



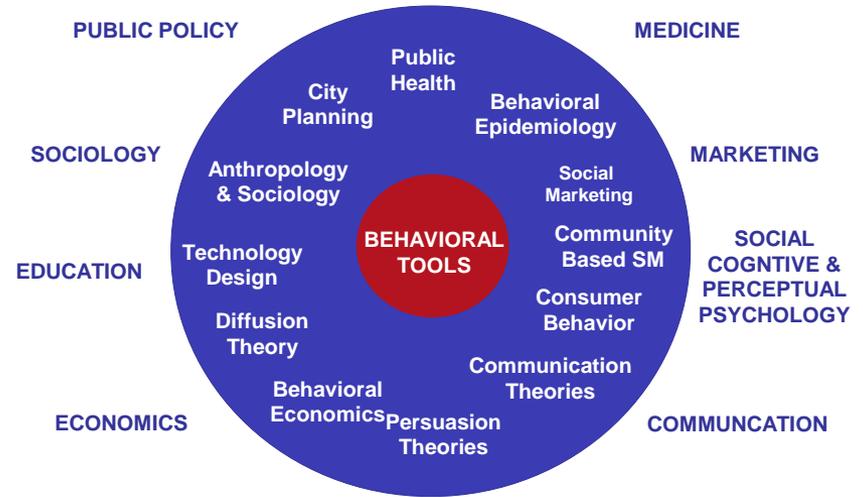
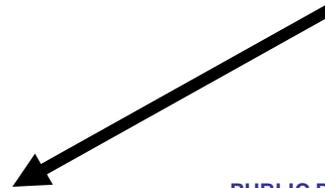
# Energy Behavior

Carrie Armel

Precourt Energy Efficiency Center, Stanford



# Behavioral Tools



Energy saving behaviors or actions:

1. Purchase and use EE technology
2. Eliminate unintended waste
3. Shift settings and install controls
4. Repair items or perform maintenance
5. Adjust patterns of use and habits
6. Etc.



# Stanford Sensor and Energy Behavior Initiative

Carrie Armel<sup>1</sup>, Byron Reeves<sup>2</sup>

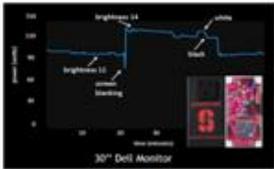
<sup>1</sup>Precourt Center for Energy Efficiency, <sup>2</sup>Department of Communication  
Stanford University

<http://peec.stanford.edu/energybehavior>



Stanford Energy Behavior Initiative 

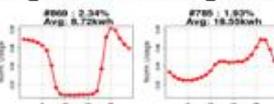
## 1. Communications network



## 2. Stanford platform

Platform	Function	Integration	Impact
Stanford Energy Dashboard	Real-time energy usage monitoring	Integration with smart meters and sensors	Increased awareness of energy consumption
Stanford Energy Behavior Initiative (SEBI)	Behavioral interventions and incentives	Integration with social media and mobile apps	Targeted energy-saving messages
Stanford Energy Modeling	Simulation of energy usage patterns	Integration with building information systems (BIM)	Optimization of energy systems

