> <i>Cool Choices</i> |
| Calculus | Deliberation of extrinsic motivators is foremost. Focus is on economically rational decision-making. | Feedback Games Incentives Home energy audits Installation | <i>Tendril, Powerly</i> <i>Take Charge Challenge</i> <i>EnergySaver Challenge</i> <i>Rock the Bulb Tour</i> <i>EnergyWise Home Diag.</i> |
| Social Interaction | Sociability and belonging are foremost. Focus is on social interaction. | Human scale (CBSM, person-to-person, peer champions, eco-teams) Online forums Gifts | <i>Neighborhood Saver</i> <i>Low Carbon Diet</i> <i>Neighborhood EE Program</i> <i>Project Porchlight</i> <i>OurGreenCommunity</i> |

Information Source: ACEEE Field Guide to Utility Run Behavior Programs, 2013.

MEASURES OF BEHAVIOR POTENTIAL

Need to define “Behavior” and “Potential”

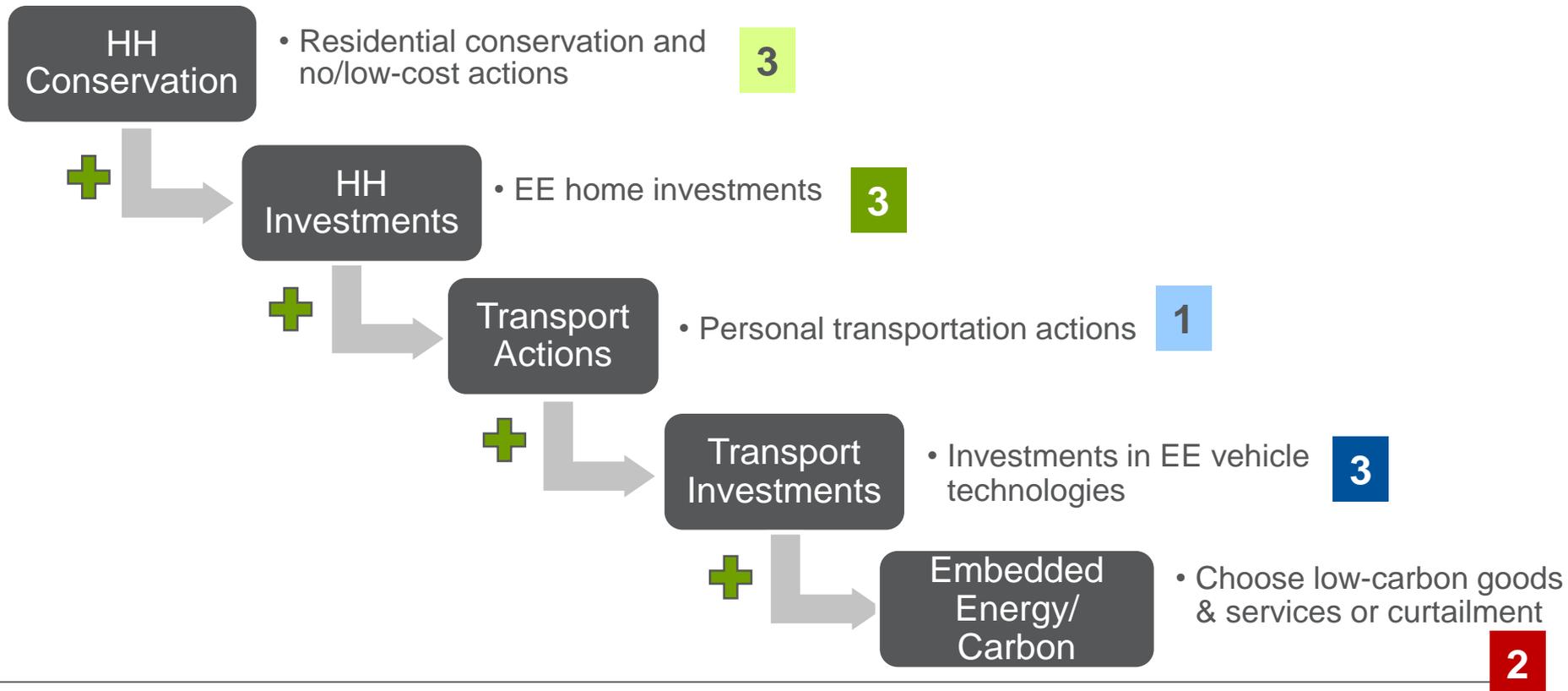
What do we mean by *Behavior* ?

| Behavior Type | Direct | | | | Indirect | |
|------------------------------|-----------|----------------------|----------------|----------------------|---------------------|------------------------|
| | Household | | Transportation | | Embedded | |
| | EE Use | EE Purchase Decision | EE Use | EE Purchase Decision | Reduce Carbon Goods | Reduce Carbon Services |
| Conservation/ Curtailment | X | | X | | X | X |
| No/Low Cost | | X | | X | | |
| Investment | | X | | X | | |

