Stanford ARPA-E Sensor & Behavior Initiative

Carrie Armel
Precourt Energy Efficiency Center, Stanford

We are creating a human-centered system that leverages pervasive sensor and communication technologies to achieve large-scale energy savings

Advanced Research Projects Agency – Energy (ARPA-E)

- Created in 2009, modeled after DARPA
- First FOA: 3,700 applications → 37 awards (1 behavioral)
- Duration: 2-3 years beginning April 1, 2010
- **Cost-Sharing from CEC and Stanford**

Interdisciplinary

- 15 faculty
- 10 departments, 5 schools, 5 centers
- 30+ students
- **Faculty Director: Professor Byron Reeves**
- **Project Director: Carrie Armel**

Human Sciences and Technologies Advanced Research Institute

Precourt Energy Efficiency Center

Design for Change Lab

CIFE Center for Integrated Facility Engineering

Stanford Prevention Research Center

The **Problems**

1. **Billions** for **"smart"** infrastructure
   - Smart meters, home area networks, transportation and other sensors
2. **Energy efficiency** is **difficult**
   - Figuring out what to do and how to do it is difficult and boring

How can we address both of these issues? How can we leverage smart infrastructure to maximize energy savings?

The **Solution**

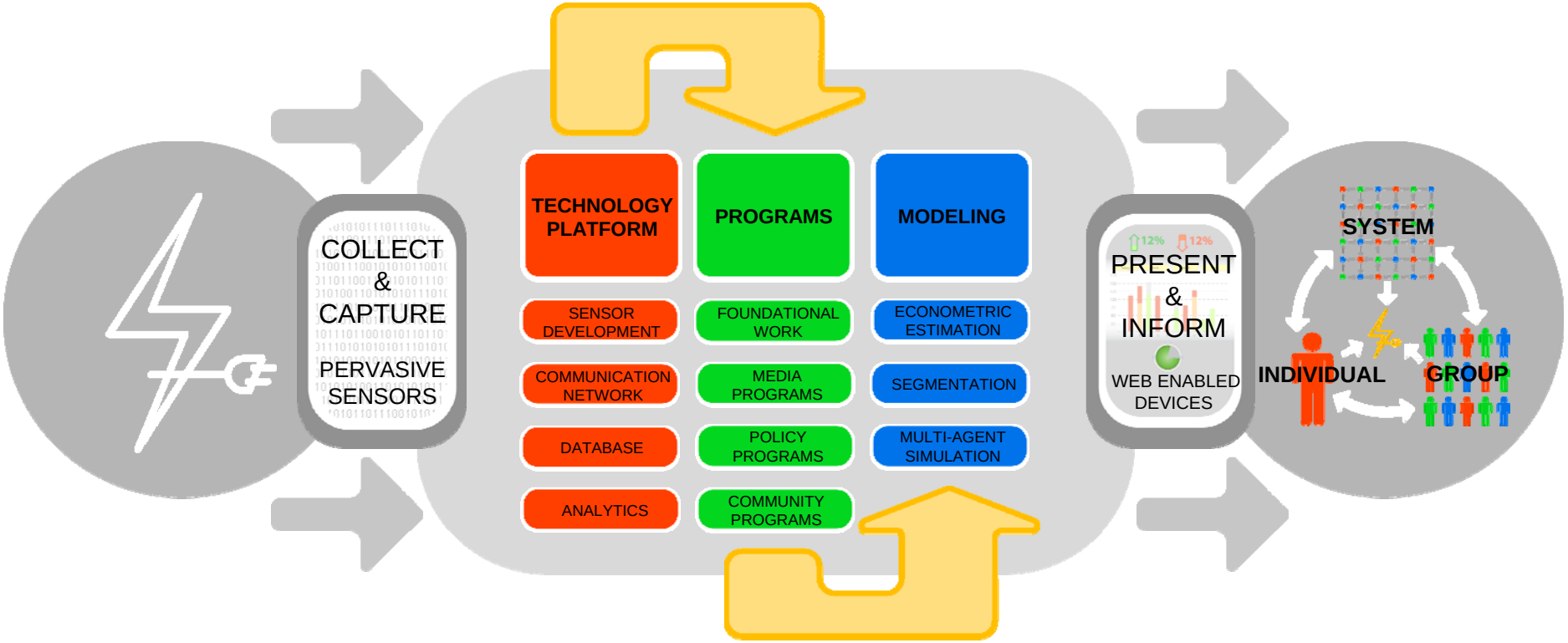
Quantification!

