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Behavior and EE Programs

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Types of energy savings

name	characteristics	example (based on dominant effect)
efficiency	Same/better service, less energy	higher COP AC unit
substitution*	substitution of different, equally desired service	radiant cooling
imperfect substitution*	substitution of different, tolerable service	fan substituted for AC
conservation	reduced service that is tolerated	raising cooling set point to point of discomfort
waste elimination	unnoticed service reduction	overnight shutdown of lights

* Note that the desirability of substitutes is subjective, so different people tend to categorize the similar measures differently.

Central challenges summary:

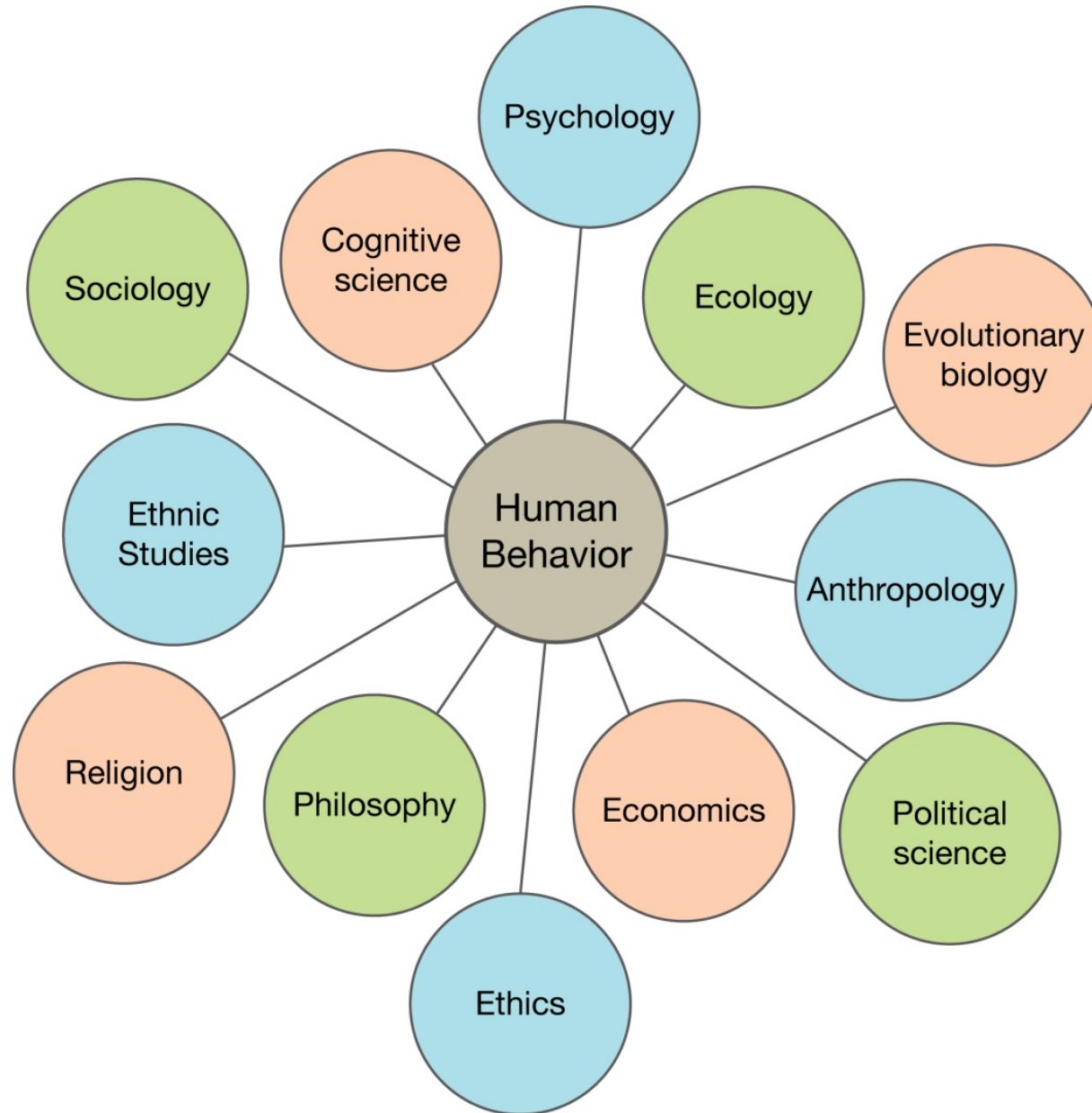
Challenge	Response
Timely changes must come from existing buildings	Focus on technologies and processes that support retrofits (e.g. improved controls)
Energy consumption characteristics vary widely in buildings	Avoid blanket prescriptions; achieve savings opportunistically and cluster like buildings to repeat successful strategies
Our track record of predicting energy consumption is poor	Evaluate projects using measured data; tune and commission underperformers; pursue organizational and behavioral opportunities
There is limited data available	Opportunistically use available data; search for lowest common denominator in measured data
We don't know how to achieve the savings we need	We must learn from projects as they unfold and actively improve tools and processes over time. We cannot predict from here what will work.