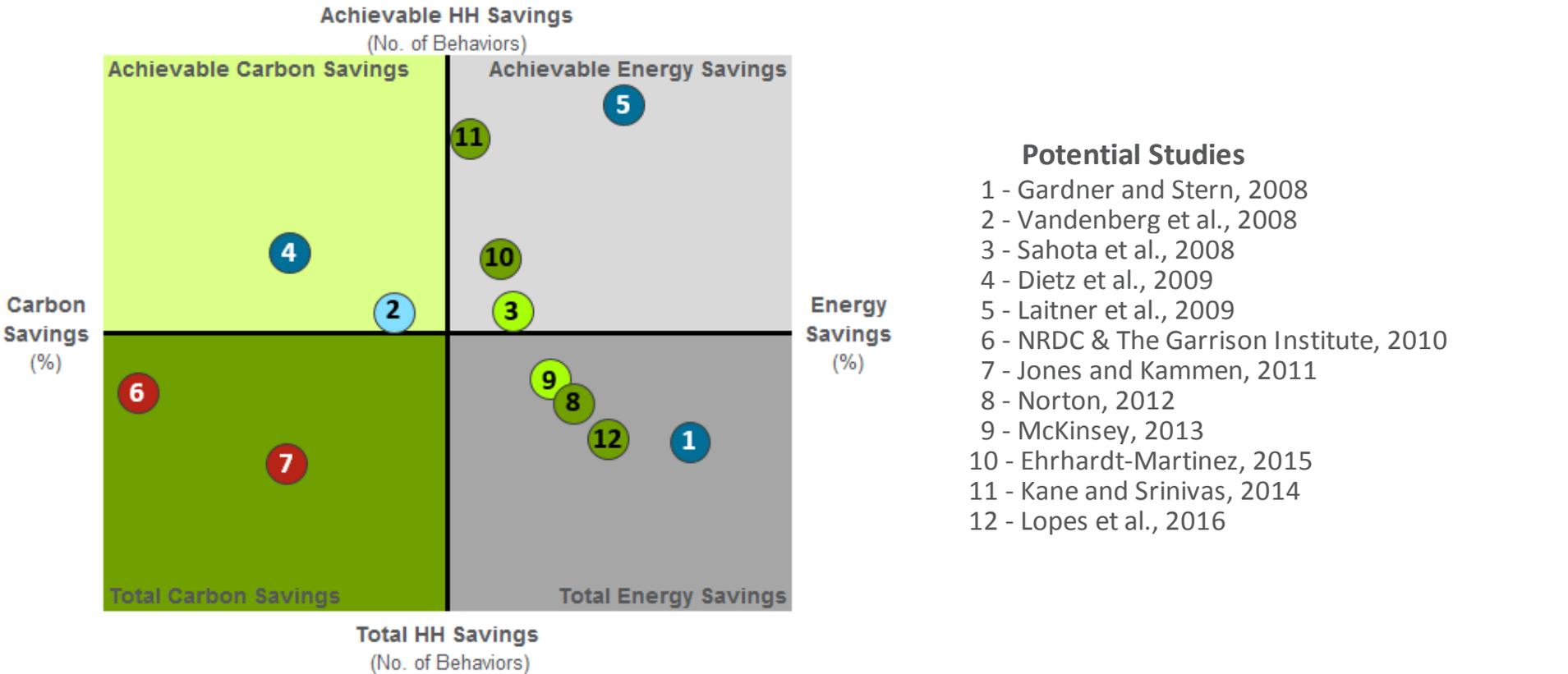
MEASURES OF BEHAVIOR POTENTIAL

Need to define “Behavior” and “Potential”

What do we mean by *Behavior* ?

