Overview of CalPlug Research




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www.calplug.org

Creating Connections. Powering Innovation. Boosting Efficiency.

CalPlug

California Plug Load Research Center

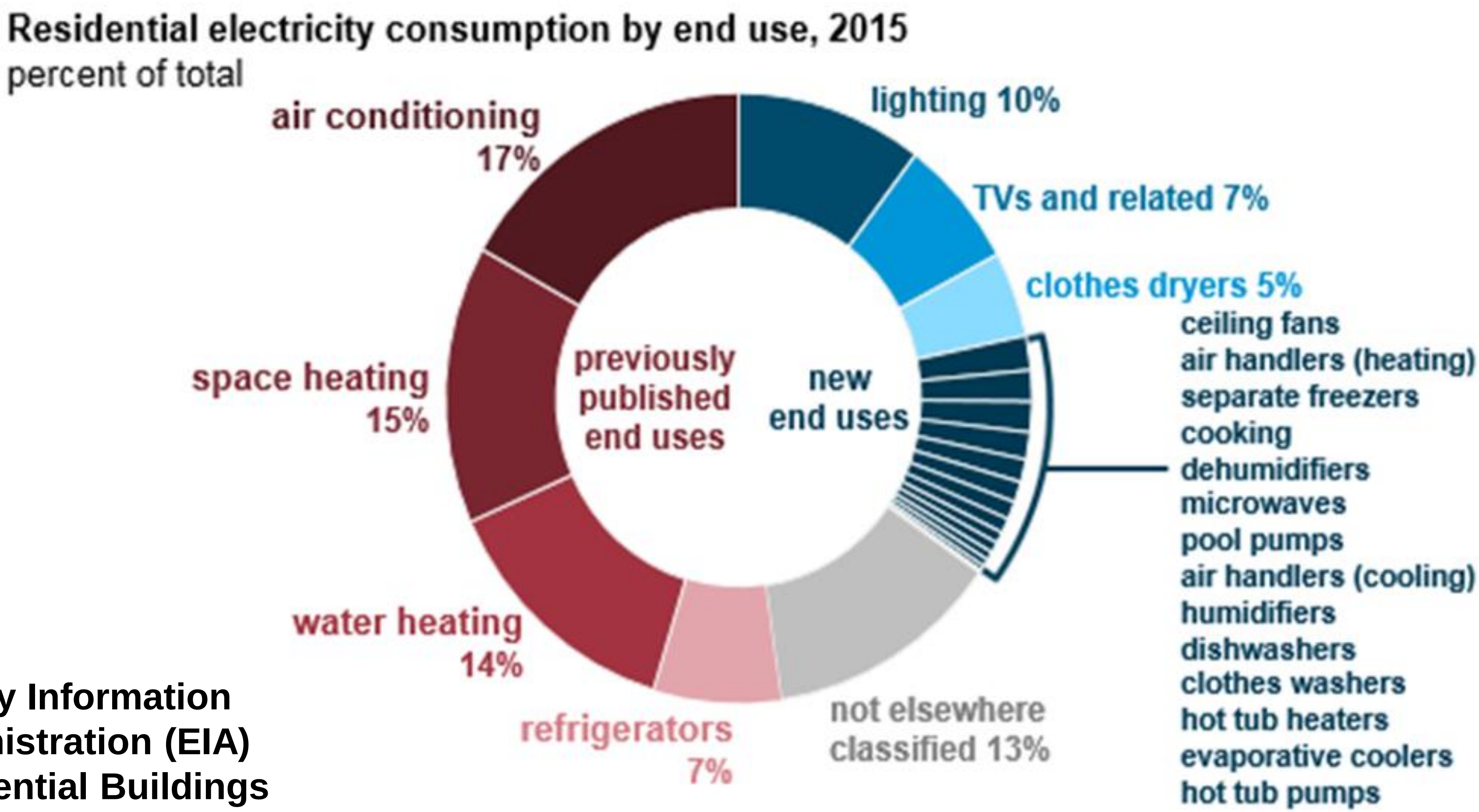
California Plug Load Research Center

- Established to study plug load devices and energy
  - Plug loads = what happens when we let people move into our EE buildings
  - Energy efficiency, TOU, DR
- Plug loads present specific challenges
  - Devices with small kWh that add up
  - Variability across devices
  - Users matter
  - Intersection of technology and user behavior
- Multidisciplinary approach
  - Engineering, social science, computer science
  - Technology and program road-mapping
  - Independent testing, evaluation, modeling, developing prototypes and methods
  - Field tests, surveys, experiments, programs

CalIT2 Building, UCI

Why Plug Loads?