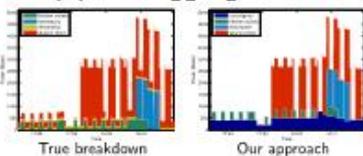
## 3. Segmentation algorithms



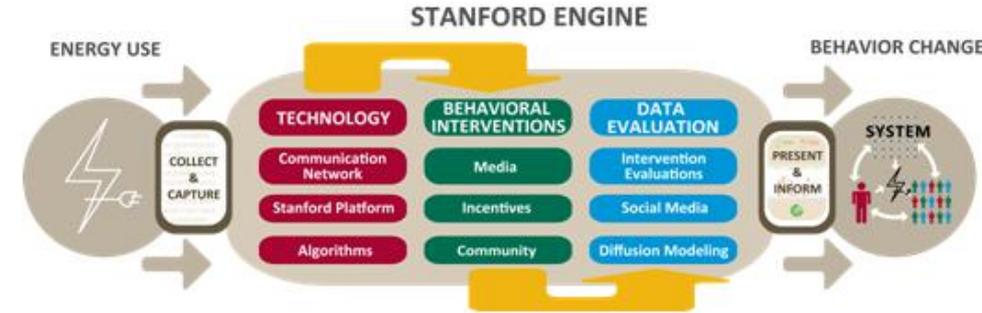
## 4. Learning & automation



## 5,6,7. Disaggregation



## 8,9. Target behaviors



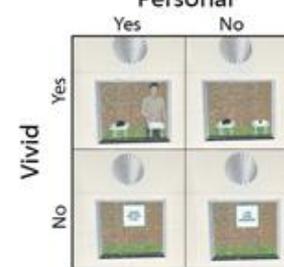
## 10. Social norms



## 11. Online game



## 12. Immersive reality Personal



## 13. Facebook apps



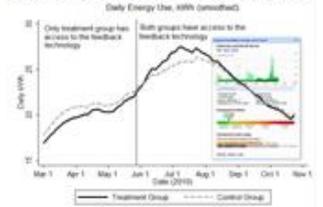
## 14. Appliance calculator



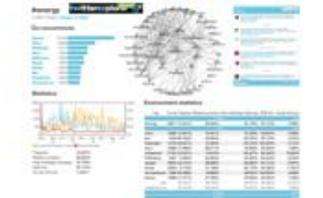
## 15. Raffle incentive



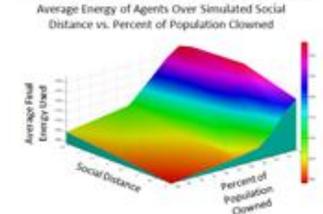
## 17. Google powermeter evaluation



## 18. Twitter explorer



## 19. Diffusion modeling



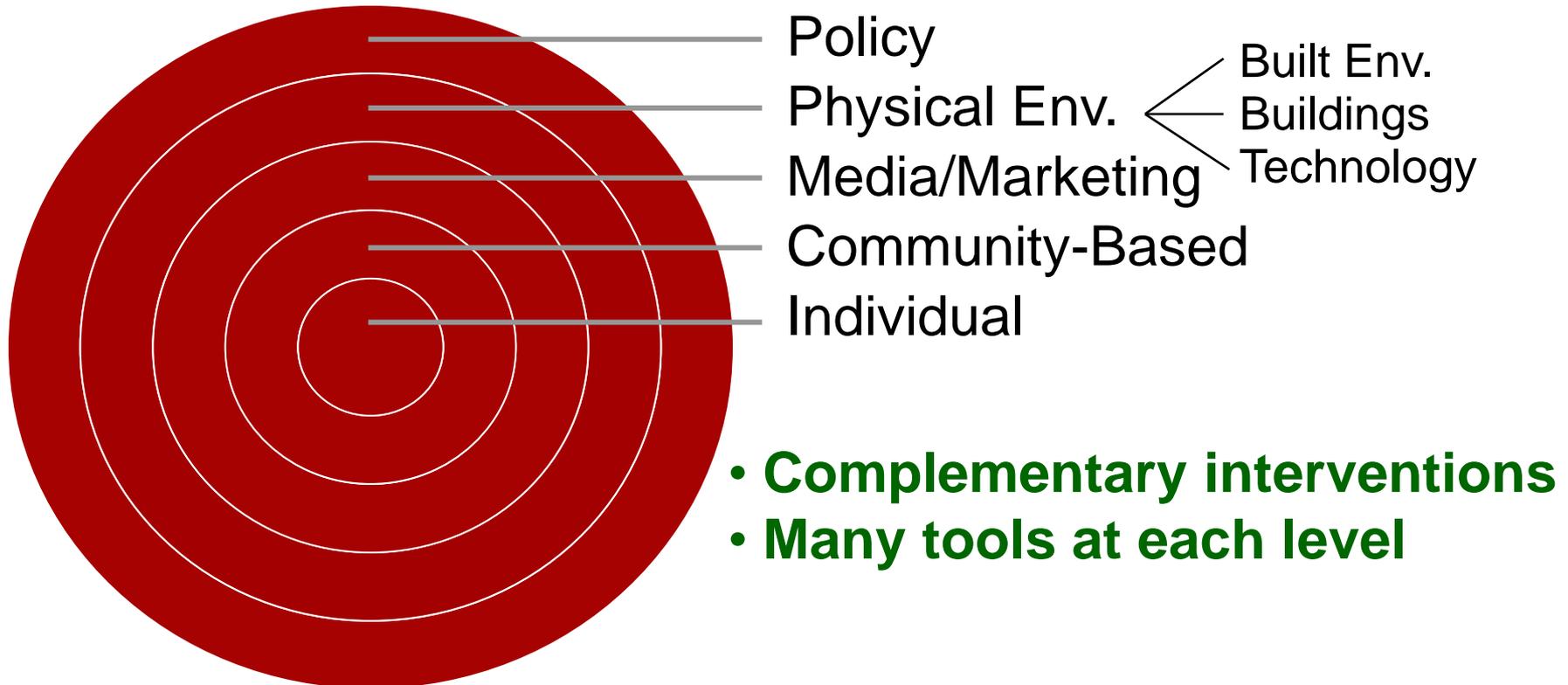
## 16. Community program



## 20. Integrative project

# Behavioral Interventions

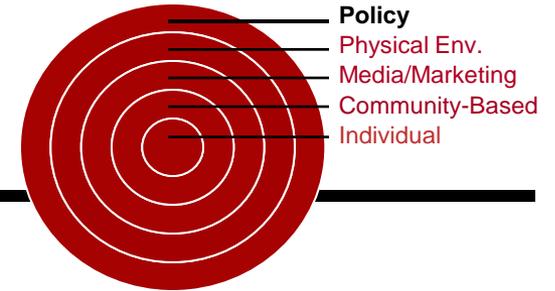
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*Based on the socio-ecological  
model of health behavior*

For a annotated PPT and detailed video presentation, see:  
<http://peec.stanford.edu/behavior/library.php> (last link)  
<http://med.stanford.edu/media/video/medcast-armel-big.htm>

# Policy



1. Default options / “Opt-out” instead of “Opt-in”
  - Organ donation, 401K, car attributes, refrigerators
  - Green electricity or carbon credits

Picherta et al. (In Press). J of Env Psy.

2. Foot in door, small commitment

**STANFORD UNIVERSITY** A Department of Energy ARPA-E Project

## Appliance Calculator

The Appliance Calculator helps you:

- Find out how much your current refrigerator is costing in electricity use.
- Determine when it makes sense to upgrade.
- Shop for a new refrigerator based on electricity consumption and other features.

Follow the instructions below—note that your Results will get updated anytime you change a dropdown selection.

### Electricity Saving Refrigerator Calculator

**Step 1: Describe Your Current Refrigerator**

State:

Refrigerator Type:

Approx. Model Year:

Size:

Icemaker:

EnergyStar:

Please Select Above Options

**Step 2: Describe Your Desired New Refrigerator**

Price Range:

Brand:

Refrigerator Type:

Color:

Size:

Icemaker:

EnergyStar:

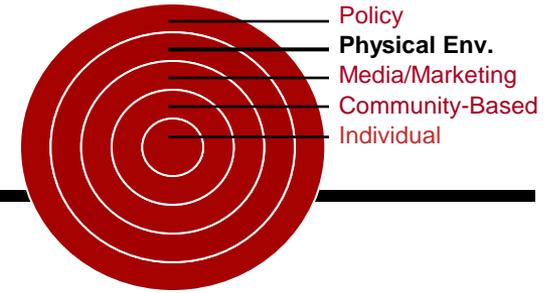
Electricity Consumption(Select Min & Max kWh/year) : 0 - 1500

Reset

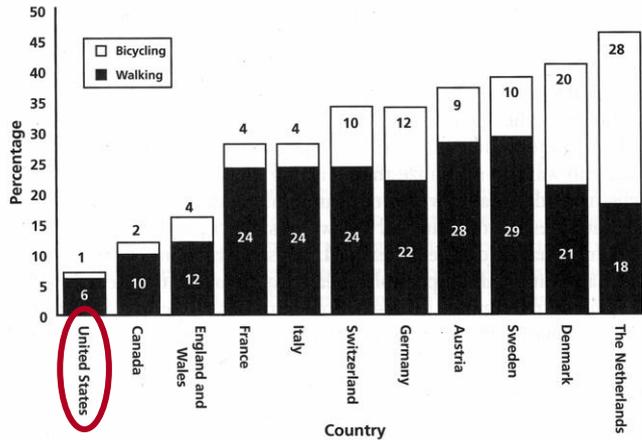
#### Your New Refrigerator Search Results

Save/Compare	New Refrigerators	Price	Annual Electricity Use	Lifetime Electricity Cost	Annual Cost Savings for New Vs Old
<input type="checkbox"/>	 LG 22.4 cu. ft. Bottom Freezer LDC22720S <a href="#">See at Sears</a>	\$1,100	465 kWh	\$633	0.00
<input type="checkbox"/>	 LG 22.4 cu. ft. Bottom Freezer LDC22720S <a href="#">See at Sears</a>	\$1,400	465 kWh	\$633	0.00
<input type="checkbox"/>	 Whirlpool 17.0 cu. ft. Top Freezer WPTXNGF White <a href="#">See at Sears</a>	\$680	470 kWh	\$639	0.00

# Built Environment



■ **FIGURE 5-4** Proportion of trips in urban areas made by walking and bicycling in North America and Europe, 1995



**Model City:  
Muenster, Germany**

- 35% of all vehicle trips made by bike
- Popul.: 300,000

SOURCE: J. Pucher and L. Dijkstra, "Promoting Safe Walking and Cycling to Improve Public Health: Lessons from the Netherlands and Germany," *American Journal of Public Health* 2003;93(9):1509-16.

**Infrastructure**



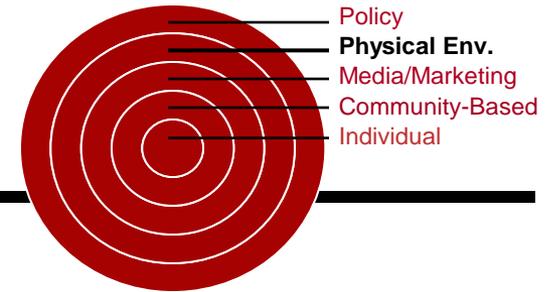
**Safety**



**Promotion**



# Technology



## BEHAVIOR IMPACTS

- Purchasing
- Installation
- Proper & persistent use

## PROGRAMMABLE THERMOSTATS

- 70% of homeowners find them too difficult to operate and lose out on energy savings benefits (Honeywell, 2004)
- Designed from engineer's perspective of what's easiest to implement
- Should be designed from user's perspective of what's easiest to use

## ELEMENTS OF DESIGN

- Learnability
- Usability
- Motivation, incl. identity signaling
- Aesthetics (Decision Analyst, 2007)