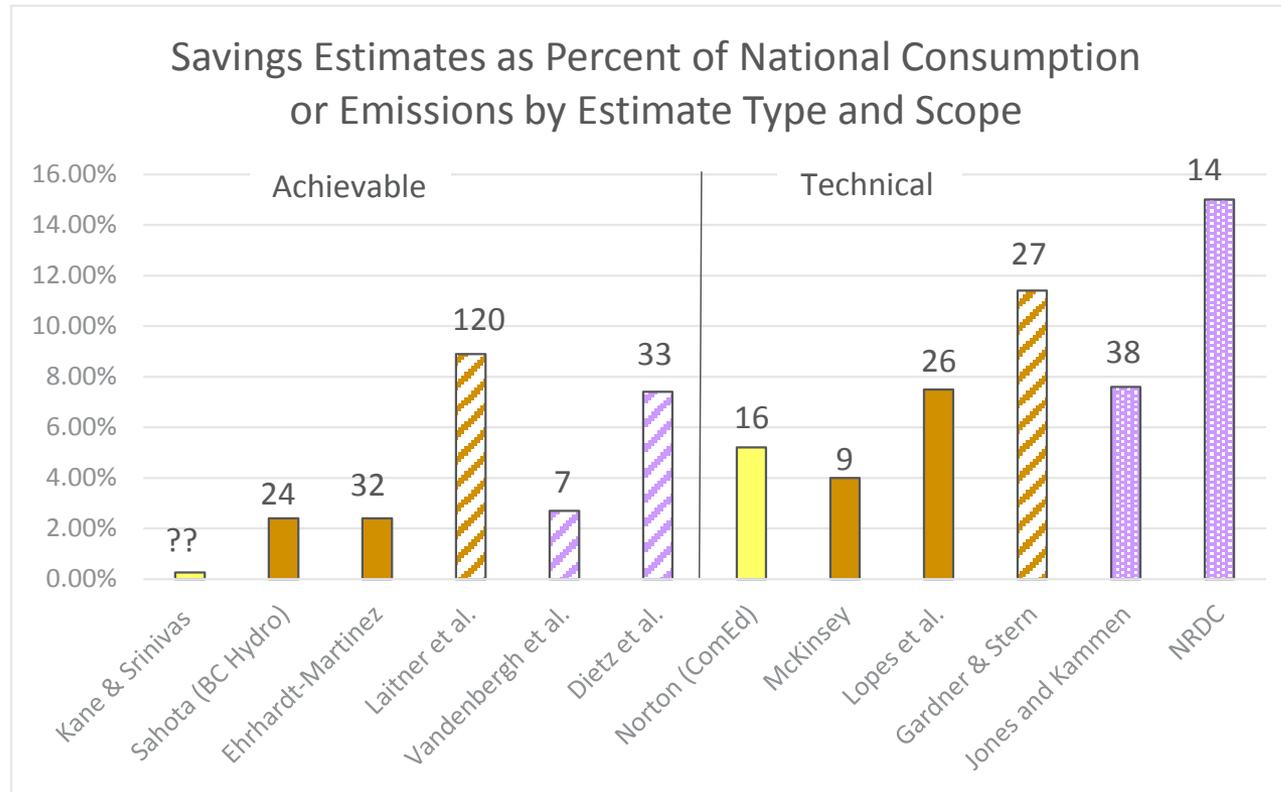


MEASURES OF BEHAVIOR POTENTIAL

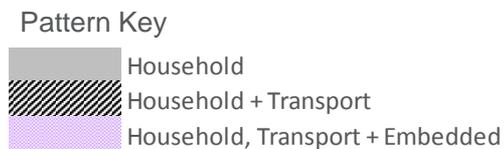
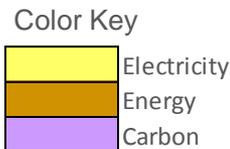


Notes: Circle colors indicate range of behaviors. Number (1-12) indicates study. Location indicates whether focus is on energy or carbon, technical or achievable savings, the number of behaviors examined and the size of the savings.

MEASURES OF BEHAVIOR POTENTIAL



Notes: Number above each bar indicate the number of behaviors



MEASURES OF BEHAVIOR POTENTIAL

Estimation Methods and Data Inputs

| Focus | Existing Data | | Survey Data | | Other |
|--------------|--|--|--|--|---|
| | National | Model | Survey | Survey+ | |
| Carbon | <ul style="list-style-type: none"> • Dietz et al. • Vandenberg • NRDC | <ul style="list-style-type: none"> • Jones & Kammen | n.a. | n.a. | n.a. |
| Energy/Elec. | <ul style="list-style-type: none"> • Laitner et al. • Gardner & Stern | <ul style="list-style-type: none"> • Ehrhardt | <ul style="list-style-type: none"> • Sahota | <ul style="list-style-type: none"> • McKinsey • Norton | <ul style="list-style-type: none"> • Lopes • Kane |

MEASURES OF BEHAVIOR POTENTIAL

Estimation Methods and Data Inputs

| | Existing Data | | Survey Data | | |
|--|---------------|-------|-------------|---------|-------|
| | National | Model | Survey | Survey+ | Other |

Existing National Data Resources: Use secondary data sources (EIA, Bureau of Transportation Statistics, EPA, RECS) to determine current behaviors and technologies and savings opportunities and calculate national-level savings estimates.



Example: Use of cold water for laundry (achievable potential)

Of the 91.8 million households that use a clothes washer, 72.0 million use a setting of 'Cold' for the Rinse Cycle, yielding a penetration rate of 78.5%. If clothes are washed using a warm/cold cycle instead of a hot/warm cycle, the emissions associated with water heating for clothes washing are reduced by 75% which gives a PER of 0.5 MTC, or 0.1% of I/H emissions.

$$\begin{aligned} \text{RAER} &= \text{Technical Potential} \times \text{Plasticity} \\ &= 0.5 \text{ MTC} \times 35\% \text{ plasticity} \\ &= 0.2 \text{ MTC} \end{aligned}$$

Source: Dietz et al. 2009

MEASURES OF BEHAVIOR POTENTIAL

Estimation Methods and Data Inputs

| | Existing Data | | Survey Data | | |
|--|---------------|-------|-------------|---------|-------|
| | National | Model | Survey | Survey+ | Other |

Existing Data Resources as Model Inputs: National-level data are used to determine the impact of household size and household income on consumption patterns using regression analysis. National patterns are combined with local consumption statistics to estimate local consumption patterns. GHG emissions of particular goods and services are calculated using the Economic Input-Output Life Cycle Assessment model. Estimates of savings potential are generated for particular scenarios of behavioral or technological changes.



Example: Line drying laundry (technical potential)

Carbon Savings = loads per year **x** energy per load **x** electricity emissions factor

Source: Jones and Kammen, 2011

MEASURES OF BEHAVIOR POTENTIAL

| | Existing Data | | Survey Data | | Other |
|--|---------------|-------|-------------|---------|-------|
| | National | Model | Survey | Survey+ | |

Survey Data Measures: Household surveys use self-reported data to determine baseline behaviors and energy use and opportunities to reduce consumption. Some surveys assess achievable potential by asking people how likely they are to take a particular action in the future. Some studies supplement survey data with ethnographic interviews (McKinsey), site visits (Norton) and/or data loggers (Norton).