Behavior, consumption and energy

- Consider how dramatically the following behaviors impact energy use and how well you think we can predict them:
 - Technology adoption **behavior**
 - Technology operation **behavior**
 - Decision making **behavior**
 - Organizational **behavior**
 - Consumption **decisions**

EE for cost containment vs. climate mitigation

- Climate change mitigation in buildings is **significantly different** from traditional energy efficiency and demand response program motivations and will require **significant changes to programs**
- Efficiency programs designed to **pursue “least cost resource”**
 - Procurement oriented
 - Regulators determine viable implementation pathways one evaluation rule at a time
- Grid integration/climate mitigation is about long term **market transformation**
 - Commercializing and scaling low-carbon technologies
 - Need room to fail/learn
 - Need to pay for activity whose benefits are difficult to assign precisely



CEC research/reports on the behavior

2006-2008 Behavior Studies

Behavior Study	Energy Division Project Manager	Lead Firm
Energy efficiency potential studies and behavior	Pam Wellner	CIEE
Measurement and evaluation of energy savings and non-energy impacts from energy efficiency behaviors	Pam Wellner	CIEE
Process evaluation's insights on energy efficiency program implementation	Pam Wellner	CIEE
Behavioral assumptions underlying energy efficiency nonresidential programs	Pam Wellner	CIEE
Behavioral assumptions underlying energy efficiency residential programs	Pam Wellner	CIEE
Market segmentation and energy efficiency program design.	Pam Wellner	CIEE
Experimental design for energy efficiency programs.	Pam Wellner	CIEE
Motivating policymakers, program administrators, and program implementers to pursue behavioral change strategies.	Pam Wellner	CIEE
Encouraging greater innovation in the production of energy-efficient technologies and services.	Pam Wellner	CIEE

Useful model of energy behavior

- Energy is used **by and for people**
- **Energy is cheap**, EE \$ savings are small, and utility is subjective
- People/organizations **aren't paying attention** and don't want to
 - Not energy nerds!
 - Warehouse supply, defaults, and interfaces matter (see programmable thermostats for cautionary tale)
 - Undiagnosed malfunction and waste are the rule, not exceptions
- There is **low “energy literacy”**
 - Even if you have their attention, they are likely to implement something suboptimal for their circumstances and preferences (see HERs)
- Meter data teaches us that there is **dramatic diversity** in patterns of energy consumption, even among “similar” customers
 - Prescriptive measures don't do justice to site-specific potential
- We need **individualized information** to reduce waste, correct malfunctions, and plan appropriate interventions

Buildings in use

Almost no buildings adapt well. They're *designed not to adapt*; also budgeted and financed not to, constructed not to, administered not to, maintained not to, regulated and taxed not to, even remodeled not to. But all *buildings adapt anyway*, however poorly, because the usages in and around them are changing constantly.

Stewart Brand “How Buildings Learn”

Building science view of EE

Study	EE resource contribution
Twin Rivers (1977)	Shell tightness; defects ; PRISM; info/ feedback ; price inelasticity; occupants matter
Vital Signs (1996)	“lack of knowledge usually means wasted power and energy”; “ instrumented diagnostic examination rarely fails to identify energy conservation opportunities”
PROBE (2001)	“Monitoring, feedback, and effective motion are what create continuous improvement – but are sadly rare...”; “... seeking where possible to use information rather than energy to achieve the required conditions with minimum waste.”
LBNL Cx (2004,2009)	Major potential in tuning buildings to work as designed – much of what is found is the results of mistakes or neglect. Significant savings from tweaks to controls and hardware.
TIAX controls (2005)	Three faults , “HVAC Left on When Space Unoccupied,” “Lights Left on When Space Unoccupied,” and “Duct Leakage,” appear to account for about two-thirds of a quad of waste.
NREL case studies(2006)	“All six buildings showed that they used more energy and produced less energy than predicted in the design/simulation stage”; “lack of control ”; “too optimistic about the behavior of the occupants ”
NBI / LEED (2008)	“Projects with more aggressive energy performance goals seem to generate overly optimistic predictions of actual energy use.”

[illegible]

Image source: Stewart Brand: "How Buildings Learn"

