New Boundaries for Ecodesign:
From Stovepipes to Umbrellas

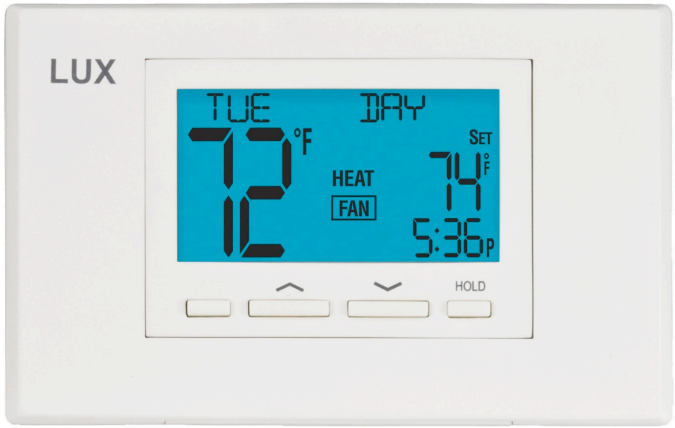
Alan Meier
Energy Efficiency Center
University of California, Davis
Brussels, 4 February 2014

Measuring the Usability of Programmable Thermostats
(and Other Really Annoying Devices)

Programmable Thermostats

~10% of US energy

- 1995: Energy Star created an endorsement program for "energy-saving" programmable thermostats
- Energy Star concluded that homes with programmable thermostats used more energy than homes with manual thermostats
- Problem attributed to consumer confusion about operation, e.g. nobody could operate them
- Energy Star terminated the specification for programmable thermostats until it could "fix" the usability problem



Premise: Improving the usability of thermostats will *facilitate* energy-saving behavior

Survey of a Home

- "Do you use the programming features of the thermostat?"

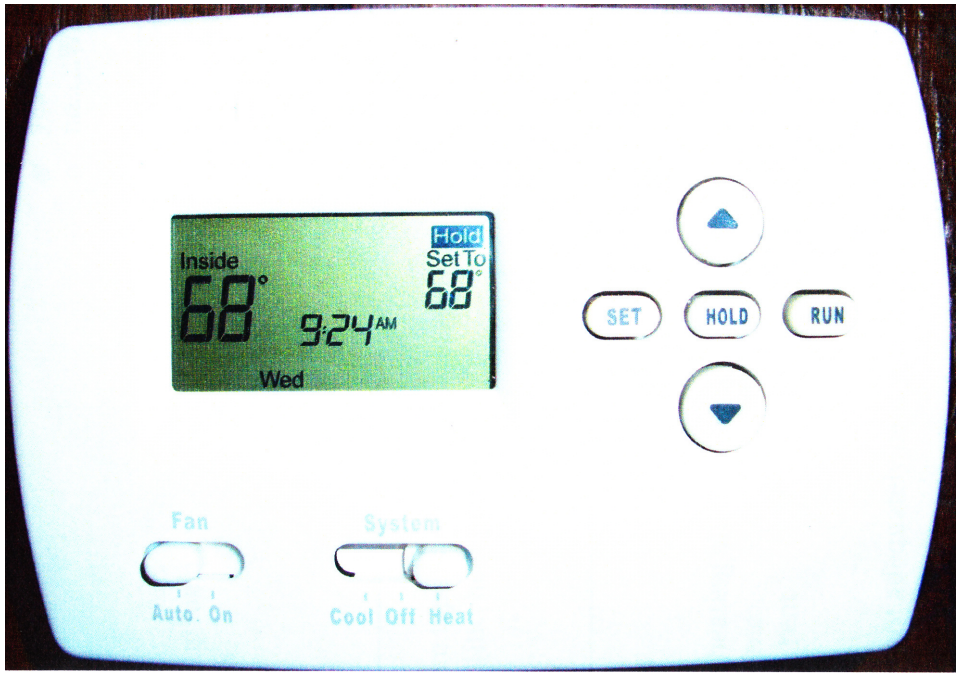
- "Yes"

- "Are you satisfied with your thermostat?"

- "It's OK"

- "If you could have a new thermostat, what would you like it to do differently from your current thermostat? (language, font size, button size, technical terms)?"