U.S. Patent Nov. 10, 1981 Sheet 7 of 44 4,300,199

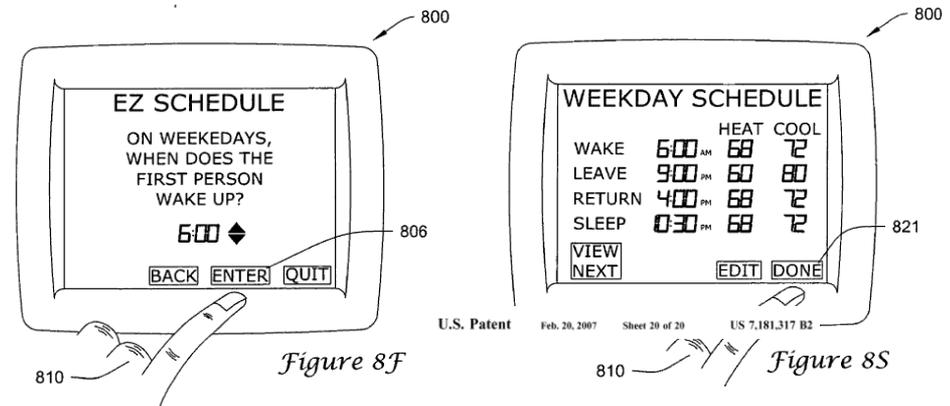
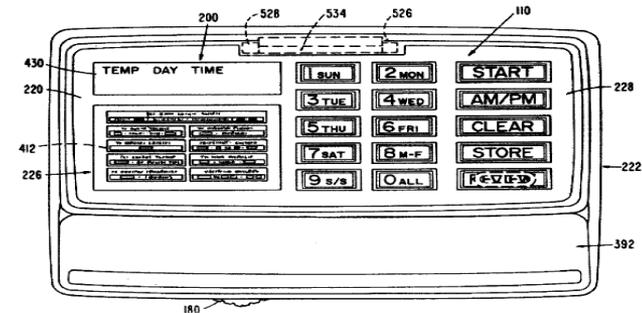
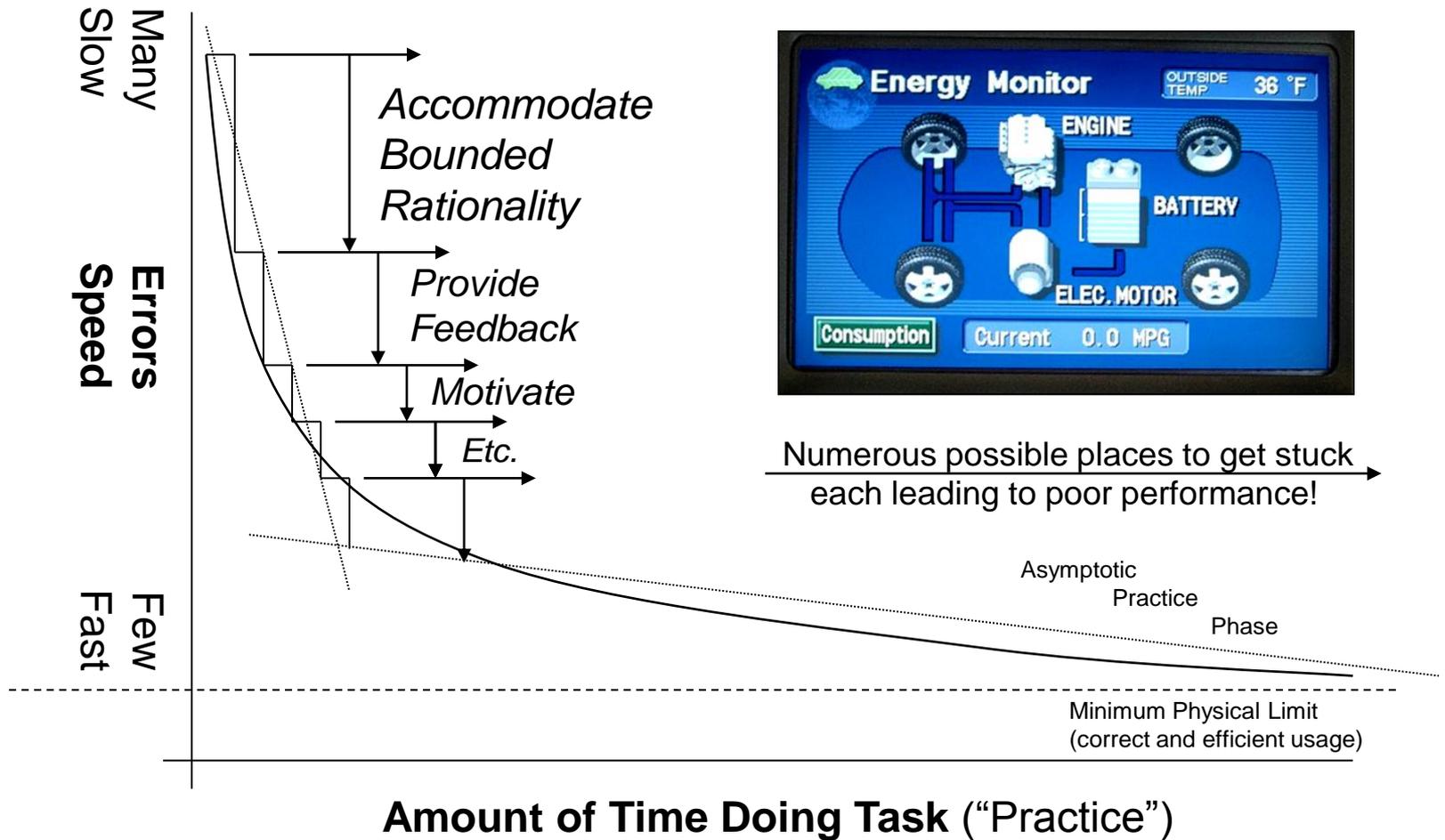


Figure 8F

Figure 8S

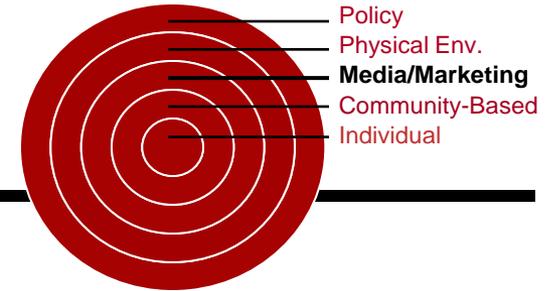
Tom Kelley. (2001). The Art of Innovation.  
BJ Fogg BJ. (2003). Persuasive Technology.  
Don Norman. (1998). The Design of Everyday Things.  
Francis Durso (ed.). (1999). The Handbook of Applied Cognition.

# How the User Thinks



Based on Rosenbloom & Newell

# Media/Marketing



## Entertainment Education

Serial dramas are extremely effective for positive societal change

How do they work?

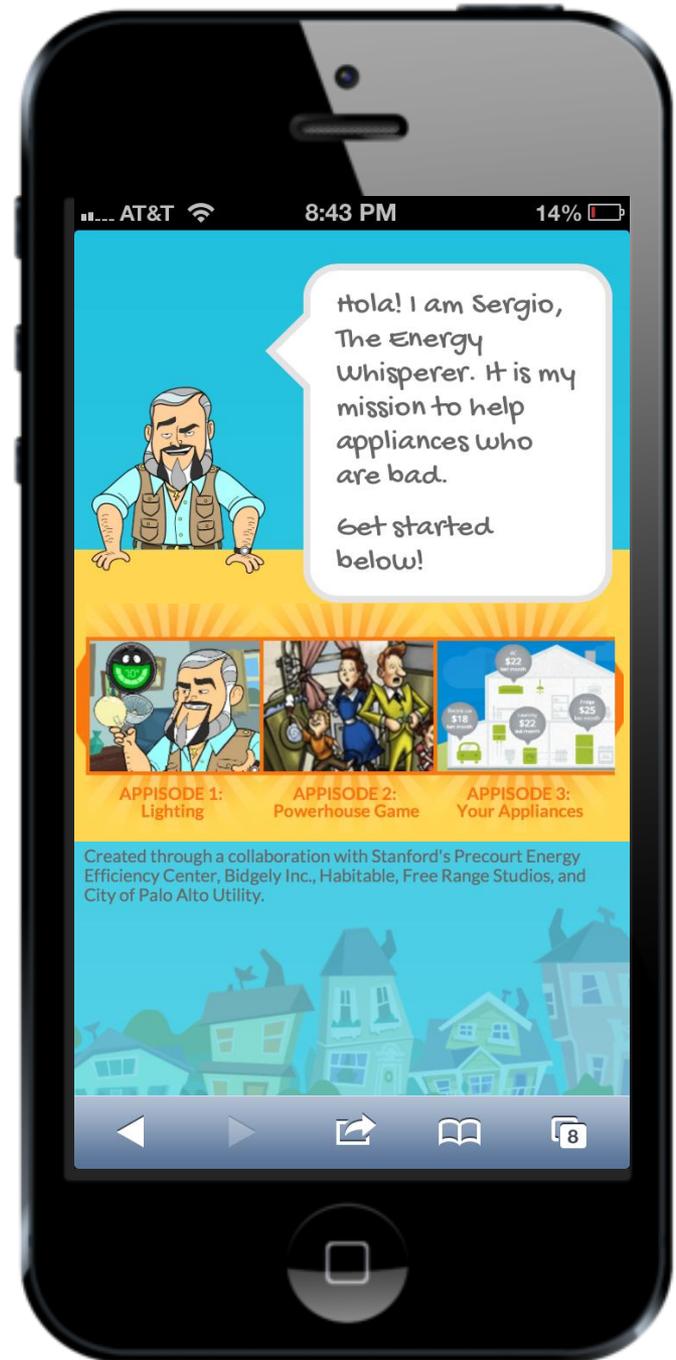
1. 2/3 Entertainment

2. Modeling

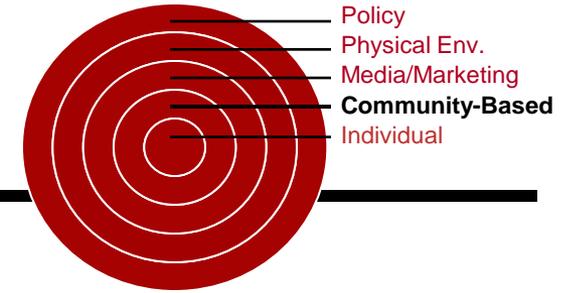
- Instruct
- Create norms
- Build self-efficacy (confidence)
- Demonstrate expected outcomes
  - Pos., Neg., & transitional chars.