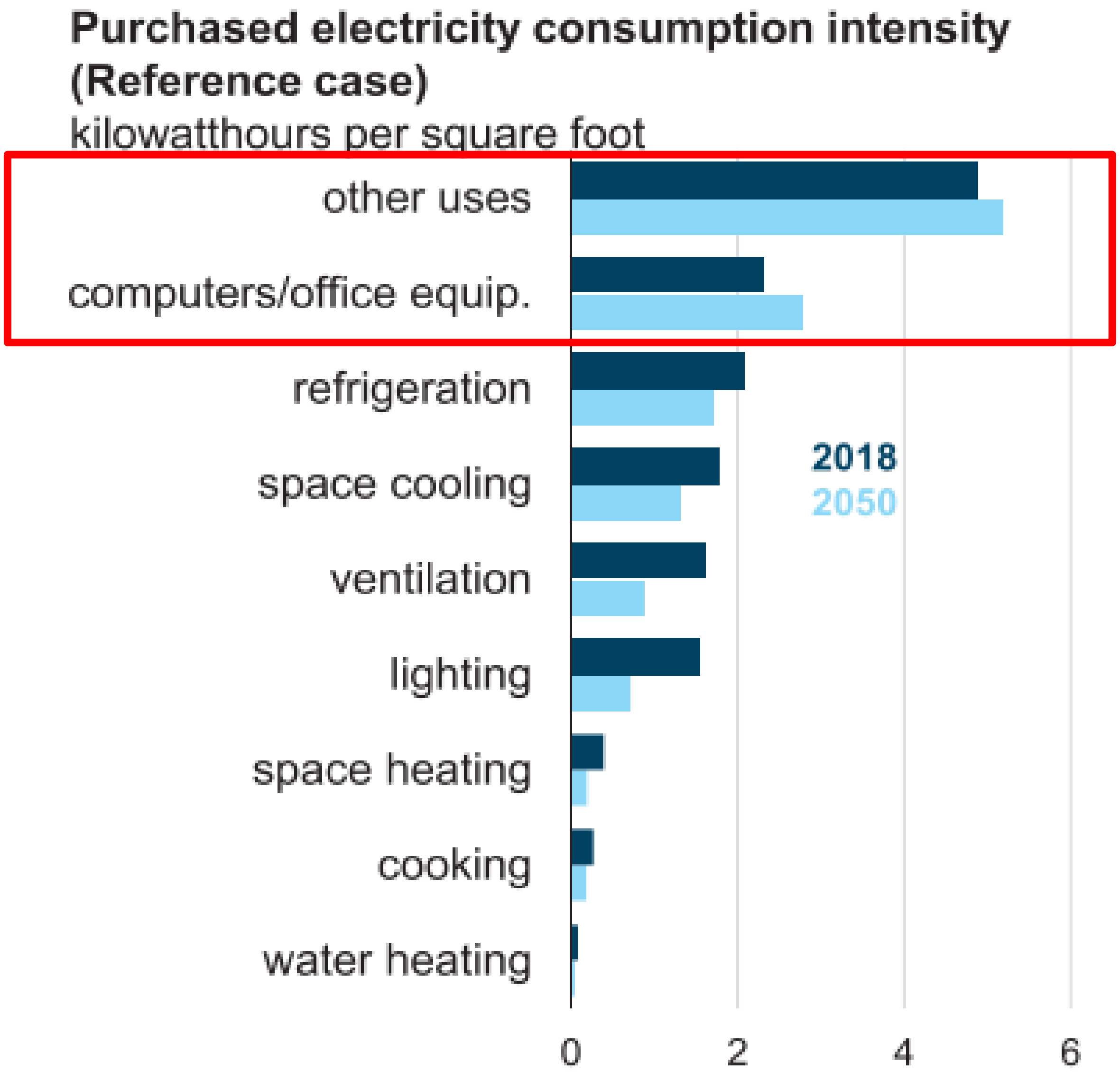
- **Evolving category with growth expected across many types**
  - **number of devices**
  - **proportion of energy waste**



Energy Information Administration (EIA) Residential Buildings

Why Plug Loads?

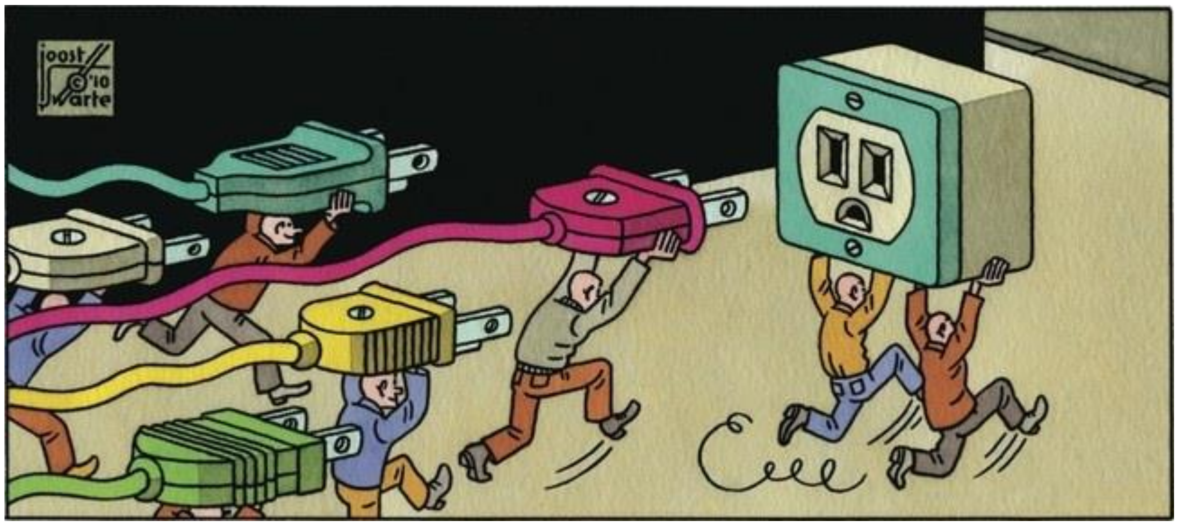
- **Increasing electricity consumption intensity**



Energy Information Administration (EIA) Projections 2018 – 2050 Commercial Buildings

CalPlug Approach, with Examples

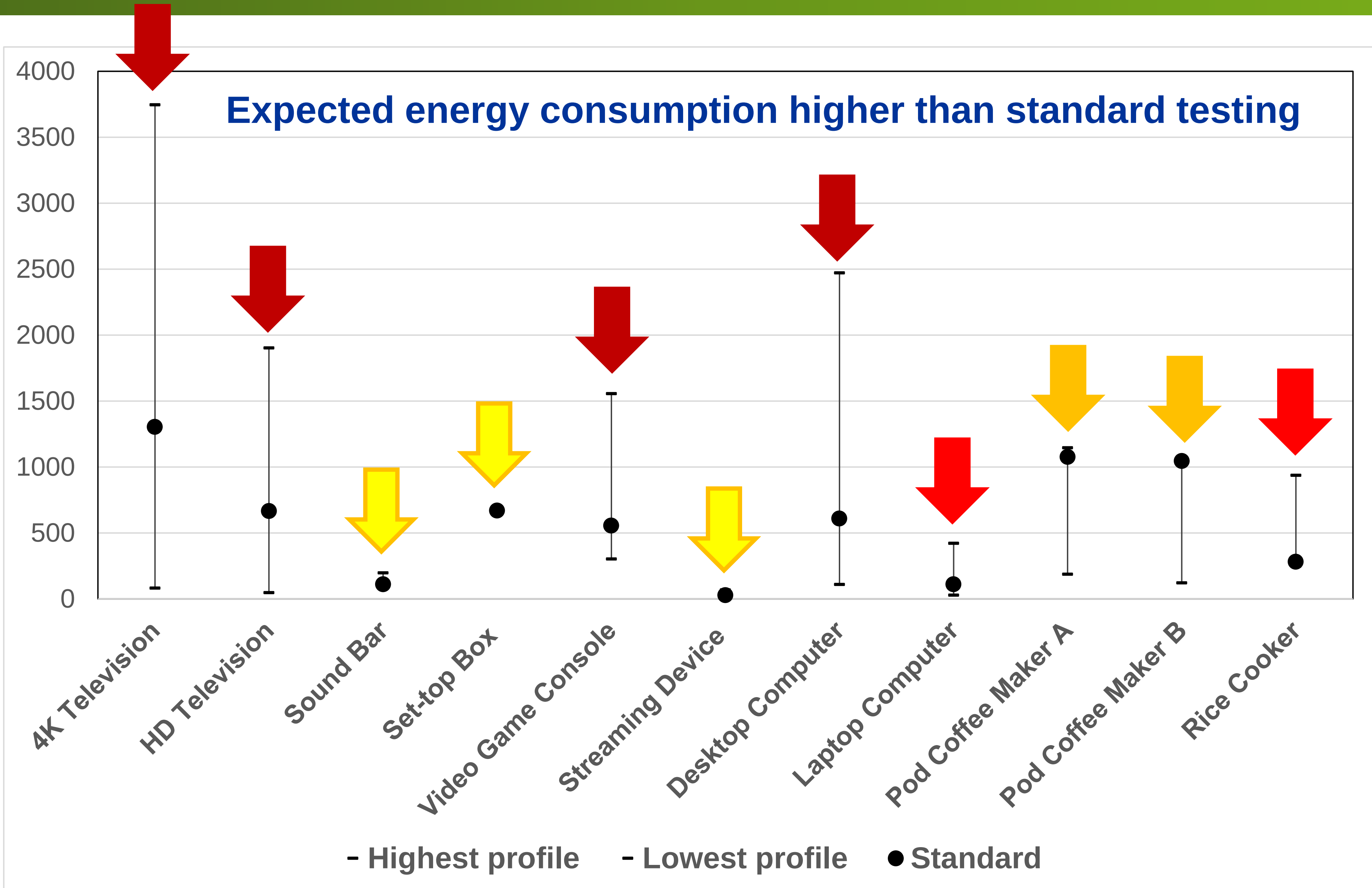
- **Joy Pixley**
  - **Selected past projects**
  - **Commercial plug load devices and EE programs (ComEd)**
- **Katie Gladych**
  - **Connected residential devices and EE assessment (SDG&E)**
- **Michael Klopfer (tomorrow)**
  - **Future of plug loads**