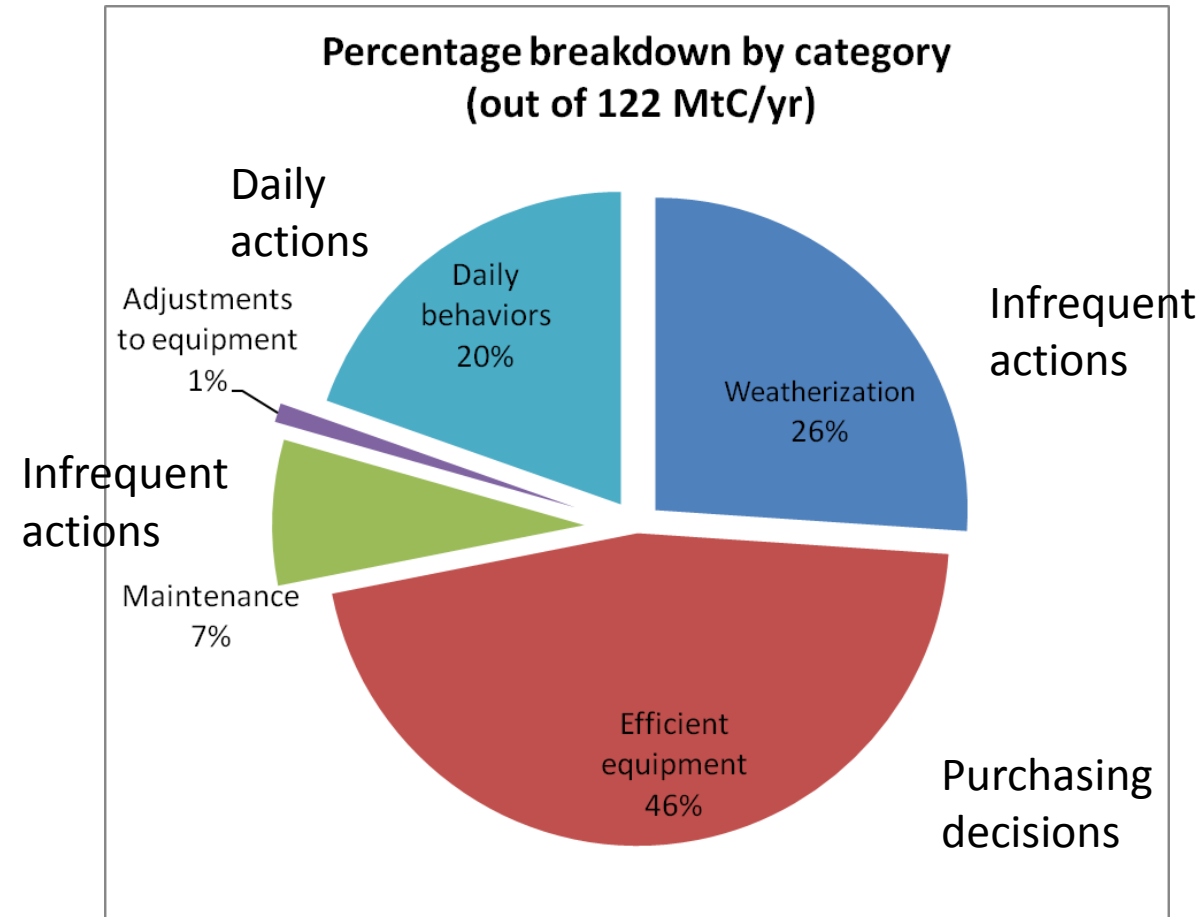
Lifecycle feature	Timescale	Policy intervention type	Common?
Site, orientation, shell	40+ yrs	Zoning; Buildings codes	Yes
Retrofit and renovation	10-20yrs	Mandates, incentives, some codes	No
Equipment	1-10yrs	Appliance/equipment standards	Yes
Operations; behavior	Days- years	Performance standards	No

EE and DR types

EE categories	DR categories
Equipment upgrade	
Equipment repair	
Control timing change	Control timing change
Control setpoint change	Control setpoint change
↓ service intensity	↓ service intensity
Substitution of services	Substitution of services
Service shutdown	Process/service shutdown

Both require control

Behavior wedge: dominated by purchasing and infrequent actions



Dietz 2009: **“Household actions can provide a behavioral wedge to rapidly reduce U.S. carbon emissions”**: 20% of household emissions in 10 years using “behavioral change...without waiting for new technologies or regulations or changing lifestyle.”