# Integrative Project



# Community-Based

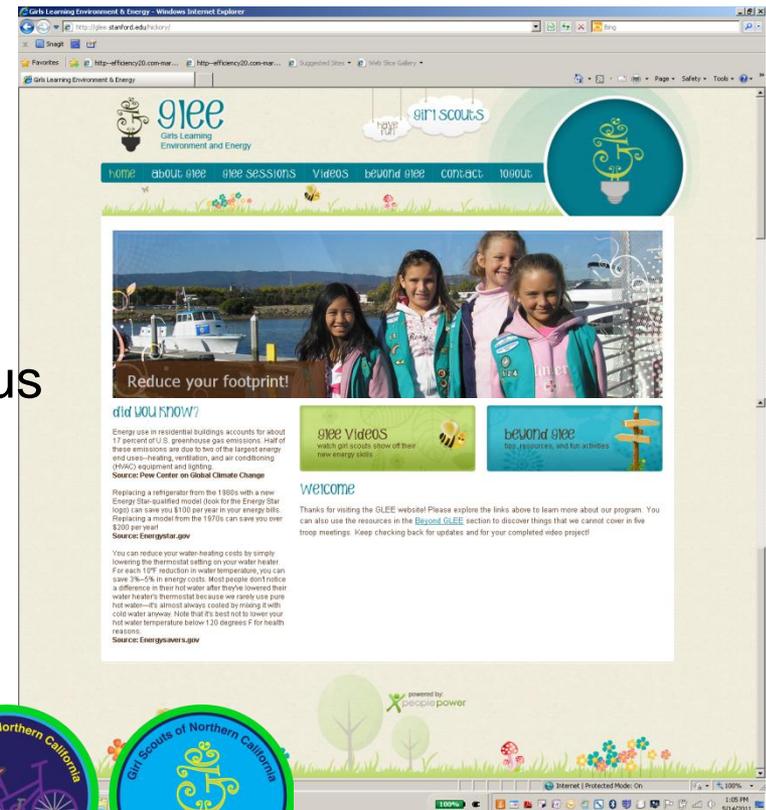


## SUCCESSFUL PROGRAMS

- Hood River Project
- EnergyMark
- Gore's 1000 soldiers
- Interfaith Power and Light

## ADVANTAGES

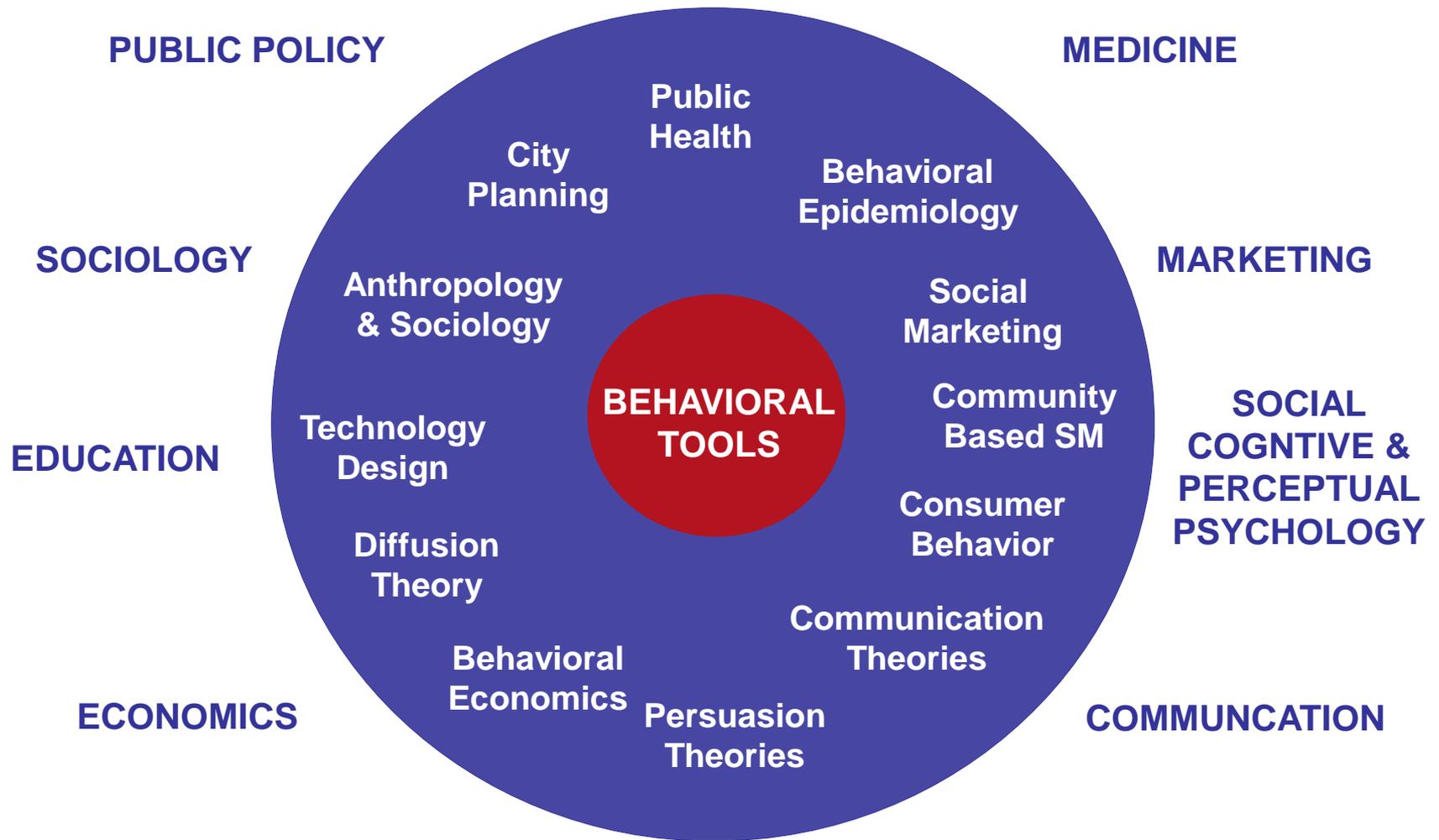
- Messages feel personal, not anonymous
- Caters information for people like me
- Enhanced learning - Direct experience
- Additional tools
  - Goals, Feedback, Barriers, Practice
  - Group feedback & competitions
  - Commitment



Can we expedite the development  
of successful interventions?

# Behavioral Sciences

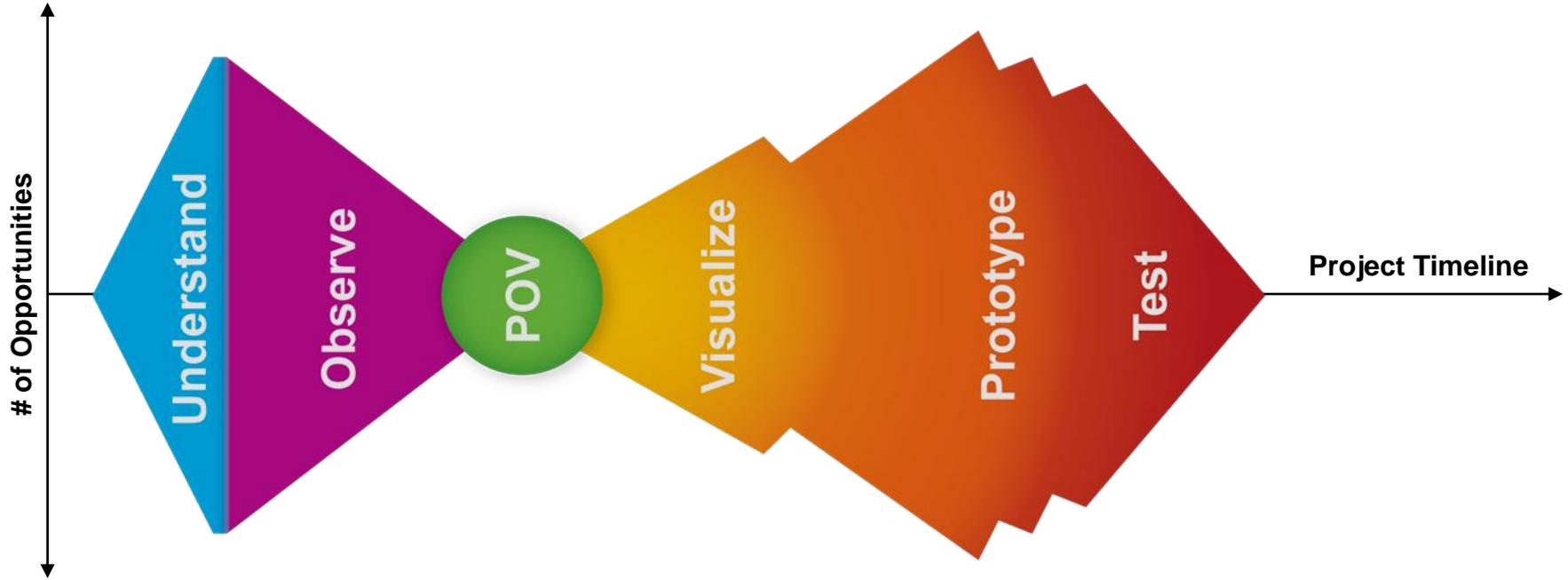
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<http://piee.stanford.edu/behavior>