- "NO"

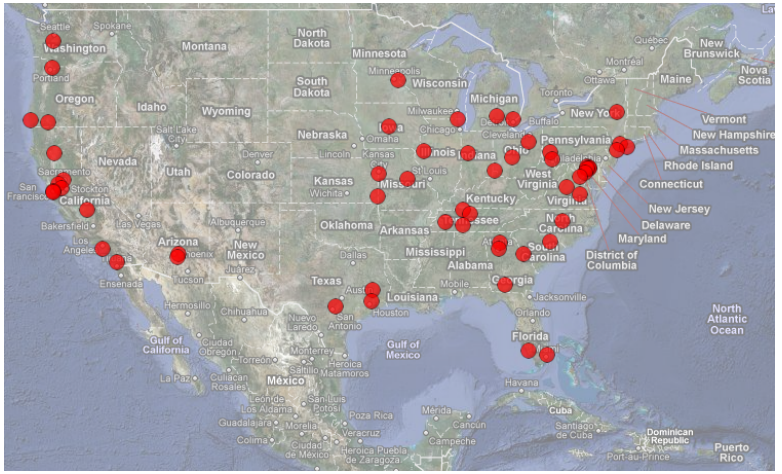


"The thermostat is on Hold"

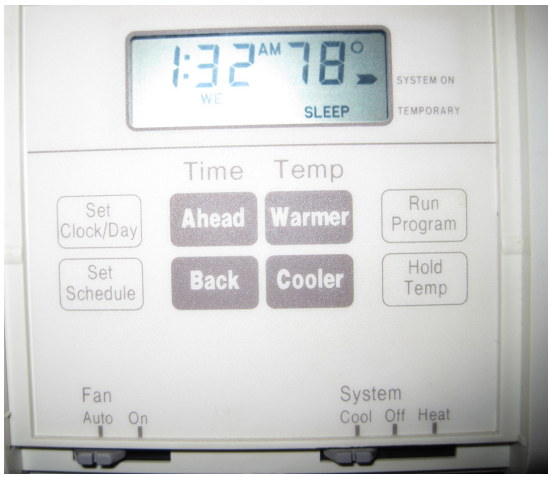
National Survey Results

using Amazon Mechanical Turk

- ~20% had errors in time setting
- ~50% on long-term hold
- 63 responses in 24 hr







Examples of uploaded photos

And Now the Video…

How to Measure a Product's Usability?

1. Define tasks
2. Quantify peoples' ability to accomplish tasks
   - Average elapsed time for completion
   - % that accomplished task
   - "other?"
3. Compute "usability score" based on metrics

Define Tasks

Task 1: Turn the thermostat from “off” to “heat.”

Task 2: Set the correct time.

Task 3: Identify the temperature the device is set to reach.

Task 4: Identify what temperature the thermostat is set to reach for Thursday at 9:00 PM.

Task 5: Put the thermostat in “hold” or “vacation” to keep the same temperature while gone.

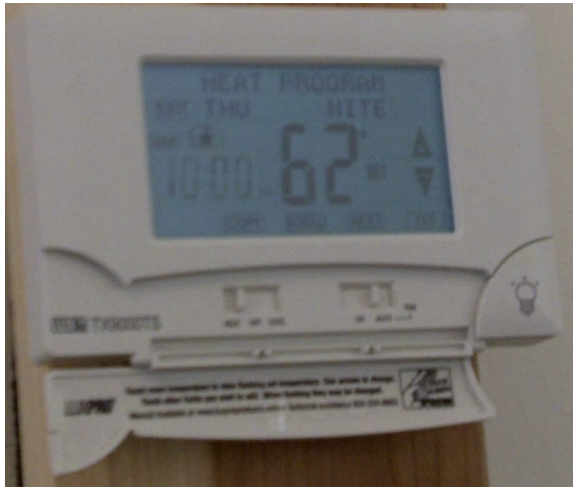
Task 6: Program a schedule and temperature preferences for Monday through Friday.

Details of Usability Tests

- 5 thermostat interfaces
- 31 participants
- 2 interfaces per person
- 6 tasks for each test
- 62 tests total