Example: Nighttime thermostat setbacks (achievable potential)

About 61% of HHs reported turning down the temperature at night with only 3% reporting an occasional or frequent lapse. 17% of HHs indicated that they would respond to an information message on the benefits of turning down the temperature.

$$\begin{aligned} \text{Achievable potential} &= \text{Eligibility} \times \text{Willingness} \times \text{Avg. end use savings} \\ &= 39\% \text{ HHs} \times 17\% \text{ willingness} \times \text{Savings factor} \end{aligned}$$

Source: Sahota. 2008

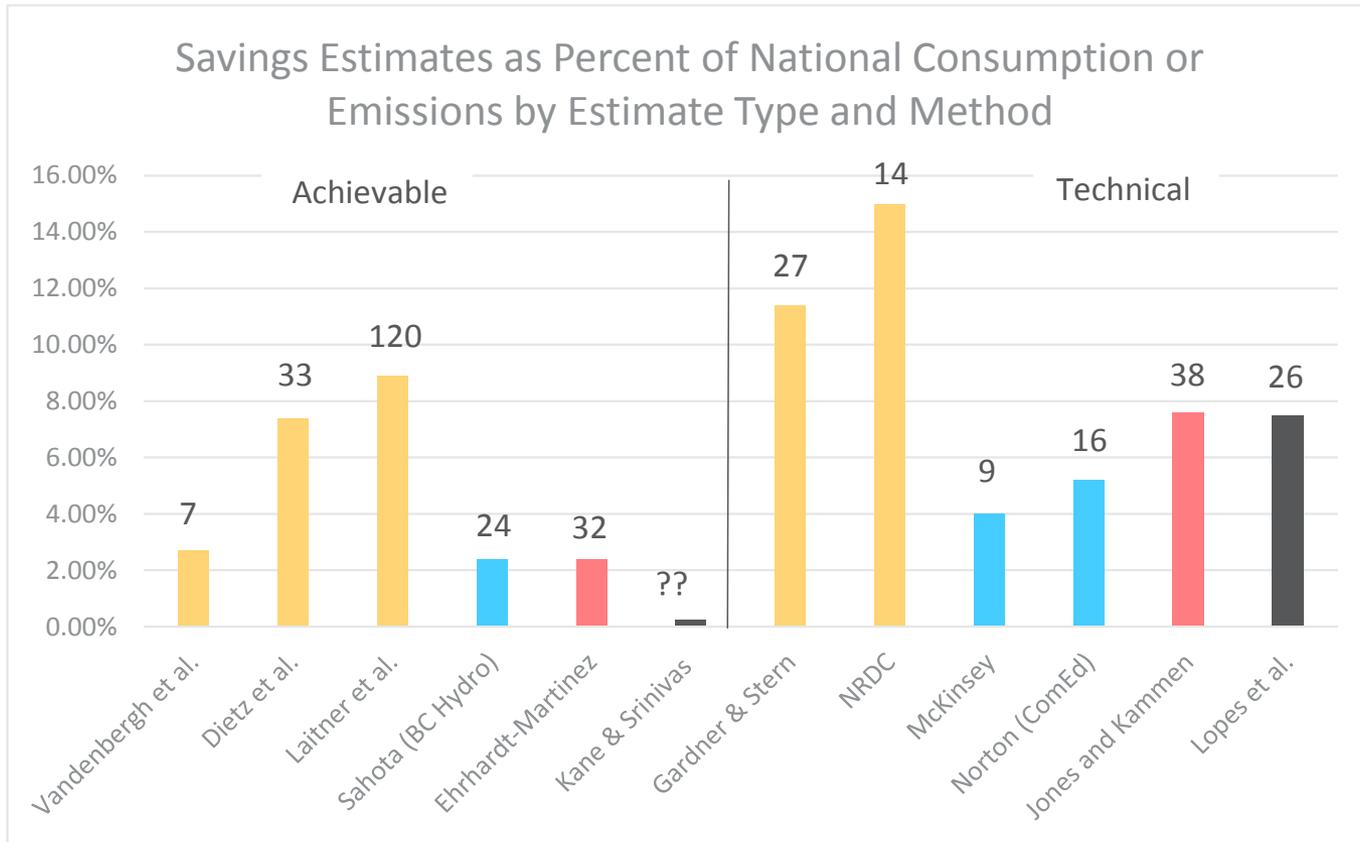
MEASURES OF BEHAVIOR POTENTIAL

| | | | | | |
|--|---------------|-------|-------------|---------|-------|
| | Existing Data | | Survey Data | | |
| | National | Model | Survey | Survey+ | Other |

Other Estimation Approaches:

- A) Lopes et al. use building simulation models combined with 3 behavioral scenarios representing normal, efficiency and inefficient households behaviors to estimate technical potential from technologies and behaviors.
- B) Kane and Srinivas use Opower program data to estimate the savings potential from the deployment of home energy reports to all U.S. utilities that serve a minimum of 50,000 HHs through regression analysis of current program data.