1. **Provide diagnostics / personalized recommendations**

2. **Increase motivation through specialized behavioral techniques**
   - Feedback
   - Incentives
   - Markets
   - Competitions
   - Data visualization

3. **Create the best programs** with unprecedented speed, ease, cost, and scale – via objective evaluation of program energy savings

Transformation Eco-System



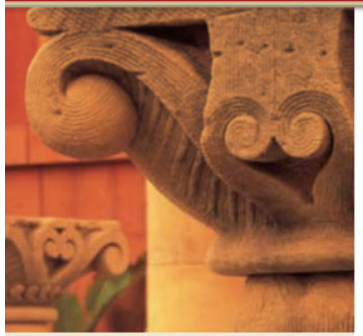
ENERGY USE

STANFORD ENGINE

BEHAVIOR CHANGE

STANFORD UNIVERSITY

A Department of Energy ARPA-E Project



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.

visergy

Change Labs

Facebook apps to save energy.

changeLabs

energy

water

transit

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

Contact Sign Out

JOIN IN! People in your community are working together to save energy!

Progress Meter

How am I doing?
12% Reduction

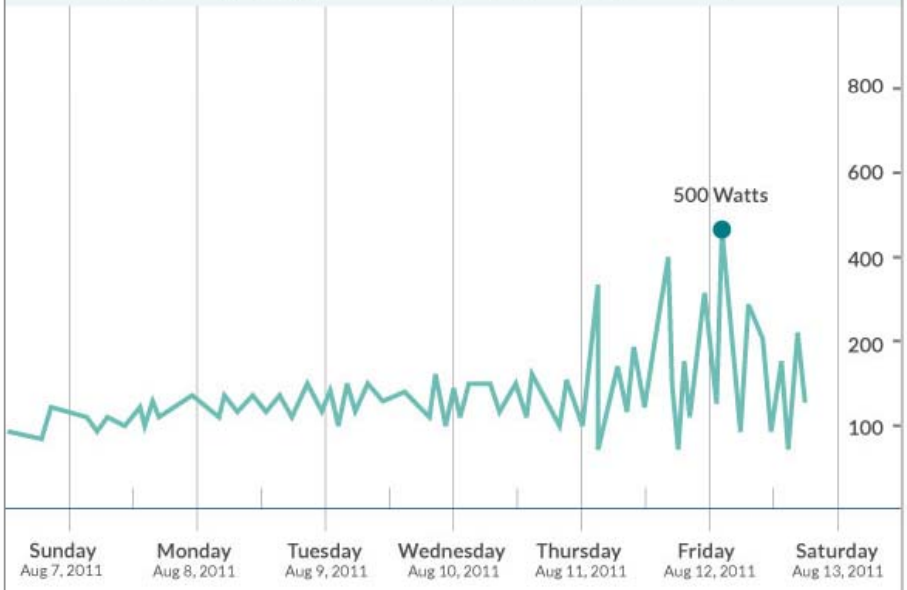
How are others doing?
12% Increase

People in your community are saving energy and you are saving more than most!

Over the last week, your energy use decreased by 12%. Over the same period, other homes' use in your community increased by 12%.

This Week's Energy Usage

Zoom: 1 Day 7 Days 1 Month 1 Year



Energy Tips of the Month:

Off isn't off: Use power strips

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What to do? Use power strips!