Tensions inherent in EE programs

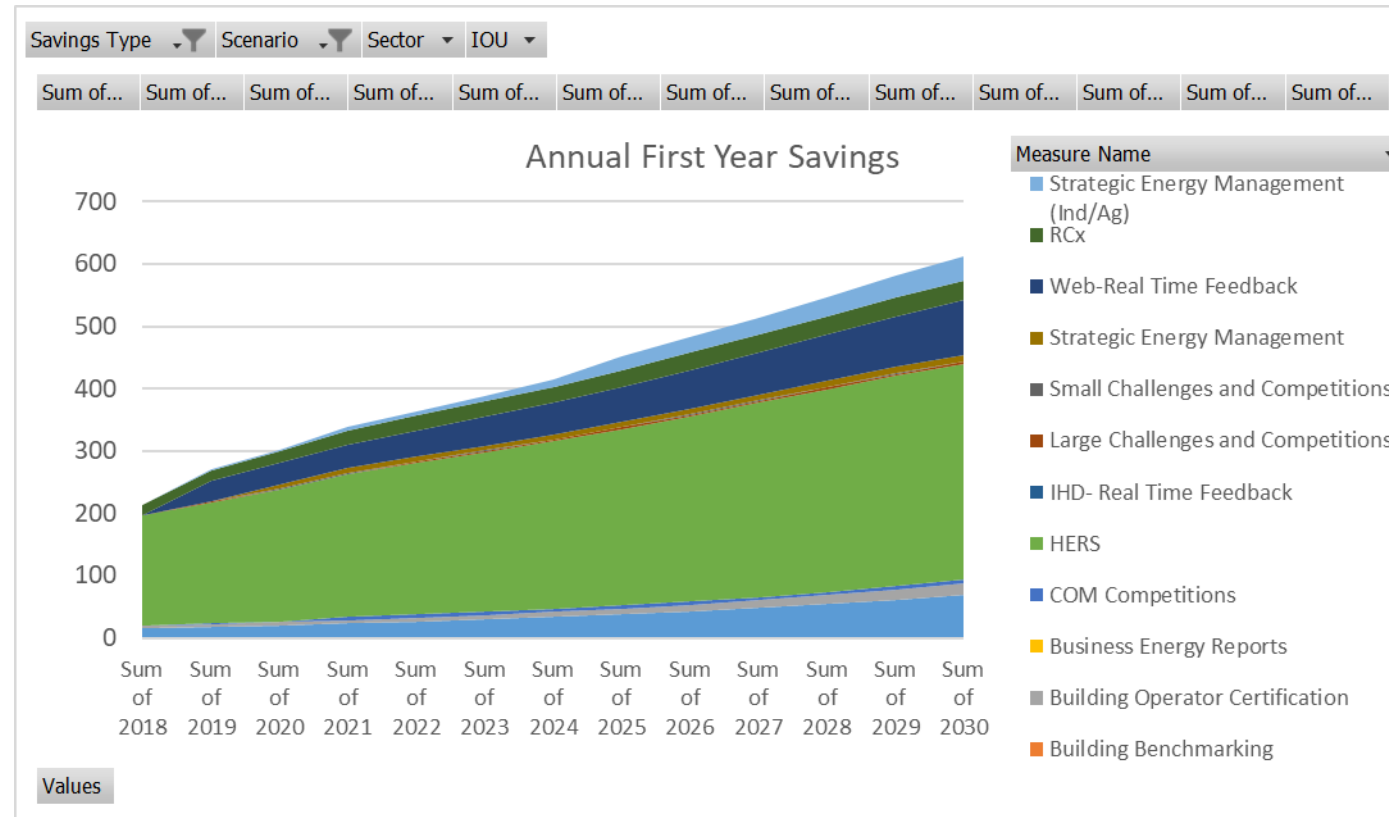
Program administration
requires countable savings

BUT

“Program evaluation cannot precisely and accurately determine the counterfactual”

-Carl Blumstein (CIEE)

BROs in the potential study: mostly HERS



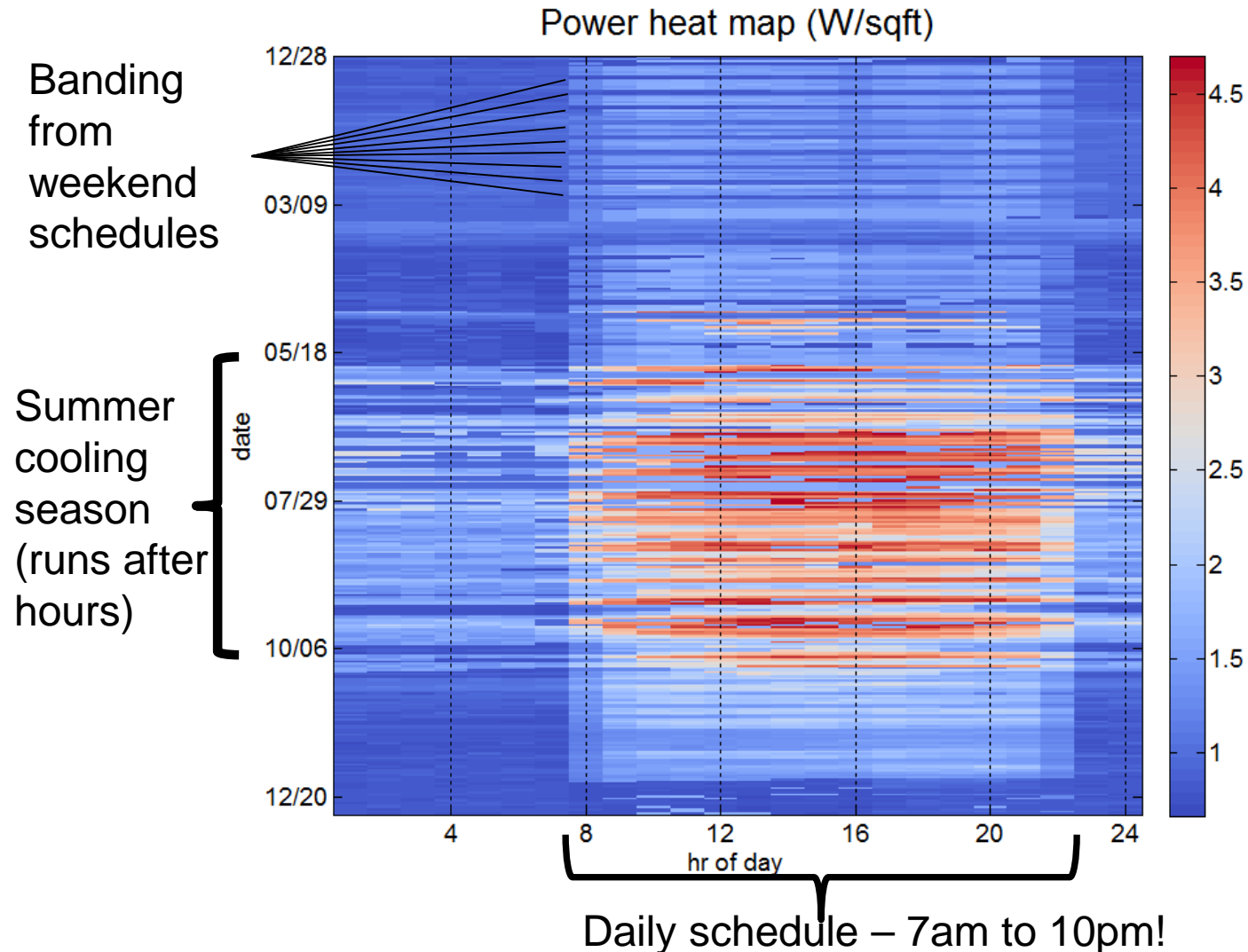
“For the purposes of this study, the Navigant team defines behavior-based initiatives as those providing information about energy use and conservation actions, rather than financial incentives, equipment, or services.”