MEASURES OF BEHAVIOR POTENTIAL



Estimation Methods Key



MEASURES OF BEHAVIOR POTENTIAL

| Focus | Existing Data | | Survey Data | | Other |
|--------------------|--|--|--|--|---|
| | National | Model | Survey | Survey+ | |
| Carbon | <ul style="list-style-type: none"> • Dietz et al. • Vandenberg • NRDC | <ul style="list-style-type: none"> • Jones & Kammen | n.a. | n.a. | n.a. |
| Energy/Elec. | <ul style="list-style-type: none"> • Laitner et al. • Gardner & Stern | <ul style="list-style-type: none"> • Ehrhardt | <ul style="list-style-type: none"> • Sahota | <ul style="list-style-type: none"> • McKinsey • Norton | <ul style="list-style-type: none"> • Lopes • Kane |
| Total | 5 | 2 | 1 | 2 | 2 |
| Technical Savings | 11.4-15.0% | 7.6% | n.a. | 4.0-5.2% | 7.5% |
| Achievable Savings | 2.7-8.9% | 2.4% | 2.4% | n.a. | 0.26% |

MEASURES OF BEHAVIOR POTENTIAL

Selection Criteria for Detailed Review

| Focus | Existing Data | | Survey Data | | Other | |
|------------------------|--|--|--|--|---|-----|
| | National | Model | Survey | Survey+ | | |
| Carbon | <ul style="list-style-type: none"> • Dietz et al. • Vandenberg • NRDC | <ul style="list-style-type: none"> • Jones & Kammen | n.a. | n.a. | n.a. | |
| Energy/Elec. | <ul style="list-style-type: none"> • Laitner et al. • Gardner & Stern | <ul style="list-style-type: none"> • Ehrhardt | <ul style="list-style-type: none"> • Sahota | <ul style="list-style-type: none"> • McKinsey • Norton | <ul style="list-style-type: none"> • Lopes • Kane | |
| Scalability | 1 | 3 | 3 | 3 | 1 | 2 |
| Rigor | 2 | 3 | 2 | 3 | 3 | 1 |
| Cost Effectiveness | 3 | 2 | 1 | 1 | 1 | 3 |
| Proprietary info/model | no | yes? | no | no | yes? | yes |
| TOTAL | 6 | 8 | 6 | 7 | 5 | 6 |

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2. Overview of Existing Estimates and Methods

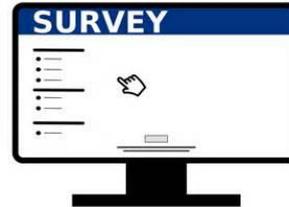
3. Review of 3 Principal Estimation Methods

4. Group Discussion

5. Conclusions and Next Steps

REVIEW OF THREE PRINCIPAL ESTIMATION METHODS

1. Survey-based Approaches



2. Municipal Behavior Wedge



3. Carbon Footprint



REVIEW OF THREE PRINCIPAL ESTIMATION METHODS

| | Survey Approach |
|------------------------|---|
| | SAHOTA, 2008: Achievable = 11% of Res. Demand |
| Research Sponsor/Scope | BC Hydro Conservation Potential Review, Utility territory |
| Sample | 1000 residential surveys |
| Data Collection Method | Internet panel data, weighted by geography and dwelling type to match customer base |
| Type of data collected | 24 behaviors (repetitive and periodic behaviors): heating (5), lighting (3), water heating (4), refrigeration (3), plug loads (7) |
| Estimation Method | Behavior defined as all people performing the behavior all of the time using self-reported data. Uses a FTE measure (always=100%, usually=66%, occasionally=33%, never=0%). Repetitive behaviors also measured. Also asked how often they experienced a lapse in stated behavior frequency within the household to adjust estimates. To assess achievable potential respondents were asked how likely they would be to do the behavior in the future. They were given a score of 80% for “definitely will” and 20% for “probably will”. For those who answered otherwise, they were asked what would motivate them (barriers). A simple engineering approach was used to estimate the amount of unused energy services that are embedded in each end use from base year consumption estimates. |

REVIEW OF THREE PRINCIPAL ESTIMATION METHODS

Survey Approach

SAHOTA, 2008: Achievable = 11% of Res. Demand

Simple engineering estimates to approximate the amount of unused energy services embedded in each end use from Base Year consumption estimates.

| Conditions | Capacity | Baseline Behavior | Failure Rate | Response to Information |
|------------------|------------------|-------------------|------------------|-------------------------|
| Survey responses | Survey responses | Survey responses | Survey responses | Survey responses |
| 100% | 100% | 61% | 3% | 17% |

Savings from thermostat setbacks: everyone has a thermostat and can set it back, 61% do set back their thermostat with a 3% failure rate. 17% would respond to information.

$$\begin{aligned} & \text{Eligibility} & \text{Participation} & \text{Savings per unit} \\ & = (39\% + (61\% \times 3\%)) \times 17\% \times \text{savings from setbacks} \end{aligned}$$

REVIEW OF THREE PRINCIPAL ESTIMATION METHODS

SAHOTA, 2008: Achievable = 11% of Res. Demand

| Space Heating | Lighting | Hot water | Refrigeration | Plug load |
|----------------------------------|------------------------------|---------------------------------|---------------------------------|---------------------------|
| Daytime thermostat settings | Turn off lights - empty room | Cold water wash | Adjust fridge temp | Brick chargers |
| Nighttime thermostat settings | Low wattage bulbs | Air dry dishes | Adjust freezer temp | Turn off TV |
| Keeping part of the house cooler | Turn off outdoor lights | Check water heater temp | Defrost freezer more frequently | Unplug after use |
| Draft-proofing | | Turn off water heater when away | | Unplug when away/vacation |
| Storm windows | | | | Turn off computer |
| | | | | Turn off monitor |
| | | | | Computer power mgmt |