- Alis ernamusa quiamus de sinime magnis volorume dignimolorae odi ius, offictem. Nam, quae. Read More
- Erum autectur accumeniet quatemquis porem harchit et doloriae dolorae preptur ma assi blautas magnaturerro modi coreped qui dolores cimpore perum sum eum aut latur sit quae. Read More
- Nulpa doluptiat eum fugia acepudam exer-ehentem eaquibust apidis aut ratum quat excerit, tent. Dit, samus, quaest deliciumquo voluptatur? Read More

Que persperitam reperovidem niminih itamus.

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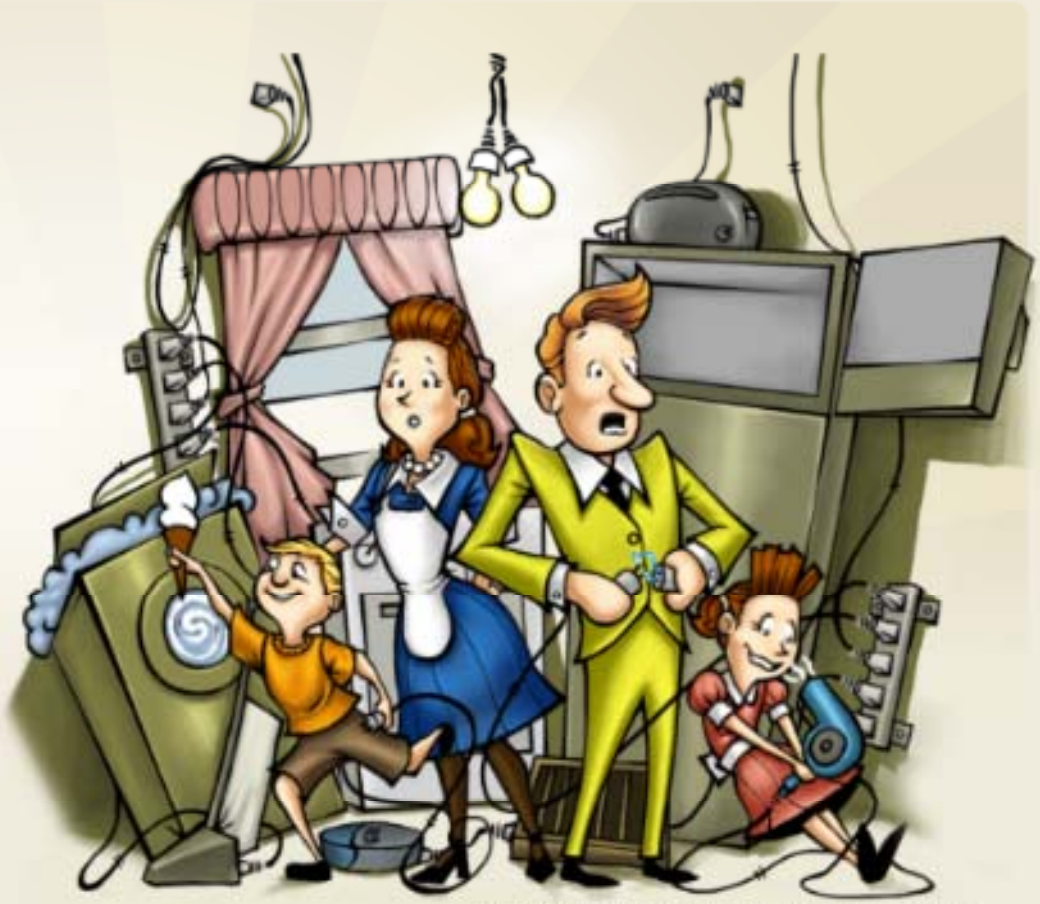
Username: Password: Login Connect

Power HOUSE

An energy-saving game that creates real results!

- Play "Power House" with your friends. It's an addictive "green" Sim with action, info and trivia!
- See your actual home energy use with Google Powermeter and then use real world savings to win contests and prizes!
- Earn Carbon offset points by playing games & use your points in the real world to plant trees, preserve rain forest, and support sustainable living!

Click **Play Now** to unlock your Power House!



A social game promoting energy conserving behaviors

PLAY NOW

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seriosity

KUMA REALITY GAMES

Kidogo

facebook | Search | Home | Profile | Account

Games
Changelabs Powerbar
Energy Change Labs1
More

changeLabs.