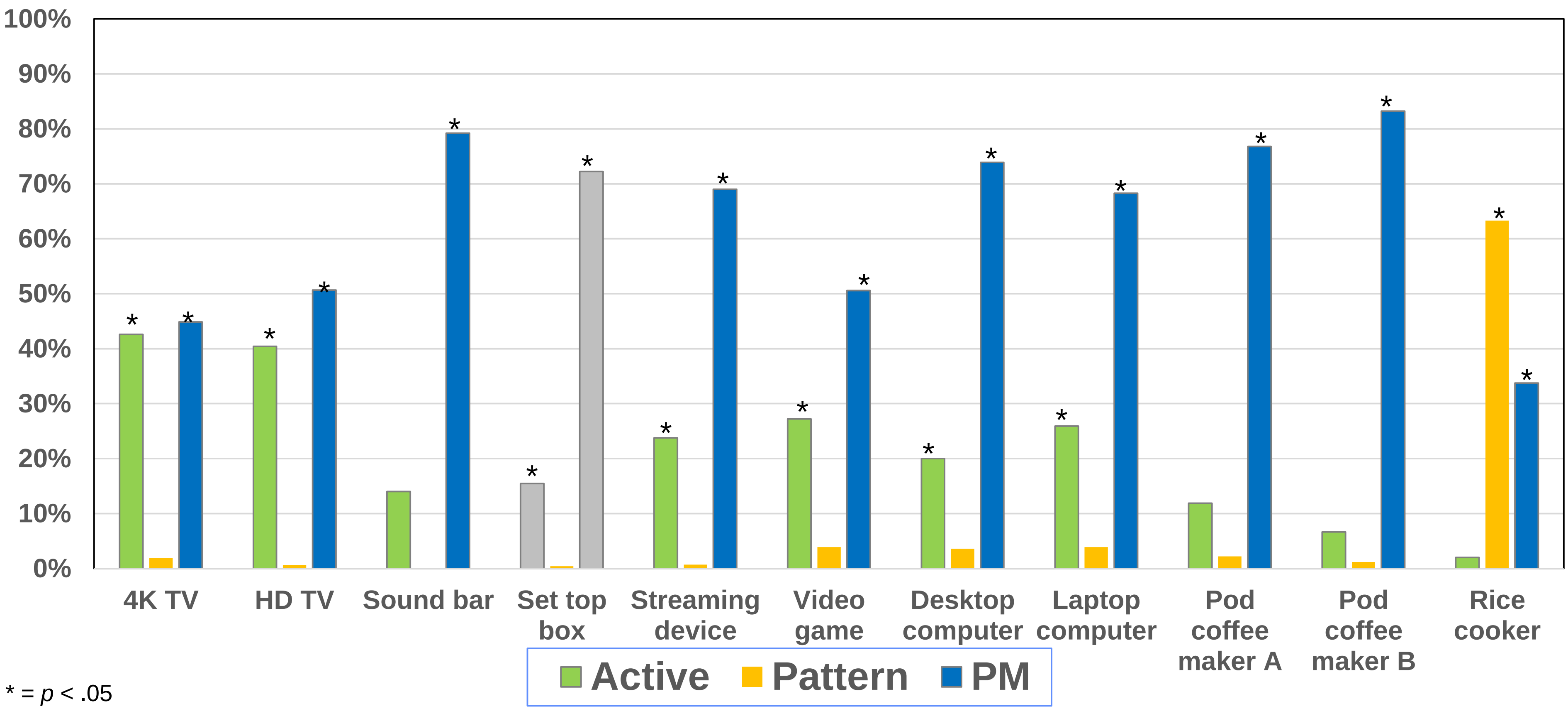
How Does Usage Matter?
Device Use Profile Approach (SIM Home)

- Determine possible states for each device
- Test power for all states of each device
- Develop a set of use profiles for each device, including standard test profile
  - Active use time
  - Pattern of use
  - Power management
- Use PLSim tool to calculate energy use for each profile
- Analysis:
  - Range of outcomes: size, and direction v. the standard profile
  - Amount of variation attributed to use, pattern, or PM

Range of Energy Use Across Device Use Profiles



Percent of Variance in Energy Usage Due to Active Use, Pattern, and Power Management

