

# **Behavior Matters!**

## **The Design, Implementation and Evaluation of Energy Efficiency Programs to Reduce Greenhouse Gas Emissions**

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&  
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**California Air Resources Board Seminar  
Sacramento, CA**

**December 12, 2008**

# Outline of Talk

1. Context
2. Historical perspective
3. What do we mean by behavior?
4. Behavior and energy efficiency program cycle
5. How do we evaluate behavior?
6. Signs of hope

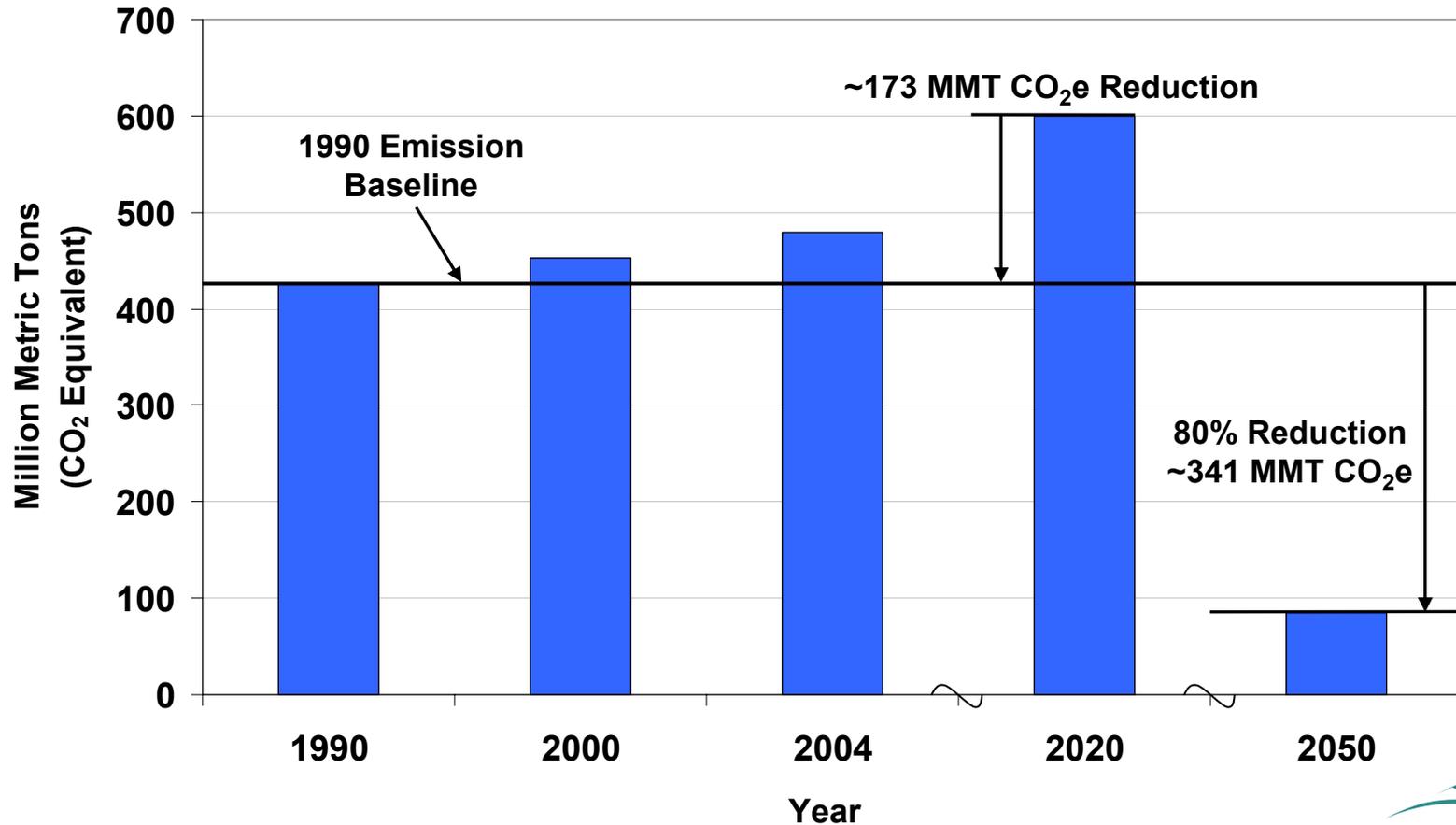
# 1. Context

# California's GHG Emissions Goals

- Reduce GHG emissions to 2000 levels by 2010
- Reduce GHG emissions to 1990 levels by 2020
- Reduce GHG emissions to 80% below 1990 levels by 2050

# Magnitude of the Challenge

ARB Emissions Inventory



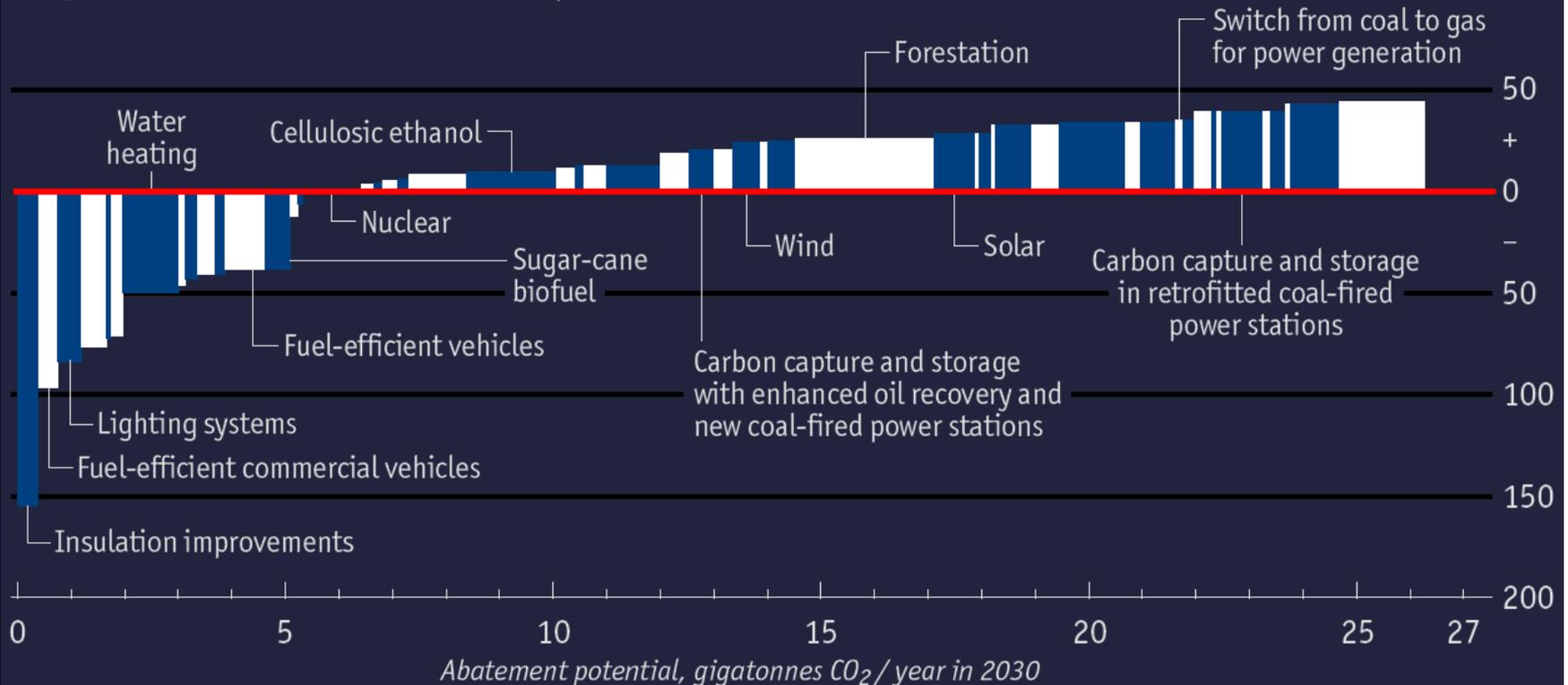
# CARB - Climate Change Scoping Plan

- Climate Change Scoping Plan (Oct. 2008)
  - Energy efficiency strategies will provide 16% of the estimated total emission reduction (169 MMTCO<sub>2</sub>E) by 2020
  - Focus: increased incentives and more stringent building codes and appliance efficiency standards
  - Focus is on technological improvements, reflecting national and international studies

# Cost of Cutting Carbon

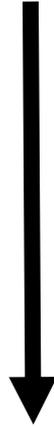
## The cost of cutting carbon in different ways

Marginal cost of abatement, examples €/t CO<sub>2</sub>



Source: Vattenfall

# But What About Behavior???



**What do we mean by behavior?**

**Let's think about past examples.**

## 2. Historical Perspective

# Changes in Energy Behavior Have Occurred in the Past

- High gasoline prices
- California energy crisis
- Saving electricity in a hurry - not just in California!