Homepage | Portfolio

Savings 0kWh

Matthew Crowley Homepage

My energy savings

Energy used this month	0kWh
Energy saved this month	0kWh
Total energy savings	0kWh

My supported entrepreneurs

This month	0
Total	0
Average contribution	0% of loan

0/75 KWh Raised

Who: Dina Lopez Diaz
Where: Nueva Guinea, Nicaragua
What: Improve living conditions. more

Give 0.0 kWh SUPPORT

Sponsored | Create an Ad

Dr Horrible Sequel coming
geek-news.mtv.com

Joss Whedon let slip that work is being done on a sequel to Doctor Horrible's Sing-Along Blog!

Win an iPad

Join the Stanford Alumni Association and get access to the online group for student members. 1 group member a month will win!

NO-ERRORS.com

Do you know how to choose a wood bat. Discover what many do not know.

Like · 984 people like this.

Cheap StanfordTextbooks!
coursesmart.com

Stanford students can save up to 60% by downloading textbooks and course material from CourseSmart!

insinc

Smart Monetary Incentives

REDUCE ENERGY

FIXED REWARD
Guaranteed 1 Cent

Bias:
small monetary rewards are not motivating

POOL REWARD $$

RANDOM REWARD
1 in 100,00 chance at $1000

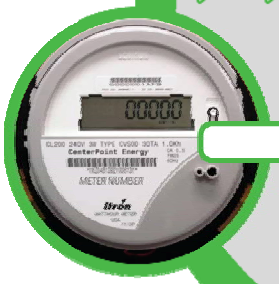
Bias:
people tend to overestimate small probabilities (behavioral economics - prospect theory)

SAME EXPECTED COST, MORE MOTIVATING

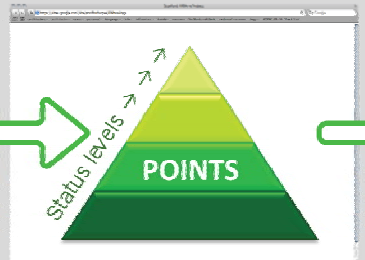
MORE KWh SAVINGS PER $

Utility program that stretches the motivational value of monetary incentives

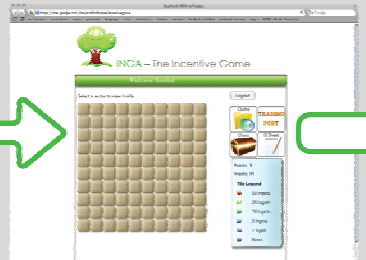
DAILY



Energy use and savings



Energy savings converted *to points*



Points played in game, winnings entered *into a chance at monetary prize*

1 in 100,000 chance at $1000

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About Contact

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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: Please Select

Refrigerator Type: Please Select

Approx Model Year: Please Select

Size: Please Select

Icemaker: Please Select

EnergyStar: Please Select

Please Select Above Options

Step 2: Describe Your Desired New Refrigerator

Price Range: Any

Brand: Any

Refrigerator Type: Any

Color: Any

Size: Any

Icemaker: Any

EnergyStar: Any

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

Reset

Feedback

Your New Refrigerator Search Results

Save/Compare	New Refrigerators	Price	Annual Electricity Use	Lifetime Electricity Cost	Annual Cost Savings for New Vs Old
☐	LG 22.4 cu. ft. Bottom Freezer LDC22720S See at Sears	$1,100	465 kWh	$633	0.00
☐	LG 22.4 cu. ft. Bottom Freezer LDC22720S See at Sears	$1,400	465 kWh	$633	0.00
☐	Whirlpool 17.6 cu. ft. Top Freezer W8TXNGF White See at Sears	$680	470 kWh	$639	0.00
☐	KitchenAid 21.1 cu. ft. Non Dispensing Side By Side KSSO36FT See at Sears	$6,200	539 kWh	$733	0.00
☐	KitchenAid 25.3 cu. ft. Non Dispensing Side by Side See at Sears	$6,700	561 kWh	$763	0.00
☐	KitchenAid 29.8 cu. ft. Non Dispensing Side By Side KSSO48FT See at Sears	$7,200	584 kWh	$794	0.00