# Design

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# Diffusion of Innovation

## Characteristics of People

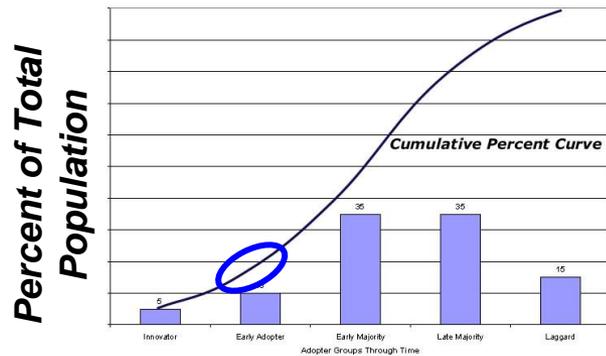
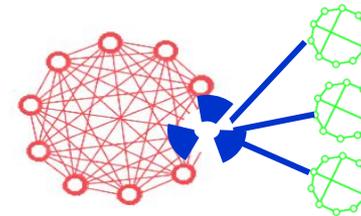
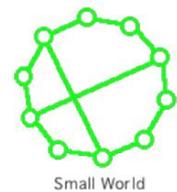


Figure 1. Percent Distribution of Diffusion Theory Adopter Groups

### Adopter Groups Through Time

## Characteristics of Networks



## Characteristics of Innovations

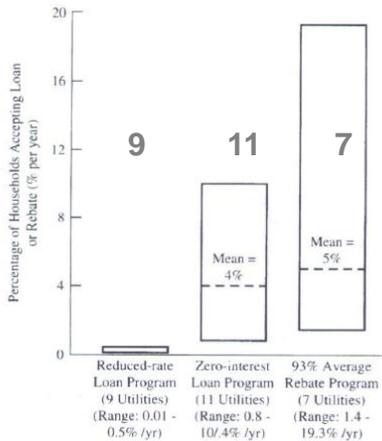
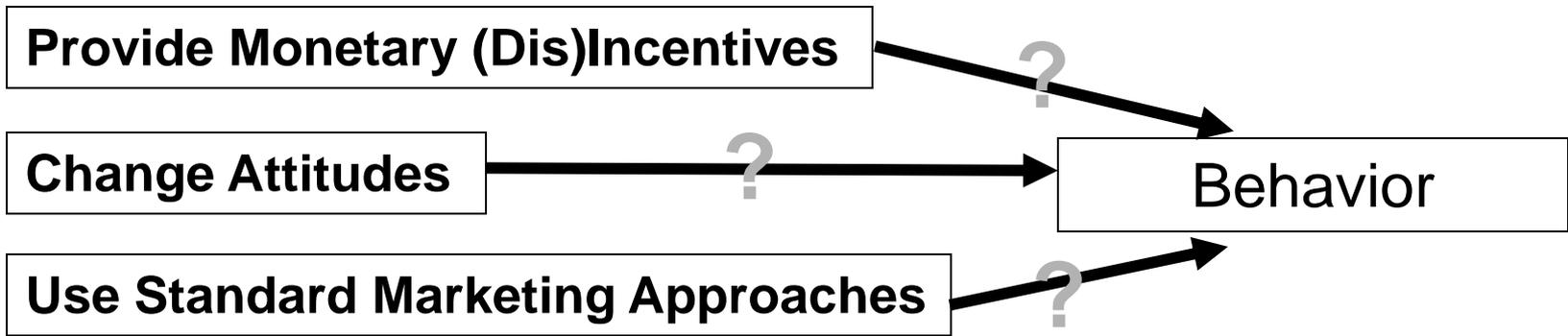
- Simplicity - Is it easy to understand and use?
- Observability - Are the results of using it visible?
- Trialability - Can it be experimented with?
- Compatibility - Is it consistent with existing values/needs?
- Relative Advantage - Is it better than the prior thing?

Everett Rogers. (2003). Diffusion of Innovation.  
Malcolm Gladwell.  
Bass Diffusion Model.  
Huggy Rao. Marc Granovetter.  
Bernardo Huberman.

It's a **design** failure,  
not a **people** failure.

**ADDITIONAL SLIDES**

# Typical Approaches



## MONEY

- Other barriers are not addressed
- Incentives are expensive, fees unpopular
- Small incentives not very motivating
- Behavior reverts back or even boomerangs



## ATTITUDES

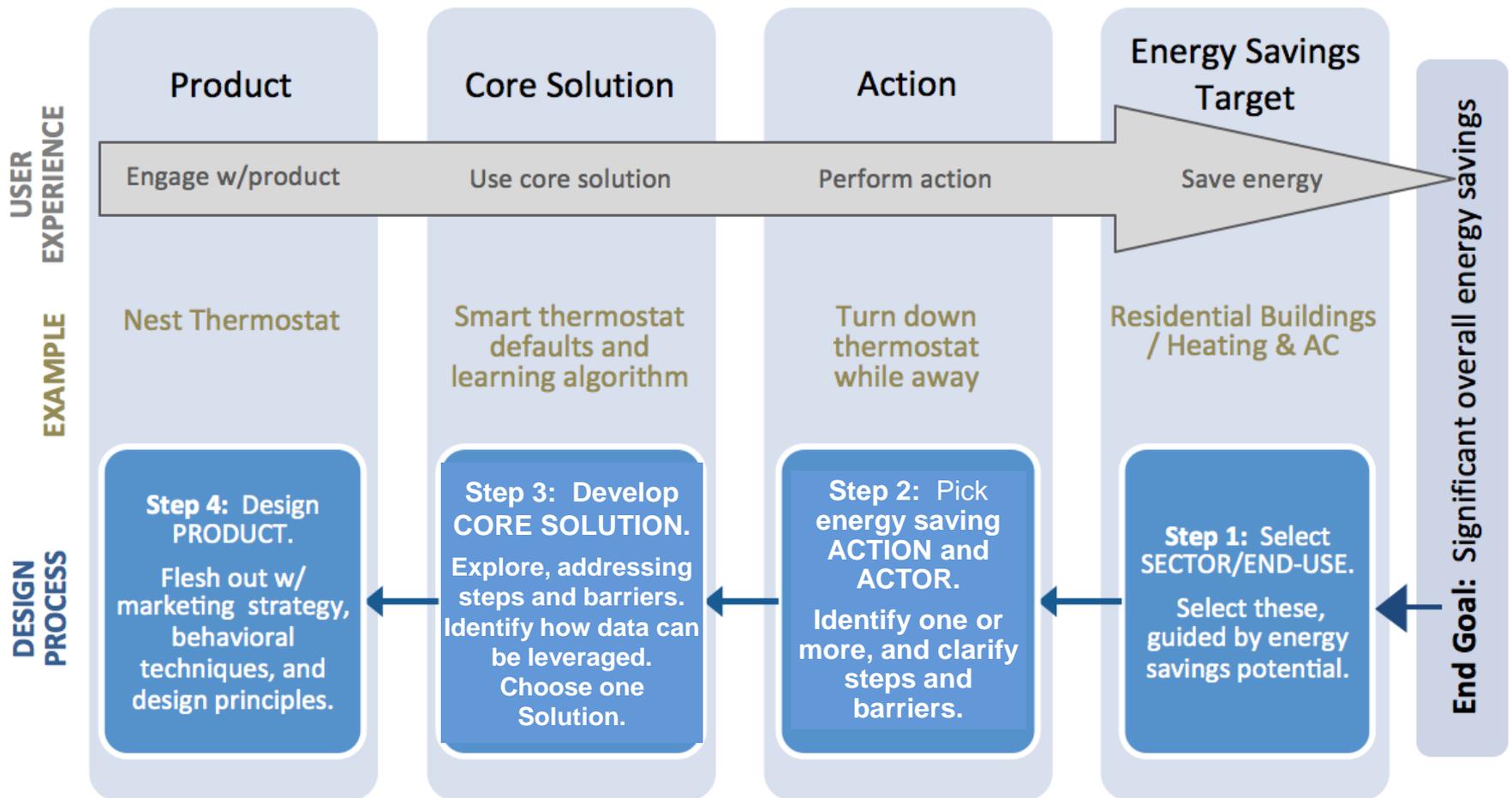
Metareviews as early as the 1960s have shown that correlations between attitudes and behavior are very weak, often near zero (e.g., Wicker, 1969)

## STANDARD MARKETING

- Small changes in market share are sufficient.
  - Target easy behaviors: switch to a new brand or indulge.
  - Messages based primarily on creative inspiration.
- Product, price, placement, & promotion. concepts are still useful though.