# 1970s

- OPEC
- Long lines
- Reduced miles and trips



# 2008



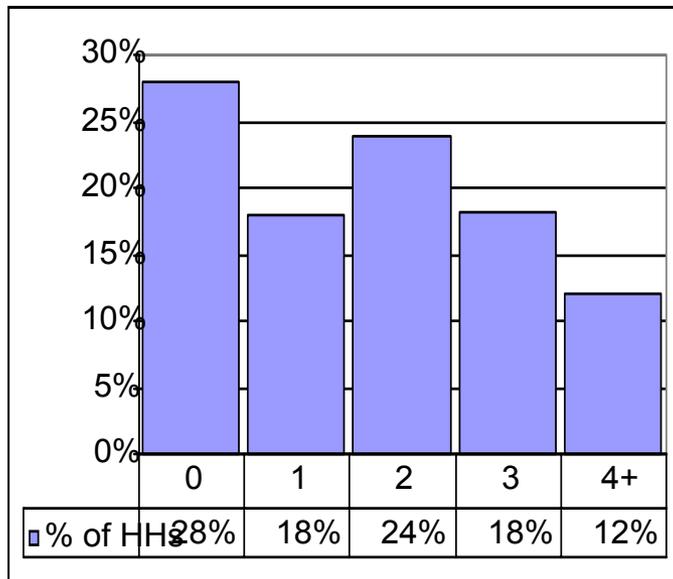
- High gas prices
- Long lines in some states
- 5% reduction in gas use compared to 2007
- Shift to smaller cars and more efficient vehicles
- Changes in driving habits
- More use of public transit
- Move from suburban to urban living



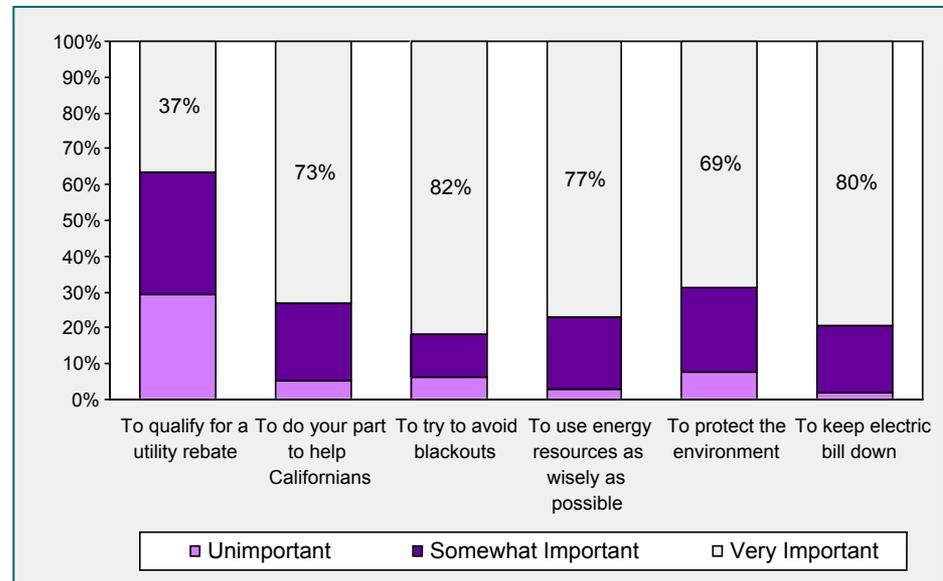
# 2001/2002 California Energy Crisis

- Unexpected reductions in consumer demand (peak down by 6,000+ MW)
- Loren Lutzenhiser (Portland State): behavior is primarily responsible (not weather or new hardware)
- From a combination of civic, economic, moral and altruistic motives

# behaviors reported

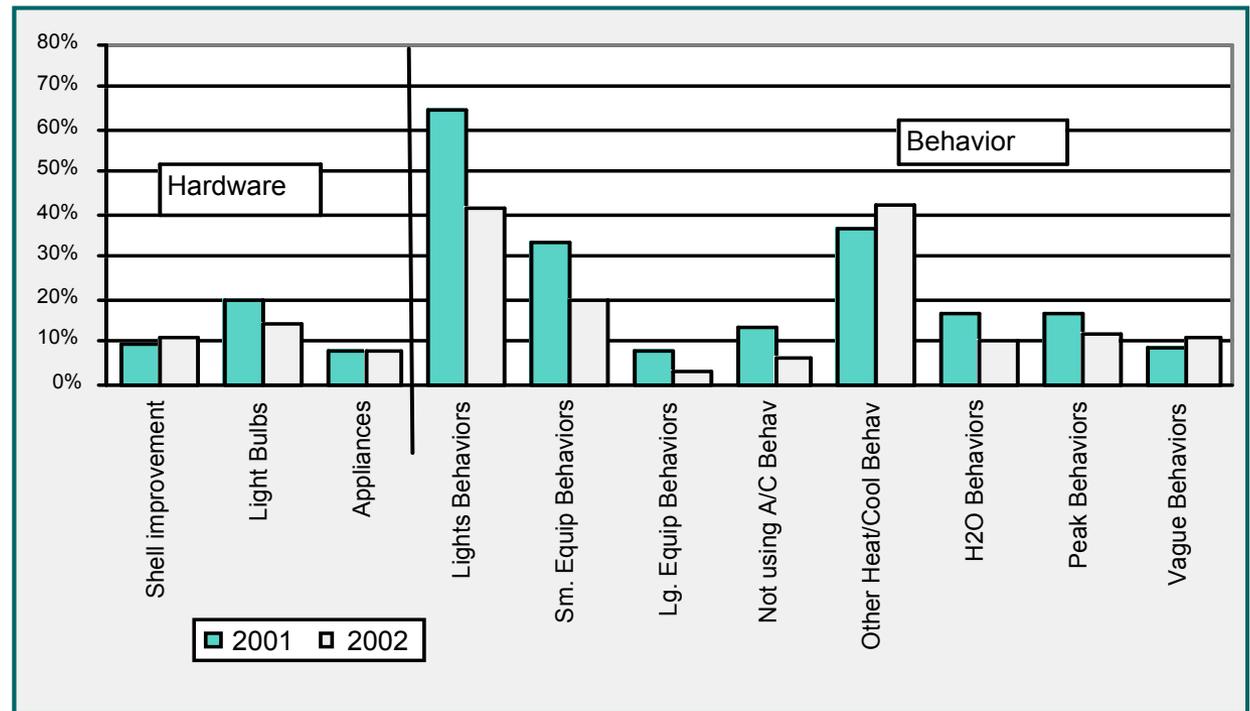


Reasons for behavior change

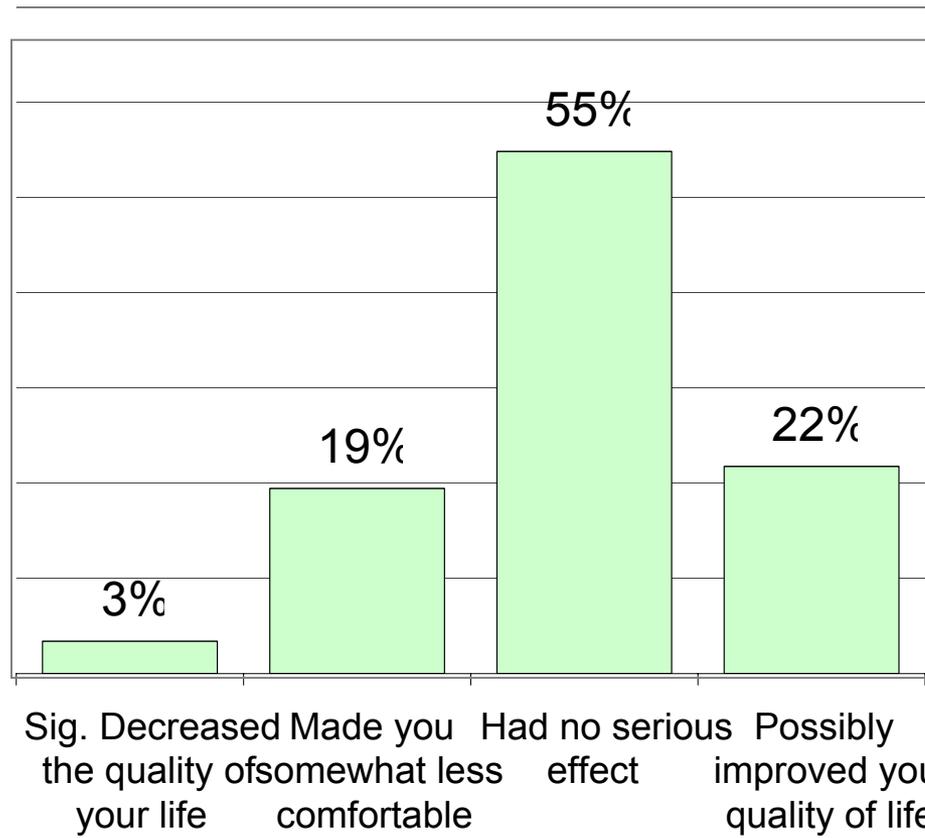


# Behavior Change

- Surprising contributor: people turning off air conditioners
- Persistence of some behaviors a year after the crisis



# Conservation is not hard - part of everyday life



# Saving Electricity in a Hurry

- Alan Meier (LBNL)'s book for the International Energy Agency: "Saving Electricity in a Hurry"  
[www.iea.org](http://www.iea.org)
- Temporary electricity shortfalls, resulting in the need for saving electricity in a hurry?
  - How did they do it?
  - Did they save electricity?