– 2018 Navigant Potential Study

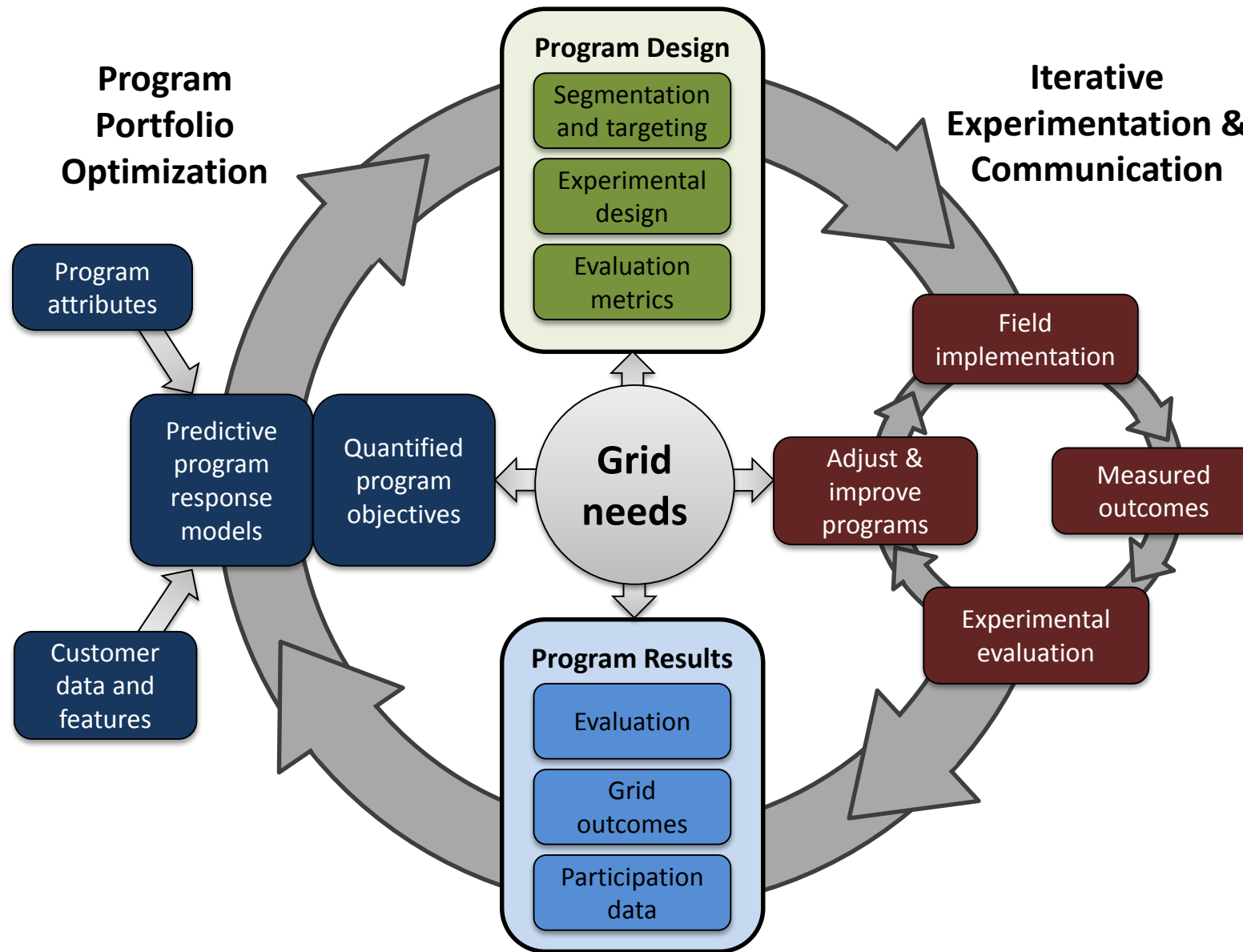
Meter data

- Smart meter data can provide information to support **more aggressive** and **more personalized** energy efficiency and demand response programs
- Meter data reveals **spatial and temporal** patterns
 - Cooling demand is dominated by a **minority of now identifiable** households
 - Overnight consumption corroborates the growing **role of always-on and plug loads** in total energy consumption
- The differences **within** demographic categories can exceed differences **across** those groups