REVIEW OF THREE PRINCIPAL ESTIMATION METHODS

| | Survey+ Approach |
|------------------------|--|
| | Norton, 2012: Achievable = 33% of Res. Elec. Demand |
| Research Sponsor/Scope | ComEd, Utility territory |
| Sample | 4414 residential surveys, 297 in-home audits, 140 monitored HHs |
| Data Collection Method | Mail surveys, in-home audits, data loggers |
| Type of data collected | 16+ actions (9 behaviors, 7 EE investments): lighting (2), cooling (4), appliances (10). [<i>Electronics, space heating and water heating were also reviewed but behaviors were not specified.</i>] |
| Estimation Method | Baseline energy use patterns established through in-home audits and monitored households (and billing data?). Savings opportunities identified through audits and surveys. Study separates behavior from technology purchases (including CFLs). Categorizes savings as coming from technology, behavior, or a “shared” category. |

REVIEW OF THREE PRINCIPAL ESTIMATION METHODS

Norton, 2012: Technical = 33% of Res. Electricity Demand (20% from non-investment behaviors)

| Space Cooling | Lighting | Appliances | Electr. | Water Htg |
|-------------------------------|-----------------|---|-----------|-----------|
| Upgrade AC Unit | Upgrade to CFLs | Upgrade appliances (fridge, freezer, clothes washer, dryer, dishwasher) | Not known | Not known |
| Add insulation & duct sealing | | | | |
| Increase temp settings | Turn off lights | Unplug unused fridge | | |
| Annual system maintenance | | Unplug unused freezer | | |
| | | Use no-heat dish drying | | |
| | | Eliminate partial loads | | |
| | | Eliminate hot water in clothes washer | | |

REVIEW OF THREE PRINCIPAL ESTIMATION METHODS

| | Survey+ Approach |
|------------------------|---|
| | McKinsey, 2013: Technical= 16-20% of Res. Energy |
| Research Sponsor/Scope | McKinsey, National |
| Sample | 2500 residential surveys, ethnographic in-home interviews |
| Data Collection Method | unknown |
| Type of data collected | 9 low and no-cost behaviors: heating/cooling set points, hot water (6), lighting (1), electronics (2). |
| Estimation Method | Optimal behavior baseline was obtained via the literature. Energy waste was calculated at the household level based on the survey sample. Method was not specified. |

REVIEW OF THREE PRINCIPAL ESTIMATION METHODS

McKinsey, 2013: Technical = 16-20% of Residential Energy Demand

| Space Heating & Cooling | Lighting | Hot water | Plug load |
|-----------------------------|---------------------------------|-----------------------------------|--------------------------|
| Heating thermostat settings | Turn off lights when not needed | Reduced hot water temps | Eliminate vampire loads |
| Cooling thermostat settings | | Use cold water appliance settings | Turn off when not in use |
| | | Increase CW load size | |
| | | Reduce "heat dry" setting on DW | |

REVIEW OF THREE PRINCIPAL ESTIMATION METHODS

| | Comparison of Survey Approaches | | |
|-----------------------|---------------------------------|-----------------------|------------------|
| | Survey | Survey+ | Survey+ |
| Authors | Sahota, 2008 | Norton | McKinsey |
| Focus | Achievable Energy | Technical Electricity | Technical Energy |
| Behavior Type | No & low-cost | All Res. | No & low-cost |
| Number of behaviors | 24 | 16+ | 9 |
| Savings Est. National | 2.4% | 5.2% | 4.0% |

REVIEW OF THREE PRINCIPAL ESTIMATION METHODS

| | Existing Data Model |
|------------------------|--|
| | Ehrhardt-Martinez, 2014-15: Achievable = 7-11% of Res. Demand |
| Research Sponsor/Scope | Urban Sustainability Directors' Network, Kresge Fdn, Funders Network for Smart Growth and Livable Communities / Municipal |
| Data Sources | RECS, Census, Literature |
| Type of Behaviors | 32 residential energy behaviors (26 low/no-cost, 6 investment) |
| Estimation Method | 1) Baseline energy consumption by end use estimated at the city level by applying state-level technology saturation and energy practices measures (RECS) to local housing characteristics (Census). 2) Algorithms are used to estimate the savings opportunities associated with 32 different residential behaviors as a function of HH eligibility (technology saturation and existing use patterns), likely participation rates and savings from a particular shift in behavior. |
| EE Behaviors | Htg equip maintenance, heat setback, prog. thermostat, weatherization, htg conservation, window insulation, AC maintenance, AC setback, prog thermostat (AC), ceiling fans, weatherization (AC), cooling conservation, use blinds (AC), discard 2 nd fridge/freezer, lower water heater settings, water heater insulation, cold water wash, reduce laundry loads, air dry, manage vampire loads, manage plug loads, CFLs, turn off indoor lighting, turn off outdoor lighting, use pool pump timers, use hot tub timers; accelerate replacement of htg equip, accelerate replacement of AC equip, buy EE clothes washer, replace desktop w/laptop, pool pumps, pool covers. |