# Temporary Power Shortfalls

## Power Shortage

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graph LR; A[Power Shortage] --> B[Supply reduced]; A --> C[Demand increased];
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### Supply reduced

- ❖ Drought
- ❖ Loss of transmission
- ❖ Loss of power plant

**Duration: 1 day – 1 year**

**Advance warning: 1 day – 1 year**

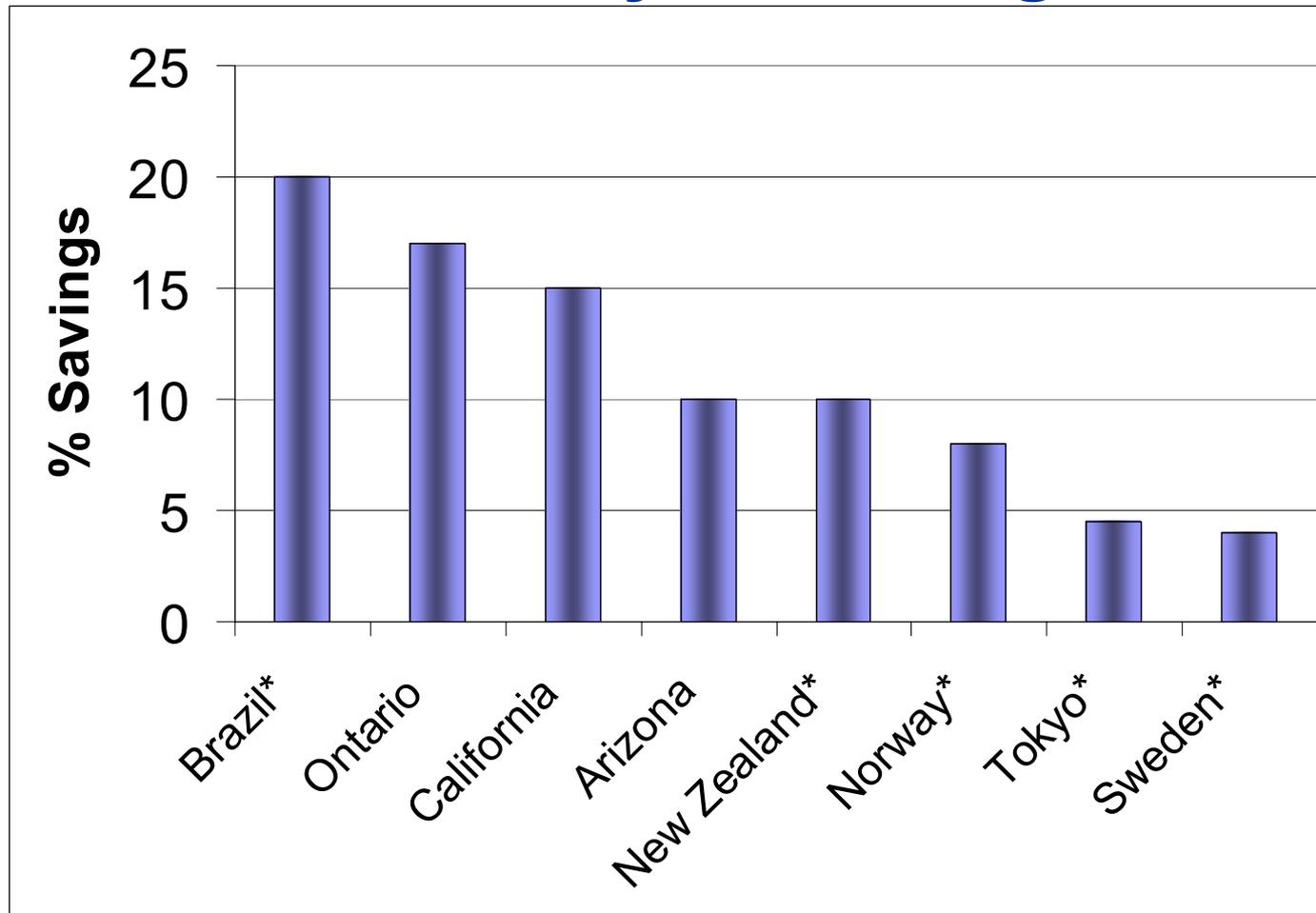
### Demand increased

- ❖ Heat wave
- ❖ Cold wave

# Saving in a Hurry is Different

- Temporary
- Must rely on changes in behavior
  - Technological improvements cannot deliver savings fast enough
  - Sacrifice may be acceptable
  - Strategies change with longer advance warning time or expected duration
- Can't rely solely on higher prices to cut demand
  - Technical and political obstacles

# Summary of Savings



\* No significant blackouts occurred

# Meier's Conclusions

- Rapid, temporary, reductions in demand are achievable without damaging economy
- Effective use of the media is critical
  - Humor works
- Many short-term reductions were achieved without raising prices
- Need to link to “saving electricity slowly”

### 3. What Do We Mean by Behavior?

# Market Perspective

- What is the behavior of key market actors?
- How to influence the behavior of key market actors in the supply chain? [Behavioral change]
- Who are the market actors?
  - Consumers
  - Manufacturers
  - Retailers and distributors
  - Building owners and landlords
  - Architects and engineers
  - Etc.
- What are the strategies?
  - Carbon taxes, carbon credits, financial incentives, education, information, codes and standards

# Program Perspective

- Who participates in energy efficiency programs & why?
- Who does not participate in these programs & why?
- How to influence consumers to participate in programs?
- What programs?
  - Private and public utilities
  - Local, state, and federal government
  - NGOs
- What are the strategies?
  - Financial incentives, education, information
  - Feedback, leveraging social norms & social networks, contests

# End User Perspective

- What consumers?
  - Residential (single family, multifamily; owners, renters)
  - Commercial (hospitals, offices (small and large), restaurants, hotels & motels, grocery stores, etc.; owners, tenants)
  - Industrial (pulp & paper, cement, plastics, steel, pharmaceutical, etc.)
  - Agricultural (food processors, growers, etc.; small and large)
- A. What energy services do they need?

# End User Perspective #2

- B. How can consumers use less energy for getting those services?
  - ♦ How to influence them to reduce their energy use? Focus on operational use of existing buildings [Habitual action; Behavioral change; Conservation behavior; Behavioral Conservation]
    - Residential: Turn off lights in unoccupied rooms, shorter showers, changes in thermostat settings, use ceiling fans coupled with raising thermostat, regularly change HVAC filters, run full loads in dishwasher and laundry, close off unused rooms, close windows when HVAC system is on, use clothes lines
    - Commercial: maintenance (O&M), process/system improvements - improve the efficiency of existing systems: seal ducts, over-haul compressed air systems, HVAC tune-ups

# End User Perspective #3

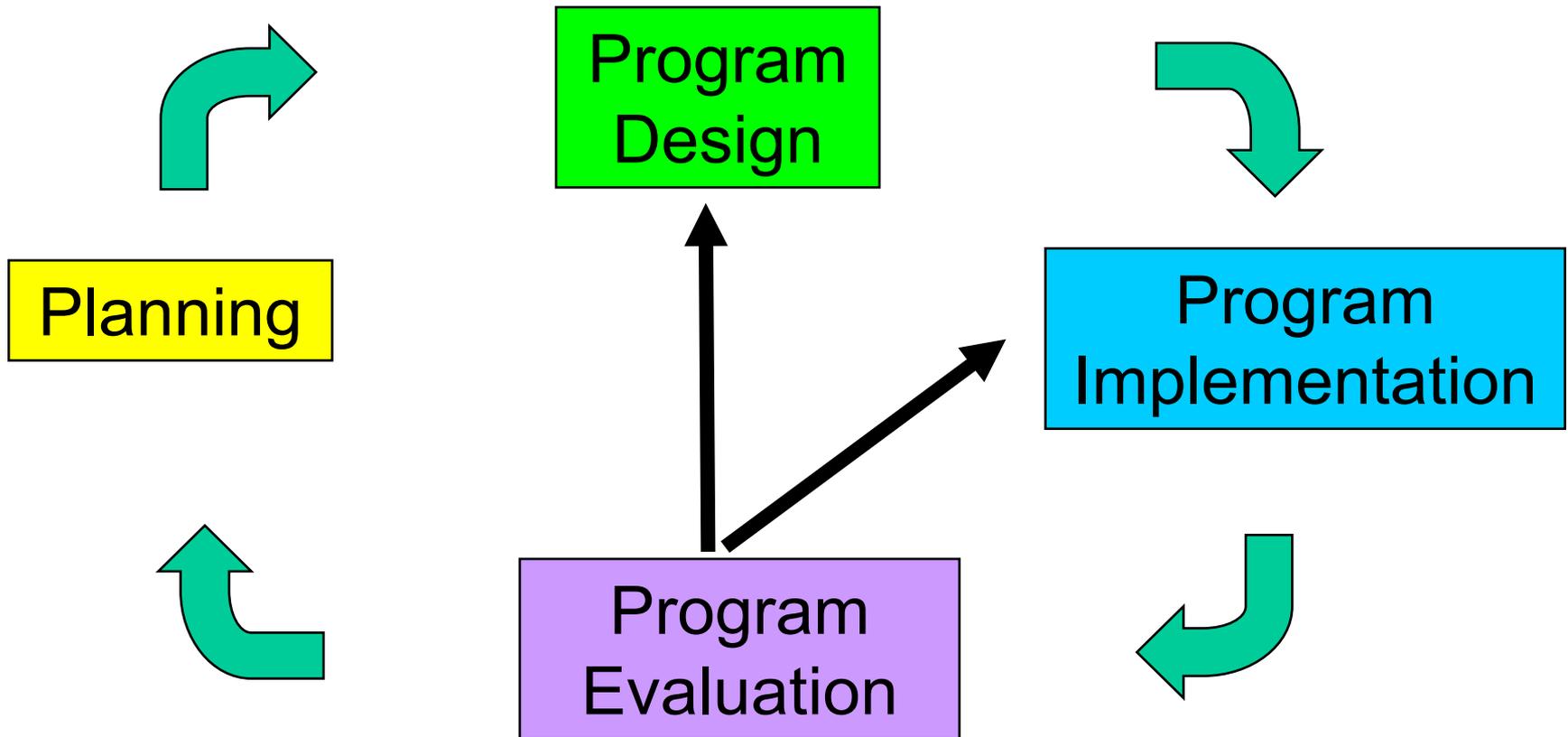
- C. How do consumers decide to invest in energy efficiency? [Purchasing Activities] [Technology Choices; Technical Efficiency]
  - ◆ How to influence consumers to make more energy efficiency investments?
  - ◆ What factors/drivers are important? Financial, regulatory, and informational
  - ◆ What barriers are important? Financial, regulatory, and informational
  - ◆ Focus on new purchases of products and services.
    - New homes and offices, appliances, lighting controls (motion sensors), whole house performance retrofit, retro-commissioning
- What are the strategies?
  - ◆ Carbon taxes, carbon credits, financial incentives, education, information (audits), codes and standards
  - ◆ Feedback, leveraging social norms and social networks, contests