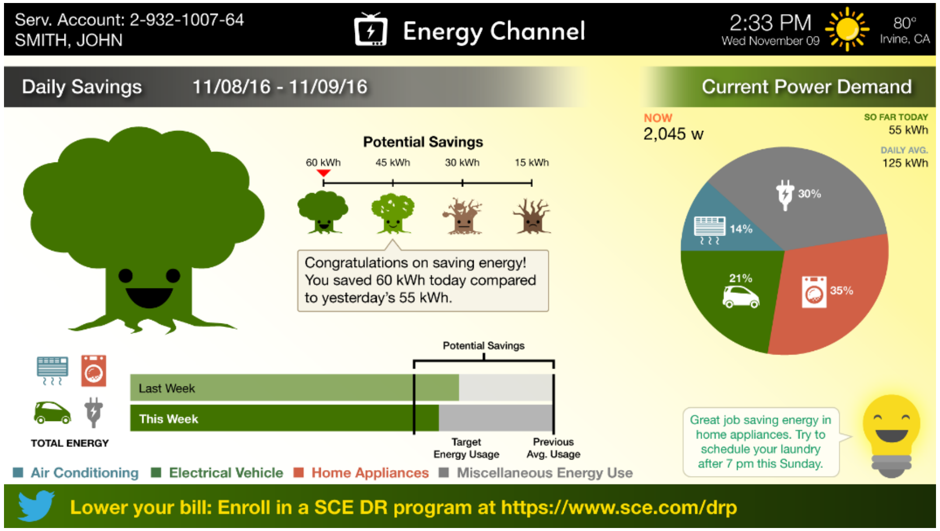


- **Power management problems**
  - **Dire consequences for disabled PM**
  - **Limited PM options**
  - **PM not enabled by default**
  - **Low-power modes not low**
  - **Long idle opportunities**

Changing User Behavior

- **Behavioral Interventions in Residential Energy Consumption**
  - Extensive literature review, systematic search using multiple sources
  - Content-coded 1470+ abstracts and 204 full-text articles and reports
  - Assess the theoretical foundations and empirical validation of various behavioral intervention strategies
    - Investment behaviors
    - Conservation behaviors
      - Load shifting

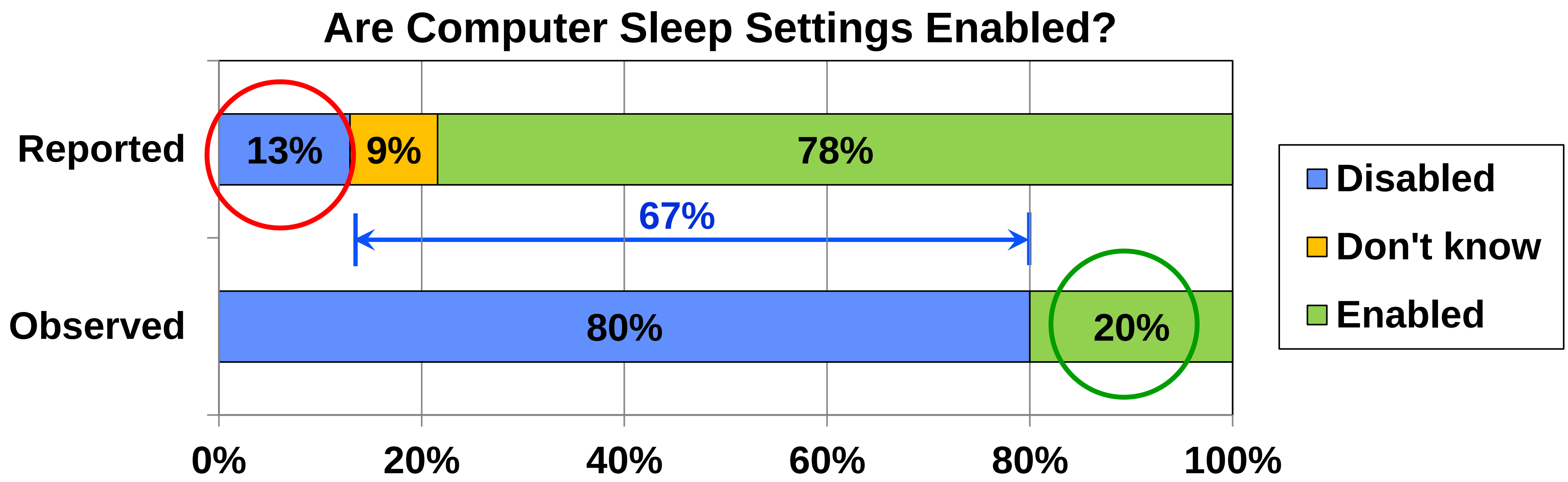
- **Energy Channel**
  - Smart meter data → TV app and mobile app
  - User feedback gives actionable information about energy use
  - Historical & social comparison
  - EE, adapt to TOU



The Other Energy Saving Behavior: Settings

Desktop computers and power management

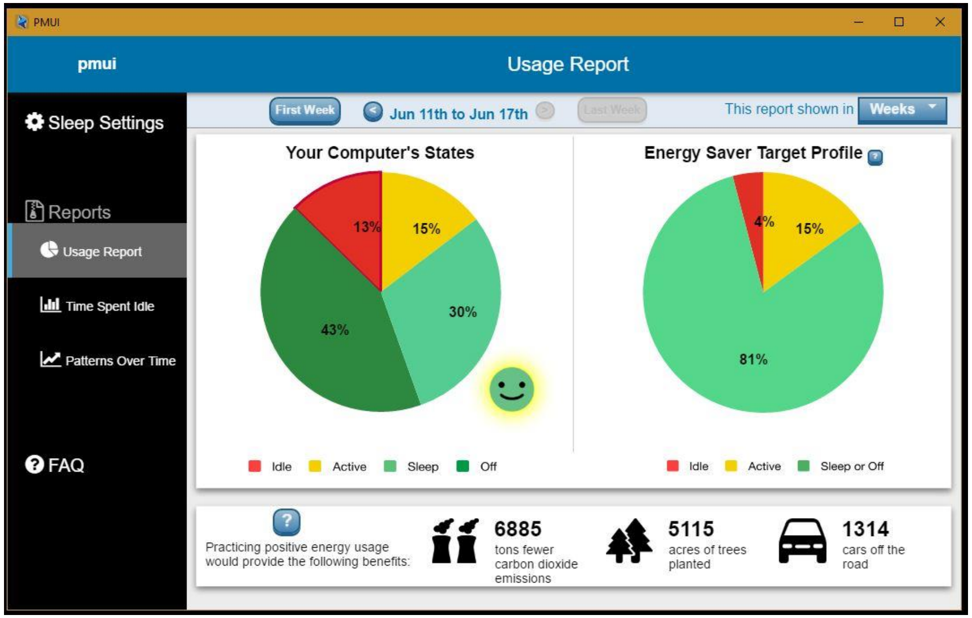
- Problem: Prior research indicated that existing low-power modes on desktops are not being efficiently employed by users.
- Studies 1 and 2: Survey of computer users + monitoring study observing their computers =



- Finding: Low rates of sleep setting engagement, high levels of confusion among users.