Page 1 of 137 6 View 1 - 6 of 819

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Girls Learning Environment & Energy - Windows Internet Explorer
http://glee.stanford.edu/hickory/
glee
Girls Learning Environment and Energy
have fun
girl scouts
home
about glee
glee sessions
videos
beyond glee
contact
logout
Reduce your footprint!
did you know?
Energy use in residential buildings accounts for about 17 percent of U.S. greenhouse gas emissions. Half of these emissions are due to two of the largest energy end uses--heating, ventilation, and air conditioning (HVAC) equipment and lighting.
Source: Pew Center on Global Climate Change
Replacing a refrigerator from the 1980s with a new Energy Star-qualified model (look for the Energy Star logo) can save you $100 per year in your energy bills. Replacing a model from the 1970s can save you over $200 per year!
Source: Energystar.gov
You can reduce your water-heating costs by simply lowering the thermostat setting on your water heater. For each 10°F reduction in water temperature, you can save 3%–5% in energy costs. Most people don't notice a difference in their hot water after they've lowered their water heater's thermostat because we rarely use pure hot water—it's almost always cooled by mixing it with cold water anyway. Note that it's best not to lower your hot water temperature below 120 degrees F for health reasons.
Source: Energysavers.gov
glee videos
watch girl scouts show off their new energy skills
beyond glee
tips, resources, and fun activities
welcome
Thanks for visiting the GLEE website! Please explore the links above to learn more about our program. You can also use the resources in the Beyond GLEE section to discover things that we cannot cover in five troop meetings. Keep checking back for updates and for your completed video project!
powered by: peoplepower
Girl Scouts of Northern California
Stanford University
Girl Scouts of Northern California
Stanford University

Energy Services Platform Architecture

Presentation

- Device - computer, ipad, handheld, voice
- Medium - Text messaging, widgets, flash animation, social media
- GUI – control and flexibility in the development and editing of:
  1. Style and layout
  2. Type of content (i.e., which widgets?)
  3. Content (the specific text, images, sounds)

Services

- Subject Management System
  - User registration, consent, etc.
  - Participant assignment
  - Data retrieval by experimenter
- Surveys
- Web Collector for energy data
- Base Stats – w/stats package (mean, etc.)
- Analytics - e.g., disaggregation, baselining, diagnostics, channeling into programs

Storage (Data)