# What's Missing?

- Physical, social and cultural infrastructure
  - Urban planning
  - Sustainable communities
- Lifestyles

# 4. Behavior and Energy Efficiency Program Cycle

# Energy Efficiency Program Planning Cycle



# Behavior and Planning

- Forecasting
- Baselines
- Scenario analysis
- Energy potential studies
- Energy analysis
- Energy modeling
- Market analysis
- Risk/uncertainty analysis

Planning

Program Design

Program Implementation

Program Evaluation

- Program participation
- Nonparticipant analysis
- Energy attitudes & behavior
- Cost effectiveness
- Energy & non-energy impacts
- Market effects

# Behavior and Program Design

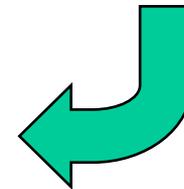
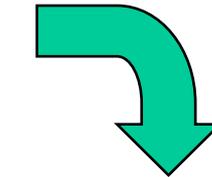
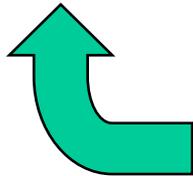
- Market segments
- Program types
- Measures & measure life
- Program participation
- Market stakeholders
- Program & market logic models
- Evaluation needs
- Energy & non-energy impacts
- Cost effectiveness

Planning

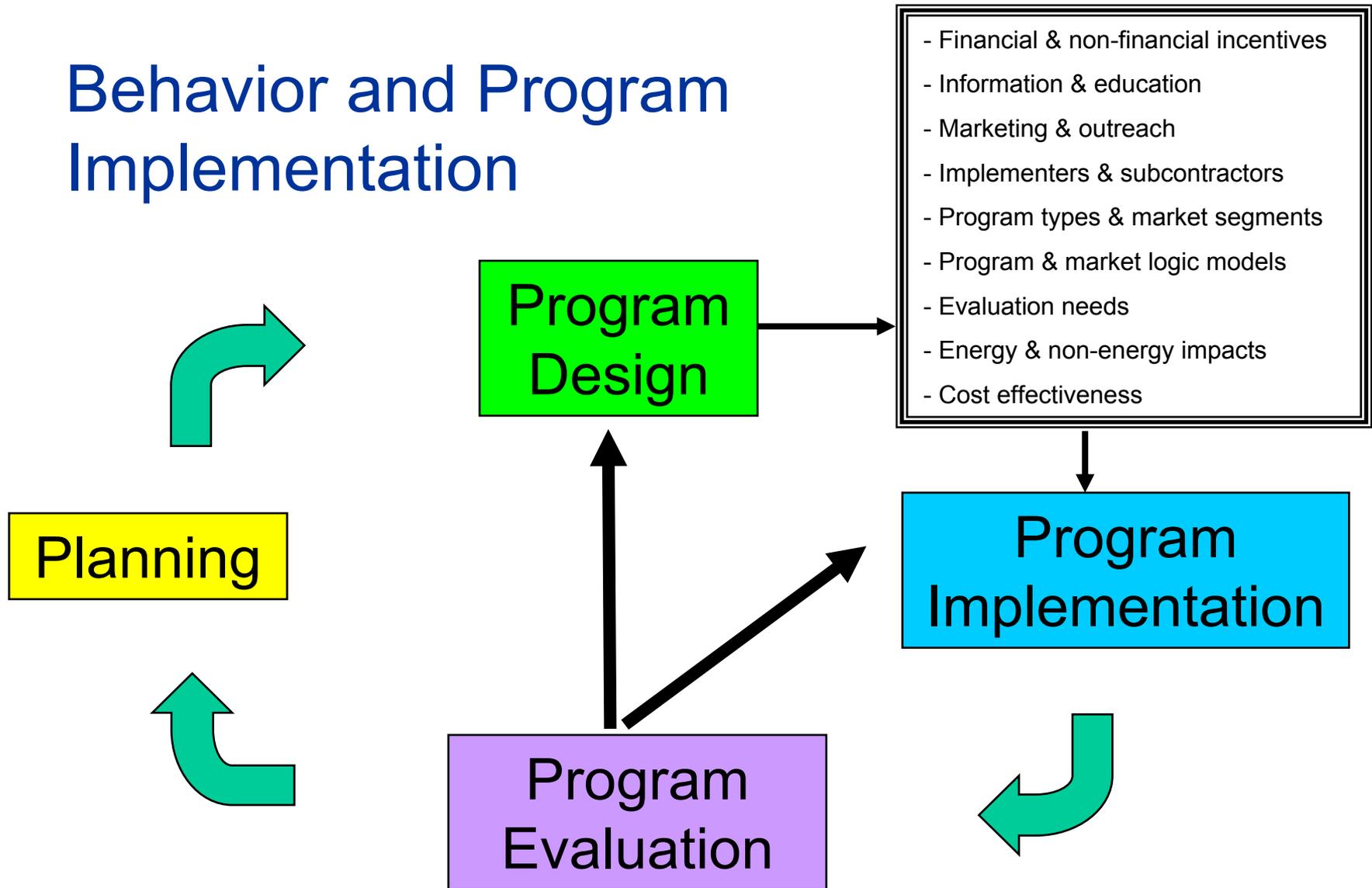
Program Design

Program Implementation

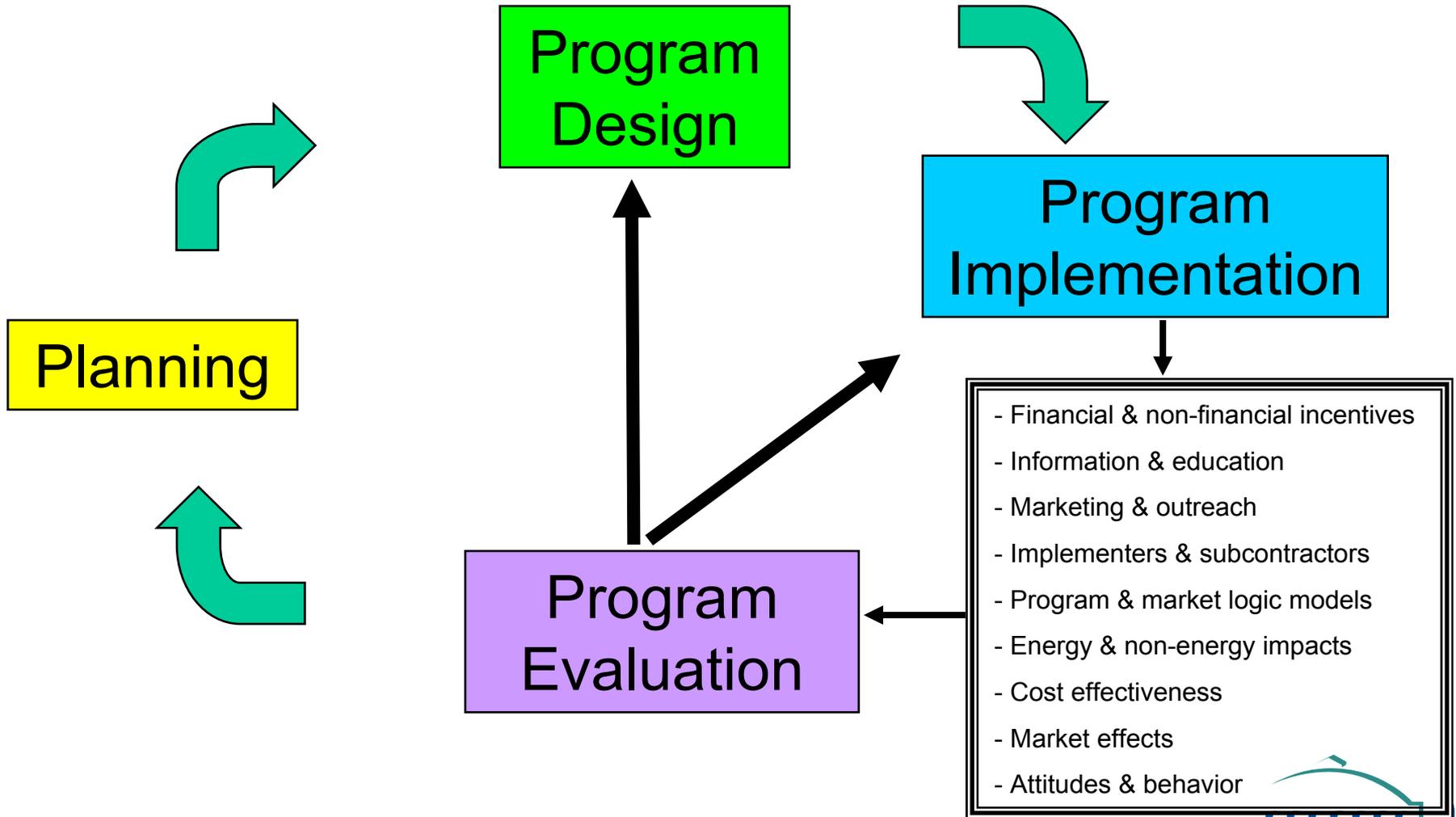
Program Evaluation