Power Management User Interface

- **Study 3: PMUI**
  - **Design and test new user interface software to facilitate and encourage engagement of power management options.**
  - **Field test with 407 staff desktops, 75% treatment group, one month baseline measures, two month treatment period**
- **Results**
  - **Initial enabling rate =14%**
  - **Treatment group significantly more likely to enable sleep than control group (59% v. 14%)**
  - **“Idle time” effective way to communicate energy waste**
  - **Remote access; misuse of APS, controlled outlets**



Emerging Technology

- **Report: "Technology Roadmap towards 2030 and Beyond: Miscellaneous Electrical Loads and Mitigation Strategies in the Era of Zero Net Energy"**
  - **Future trends in plug and process loads**
  - **Plug load devices and ZNE building goals**
  - **Energy impacts of connected bulbs, IoT, cloud computing**
  - **Home healthcare and medical devices**

- **Modeling and testing power management**
  - **Device energy use with Tier 2 APS**
  - **Motion sensors to control set-top boxes, put computers to sleep**
  - **External "smart" management of standard projectors**

Control Strategies and Plug Load Devices

- **Individual solutions**
  - **Tier 1 APS**
  - **Tier 2 APS (occupancy sensor)**
  - **Smart plugs with timers**
- **Smart Buildings**
  - **Built-in controlled outlets**
  - **Centralized control, settings**
  - **Local occupancy sensors**
- **IoT Technology**
  - **Integrating sensor data**
  - **Enhanced automation, control processes**
  - **Real time data analytics**
  - **Enhancing building flexibility**

Challenge:

Many plug load devices do not respond effectively to power cuts

New Project: Plug Load EE Program Analysis

- Provide guidance on future programs that help reduce commercial plug load energy consumption
- Review existing programs, third-party evaluation reports, databases, and the academic literature
- Identify promising
  - devices
  - utility programs
  - program approaches

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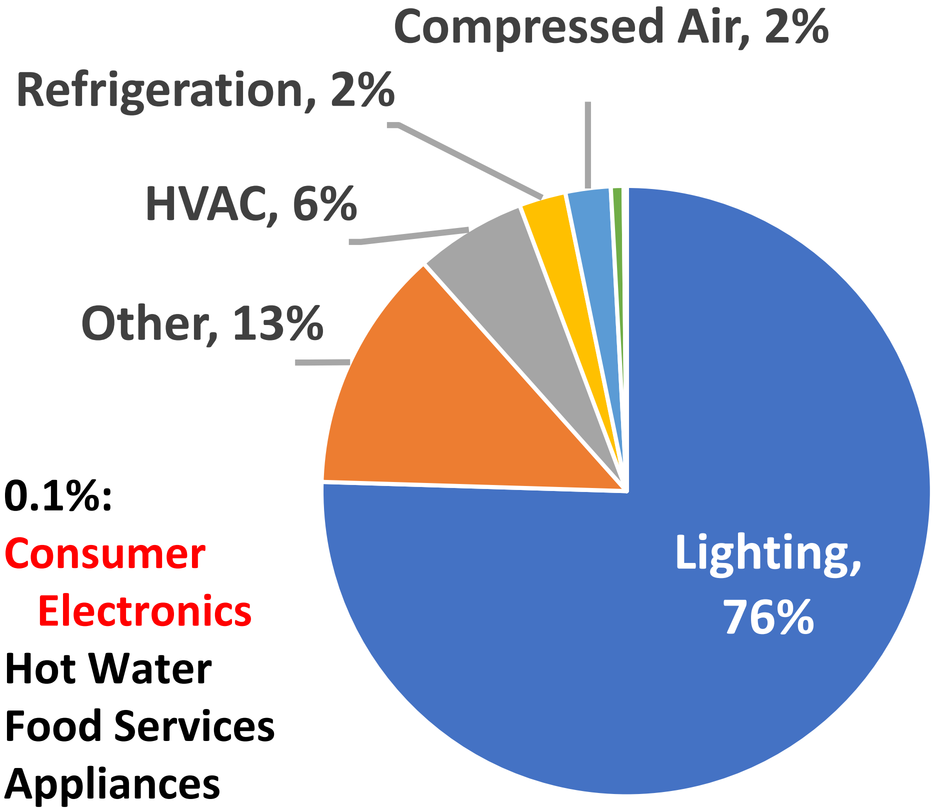
Traditional End Use EE Programs



0.1%:
Consumer Electronics
Hot Water
Food Services
Appliances
Shell

Fig 1. Electricity Savings for Com Ed Commercial EE Programs, by Measure Category