Figure 2. Effectiveness of three home energy conservation programs. Source: Stern et al. (1986).

# Developing an Intervention: Work Backwards, Establish Constraints



Intervention dev't materials: <http://peec.stanford.edu/behavior/library.php>  
[http://peec.stanford.edu/energybehavior/events\\_datajam.php](http://peec.stanford.edu/energybehavior/events_datajam.php)

# Identify Target Action(s)

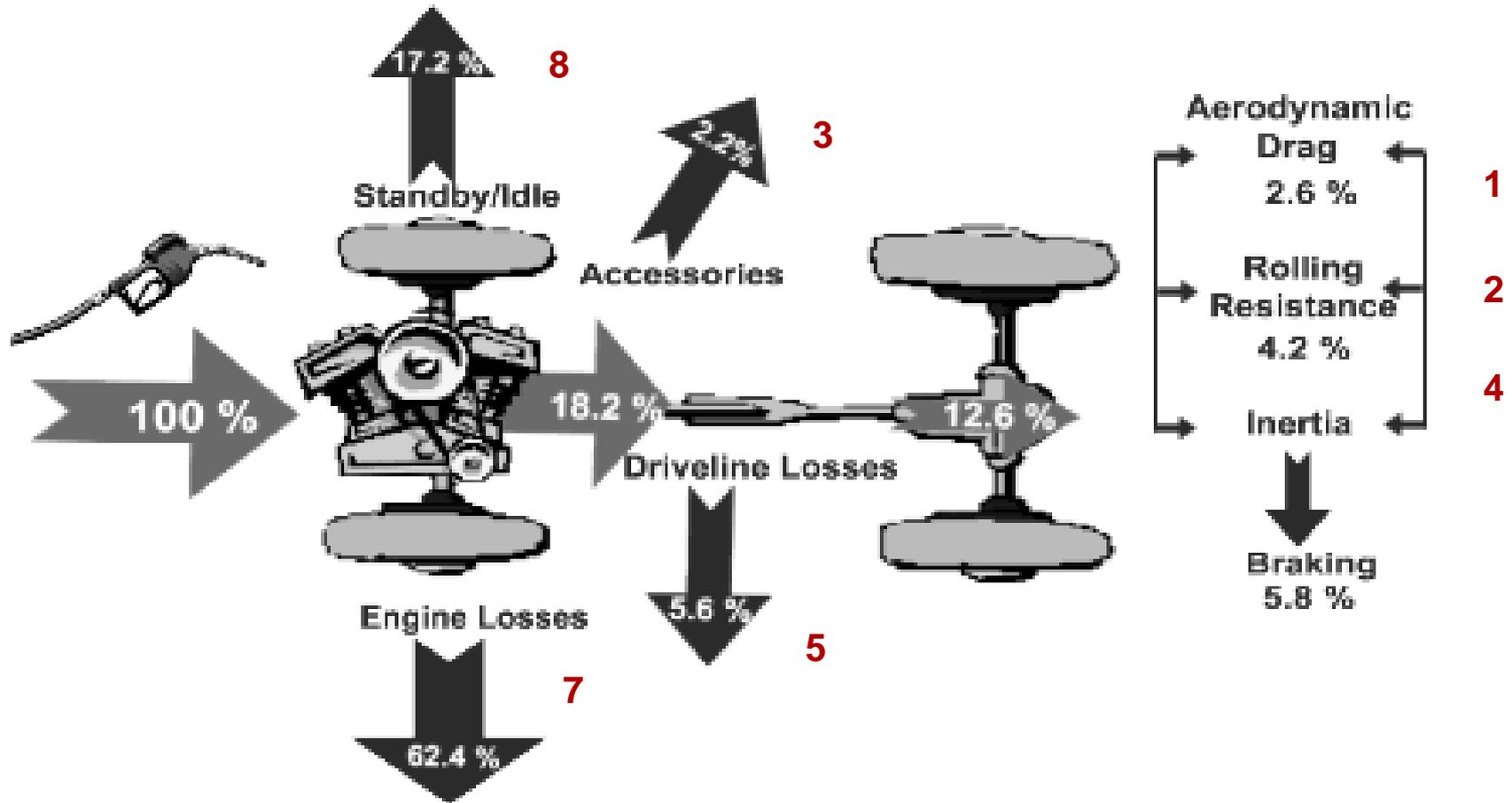
Which are worth pursuing?

1. What are their energy saving impacts?
2. How malleable are they? (How much will people be able to change?)

## Examples

- Time shift / avoid congestion
- Rideshare
- Mode shift (to public or non-motorized transit)
- Identify parking spaces with less/no circling
- Work from home (?), live close to work and stores
- Car choice (hybrid EV, etc.)
- Driving patterns etc. (e.g., glide, reduce car weight)

# Elaboration of Specific Driving Action(s)



**\*Numbers correspond to descriptions in the notes section of the slide.**

# Help People Execute the Action: Walk Through Steps, Address Barriers

- What are the steps people need to do to execute the action? How will you guide them through these?
- People gravitate to actions with high benefits and few barriers.
- Change behavior by altering the balance of benefits and barriers.

	Existing Behavior: Drive to work	New Behavior: Bike to work
Benefits	Time	Add lights to bike paths
Barriers	Add speed bumps	Safety

## Internal barriers

- Unaware of the activity, its benefits, or how to perform the activity
- **Perceived** difficulty, inconvenience, unpleasantness
- Myths & cultural habits