# Behavior and Program Implementation



# Behavior and Program Evaluation



# PG&E's Next Generation of Energy Efficiency Programs



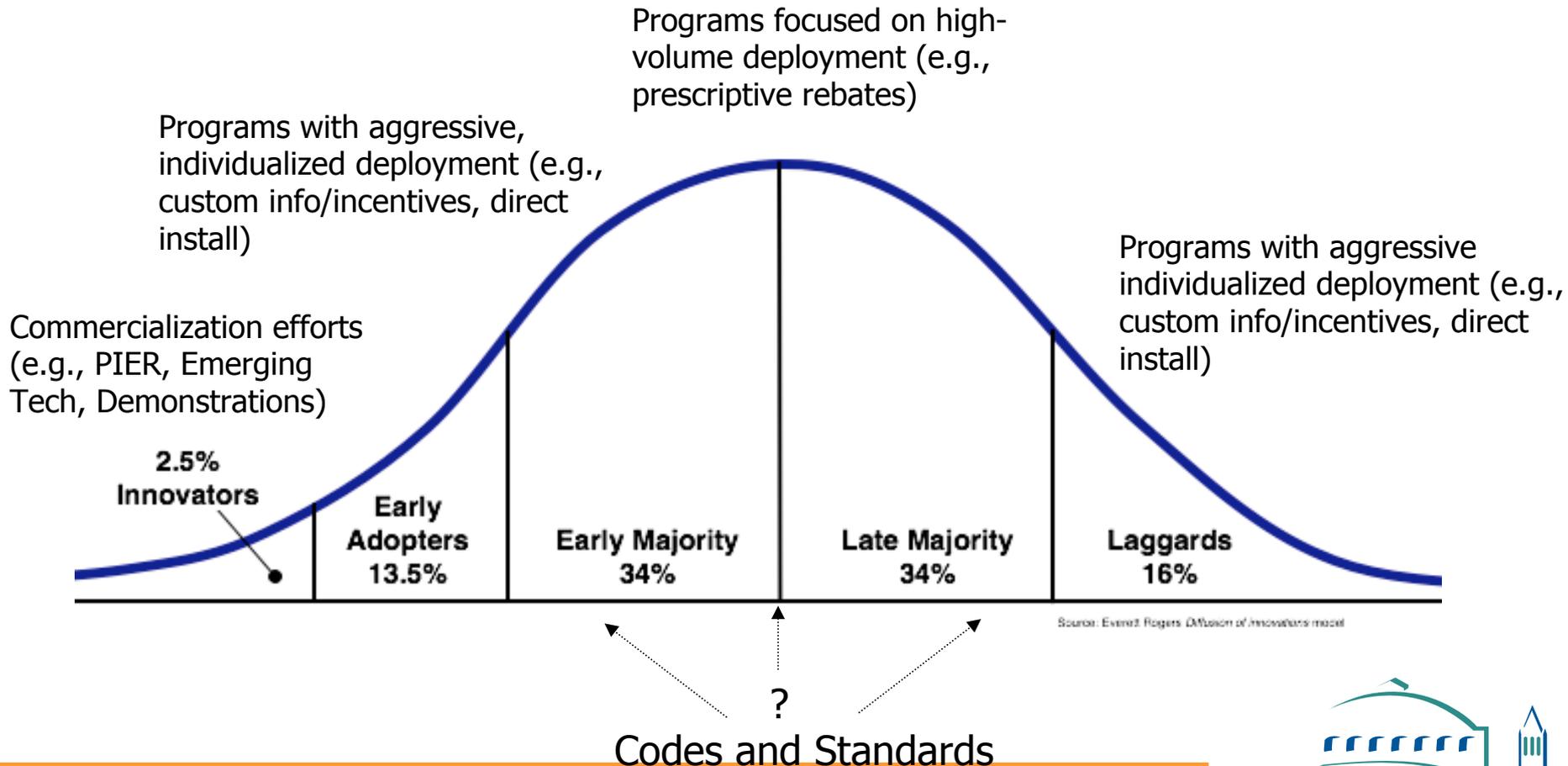
# PG&E 2009-2011 Programs

<b>Core Programs</b>	<b>Number of Programs</b>	<b>\$ Requested</b>
Targeted	7	\$312M
Mass Market	1	\$539M
Other	4	\$102M
<b>Government Partners</b>		
Energy Watch	17	\$122M
State Departments	1	\$41M
Green Communities	1	\$17M
<b>Third Parties</b>	57	\$324M
<b>Long Term Initiatives</b>	6	\$262M
<b>Total</b>	94	\$1.8B

# Key Behavioral Issues

- Behavioral assumptions
  - Physical-technical-economic model (PTEM) = Rational actor model
- Need to look at
  - Barriers
  - Diffusion of innovation
- Market segmentation
  - Diffusion of innovation
  - Lifestyles

# Technology Diffusion and Program Life-Cycle



# Cost-Effectiveness

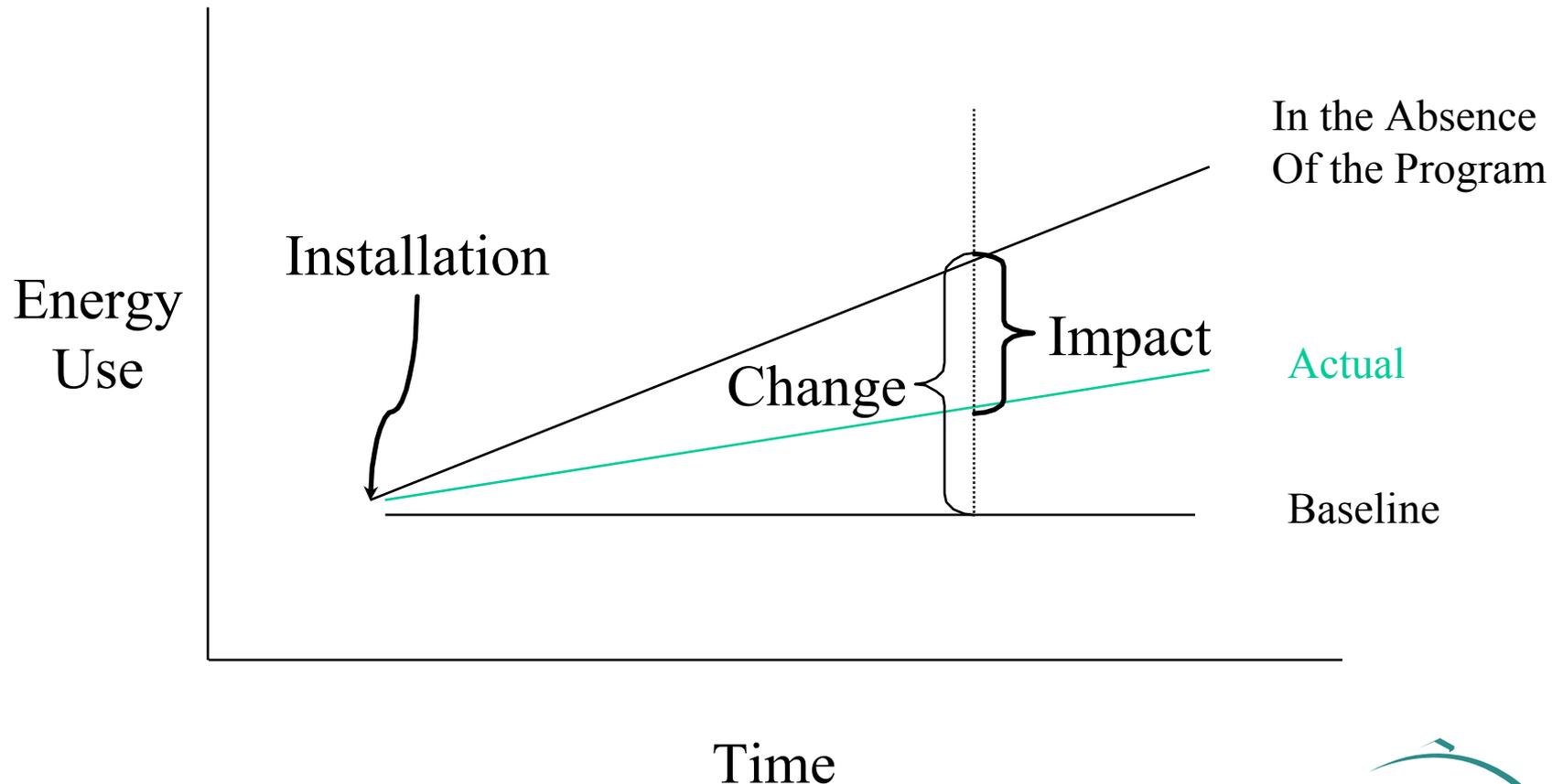
- Total Resource Cost (TRC) test
  - Net energy savings versus gross savings
  - Net-to-Gross (NTG) adjustment factor
    - ◆ Free riders
    - ◆ Program spillover
      - Participant spillover
      - Nonparticipant spillover
  - Non-energy impacts (including GHG emissions reduction)
  - Market effects (market transformation)