- Meter data can be used to identify qualitatively **different behavioral groups**
- Current practice is not capturing some of the **most promising** potential benefits of meter data
- Creative uses of meter data for public benefit are compatible with practical **privacy protections**, but **require support** from policy makers

A year of demand data made legible



Personalized programs: energy data in programs



Thank you.

I am happy to continue this discussion and field follow up questions.

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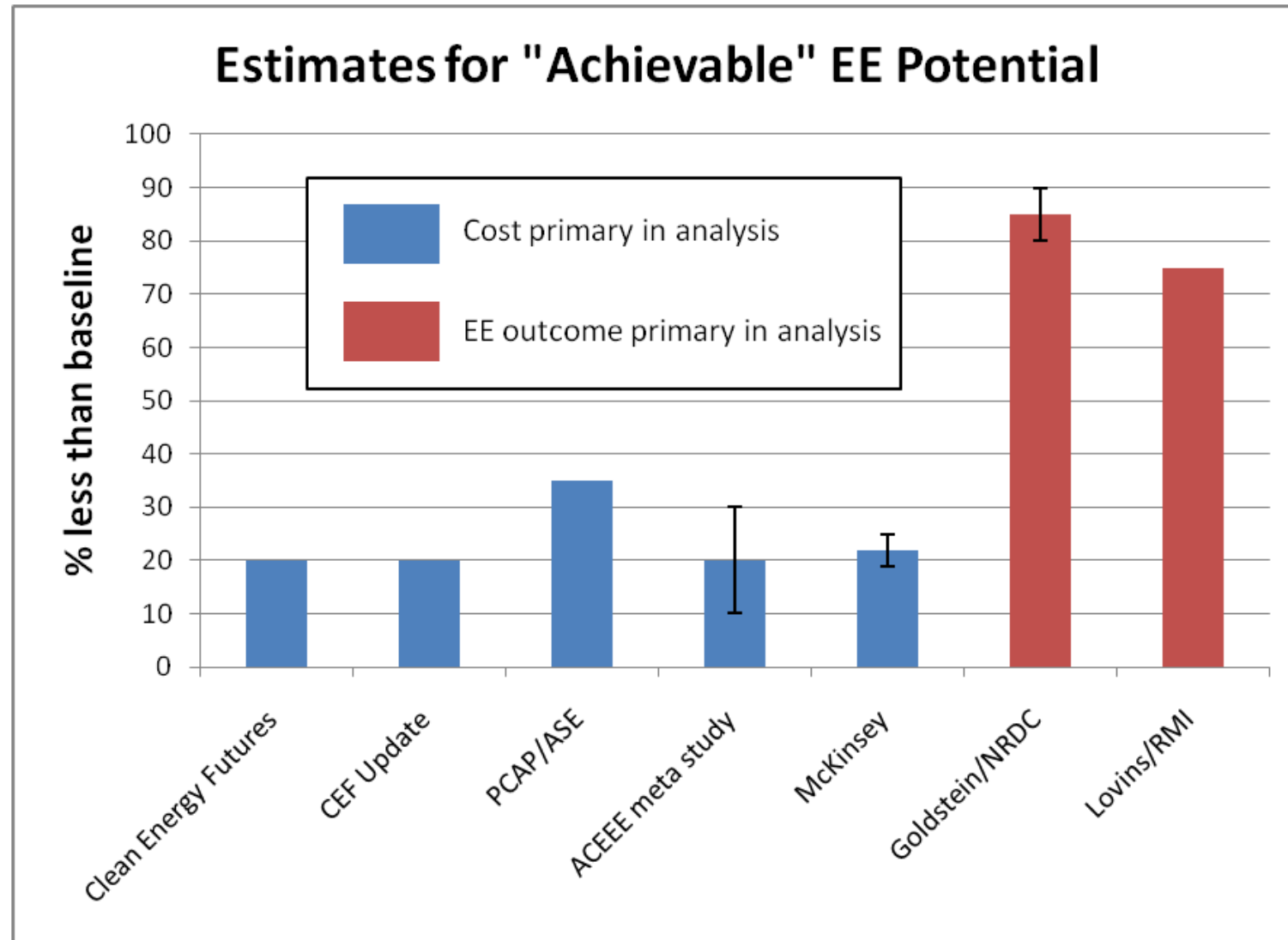
Targeting operational energy: Commissioning