REVIEW OF THREE PRINCIPAL ESTIMATION METHODS

| | Existing Data Model |
|------------------------|---|
| | Jones & Kammen, 2011: Technical Carbon = 7.6% of national emissions |
| Research Sponsor/Scope | California Air Resources Board, Energy Foundation, Karsten Family Fdn./Municipal |
| Data Sources | Consumer Expenditures Survey (CES), Bureau of Transportation Statistics, EIA, Bureau of Economic Analysis (expenditures on food, goods and services) |
| Type of Behaviors | 38 mixed behaviors (11 transport, 18 HH energy (10 investment, 8 non-investment), 9 embedded |
| Estimation Method | 1) Use national level data and regression analysis to determine the relationship between household income and household size with consumption of a wide variety of goods and services. 2) Apply the regression model to local measures of household income and household size to estimate local consumption patterns. 3) Estimate the carbon footprint of consumption patterns. 4) Savings opportunity is determined through the application of particular scenarios, i.e. if x% of population engaged in “y” behavior. |
| EE Behaviors | Turn down winter thermostat, turn up summer thermostat, computer power mgmt., line dry, print double sided, turn off lights, use CFLs, install low-flow shower heads; switch from T12 to T8, buy Energy Star copier, Energy Star printer, Replace desktop with Energy Star, buy high-eff cooling equip, buy high eff. heating equip, install low flow faucets, low flow toilet, install tankless water heater, install solar water heater. |

REVIEW OF THREE PRINCIPAL ESTIMATION METHODS

| | Comparison of Leading Approaches | | |
|-----------------------|----------------------------------|-----------------------------|--------------------------|
| | Survey | MBW Model | Carbon Footprint |
| Authors | Norton | Ehrhardt-Martinez | Jones and Kammen |
| Focus | Technical Electricity | Achievable Energy | Technical Carbon |
| Behavior Type | Res No & low-cost + Invest | Res No & low-cost + Invest. | Res, Transport, Embedded |
| Number of behaviors | 16+ | 32 | 38 |
| Savings Est. National | 5.2% Energy | 2.4% Energy | 7.6% Carbon |

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GROUP DISCUSSION

- Individual Worksheet (10 min)
- Merits and disadvantages of each (20 min)
- Suggested modifications for improvement of each (20 min)
- Group Ranking of preferred approach (10-15)
- Flip Chart Documentation (10 min)

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SUPPLEMENTAL MATERIAL

SAN FRANCISCO, CA

JUNE 13, 2016

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1 - GARDNER AND STERN, 2008

The Short List: The Most Effective Actions U.S. Households can take to Curb Climate Change

- Geographic Coverage: United States
- Behaviors: 27 (7 investment behaviors)
- Methodology: **Existing National Data Resources**

Gerald T. Gardner and Paul C. Stern. The Short List: The Most Effective Actions U.S. Households Can Take to Curb Climate Change. Updated on December 15, 2009.

| Savings as % of National Consumption or Emissions | Focus | Technical/ achievable | Range of Behaviors |
|---|--------|-----------------------|---|
| 11.40% | Energy | Technical | Any res. actions & invest. + personal transport investments |

2 – VANDENBERG, ET AL., 2008

Individual Carbon Savings Potential

- Geographic Coverage: United States
- Behaviors: 7 (0 investment behaviors)
- Methodology: **Existing National Data Resources**

Vandenbergh, Michael P., et al. (2008). Individual Carbon Emissions: The Low-Hanging Fruit. Vanderbilt University Law School.

| Savings as % of National Consumption or Emissions | Focus | Technical/ achievable | Range of Behaviors |
|---|--------|-----------------------|---|
| 2.70% | Carbon | Achievable | Any res. actions & invest. + personal transport actions |

3 – SAHOTA, ET AL., 2008

Behaviour and Energy Savings in Residential Dwellings

- Geographic Coverage: BC Hydro territory
- Behaviors: 24 (0 investment behaviors)
- Methodology: [Survey Data Measures](#)

Sahota, Ron, et al. (2008). Behaviour and Energy Savings in Residential Dwellings. ACEEE Summer Study on Energy Efficiency in Buildings.

| Savings as % of National Consumption or Emissions | Focus | Technical/ achievable | Range of Behaviors |
|---|--------|-----------------------|---|
| 2.40% | Energy | Technical | Res. conservation + no/low cost actions |

4 – DIETZ, ET AL., 2009

The Behavioral Wedge: Household Actions can Rapidly Reduce U.S. Carbon Emissions

- Geographic Coverage: United States
- Behaviors: 33 (4 investment behaviors)
- Methodology: **Existing National Data Resources**

Thomas Dietz, Gerald T. Gardner, Jonathan Gilligan, Paul C. Stern, and Michael P. Vandenberg. Household actions can provide a behavioral wedge to rapidly reduce US carbon emissions. PNAS 2009 106 (44) 18452-18456; published ahead of print October 26, 2009.

| Savings as % of National Consumption or Emissions | Focus | Technical/ achievable | Range of Behaviors |
|---|--------|-----------------------|---|
| 7.40% | Carbon | Achievable | Any res. actions & invest. + personal transport investments |

5 – LAITNER, ET AL., 2009

Examining the Scale of the Behaviour Energy Efficiency Continuum

- Geographic Coverage: United States
- Behaviors: 120 (unknown number of investment behaviors)
- Methodology: **Existing National Data Resources**

Laitner, John A. "Skip", et al. (2009). Examining the Scale of the Behaviour Energy Efficiency Continuum. European Council for an Energy-Efficient Economy.

| Savings as % of National Consumption or Emissions | Focus | Technical/ achievable | Range of Behaviors |
|---|--------|-----------------------|---|
| 8.90% | Energy | Achievable | Any res. actions & invest. + personal transport investments |

6 – NRDC, 2010

Simple and Inexpensive Actions Could Reduce Global Warming Emissions by One Billion Tons