# 5. How Do We Evaluate Behavior?

# Six Types of Evaluation

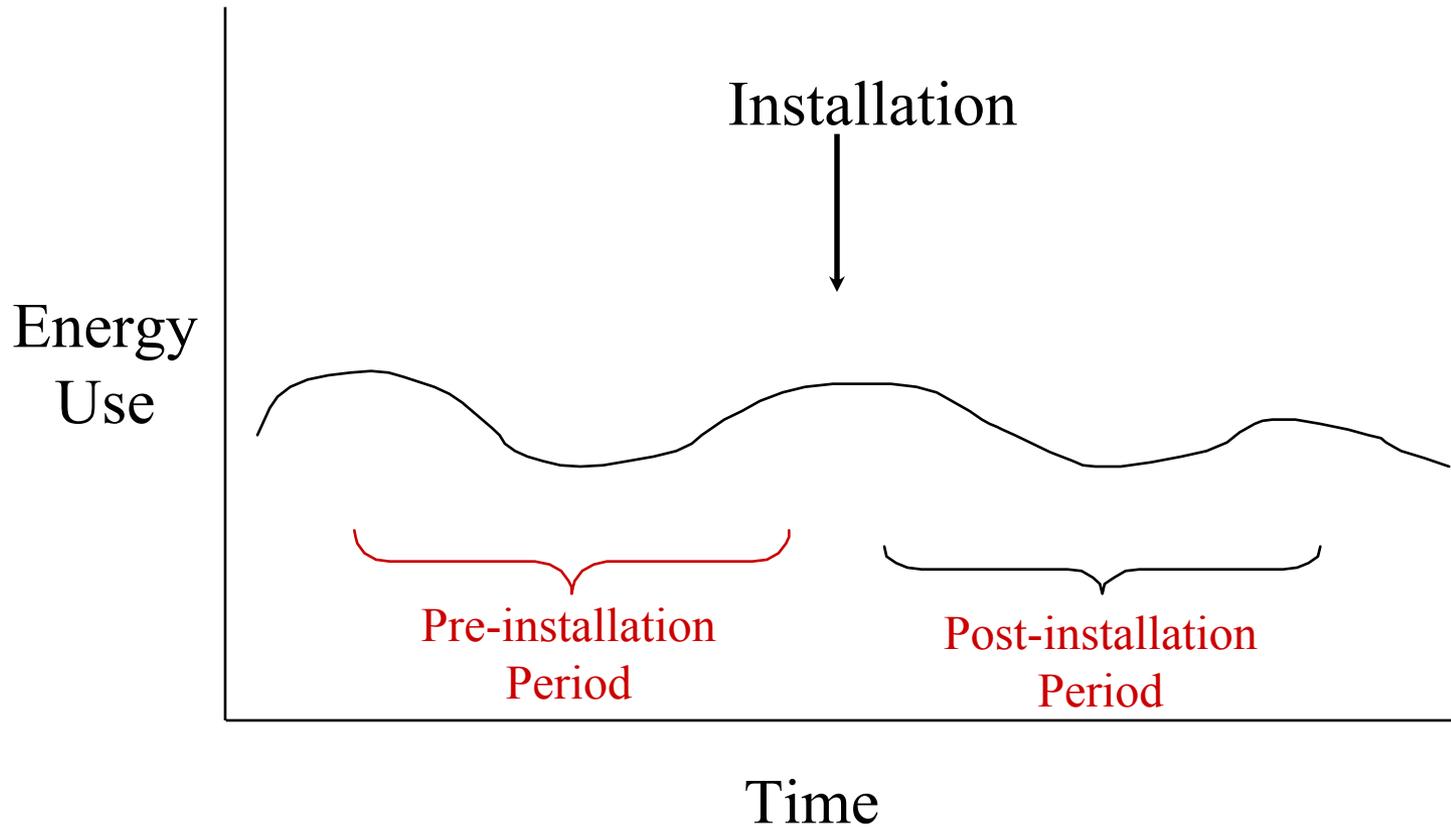
Evaluation Category	Phase at which Implemented	Evaluation Type	Assessment Level
Formative	Pre-program planning phase (a priori)	<b>1. Market assessment (includes market characterization, baseline studies)</b>	Market and/or Program
		<b>2. Potential or feasibility studies</b>	Market and/or Program
	Implementation phase (post-hoc)	<b>3. Process evaluation</b>	Program
Outcomes	Implementation phase (post-hoc) and/or post-implementation (ex-post)	<b>4. Impact evaluation</b>	Program
		<b>5. Market effects evaluation</b>	Program & Market
		<b>6. Cost-Effectiveness evaluation</b>	Program or Portfolio

# Change in Energy Use vs. Impact of Program





# When Do You Evaluate? (Impact Evaluations Only)



# Impact Data Needed to Collect

- Monthly energy consumption
- Metered or monitored energy usage
- Load shape data (day, season, year)
- Hours of operation for building or measures
- Physical characteristics of the building and equipment (size and location)
- Other physical variables: temperature, flow, weather
- Building occupancy schedules and occupant data

# Data Collection and Analysis Methods for Impact Evaluation

- Engineering methods
- Basic statistical billing analysis
- Multivariate statistical analysis
- End-use metering
- Short-term monitoring
- Integrative methods

# Process Evaluation

- To recommend ways to improve a program's efficiency of services, effectiveness of promotional strategies, and level of customer satisfaction
- Timing:
  - For a new program
  - Whenever there are major changes to a program

# Focus of Process Evaluation

- Explaining why the program succeeds or fails to deliver savings
  - Barriers to participation
  - Unanticipated behavioral response
  - Program operations

# Content of Process Evaluation

## □ Begin with:

- Program design
  - ◆ Program activities
- Program theory
  - ◆ Explains causal links of how program activities lead to desired program outcomes

## □ Examine how the program was actually implemented

- What did the program do effectively?
- How could efficiency and effectiveness be improved?
- Did the causal links work as expected? If not, why?

# Process Evaluation Activities

- Review of program theory, program plan, and all available program materials and records
- Interviews with program managers, others involved in the program, and key stakeholders
- Comparisons with similar programs
- Evaluation of available information on the targeted market and its structure
- Development of recommendations for program improvement

# Evaluation Toolkit

- Measurement and evaluation protocols
- Theory and modeling
- Converting energy savings to GHG emissions reductions

# Existing EM&V Protocols & Guidelines

## Energy Efficiency

### □ Program Evaluation

- 2006 California Energy Efficiency Evaluation Protocols  
<http://www.cpuc.ca.gov/PUC/energy/electric/Energy+Efficiency/EM+and+V/>
- 2007 National Action Plan for Energy Efficiency (NAPEE) Model Energy Efficiency Program Impact Evaluation Guide  
[http://www.epa.gov/cleanrgy/documents/evaluation\\_guide.pdf](http://www.epa.gov/cleanrgy/documents/evaluation_guide.pdf)
- 2007 US DOE Impact Evaluation Framework for Technology Deployment Programs  
[http://www.eere.energy.gov/ba/pba/km\\_portal/docs/pdf/2007/impact\\_framework\\_tech\\_deploy\\_2007\\_main.pdf](http://www.eere.energy.gov/ba/pba/km_portal/docs/pdf/2007/impact_framework_tech_deploy_2007_main.pdf)

# California's EM&V Protocols

- Evaluator or “How to” Protocols
  - Energy impact evaluation protocol
  - Measurement and verification protocol
  - Process evaluation protocol
  - Market effects evaluation protocol
  - Sampling and uncertainty protocol
  - Evaluation reporting protocol
  - Emerging technology evaluation protocol
  - Codes and standards evaluation protocol
  - Effective useful life evaluation protocol (persistence and technical degradation)

# USDOE Impact Evaluation Guide

- Joins Everett Rogers' diffusion of innovation theory with logic models to examine linkages between program activities, target audiences, behavioral and institutional changes, and energy savings or adoption of cleaner energy sources
- The framework covers effects on end users and three market infrastructure domains: knowledge industry, government, business
- Using the framework's templates:
  - A program can describe its outcome goals and program logic, as well as identify key outcome questions and indicators (metrics)
  - Evaluators can identify measured outcomes, such as sales or adopted technologies and practices
  - Evaluators can test causal links between the program and outcomes and investigate alternative explanations

# Theory and Modeling

- Program theory
  - Work with existing models (PTEM) or create new models
- Market theory
  - Need to link with program theory
- Logic modeling
- Diffusion of innovation
  - Awareness of products
  - Willingness to adopt
- Social network analysis