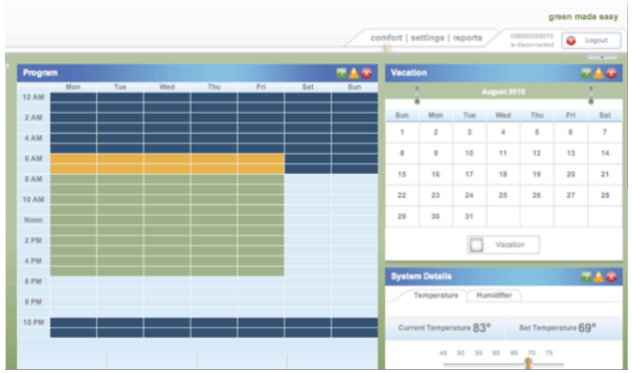
Thermostats Tested



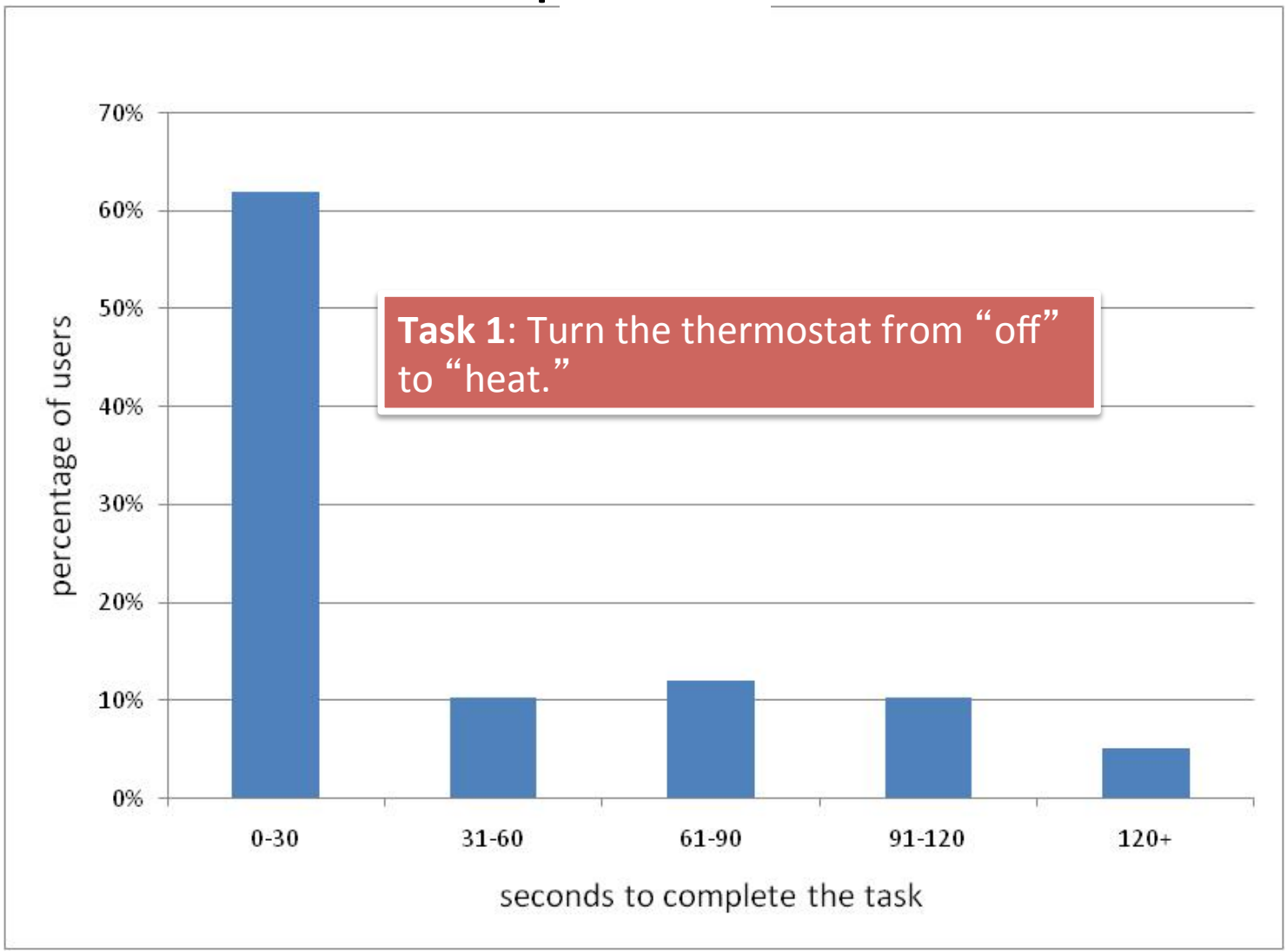




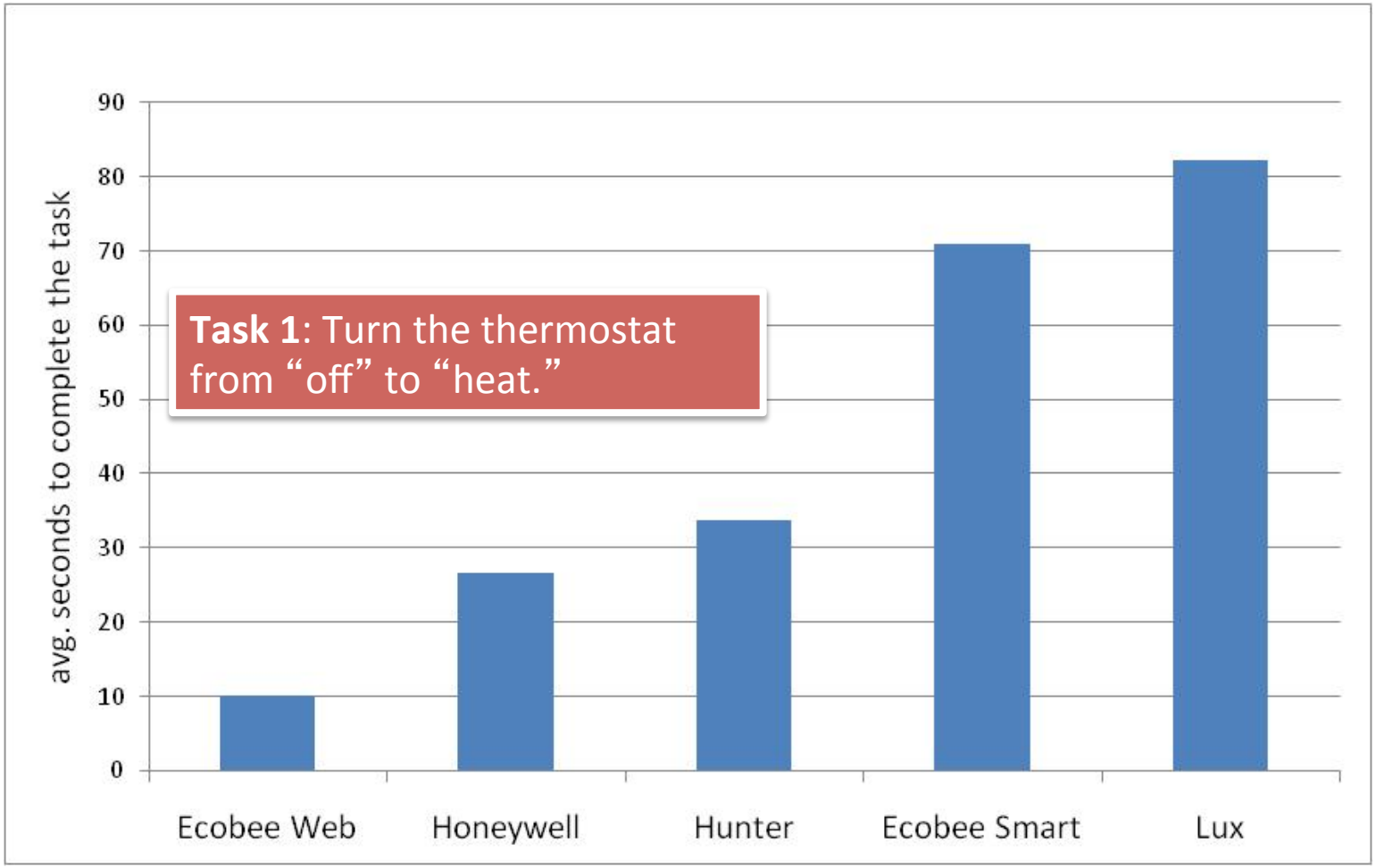




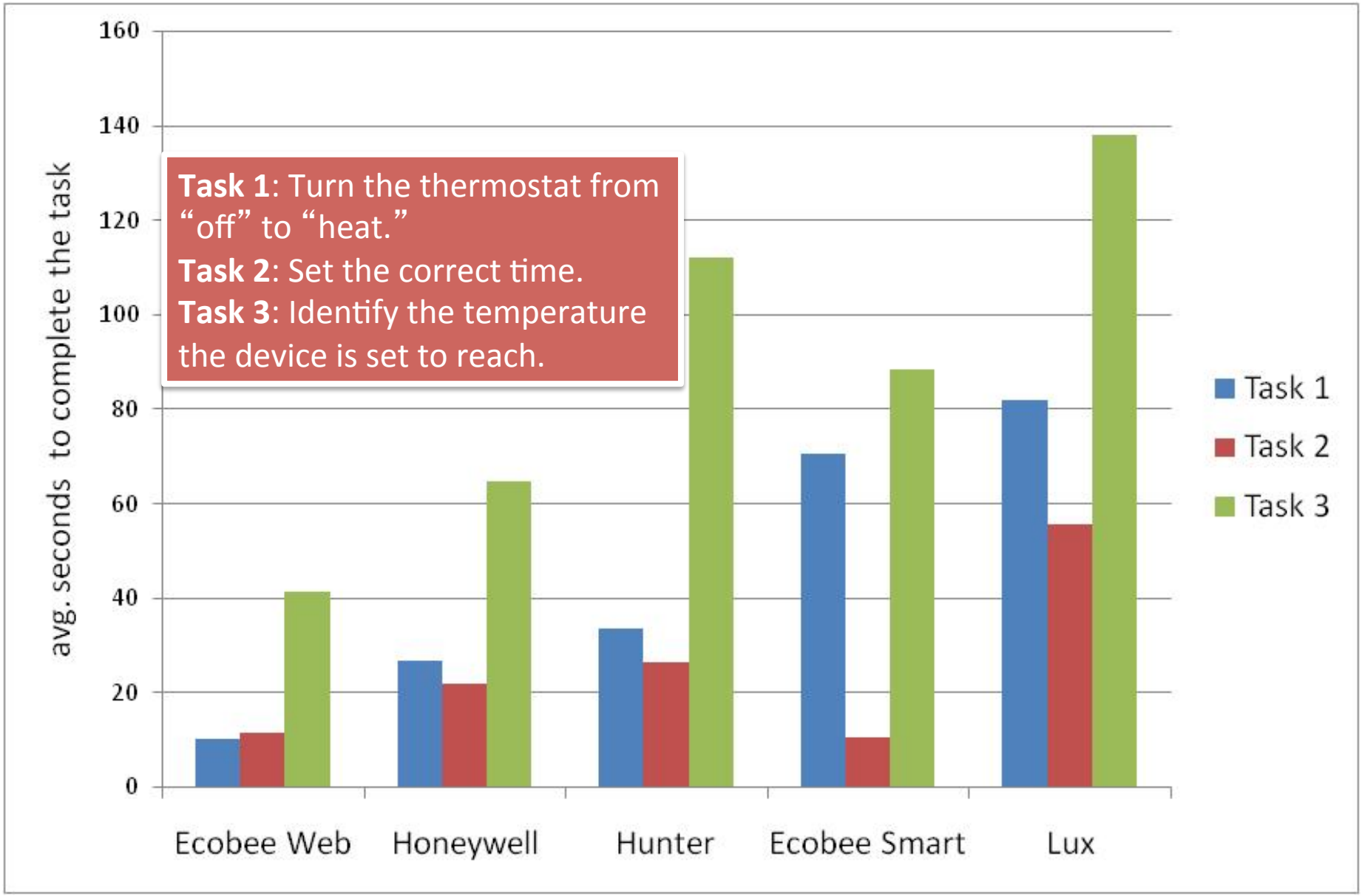
Distribution of Times for Subjects to Complete Task 1



Average Time to Complete Task by Model



Time to Complete Tasks by Model



Defining a Metric for Usability

- Relies on actions that are easy to observe, measure, and are unambiguous
- Captures essence of device's usability
- Closed-end scale, e.g. values between 0 and 1 to allow combination of task metrics and creation of a usability "score"

Converting Task Time & Success into a Metric

"Combined Completion Coefficient"

$$M_i = 2c\left(1 - \frac{e^x}{1+e^x}\right)$$

Where,

$$c = \begin{pmatrix} 0, \text{ if subject failed to complete task} \\ 1, \text{ if subject completed task} \end{pmatrix}$$