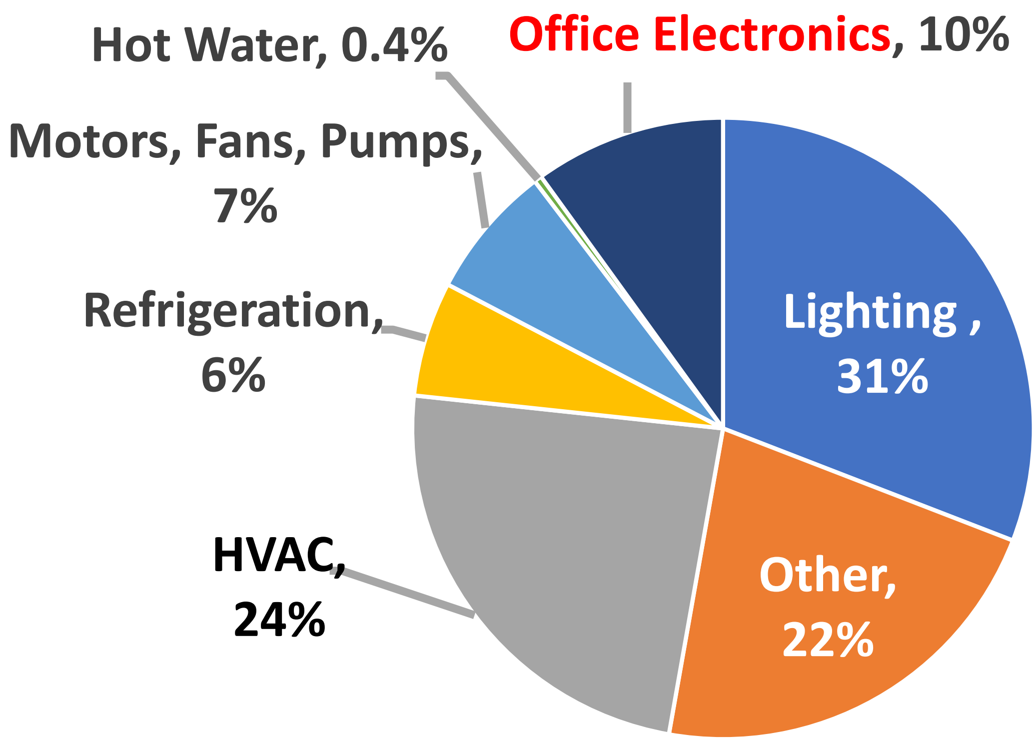


Fig 2. Electricity Usage by End Use Category for Com Ed Commercial Accounts

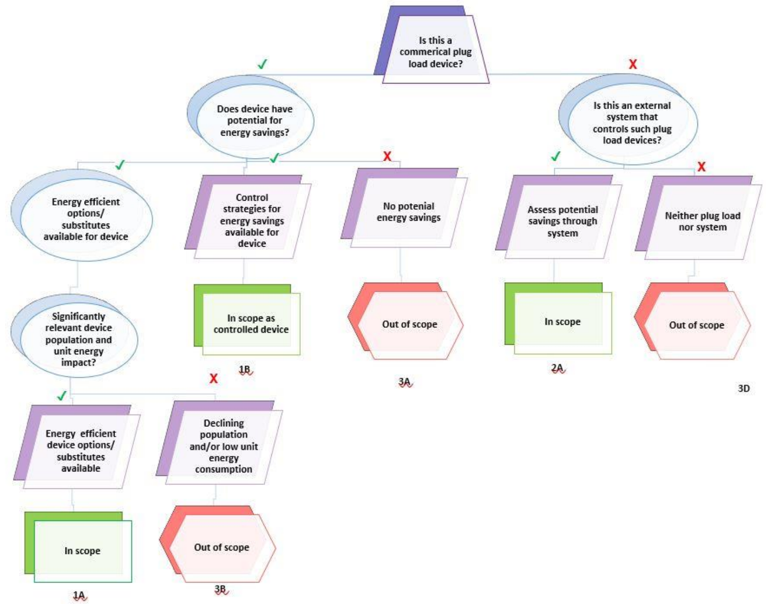
Source: Navigant Consulting, 2019

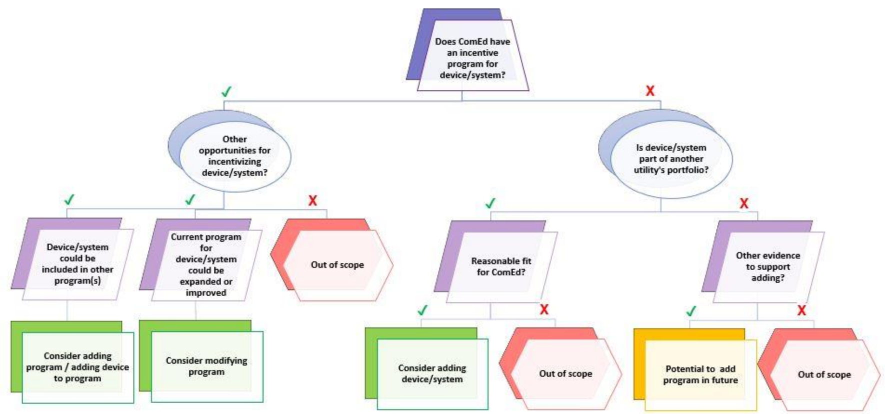
Key Plug Load Categories

Category	Examples
Traditional end use	HVAC, Lighting, Water heating, Major Appliance
Plug load	Electronics, e.g., • computer, display, peripherals, networking, server • Imaging (copier, receipt printers) • audio visual equipment • money exchange (credit card readers, scanners) • telephony Other equipment, e.g.,: • business equipment (e.g., shredder, cash drawer) • portable HVAC units (e.g., space heaters) • portable lighting • kitchen equipment, electric housewares • power (e.g., uninterruptible power supply) • medical equipment • vending machines
Hard-wired loads	Escalators, elevators, security systems, fire detectors

Program Analysis Approach

- Assess and select devices, including plug load control systems
- Compare programs across utilities
- Device → programs
- Program → devices
- Recommendation categories:
  - Add device to existing program
  - Modify existing program
  - Add program addressing device(s)





Early Results

- **ComEd boasts a very comprehensive program portfolio**
- **Promising avenues:**
  - **Individual device incentives**
  - **Adding devices to company/unit-level programs**
  - **Power management for computers**
  - **Office equipment and control systems**
  - **Communication, education**

Facility Assessments

Incentives

Building Optimization

Energy Management

Next: Our Latest Findings

Presenting Katie Gladych!

EE and DR Program Opportunities in Connected Plug Load Devices (SDG&E)

Project Goals:

- Provide insight into under-researched connected devices
- Assess potential energy savings for connectivity in residential plug loads
- Make relevant EE and DR program recommendations

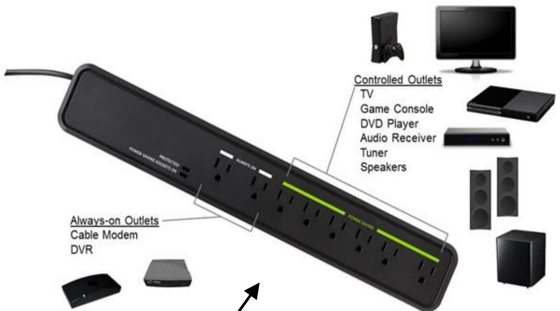
Approach

1. Initial Device List
2. Device Selection (Flowchart)
3. Device Characterization/Energy Savings Mechanisms
4. Deep Dives
5. TRC Calculation (and development of new TRC tool)
6. Results
7. Connectivity Discussion: EE & DR

Initial Device List and Selection

Significant Residential Plug Loads → **Device <u>OR</u> System** → **<u>Evaluation for</u>:**