User
- Property
- Survey
- Utility usern/psswd

Project
- Project specific data
- Website usage stats

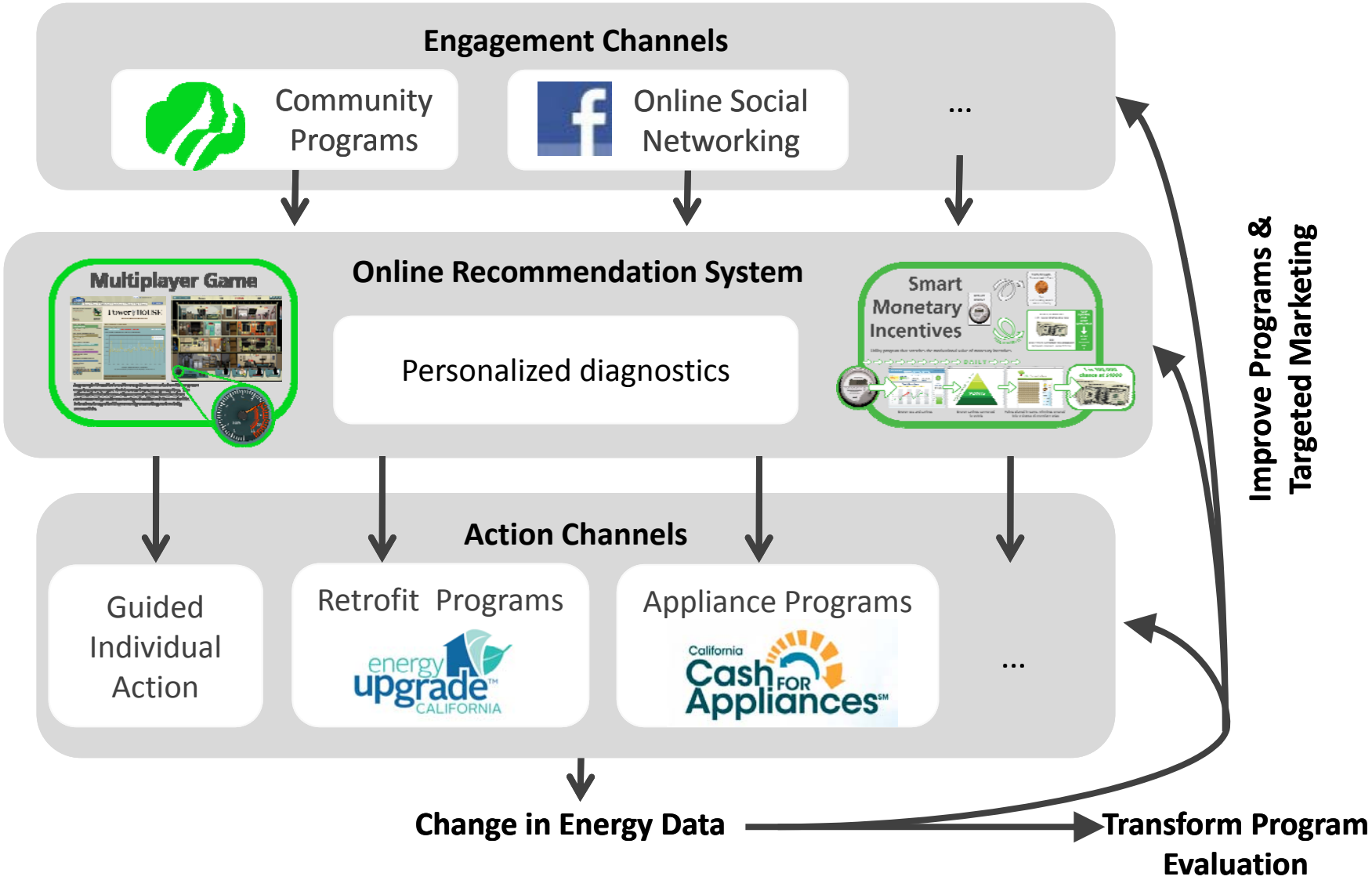
Energy
- From web collector

Environment
- Weather
- Regional (not property specific)

