Where are the People? Findings from the Advanced Residential Energy and Behavior Analysis (AREBA) Project

Sponsored by the
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AREBA Project Purposes

- ✓ A comprehensive assessment of what is known about California residential energy uses and energy users.
- ✓ Identify knowledge gaps, problems and opportunities for improved understanding.
- ✓ Explore new approaches that . . .
  - go beyond the limits of current energy efficiency-focused policies, programs, and frameworks
  - inform evolving climate change policy.

Most Comprehensive Assessment yet of Residential Demand

PART I: Laying the Groundwork

CHAPTER 1: The Advanced Residential Energy and Behavior Analysis Project

CHAPTER 2: Why People and Energy? Why Now?

PART II: Background: Energy and the People of California

CHAPTER 3: California Residential Energy Use Patterns

CHAPTER 4: Variability in California's Weather, Housing and Socio-Demographics

CHAPTER 5: Thinking Carefully about Variability

PART III: Mapping the Policy Landscape

CHAPTER 6: California's Ecosystem of Models

Chapter 7: What and How You Measure Matters (a Lot)

CHAPTER 8: The Information You Have (and Don't Have) to Work With Matters

CHAPTER 9: Appreciating Policy Contexts and Legacy Models (Why People are Marginal)

PART IV: Thinking Ahead: Next Generation Models of People and Energy

CHAPTER 10: What Do We Know from Decades of Research?

CHAPTER 11: Disciplinary Perspectives and Multidisciplinary Integration

CHAPTER 12: Taking a Social View of Energy Use: New Models of Systems and Practices

Part V: Studies from a New Vantage Points: People, Policy, and the Complexity of Demand

CHAPTER 13: How Much Does Behavior Matter?

CHAPTER 14: Variability in Practice: Illustrations with Heating and Hot Water Use

CHAPTER 15: Saving Energy in the Home

CHAPTER 16: Energy Savings from Behavior Change

CHAPTER 17: Changes over Time

CHAPTER 18: People and Technology Futures: ZNE and PV

PART VI: What's Next? Conclusions and Recommendations

CHAPTER 19: Summary of Key Findings

CHAPTER 20: Recommendations for Policy and Research

Only a few topics are considered here

Particularly relevant to understanding and reducing GHG emissions in the residential sector

- ✓ How important is human behavior (or *what people do*) in determining energy demand?
- ✓ Where are the people in energy models and policies?
- ✓ What improvements are needed in analysis and modeling to better inform policy?
- ✓ What are the implications for current programs and policies?

Key AREBA Findings about Residential Demand

1) Residential demand is about behavior
   - Traditional energy efficiency perspectives focus narrowly on buildings and technology, while overlooking very large effects of behavior and social choices.
   - How people use energy is highly variable and diverse; also usually ignored.

2) Models of demand have fundamental problems
   - Architecture of models limit how people are depicted.
   - "Averages" are widely used and are often misleading.
   - Empirical data on household energy use behavior are very limited.
   - Metrics used in models and policies create blind spots.
   - Statistical techniques for representing people are rudimentary.
   - The knowledge base is incomplete and many basic questions remain unanswered.

Key AREBA Findings about Residential Demand

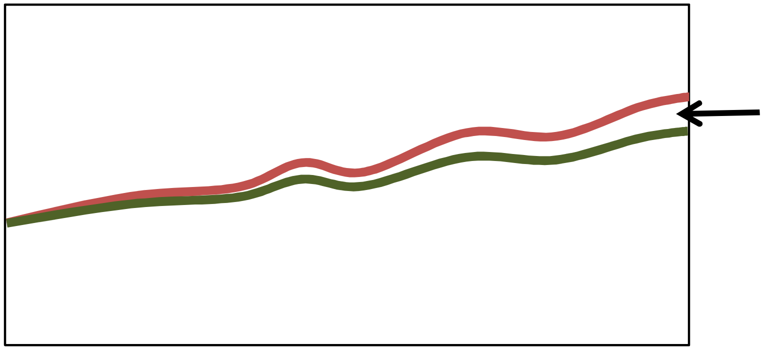
3) New approaches are necessary and possible

- Meeting climate policy goals require breaking from constraints of current regulatory, scientific and communications frameworks.
- A broader perspective and improved models are can be demonstrated.
- By taking a new vantage point—that combines technical, environmental and human elements and their dynamic interactions—new insights and possibilities are revealed.