1. **Connectivity**
2. **Market Trends**
3. **Program Savings Potential**



APS with controlled devices

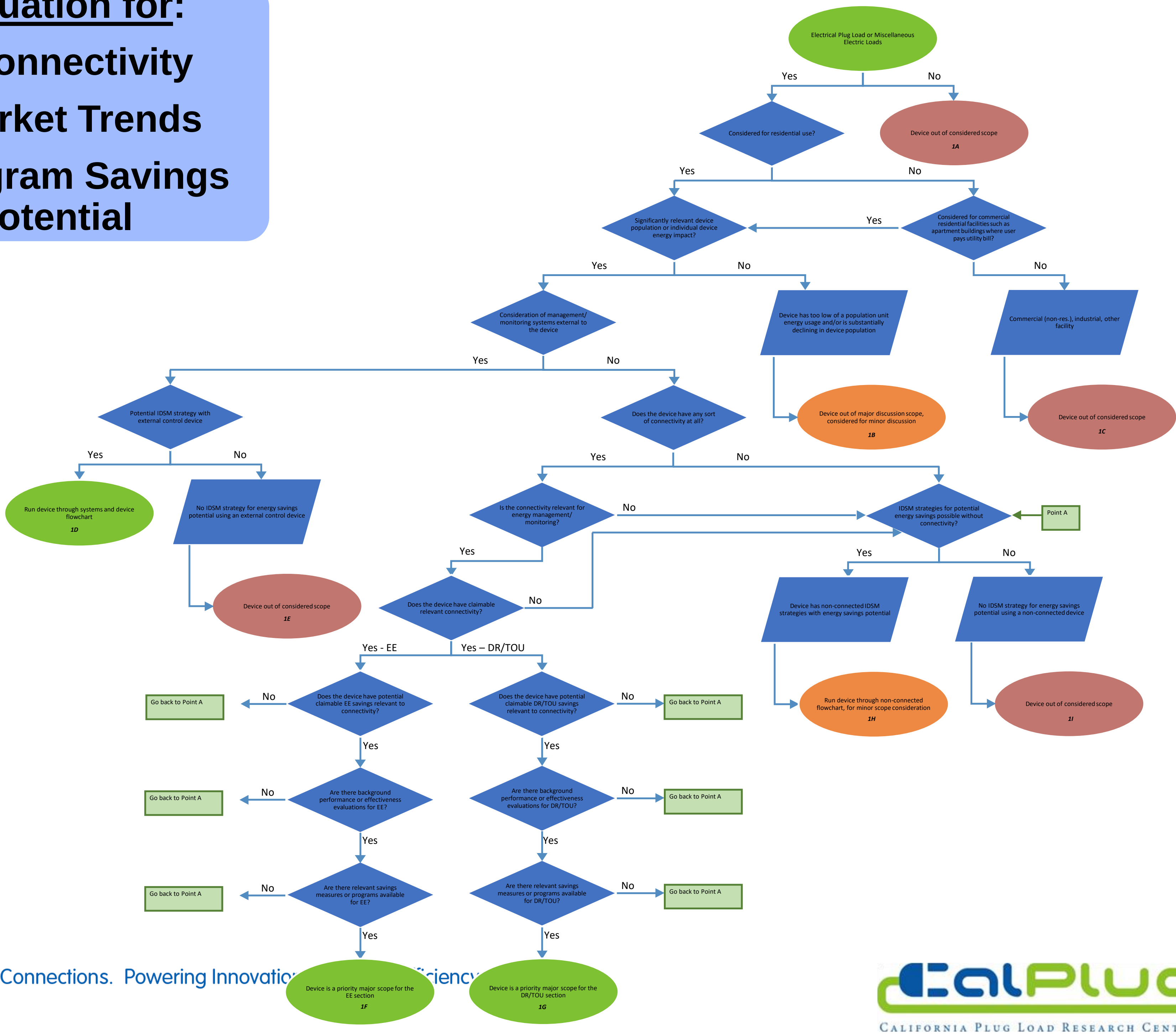
Device with onboard energy management

Evaluation for:

1. Connectivity

2. Market Trends

3. Program Savings Potential



CalPlug Connectivity Classification

Connectivity Class	Class Identification	Class Description
0	Non-Connected (Null Case)	Power management w/out connectivity
1	Reporting Only	Energy usage reporting; manual DR notifications
2	Real Time Monitoring w/Control	Connectivity class 1 + ability to adjust settings remotely
3	Demand Response (Automated)	Remote triggering for DR actions
4	Network-Based Device Management	Remote/cloud capability to control or fine tune device operation
5	Network-Based Management w/ Edge Computing Control	Connectivity class 4 + capability of local (edge) processing

Assessing Cost Effectiveness

- **TRC = Total Resource Cost**
- **Problem: Insufficient data**
- **Solution: We created a new assessment tool for modified TRC calculation**
  - **Simplifies and streamlines the variables**
  - **Allows a range of inputs to reflect uncertain data**
  - **Produces reasonable program performance bounds to assess cost-effectiveness**

Simplified TRC Calculation

Equation: $$TRC = \frac{Benefit}{Cost} = \frac{UAC_t + TC_t}{PRC_t + PCN + UIC_t}$$