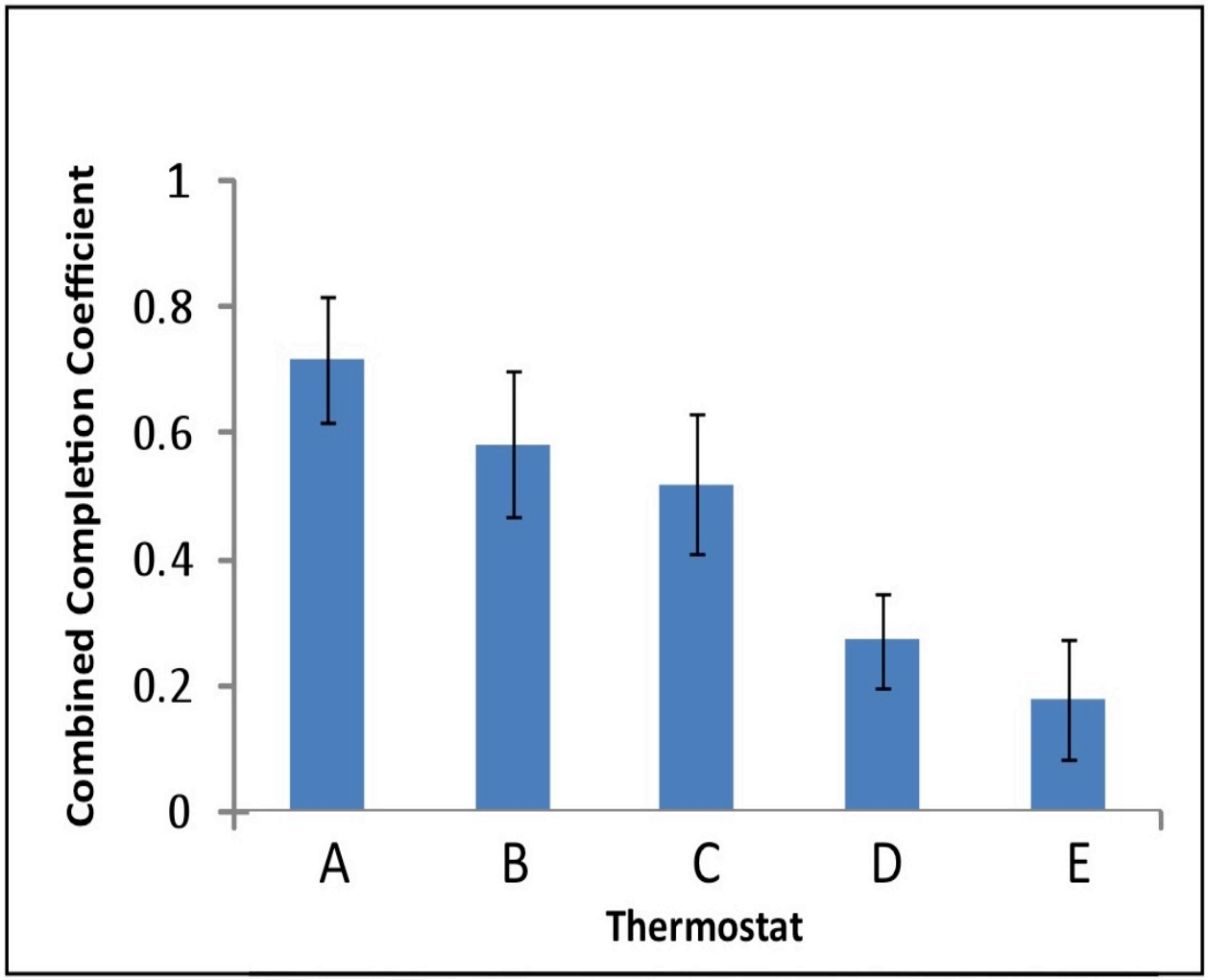
$$x = \frac{t}{k}$$

t = time for subject to complete task (in seconds)

k = an empirically - derived constant weighting value of failures to complete

Note that M_i will always be between 0 and 1.

Combined Completion Coefficient based on 3 tasks – A Usability "Score"



The Next Thermostat You Buy May Be Easier to Use

- Partial verification of methodology has been done by one manufacturer and one utility
- Energy Star wants to adopt this methodology and include a minimum level of usability in its thermostat specification

Other lousy interfaces...

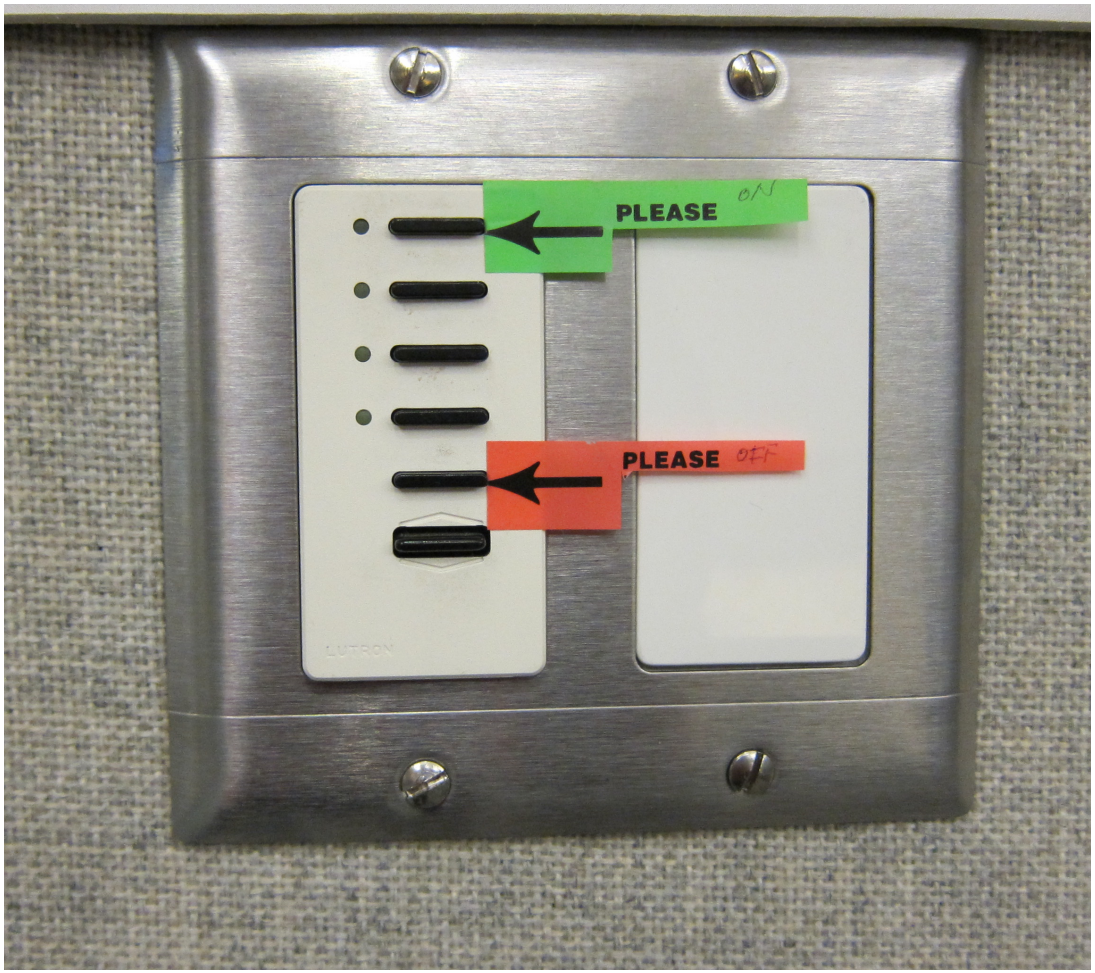
Meanwhile...