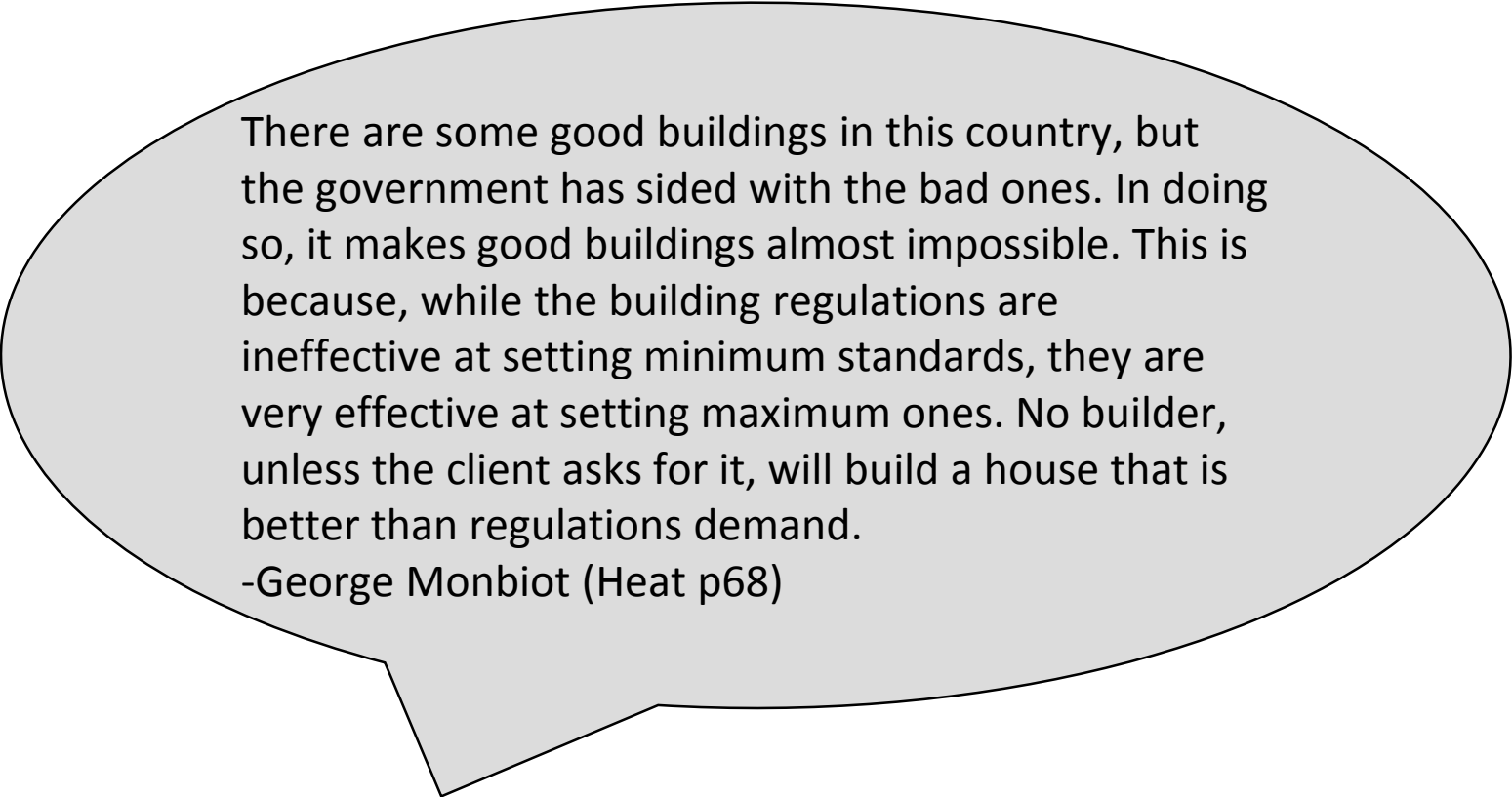
- Paying attention to how your building is operating and fixing problems you find
- **Bad news:** we aren't even getting elementary installation, operating practices, and maintenance right
- **Good news:** it is very easy to find savings in uncommissioned buildings!
 - Savings are consistent and feature attractive ROIs (Mills)

Energy is used by and for people in buildings

- People shape building energy consumption
 - Variations in the energy usage between identical houses with different occupants of more **than a factor of two** (Socolow, 1978)
 - Electricity and gas consumption in nine identical homes in London showed a variation of **40% in the gas consumption and 54% in the electricity consumption** (Levermore, 1985)
 - Nine identical low- energy social housing units found variations in **the electricity consumption of up to 600%** (Bahaj and James, 2007)

Estimating Efficiency Potential





There are some good buildings in this country, but the government has sided with the bad ones. In doing so, it makes good buildings almost impossible. This is because, while the building regulations are ineffective at setting minimum standards, they are very effective at setting maximum ones. No builder, unless the client asks for it, will build a house that is better than regulations demand.