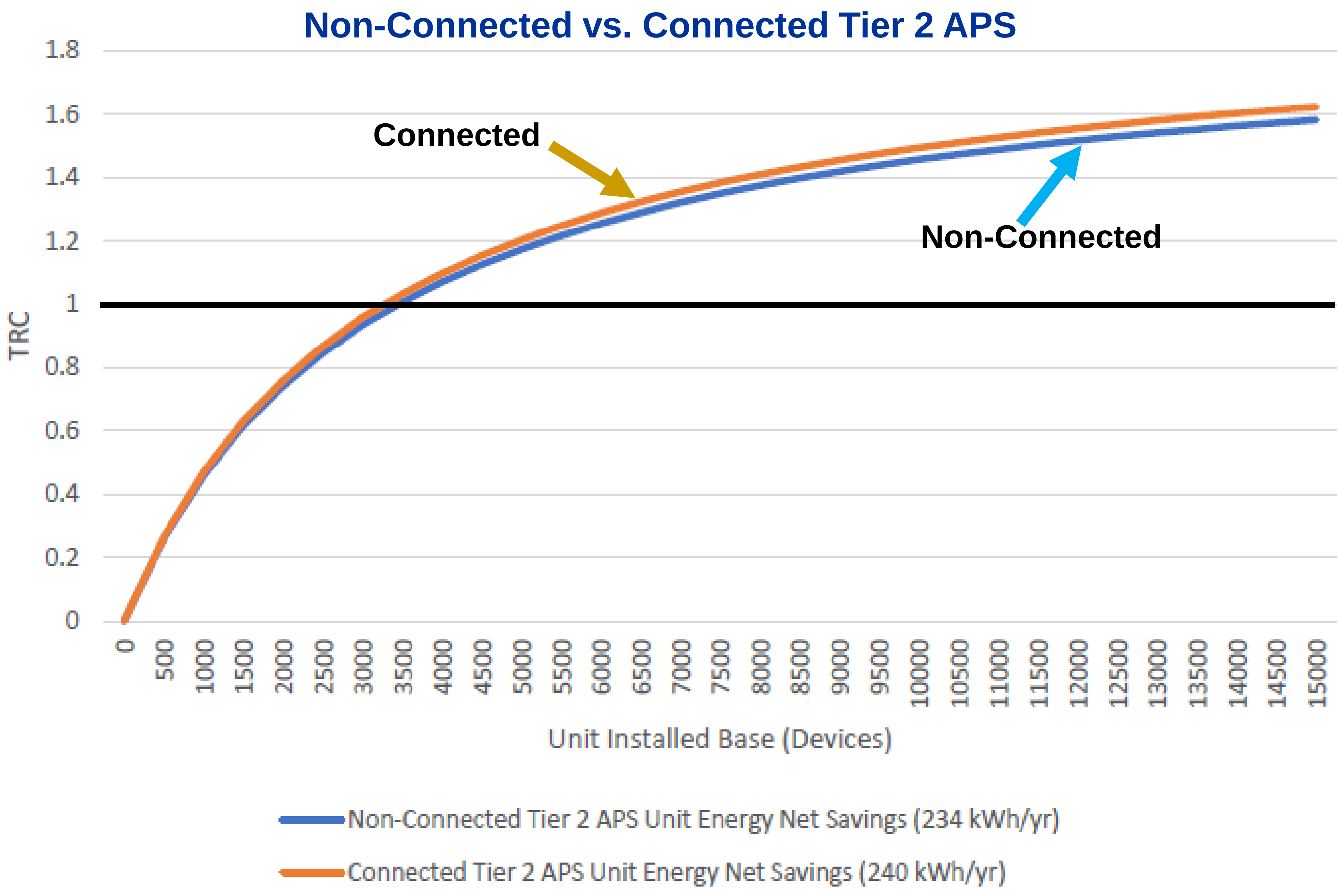
Cost Effectiveness = TRC > 1

	Variables	Definition of Variables
Benefits	UACt	*Utility* avoided supply costs in year t (Energy savings)
	TCt	Tax credits in year t
Costs	PRCt	Program Administrator program costs in year t
	PCN	Net Participant Costs
	UICt	Utility increased supply costs in year t

Results: Devices/Systems (EE)

Device/System	CA Work Paper	Energy Star Specific Product Category	Modeled lifetime (yr)	Model Max TRC
Connected Refrigerator (v. non-connected) Class 1,2,3,4	✓	✓	14	0.05
Connected Washing Machine (v. non-connected) Class 1,2,3,4	✗	✗	11-15	0.62
Variable Speed Pool Pump (v. 2-speed) Class 1,2,3	✗	✓	9-11	5.71
Smart Plug with Window AC Unit (v. without smart plug) Class 1,2,3	✗	✗	3-5	1.6
Smart Plug with Hot Water Dispenser (v. without smart plug) Class 1,2,3	✗	✗	3-5	0.97
Tier 2 APS with AV/Entertainment (v. without APS) Class 1	✓	✗	3-5	1.6

Example TRC Calculation – Tier 2 APS Comparison



So Does Connectivity Save Energy?

- **Comparison between connected and non-connected Tier 2 APS shows almost identical hardware, software, and functionality**
  - **Connectivity adds user monitoring features, but no real extended EE**
  - **Connectivity features lead to only about 6 kWh/year additional savings per field trial results**

- **Similar findings for other devices:**
  - **Washing machines**
  - **Refrigerators**
  - **VSD pool pumps**
  - **Smart plugs**

Technical Considerations of Connectivity

Role of Connectivity and Decision Space

Assessing value, accuracy, and actionability

<u>Human in the loop (HIL) control</u>

Summarized user feedback in a convenient user interface improves both usage efficiency and reduction of wasteful use estimated at 2-6% savings <u>in many cases.</u>

<u>Automatic and Coordinated Control</u>

More parameters and potentially more stable decision space. **Often logical rules: What added benefit can coordination, AI, or connectivity add?**

Energy Efficiency and Connectivity: Discussion

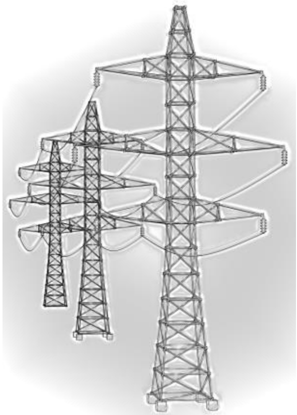
- **Current status of EE with Connectivity**
  - **Limited CA work completed to current date**
    - **Need further device field tests**
  - **Limited EE connectivity opportunities for plug load appliances**
    - **Role of user interfaces and device interaction, expanding actionability and decision space**
    - **Connectivity enabling operation towards Human-in-the-Loop/User behavior**
- **Extended considerations**
  - **Costs/overhead of connectivity**
  - **Integration into IoT systems/SHEMS**

Connectivity and DR: Results

Device	Shift period duration (ENERGY STAR)	Shift savings (261 periods/yr) kWh/yr	Shed period duration (ENERGY STAR)	Shed savings (261 periods/yr) kWh/yr
Connected Refrigerator	4 hr	15.97 kWh/yr	10 min	1.53 kWh/yr
Connected Washing Machine	4 hr	15.40 kWh/yr (at 100%)	10 min	1.55 kWh/yr (at 100%)
VSD Pool Pump	4 hr	63.20 kWh/yr	20 min	8.10 kWh/yr

Connectivity and DR: Discussion

- ENERGY STAR Smart Connected Devices category largely is focused on DR action.
- AutoDR relies on connectivity for control
- Load shift/shed limited for plug load devices
  - User experience
- DR solutions better suited to major appliances than smaller plug loads
  - Larger peak loads to shed
  - Physical control limits



Summary

- Connectivity offers limited EE savings in plug load devices
  - IoT systems in future may address this challenge

- Connectivity offers limited DR savings in plug loads
  - Potential for Human-in-the-Loop

- Recommendation: Continued collaboration between utilities, DOE/ ENERGY STAR program, and manufacturers to improve EE standards and DR protocols for plug loads

Questions?

Thank you!

CalPlug Team Presenters:

Joy Pixley, Katie Gladych, Michael Klopfer