1) Demand is about Behavior: Efficiency Industry Focus on Technology Leaves People Out

- Regulatory logic of collecting Nega-Watts drives <u>a focus on technology</u>
- Tech installation key: People are incidental or problematic (e.g., "free-riders")
- Low levels of efficiency adoption are glossed over as "market failures," "efficiency gaps," etc.
- Models of what to expect are fundamentally wrong?
- Only modest marginal savings and limited understandings of people have been required to **slow system growth**

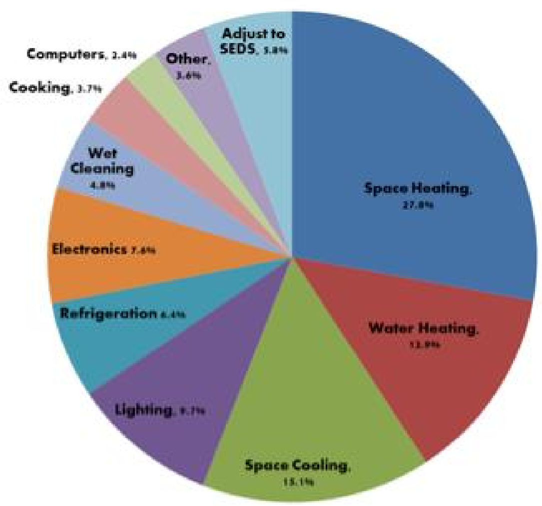
- Now climate goals require absolute **reductions in demand**

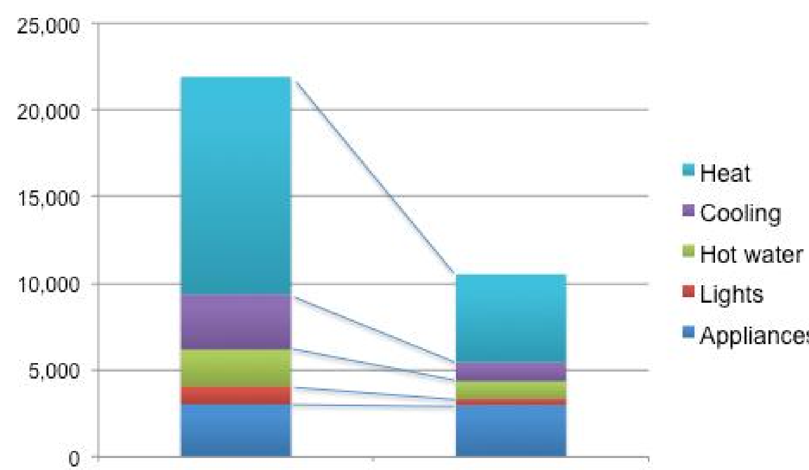


Only modest savings at the margin are required

The Overlooked Effects of Behavior are <u>Very Large</u>

- Behavior can account for up to <u>80% of consumption</u> (vs. weather, buildings or tech)
- Biggest residential energy uses in California are home heating, water heating and air conditioning
- These are all behaviorally determined