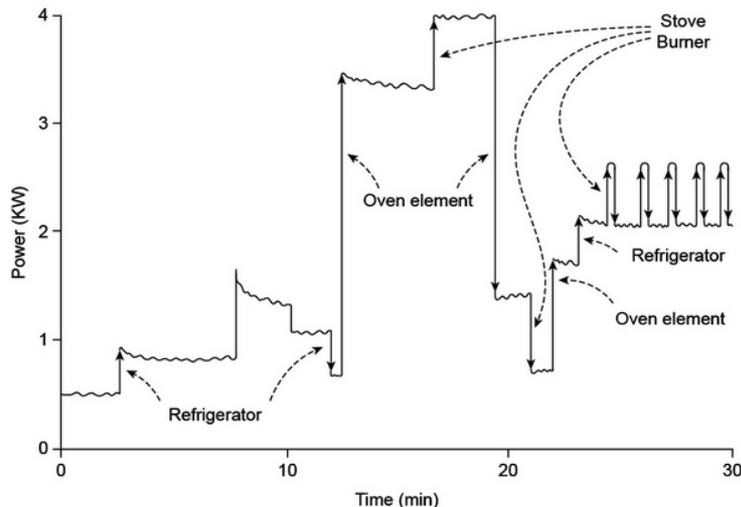
## External barriers

- Actual difficulty, inconvenience...
- Infrastructure, technology

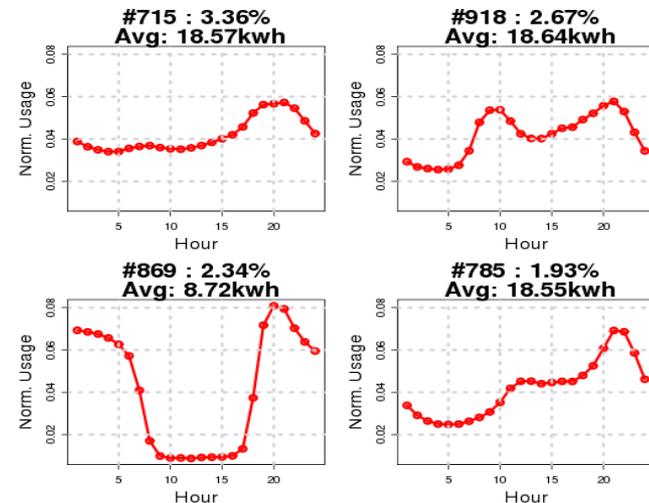
	<b>Existing Behavior: Drive to work</b>	<b>New Behavior: Carpool</b>	<b>New Behavior: Public transit</b>	<b>New Behavior: Bike</b>
<b>Benefits</b>	<ul style="list-style-type: none"> <li>-Short travel time</li> <li>-Delayed &amp; hidden costs</li> <li>-Time &amp; route flexibility</li> <li>-Large cargo capacity</li> <li>-Privacy</li> <li>-Enjoyment of driving</li> <li>-Prestige</li> </ul>	<ul style="list-style-type: none"> <li>-<i>School/work sets up program and incentives</i></li> <li>-<i>Matching service</i></li> <li>-<i>Cheaper parking</i></li> <li>-<i>Closer parking</i></li> <li>-<i>Carpool lanes</i></li> <li>-<i>Savings in gas &amp; wear/tear</i></li> <li>-<i>Time savings for parents</i></li> <li>-<i>Get to know their children's friends etc.</i></li> <li>-<i>Networking with neighbors</i></li> </ul>	<ul style="list-style-type: none"> <li>-Time to read</li> <li>-Making friends</li> <li>-<i>Guaranteed emergency ride home</i></li> <li>-<i>Advertise routes, frequency, reliability guarantee</i></li> <li>-<i>Additional shuttle service and loaner bikes; bike racks on buses</i></li> <li>-<i>Clean, comfortable, warm transport</i></li> <li>-<i>Reduced or free group rates</i></li> </ul>	<ul style="list-style-type: none"> <li>-Exercise</li> <li>-Time outside</li> <li>-De-stress, time to self</li> <li>-Parking closer to destination</li> <li>-<i>Bike &amp; clothes lockers/cages</i></li> <li>-<i>Showers</i></li> <li>-<i>Convenient services for installing panniers/baskets</i></li> <li>-<i>Sell wind/rain gear</i></li> <li>-<i>Safe, convenient bike routes</i></li> <li>-<i>Other incentives (e.g., prizes)</i></li> </ul>
<b>Barriers</b>	<ul style="list-style-type: none"> <li>-Traffic congestion</li> <li>-Gas costs</li> <li>-Maintenance costs</li> <li>-Air pollution</li> <li>-<i>Parking distant from work; traffic slowing</i></li> <li>-<i>Limit # of permits</i></li> <li>-<i>Parking more costly</i></li> <li>-<i>Commute Calculator</i></li> </ul>	<ul style="list-style-type: none"> <li>-Time &amp; effort of setting it up</li> <li>-Belief others won't want to</li> <li>-Don't know who to carpool with</li> <li>-Different schedules; individuals running late</li> </ul>	<ul style="list-style-type: none"> <li>-Emergency (sick child)</li> <li>-Limited route &amp; time selection</li> <li>-Unpredictability</li> <li>-Long travel/walking time</li> <li>-Discomfort, noise, dirt</li> <li>-Immediate costs</li> <li>-Small cargo capacity</li> <li>-Weather</li> <li>-Surly personnel, passengers</li> </ul>	<ul style="list-style-type: none"> <li>-Bike security</li> <li>-Work clothes</li> <li>-Small cargo capacity</li> <li>-Weather</li> <li>-Safety</li> </ul>

# Identify Existing Data Sets, and Analytics that Can Help Address Barriers...

1. Public transit APIs
2. OMDbII data (e.g., Progressive Insurance)
3. FastTrak data... (toll, university or commercial campus sensors)
4. Parking meter sensors
5. Bus/fleet location tracking sensor data
6. DMV records
7. Other? E.g., car manufacturer, car lot, car share company data



Kolter and numerous others



Rajagopal and Fischer

# Examples of Existing Work

- Balaji Prabhakar – Insinc, etc. <https://insinc.sg/>
- Streetline <http://www.streetline.com/>
- Sidecar & other ride sharing apps <https://www.side.cr/>
- Google etc. buses in SF?
- EV Virtual Test Drive App  
<http://www.youtube.com/watch?v=u2SNMsJFYaE>

# Transport Brainstorm

From DOE & Stanford Steyer-Taylor Center 'Data Jam'

NECESSARY:

- \* OPTIMAL CAR CHOICE ENGINE + social, EPA + GREEN BUTTON + OBO + BTS + ...
- \* ANTICIPATE INFRASTRUCTURE PURCHASING DECISIONS (SCHOOL, JOB, HOUSE, CAR) LINKED IN - ziplo
- \* DRIVING + PARKING recommendations
- \* EV-SCORE ... are you / your neighborhood ready for EV / alt fuel.
- \* FINANCING + OSD / social cash for clunkers / kickstart
- \* ALT TRANSPORT RECOMMENDATION ENGINE (google bike / walk)
- \* FLYING VS VIDEOCONFERENCING
- \* SAFETY = VMT + Car performance - appeal to more

WHIMSY - "COOLING POOLING TO SCHOOLING"

- "DATE WHILE YOU WAIT" ... in traffic → pool
- "BEER NEAR HERE"
- "EFFICIENCY RADIO - soothing driving music"
- "OPT IN GUILTOMETER / GAMING ENGINE."

\* ACCELERATE "GREEN-BUTTON" (BLACK BUTTON) DATA COLLECTION FOR PERSONAL VMT

\* CONTEXTUALIZE DRIVING ENERGY AMONGST TOTAL PERSONAL ENERGY USE.



DRIVING

EAT

WALK TO SCHOOL

MSU

RESEARCH

TRAVEL

STAY

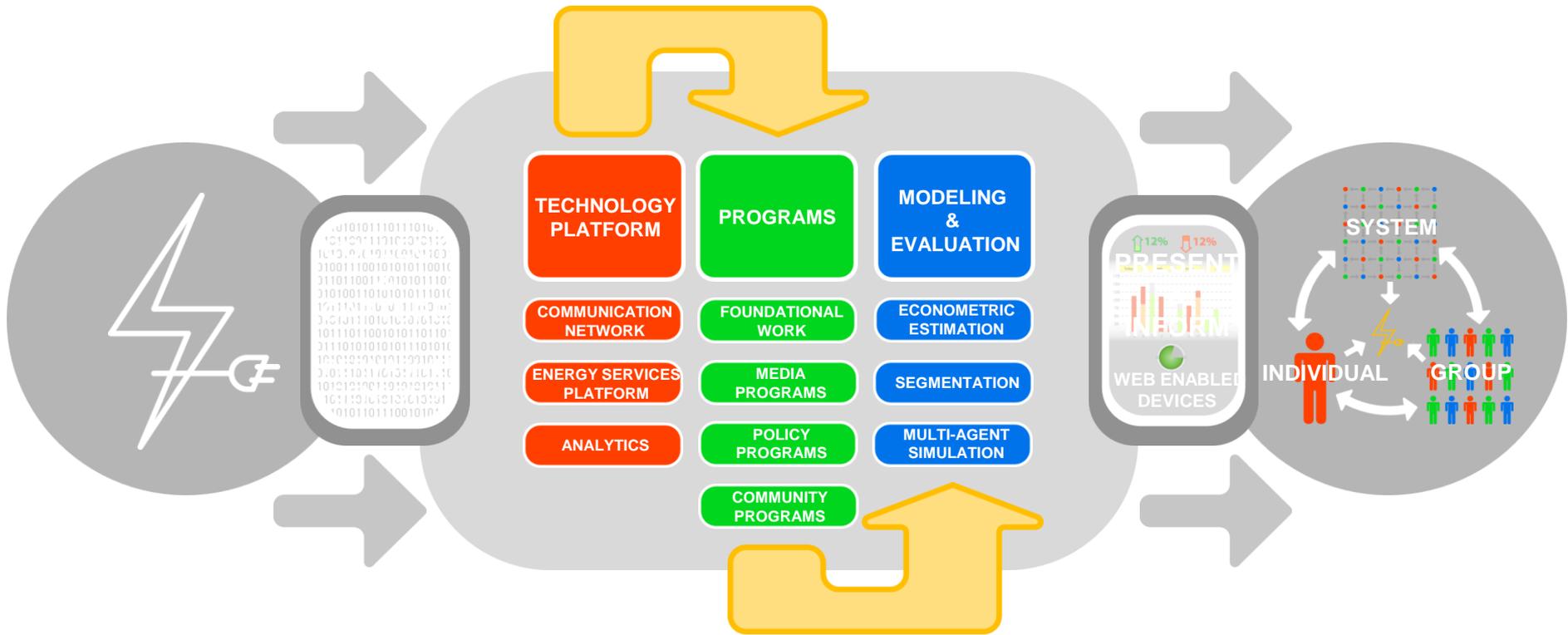
WORK

LEISURE

SHOPPING

\*Brainstorm group led by Saul Griffith of Otherlabs

**SOME ADDITIONAL  
STANFORD ARPA-E  
PROJECTS**





Click on a project to learn more or join. Have fun!