- Geographic Coverage: United States
- Behaviors: 14 (0 investment behaviors)
- Methodology: **Existing National Data Resources**

"Simple and Inexpensive Actions Could Reduce Global Warming Emissions by One Billion Tons." NRDC. March 18, 2010. http://www.nrdc.org/energy/files/billiontons4pgr_r3_final.pdf.

| Savings as % of National Consumption or Emissions | Focus | Technical/ achievable | Range of Behaviors |
|---|--------|-----------------------|--|
| 15.0% | Carbon | Technical | Any res. actions & invest. + personal transport + embedded energy/carbon |

7 – JONES AND KAMMEN, 2011

Quantifying Carbon Footprint Reduction Opportunities for U.S. Household and Communities

- Geographic Coverage: multiple levels (city, state, MSA)
- Behaviors: 38 (13 investment behaviors)
- Methodology: **Existing Data Resources as Model Inputs**

Jones, Christopher M. & Daniel M. Kammen. (2011). Quantifying Carbon Footprint Reduction Opportunities for U.S. Household and Communities, Environmental Science & Technology.

| Savings as % of National Consumption or Emissions | Focus | Technical/ achievable | Range of Behaviors |
|---|--------|-----------------------|--|
| 7.60% | Carbon | Technical | Any res. actions & invest. + personal transport + embedded energy/carbon |

8 – NORTON, 2012

Saving Waste: Energy Use and Waste Analysis by End-Use; ComEd Residential and C&I Saturation/End-Use, Market Penetration & Behavioral Study

- Geographic Coverage: ComEd utility territory, IL
- Behaviors: 15 (6 investment behaviors)
- Methodology: [Survey Data Measures + Site Visits + Data Loggers](#)

Norton, Bill. "Saving Waste: Energy Use and Waste Analysis by End-Use." Opinion Dynamics. November 13, 2012.

"ComEd Residential and C&I Saturation/End-Use, Market Penetration & Behavioral Study." Opinion Dynamics. March 20, 2013.

| Savings as % of National Consumption or Emissions | Focus | Technical/ achievable | Range of Behaviors |
|---|-------------|-----------------------|------------------------------|
| 5.20% | Electricity | Technical | Res. actions + EE investment |

9 – MCKINSEY, 2013

Sizing the Potential of Behavioral Energy-Efficiency Initiatives in the U.S. Residential Market

- Geographic Coverage: United States
- Behaviors: 9 (0 investment behaviors)
- Methodology: [Survey Data Measures + Ethnographic Interviews](#)

Heck, Stefan & Humayun Tai. (2013). Sizing the Potential of Behavioral Energy-Efficiency Initiatives in the U.S. Residential Market, McKinsey&Company.

| Savings as % of National Consumption or Emissions | Focus | Technical/ achievable | Range of Behaviors |
|---|--------|-----------------------|---|
| 4.0% | Energy | Technical | Res. conservation + no/low cost actions |

10 – EHRHARDT-MARTINEZ, 2015

Behavior Wedge Profile: Model Development and Documentation; Municipal Behavior Wedge Project: Methodology Report; Behavior Wedge Profiles for Cities: Estimating Achievable Savings and Critical Behaviors

- Geographic Coverage: City-level estimates (could be state, regional, national)
- Behaviors: 32 (6 investment behaviors)
- Methodology: **Existing Data Resources as Model Inputs**

Ehrhardt-Martinez, Karen, et al. (2013). Behavior Wedge Profile: Model Development and Documentation, Garrison Institute Climate, Mind and Behavior Program.

Ehrhardt-Martinez, Karen. (2015). Municipal Behavior Wedge Profile: Methodology Report, Garrison Institute.

Ehrhardt-Martinez, Karen. (2015). Behavior Wedge Profiles for Cities: Estimating Achievable Savings and Critical Behaviors, eceee Summer Study.

| Savings as % of National Consumption or Emissions | Focus | Technical/ achievable | Range of Behaviors |
|---|--------|-----------------------|------------------------------|
| 1.5-2.4% | Energy | Achievable | Res. actions + EE investment |

11 – KANE AND SRINIVAS, 2014

Unlocking the Potential of Behavioral Efficiency: Methodology for Calculating Technical, Economic, and Achievable Savings Potential

- Geographic Coverage: United States
- Behaviors: ~100 (unknown number of investment behaviors)
- Methodology: Opower Program Data

Kane, Rachel & Nathan Srinivas. (2014). *Unlocking the Potential of Behavioral Efficiency: Methodology for Calculating Technical, Economic, and Achievable Savings Potential*, Opower.

| Savings as % of National Consumption or Emissions | Focus | Technical/ achievable | Range of Behaviors |
|---|-------------|-----------------------|------------------------------|
| 0.26% | Electricity | Achievable | Res. actions + EE investment |

Estimating Energy Savings from Behaviours Using Building Performance Simulations

- Geographic Coverage: Portugal
- Behaviors: 26 (11 investment behaviors)
- Methodology: Building Simulation Models

Marta A. R. Lopes, Carlos Henggeler Antunes, Ana Reis & Nelson Martins (2016): Estimating energy savings from behaviours using building performance simulations, Building Research & Information, DOI: 10.1080/09613218.2016.1140000

| Savings as % of National Consumption or Emissions | Focus | Technical/ achievable | Range of Behaviors |
|---|--------|-----------------------|------------------------------|
| 7.50% | Energy | Technical | Res. actions + EE investment |