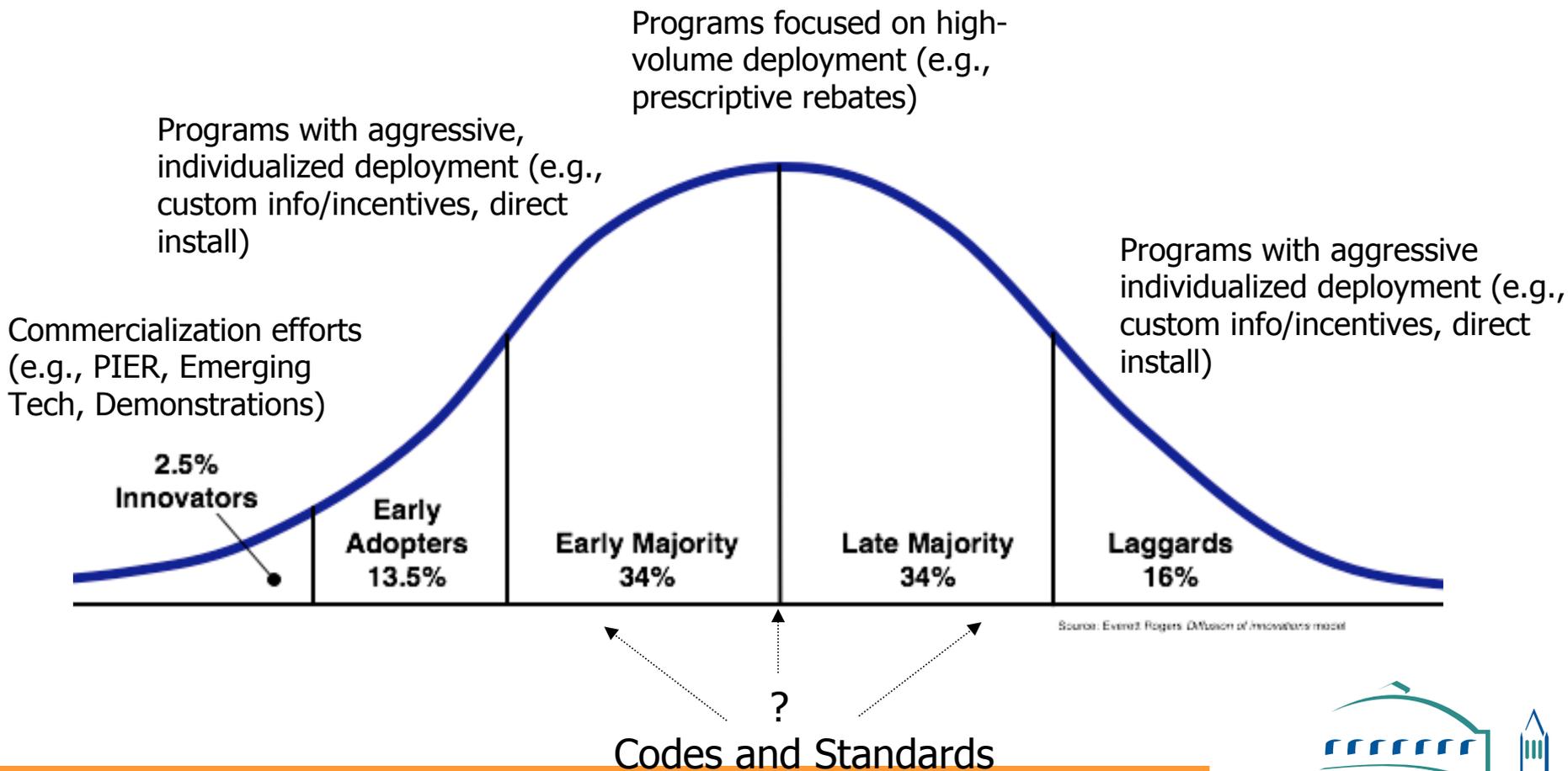
# Logic Modeling

- Logic models build a concise description of a technology deployment program's performance path
  - Shows a sequential set of activities, the resources required for these activities, the outputs, the target audience, and the short-, intermediate-, and long-term outcomes
  
- Evaluation research design is based on program theory, so that one can:
  - Credibly explain how program actions influence target audiences to take actions that result in long-term outcomes (e.g., energy savings)
  - Measure whether the program activities are effective in actually influencing the actions of target audiences
  - Measure intermediate progress and then attribute long-term outcomes to program actions

# Diffusion of Innovation

- USDOE's deployment programs are about the diffusion of a new technology (an innovation)
  - Program logic must describe how the diffusion occurs
  - This is aided by joining Rogers' theory of change about the diffusion of innovations with the logic model [different than current practice]
- Diffusion of innovation theory
  - Comprehensive theory that describes how ideas, technologies and practices find their way into markets and cultures
  - Rogers' theory of change provides a set of hypothesized concepts and linkages that can be used as a guide when describing how outputs generate the desired long-term results
  - Rogers theory includes 5 interrelated models

# Technology Diffusion and Program Life-Cycle



# IEPEC Conference

- International Energy Program Evaluation Conference (IEPEC)
  - August 12-14, 2009
  - Portland, OR
  - <http://www.iepec.org>

## 6. Signs of Hope

# Recent Activity on Behavior

- CARB
- CPUC
- Utilities (IOUs, SMUD)
- CEC
- BECC Conference

# CARB - Climate Change Scoping Plan Revisited

- Climate Change Scoping Plan (Oct. 2008)
  - Behavior is implicitly or explicitly mentioned:
    - Price signals from cap & trade will influence consumer behavior
    - Individual behavior will influence California's effort to reduce GHG emissions
    - California's statewide programs support positive changes in home and business behavior
    - Implementation of Plan places “personal action” and “public outreach and education” at the forefront

# CARB - Behavioral Change Research

- FY 2008-2009 Annual Research Plan
  - Approved by the Board on July 24, 2008
  - Identifies behavioral change research/knowledge gaps:
    - What determines household consumption of energy, water, natural gas, and transportation resources?
    - How do choices upstream of households affect home energy efficiency?
    - What determines household choices among available homes and equipment?
    - How can better systems be designed to inform consumers about their best options for improving home energy efficiency and reducing their carbon footprints?
    - What can be done to decouple energy consumption from perceptions (and misperceptions) of well being?
    - How can improved government links to energy users promote policy goals?

<http://www.arb.ca.gov/research/apr/plan/fy08-09/plan08-9.pdf>

# CARB - Behavioral Research Project

- FY 2008-2009 Annual Research Plan
  - Approved \$250,000 for behavioral change research
  - Based on concept to investigate “Behavioral and Demographic Determinants of Low Residential Consumption Patterns Observed in California Households”
  - *Role of individuals’ behaviors acknowledged to be a primary determinant of residential energy and water consumption, often accounts for greater variability in consumption patterns than does appliance efficiency or household size.*
  - Research concept includes in-home interviews of residents with low energy and water use
    - What strategies do low-use customers use?
    - What motivates them?
    - How can ARB’s outreach support replication of voluntary low consumption?

# CPUC-Funded White Papers on Behavior and Energy Consumption

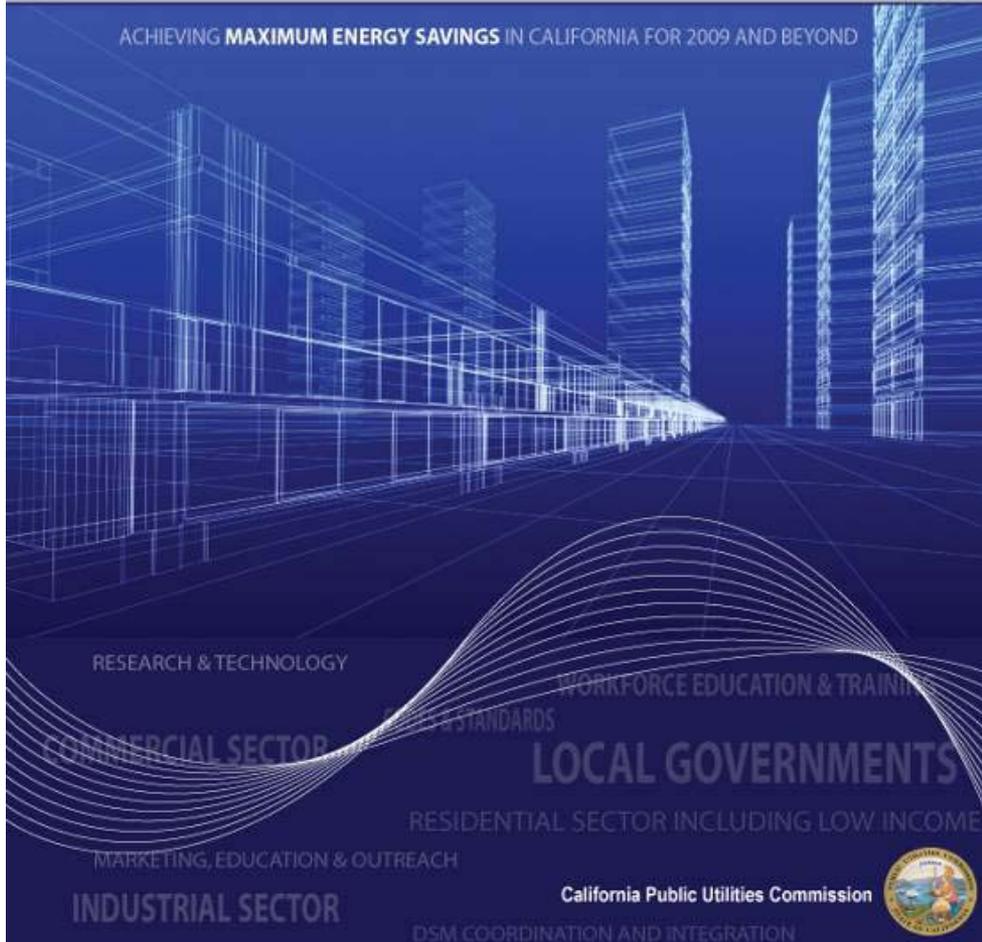
1. Energy efficiency potential studies & behavior
2. Measurement & evaluation of energy savings & non-energy impacts from energy efficiency behaviors
3. Process evaluation's insights on energy efficiency program implementation
4. Behavioral assumptions underlying energy efficiency nonresidential programs
5. Behavioral assumptions underlying energy efficiency residential programs
6. Market segmentation & energy efficiency program design
7. Experimental design for energy efficiency programs
8. Motivating policymakers, program administrators, & program implementers to pursue behavioral change strategies
9. Encouraging greater innovation in the production of energy-efficient technologies & services