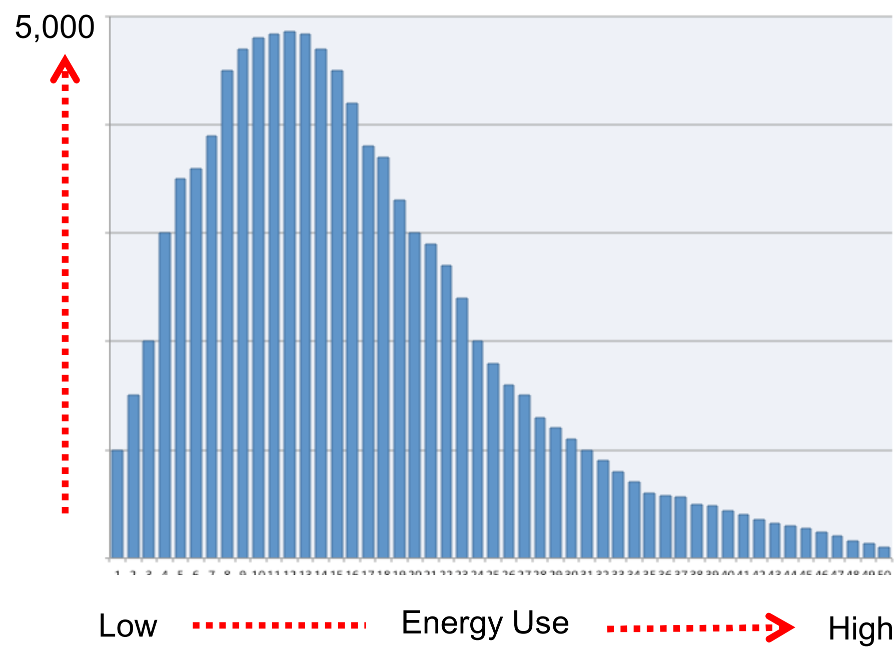




Possible GHG reductions from behavior change

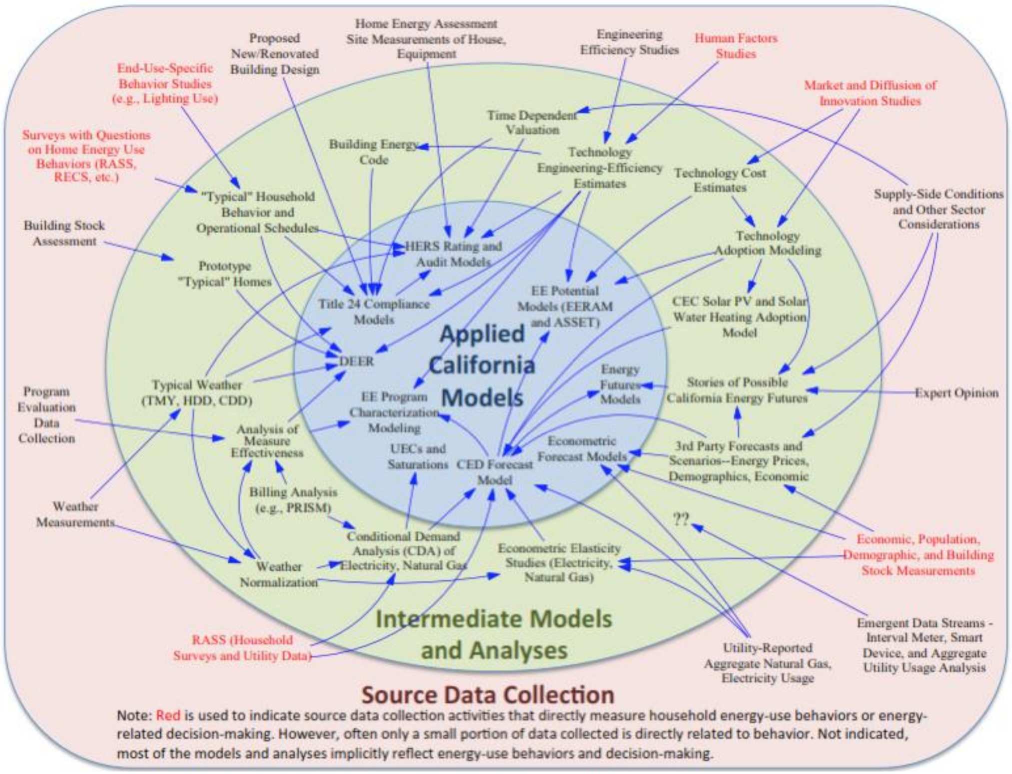
Behavior is Highly Variable and Diverse

- Energy use varies A LOT across the population
- People have widely different patterns of end use
- Different everyday lives
- Different priorities/understandings
- Different savings possibilities



2) Models are Important: But Where Exactly are the People?