Profile
- Rec. profiles developed through our data
- Disagg. learnings

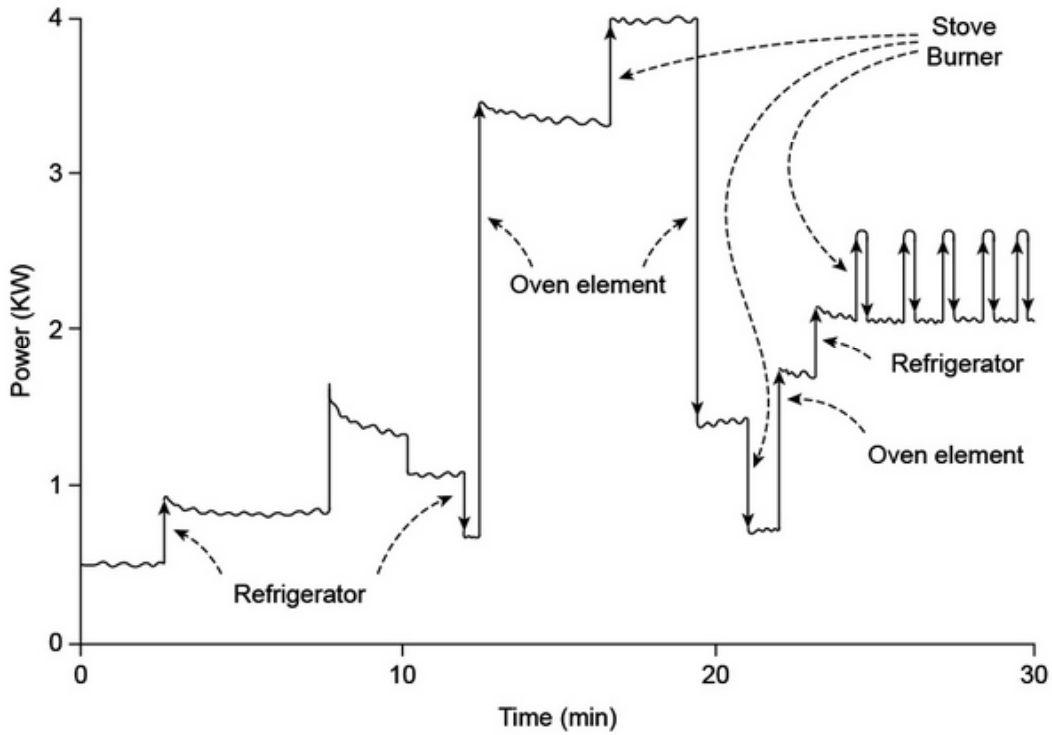
Recommendation
- Programs, incentives, appliance costs/ purchase links, savings per yr, contractors

Appliance Feedback Augmented



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.



Stanford ARPA-E Team

Principal Investigator
Byron Reeves

Project Director
Carrie Armel

Core Investigators
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Investigators
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Post Docs
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ARPA-E Goals for Behavioral Work

1. Develop behavioral intervention(s)
2. To achieve substantial energy reductions
3. Validated with empirical data in real world test(s)
4. At or ready for scale by grant end

Team

1. Develop behavioral intervention(s)
    - Academics & lit review / databases - behavioral principles.
    - ‘Creative’ professionals, intervention developers – marketing, business, game developers, etc.
    - Technical implementation
2. To achieve substantial energy reductions
    - Engineer focused on energy to keep focused on thinking through best ways of getting substantial energy savings
3. Validated with empirical data in real world test(s)
    - Evaluation professional and/or academic for evaluation
    - Partner for real world test
4. At or ready for scale by grant end
    - Real world partner(s) to scale. Same as real world test makes scaling easier. These partners can be a “champion” for the project, especially if it fits in with their existing work.

Collaboration

1. Important
   - Collaboration across disciplines and sectors
   - Surprisingly, there can be a significant lack of communication among partners in a project. However, an interdisciplinary team has a unique ability to solve problems
2. How?
   - Interdisciplinary meetings to get everyone on same page
     - Terminology
     - Major questions agreed upon
     - Important, but likely insufficient because of limited time for most team members
   - Glue person: familiar w/all different directions and keeps ensuring that at critical decision points that decisions are made to keep projects towards same goal.

Data & Scaling

1. Commitment/feasibility smoked out
   - MOU
   - Legal & IT support for data approval & implementation (100+ hours) – who will keep rolling.
   - Regulatory & privacy issues, potential regulatory approval.
2. Clear data and pilot plan agreed upon
   - Data types - individual or aggregate data, which variables, who will collect and provide.
   - Experimental design doc agreed upon - how participants will be recruited, stratified, randomized.
   - Timeline, who will do what.
3. Articulation of transition to scaled program(s)
   - What is the end goal?
   - How will we get there?
   - Who will do what?

Institutional Biases

1. Nature of entity for data/scaling
   - Regulated? Slow moving? Aim for conservative image? Incentives to maintain status quo or push envelope?
   - With transportation, could be municipalities, cities, etc. Have a team member who has been effective working w/in past, and a plan.
   - Have back up plans, with one guaranteed to work.
2. Nature of academic org
   - Herding cats – Investigators are their own bosses. Grants usually allow great flexibility in doing what they want/changing course.
   - Interesting questions often trump energy savings.
   - Speed – slower than fast industry, grad students other obligations
   - Commercialization could be contentious due to poor incentives for faculty