Internet-connected thermostats

Lighting Controls

in commercial buildings



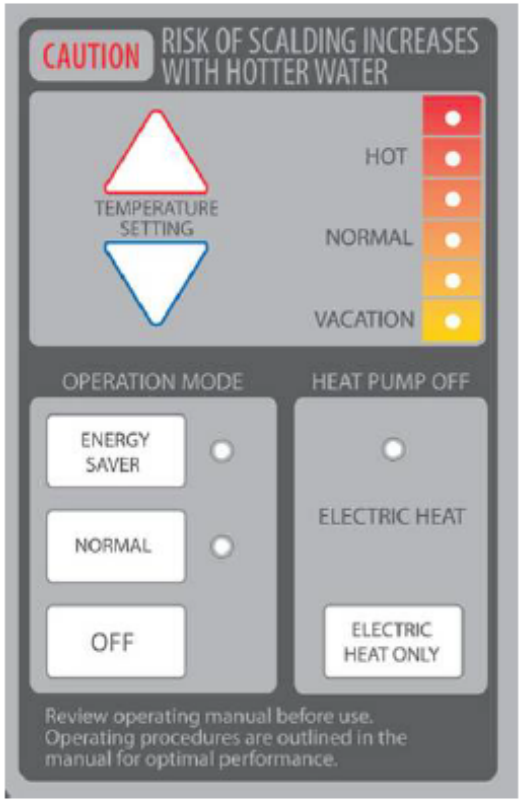
Step 1: Define Tasks…

1. Determine status of lights
2. Switch light on
3. Switch light off
4. Identify if light has dimming capability
5. Dim light to 50%

User-Unfriendly Controls for Heat Pump Water Heaters







A. O. Smith GE Rheem

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EPRI ELECTRIC POWER RESEARCH INSTITUTE

Efficiency Doesn't Stop at the Product Boundary

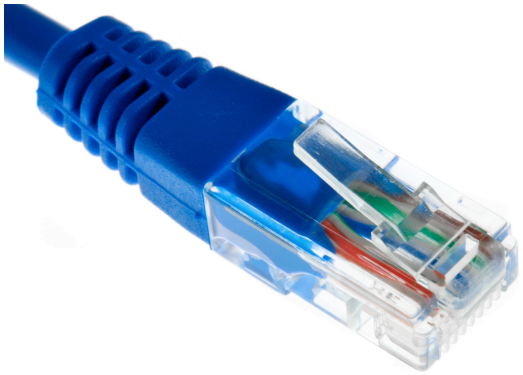
- Many people fail to exploit energy-saving features of programmable thermostats because of usability problems
  - ~50% of programmable thermostats set to long-term hold
  - ~20% do not have the correct time
- Range in completion rates for tasks demonstrates influence of usability
- We created and demonstrated a methodology to quantify usability
  - Could be applied to other products

Premise: Improving the usability of thermostats will *facilitate* energy-saving behavior

Direct Current Appliances

Suddenly DC Appliances are Possible

- USB and Ethernet now supports 50 & 100 W
- Some new homes are already being built with USB in walls, next to 115 VAC (in USA)