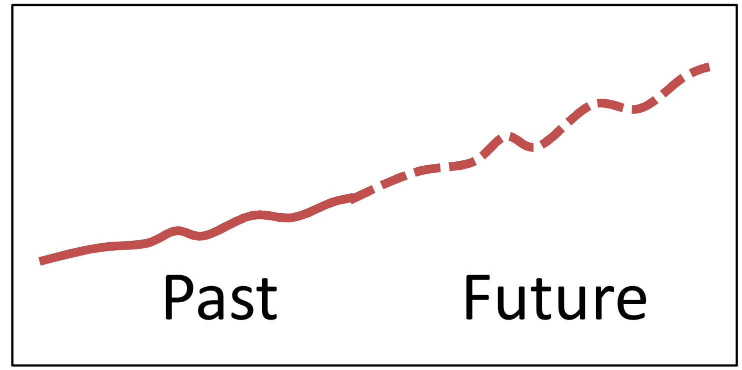
- Models are key elements of policy support
- Valuable for predicting, planning, assessing, understanding



- An entire linked *ecosystem of models* in California
- But as in Energy Efficiency, the people are hard to find

To Illustrate: Two Kinds of Models

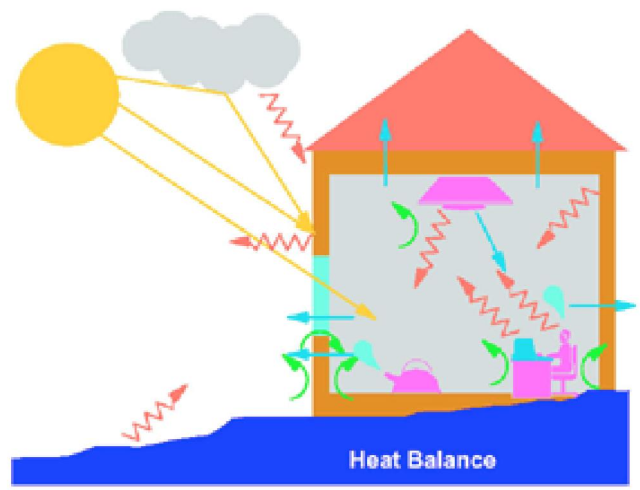
- Demand Forecasting Models
  - Population scale
  - Residential sector consumption



- Building Energy Simulation Models
  - Retrofits
  - Title 24 new construction

Both are Made up of Physical Variables

- Demand Forecasting
  - Building Types
  - Appliance Stocks
  - People? = Assumed Typical/Average Equipment Energy Usage



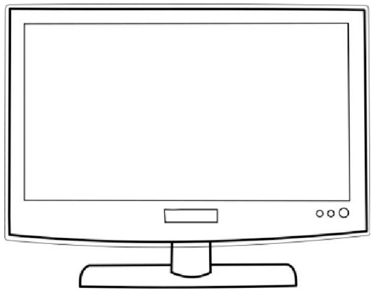
- Building Energy Performance
  - Building Shell
  - Heat loss and heat gain
  - Systems and Appliances
  - People? = Body Heat + Typical Thermostat Settings

What's Wrong with that?
Ignores Importance of Variability and Diversity

- Variation is often seen as "noise"
- People are buried in device usage coefficients

BUT…

- Appliances don't use energy: People use energy
- Buildings don't heat and cool themselves (yet)



Averages Mask Diversity

Simplest understanding of averages assume compact distributions of homogeneous elements

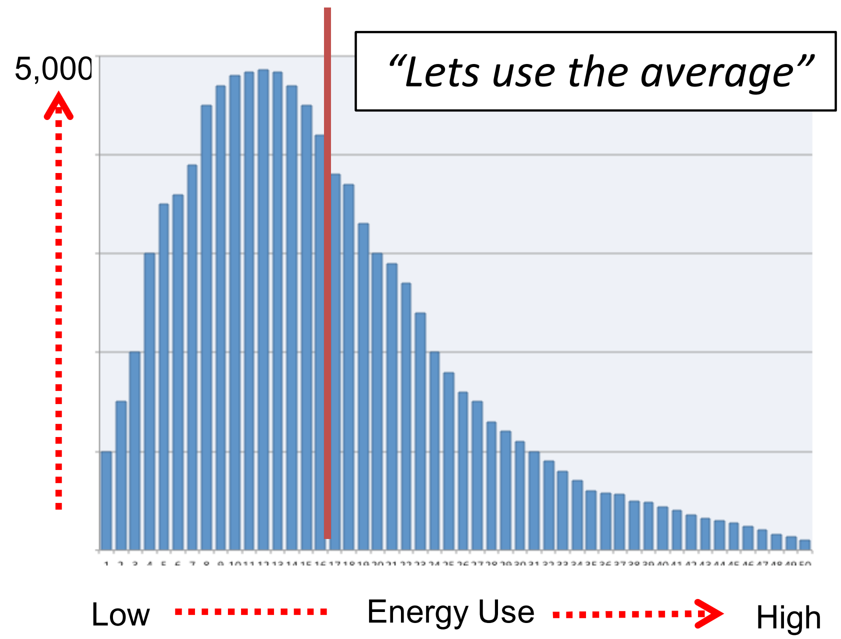
But in household energy use – little homogeneity