## Welcome to Stanford's Energy Saving Projects

### Power Down

Track and compare your energy use, and get recommendations for savings.



### Power House

Game play to reduce energy use.



### Visergy

Seeing your energy impact can be illuminating.



### Change Labs

Facebook apps to save energy.



### INSINC

Incentive Game to save energy.



### Energy Calculator

Easily find energy and cost savings on any appliance.



### GLEE

Work with your troop and family to reduce energy use.



MEDIA

POLICY

COMMUNITY



**LOWE'S** Let's Build Something Together

Dashboard Games Forum Neighborhood Leaderboards Friends Help Logout [f Connect](#)

Welcome to the Dashboard  
rees@stanford.edu  
[View/Edit Profile Details](#)

**Score** 23569  
What is this?

**PLAY THE GAME**  
Launch Power House  
**Highest Game Score** 16069  
How do I play?

**USE THOSE UPGRADE BUCKS**  
Launch Upgrade Phase  
**Upgrade Bucks** 528  
What is this?

**CHALLENGE A FRIEND**  
Challenge a Friend to an Energy Duel  
What is this?

**EARN R-LEA BONUS POINTS**  
Launch R-LEA Challenges  
**R-LEA Bonus Points** 7500  
What is this?

**BUY WITH CARBON OFFSETS**  
Launch Market Place  
**Carbon Offsets** 490  
What is this?

**ACHIEVEMENTS** 12/100

**Power HOUSE**  
Saving the planet, one game at a time

What's happening in Power House [Show](#)  
What's Happening in Your House  
View: Home Energy Use **Game Tachometer** Table View **SMART METERING ON**

Your Home's Real World Energy Consumption

Monday, August 23, 2010 (Yesterday)  
You used 4.90% less electricity yesterday than your daily average. That earns you a 250 kW bonus in the Game's Electricity Monitor! See your Game Tachometer for details.

**Real-Life Energy Action Challenges** [Show](#)  
MarketPlace [Show](#)

1718  
-0.30

Four player avatars with progress bars:

- Avatar 1: Silhouette, progress bar at ~25%
- Avatar 2: Silhouette, progress bar at ~25%
- Avatar 3: Female character with blonde hair, progress bar at ~25%
- Avatar 4: Silhouette, progress bar at ~25%

# ChangeLabs

PI: Banny Banerjee  
Scale: FaceBook

## Kidogo

**Kidogo**

changeLabs.

Home Portfolio Actions

Welcome back Alexandra!

You are supporting the Young Group. You're on track to contribute: 30/60 kWh

30/60 kWh

Great Job! Motivation etc [Add more actions](#)

Your Weekly Energy Savings: 30 kWh

Your Total Energy Savings: 112 kWh

Your Cause

Who: Young Group  
Where: Masorie Village, Sierra Leone  
What: Purchase stock for food market [more](#)

30/150 total donated

## PowerTower

Stanford changeLabs.

JOHN THOMAS  
Energy Savings: 275 kWh

Team's Lifetime Energy Savings: 31,055 EPs

Your Total Score: 20,112

Team's Available Energy Savings: 3,455 EPs

Opponent

Pledge

Menu

Blocks Remaining: 34

Next Block

Team's Height: 34

Max Height: 55m

# insinc

## insinc

insinc Insinc on Facebook  
Like 1,695

### Incentives for Singapore's Commuters

Use the MRT or LRT and earn cash rewards.  
Travel off-peak and increase your chance of winning.

Watch video

#### Ride

on a train using your transit card\*



#### Earn Credits

for making smart commutes



#### Redeem

credits for cash rewards



Join

Over \$147,100 given to more than 13,000 commuters

Learn More About Insinc

Get on Board!  
Click Here

\*Currently only EZ-Link CEPAS-enabled adult cards are accepted.



# Energy Calc.



## Appliance Calculator

### The Appliance Calculator helps you:

- Find out how much your current refrigerator is costing in electricity use.
- Determine when it makes sense to upgrade.
- Shop for a new refrigerator based on electricity consumption and other features.

Follow the instructions below—note that your Results will get updated anytime you change a dropdown selection.

### Electricity Saving Refrigerator Calculator

#### Step 1: Describe Your Current Refrigerator

State:

Refrigerator Type:

Approx Model Year:

Size:

Icemaker:

EnergyStar:

Please Select Above Options

#### Step 2: Describe Your Desired New Refrigerator

Price Range:

Brand:

Refrigerator Type:

Color:

Size:

Icemaker:

EnergyStar:

Electricity Consumption(Select Min & Max kWh/year) : 0 - 1500



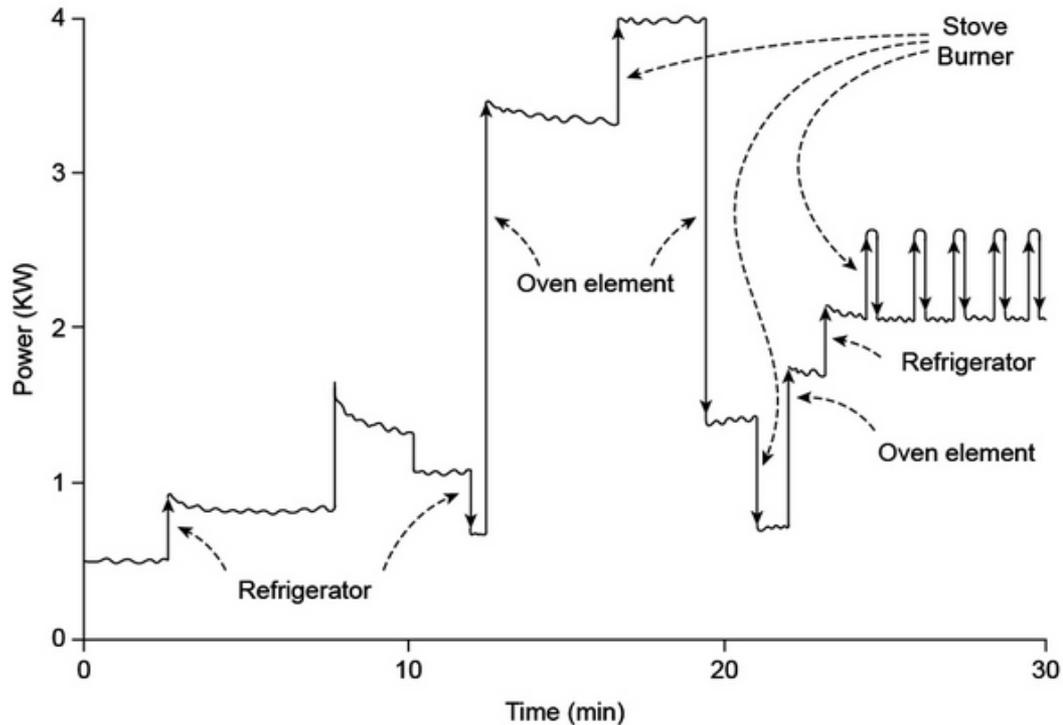
[Reset](#)

#### Your New Refrigerator Search Results

Save/Compare	New Refrigerators	Price <sup>▲</sup>	Annual Electricity Use	Lifetime Electricity Cost	Annual Cost Savings for New Vs Old
<input type="checkbox"/>	 LG 22.4 cu. ft. Bottom Freezer LDC22720S <a href="#">See at Sears</a>	\$1,100	465 kWh	\$633	0.00
	 LG 22.4 cu. ft. Bottom Freezer				

# Energy Disaggregation

Disaggregation allows us to take a whole building (aggregate) energy signal, and separate it into appliance specific data (i.e., plug or end use data). A set of statistical approaches are applied to accomplish this.



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