-George Monbiot (Heat p68)

Tackling building efficiency

I hope to convince you that:

- “Use phase” or “operational” energy use dominates the impact of most conventional buildings
- In mature real estate markets (i.e. developed countries), existing buildings provide the greatest mitigation opportunities but are poorly represented in goals, policies, and modeling efforts
- Waste is prevalent and largely a function of inattention
- Occupant behavior is central to efficiency outcomes, but our most prevalent modeling/estimation/evaluation techniques distort or ignore behavior
- In commercial spaces, energy is most often managed by organizations, and organizations don’t behave like people

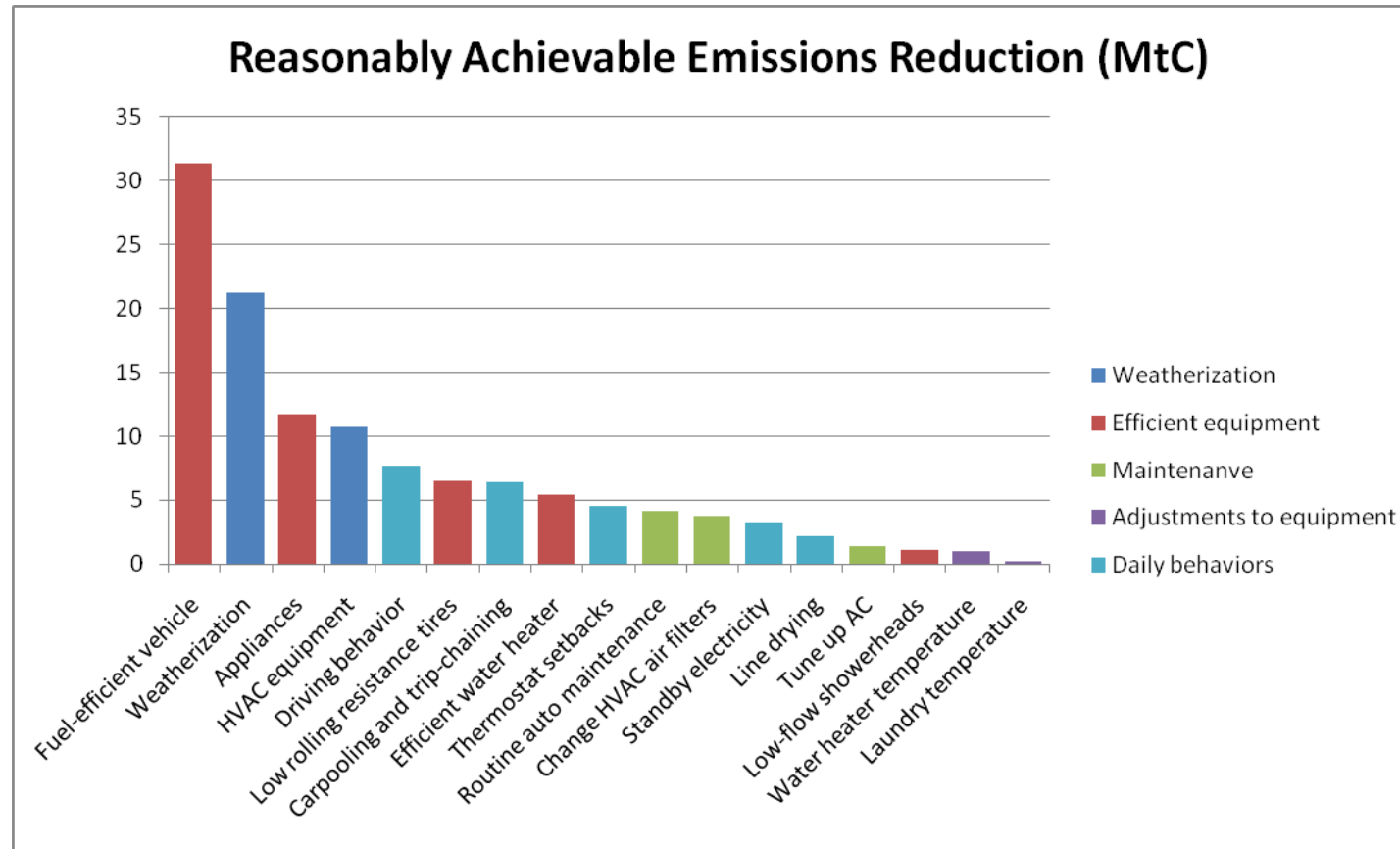
Measured performance

“How could a nation as **technologically advanced** and business oriented as this one care so little about how it spends upwards of **\$1 trillion on construction a year?**”

Barry Lapatner “Broken Buildings; Busted Budgets”

- Predict behavior
- Influence behavior
- Measure behavioral outcomes
- Individual behaviors
- Organizational behavior

Behavior wedge?



Dietz 2009: **“Household actions can provide a behavioral wedge to rapidly reduce U.S. carbon emissions”**: 20% of household emissions in 10 years using “behavioral change...without waiting for new technologies or regulations or changing lifestyle.”

- Saving in a hurry
- Blumstein – procurement vs. MT

- 2% savings as best guess for behavioral strategies
- Are we best capturing all strategies
- Institutional barriers?
- Can we track these savings
- On the supply side, we can account and be confident
- BROS – behavioral, rCx, operations