A variety of broad (and odd) distributions can have identical

"average" or "typical" point estimates

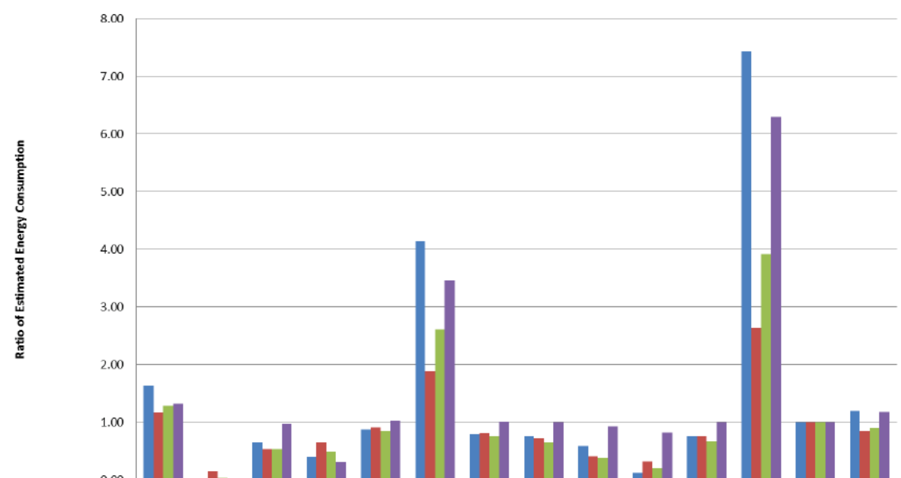
The Results are Often Misleading

- Averages dominate modeling and statistics
- Averages represent no one
- No such thing as a "typical" person or practice
- Averages are easy to believe uncritically
- How helpful is knowing the average when the top 25% use 50% of HH energy?



Heating/Cooling Example – “Typical” vs. Reality

- A narrow range of thermostat set-points assumed for heating and cooling in Title 24 and Home Audit Models
- In reality, a very wide range of setting are reported
- Some higher – many much lower
- A surprising number (42%) set to **OFF** for large parts of the day
- So the notion of “typical” values makes little sense



	Constant 68° (8%)	Constant 55° (5%)	68° am & eve, 55° day & night (4%)	Constant 63° (4%)	68° except 63° at night (3%)	Constant 73° (3%)	68° am & eve, 63° day & night (3%)	68° except 55° at night (2%)	55° except 68° in am (2%)	55° except 68° in eve (2%)	68° except 58° at night (2%)	Constant 77° (1%)	Title 24 Profile	Ratio: Weighted Avg. Across Row vs. Title 24
San Diego	1.63	0.01	0.65	0.39	0.88	4.14	0.79	0.75	0.58	0.11	0.75	7.43	1.00	1.19
Livermore	1.17	0.15	0.53	0.65	0.91	1.88	0.81	0.72	0.40	0.32	0.75	2.64	1.00	0.84
San Francisco	1.29	0.03	0.53	0.49	0.84	2.61	0.75	0.65	0.38	0.20	0.66	3.92	1.00	0.89
LA Current Title 24	1.32	0.00	0.97	0.31	1.03	3.46	1.00	0.99	0.93	0.82	0.99	6.29	1.00	1.18