# CPUC-Funded Studies on Market Effects

1. Residential new construction
2. CFLs
3. High-Bay Lighting

California long term  
**ENERGY  
EFFICIENCY**  
**STRATEGIC PLAN**

ACHIEVING **MAXIMUM ENERGY SAVINGS** IN CALIFORNIA FOR 2009 AND BEYOND



RESEARCH & TECHNOLOGY  
COMMERCIAL SECTOR  
MARKETING, EDUCATION & OUTREACH  
INDUSTRIAL SECTOR

WORKFORCE EDUCATION & TRAINING  
CODES & STANDARDS  
LOCAL GOVERNMENTS  
RESIDENTIAL SECTOR INCLUDING LOW INCOME  
DSM COORDINATION AND INTEGRATION

California Public Utilities Commission 

# Scope of Strategic Plan

- Includes everything the two state energy agencies (CPUC and CEC) are currently working on, and more
- Incorporates:
  - Market transformation
  - Voluntary market actions – to become “Business as Usual in California
  - Collaboration -- Roles for Local Governments, other State Agencies and Private Sector Players
- 4 Big Bold EE strategies as cornerstones of initial bold energy-savings/outcomes
- Behavior is mentioned throughout Plan as critical

# 4 BIG BOLD Energy Efficiency Strategies



## Commercial New Construction

- All new commercial construction in California will be zero net energy by 2030.



## Residential New Construction

- All new residential construction in California will be zero net energy by 2020.



## Residential / Small Commercial HVAC

- Heating, Ventilation, and Air Conditioning (HVAC) industry will be reshaped



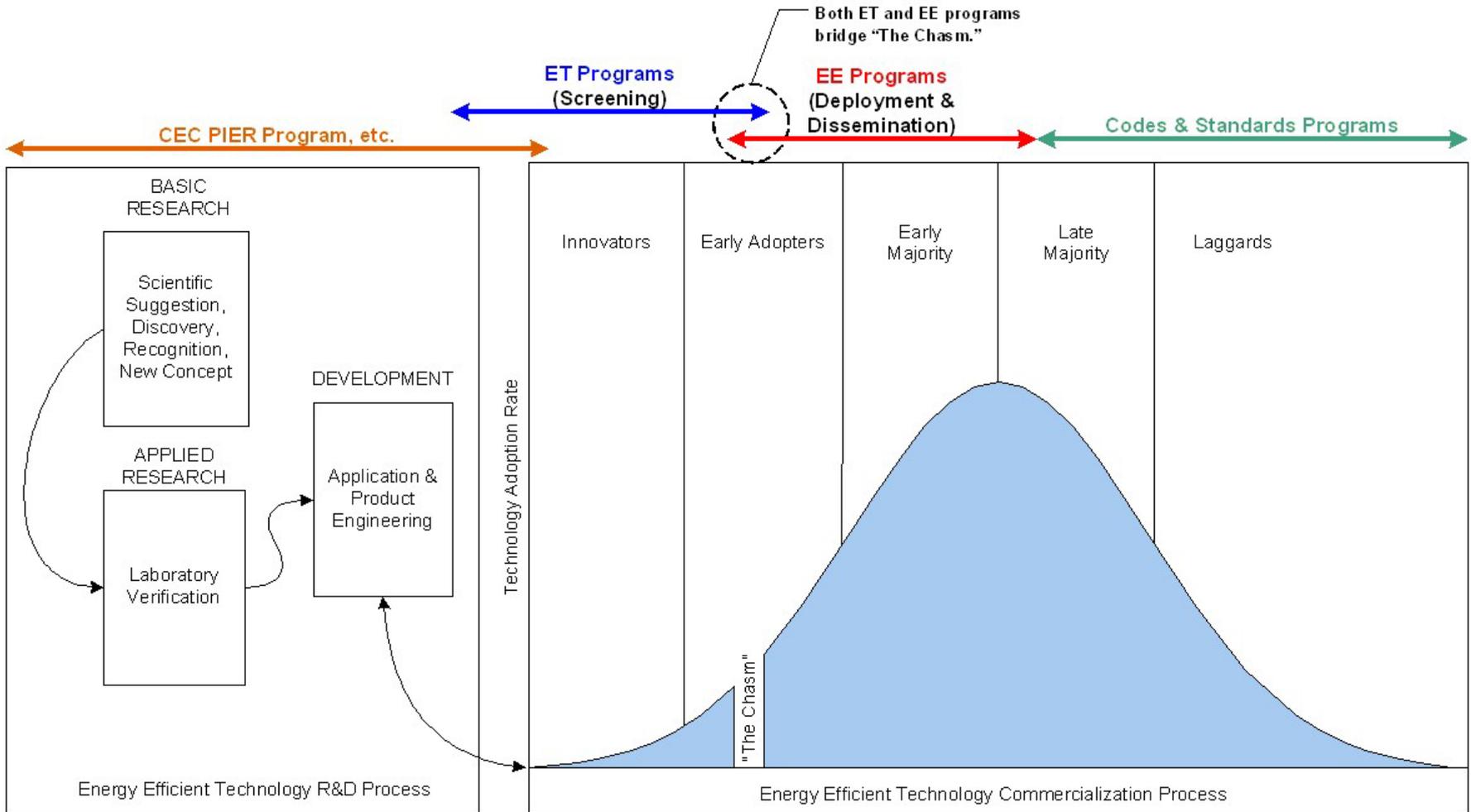
## Low-Income Energy Efficiency

- All eligible low-income homes will be energy-efficient by 2020

# IOUs - Behavioral Research

- IOUs: 2009-2011 Program Applications
  - Behavioral research is part of Emerging Technologies Program - on paper
  - No explicit research, but underlies all programs

# ET Role in Technology Deployment



# SMUD - Behavioral Research

- Pilot: Positive Energy's "Home Energy Reports"
  - Participants: randomly selected sample: 35,000 SMUD customers
  - Control sample: 50,000 SMUD customers
  - One-year test: impact of report formats on customer segments, on actions, and on energy savings
- Pilot: BlueLine's Powercost Meters (in-home feedback displays)
  - Evaluation objectives are similar to above
  - Participants: self-selected
- Developing New Evaluation Methodology
  - Estimating energy savings attributable to broad marketing, education and outreach efforts
- Completed Market Segmentation project
- Implemented Perception Tracker Tool
  - Tracks changes in attitudes, awareness of key programs, etc.

# CEC - Behavioral Research

- Behavioral Science
  - Economic studies (Center for the Study of Energy Markets - UCB)
  - Climate change program (sectoral economic impacts; impacts of climate change on consumer efficiency behavior)
  - Comfort modeling (Center for the Built Environment - UCB)
- Considering new project for PIER: “Advanced Residential Energy and Behavior Research Project”
  - Econometric and sociological behavioral analysis of energy use and demand in the residential sector
  - Modeling of energy use and demand using weather, building characteristics, HVAC systems, appliances, & behavioral variables
- Research on sustainable/ energy smart communities, land use planning, and other decision support tools
- PIER: technology design and development
  - Coupled with behavioral research.

# Behavior, Energy and Climate Change (BECC) Conference

- “Focused on understanding the behavior and decision-making of individuals and organizations and using that knowledge to accelerate our transition to an energy-efficient and low-carbon future”
- Co-sponsors: ACEEE, CIEE, PIEE
- Second conference held Nov. 16-19, 2008
- First conference:
  - “Behavior, Energy, and Climate Change: Policy Directions, Program Innovations and Research Paths,” by Karen Ehrhardt-Martinez (ACEEE), Nov. 2008.

[http://piee.stanford.edu/cgi-bin/htm/Behavior/2008\\_becc\\_conference\\_online\\_program.php](http://piee.stanford.edu/cgi-bin/htm/Behavior/2008_becc_conference_online_program.php)

[http://piee.stanford.edu/cgi-bin/htm/Behavior/foundational\\_readings.php?ref=nav4](http://piee.stanford.edu/cgi-bin/htm/Behavior/foundational_readings.php?ref=nav4)

# Time for Questions