Models (and Analyses) Cannot be Better than the Available Data, Techniques and Knowledge that Support Them

- Data are limited and inaccessible
- Metrics conceal diversity
- Analytic methods are rudimentary
- Fundamental knowledge base is scattered and fragmented
- Not clear how models or results are actually used

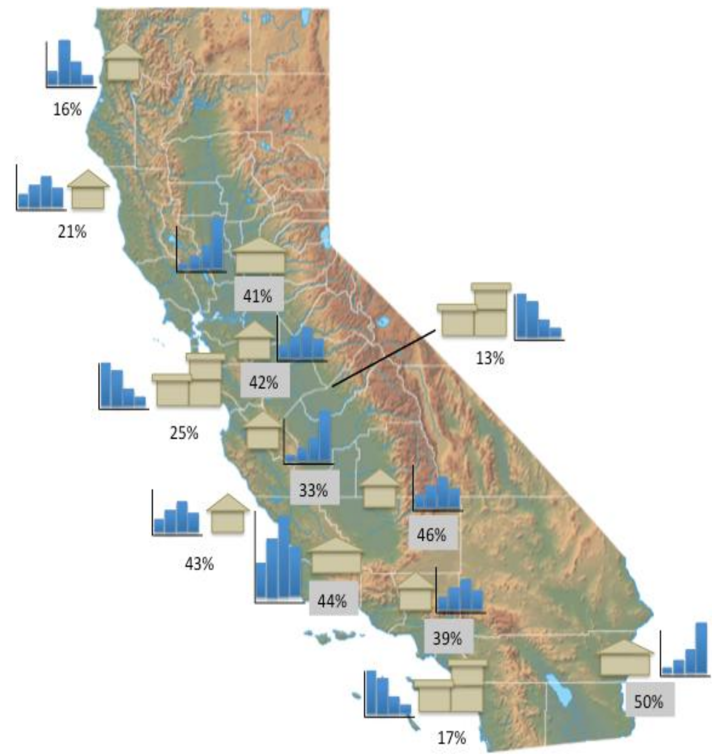
3) Climate Goals Require New Frameworks

- Climate policy targets for fossil energy reductions are very ambitious
- Large scale socio-technical system change is required
- Efficiency industry approaches are too narrow; constrained by regulatory institutions; modest goals
- Consideration of people, behavior and social patterns of demand must be part of the solution

Broader Perspectives are Easily Imagined

That consider …

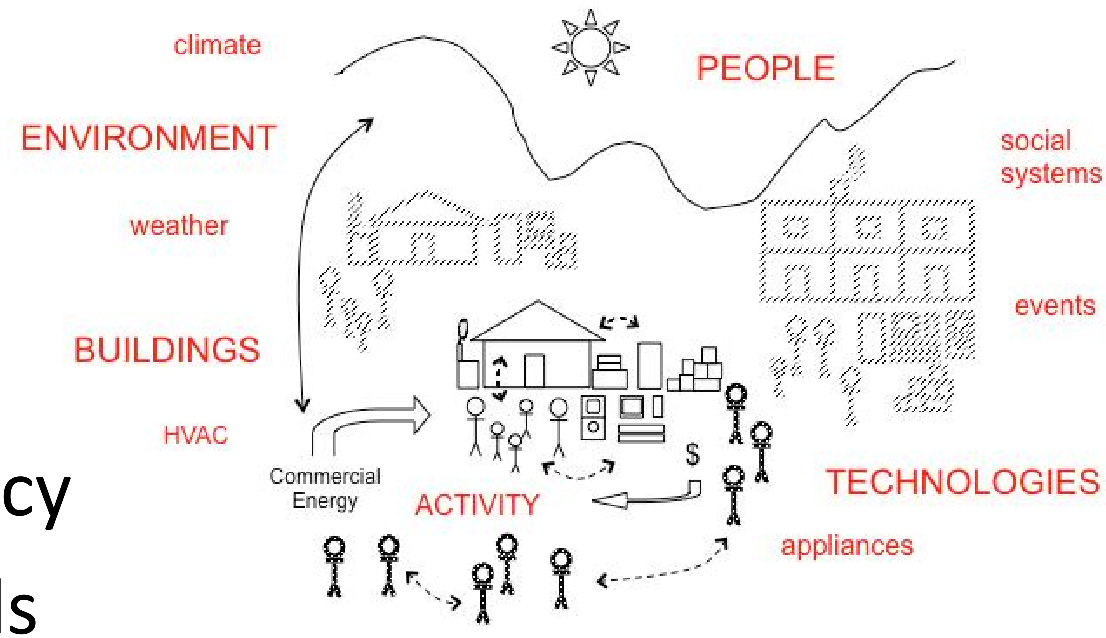
- A wider range of technology, environment and human factors together in one frame
- How people variously accumulate energy-using devices
- How people variously manage dwellings and actually use appliances, systems & plug loads
- Emissions patterns and savings potentials that vary across the population



AREBA Demonstrated Improved Models

For use in:

- Statistical estimation
- Simulation
- Examining model accuracy
- GHG reduction potentials



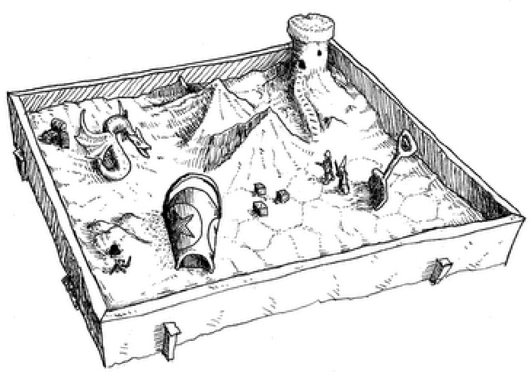
BETA Model

- Buildings
- Environment
- Technology/systems
- Activity/behavior

Energy Demand = f (Building, Environment, Technology, Activity)

Considerable work remains to be done in exploring and understanding interactions among factors

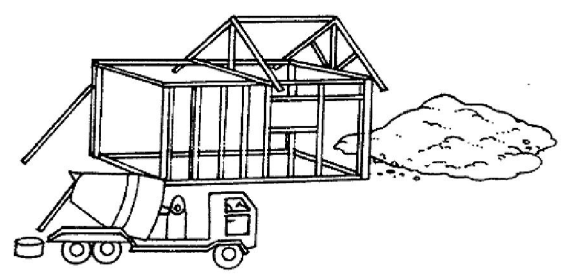
- Implications for demand forecasting practice
  - How to incorporate variation and diversity
  - How to account for uncertainty
- Implications for building energy performance modeling
  - Improving model accuracy and advice for design/retrofit
- Potential applications to climate change policy analysis
- Stress testing models (e.g., considering effects of interactions and/or alternatives to point estimates)
- Simulation “sandbox” – for careful, low-resolution, multi-disciplinary studies



In-depth Studies from a New Vantage Point Reveal New Insights and Opportunities

(only a few presented here)

- Home energy audits often ignore people, recommend retrofits that won't fit HH behaviors and needs, use technical approaches that "talk past" people, and lead to poor program results
- New building codes are fighting against forces driving higher consumption; Poor understanding of real world performance of new construction when occupied by real households
- Uncertainties about how real-world ZNE will be used by real people
- No idea whether PV plays nicely with EE



Recommendations

(a few of many)

1) Adopt a **broader policy perspective**; bring people and behavior into the frame with technologies.

2) Foster **multi-disciplinary conversations**; build integrated models; explore “what if” scenarios.

3) Acquire **much better data**; improve access to data; collect new data from primary research on how energy is actually used.

4) Develop **better analytics** relevant to the needs of climate change modeling and policy.

Recommendations

5) Stress test models and consider recent innovations in statistical methods that better incorporate uncertainty in data and prediction.

6) Improve applied models used in energy audits and new construction – e.g., incorporate behavioral effects. Improve home retrofit programs through more realistic understanding of energy use and consumer choice.

Recommendations

7) Pursue more rigorous thinking about behavior change dynamics and potentials; consider diversity and difference across population subgroups.
8) Study real world performance of new homes when occupied; study actual use of ZNE homes and retrofit homes with rooftop PV.
9) Include consideration of people as technology users and adapters (not just "adopters") in new technology RD&D.