New Possibilities with DC

- **Low power DC through USB/Ethernet is a higher-quality electricity because it is coupled with information**
- **Opens new energy-saving strategies for buildings, equipment , integration of renewables, and storage**
  - **Observation: a 600 litre refrigerator uses < 50 W (average)**
- **10% energy savings?**
- **Enables incremental transitions to renewables, local storage, grid response**

DC Boundary Problems

- DC appliances are excluded from nearly all MEPS
- No test procedures for most DC equipment
- Integration with “modest” PV and batteries not yet considered



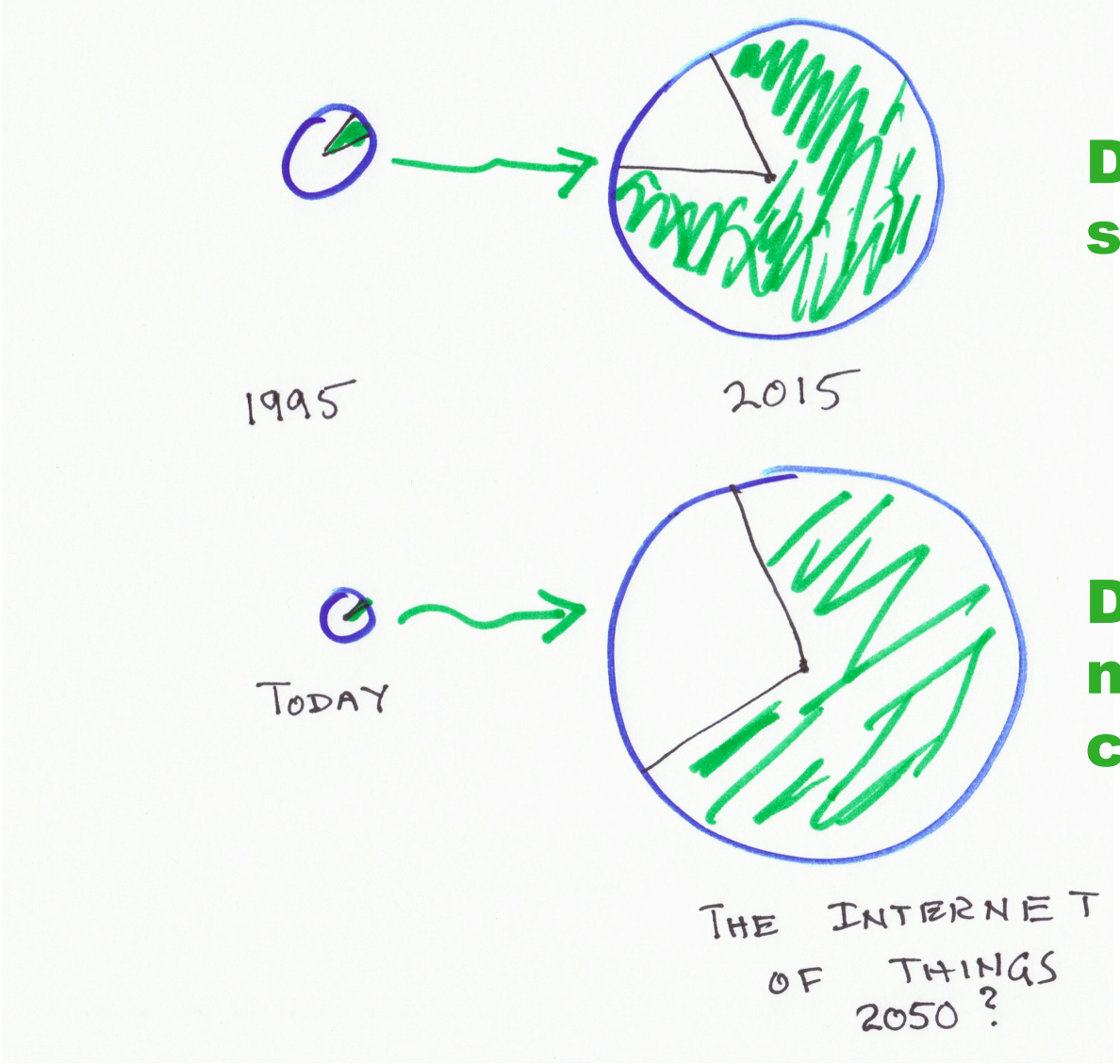
A USB Microwave!

Non-energy Benefits Will Almost Certainly Drive DC Adoption

- Simplified installation and repair (fewer electricians)
- Plug and play allows automatic recognition
- Simplified communications and control
- New services and features?

Internet of Things

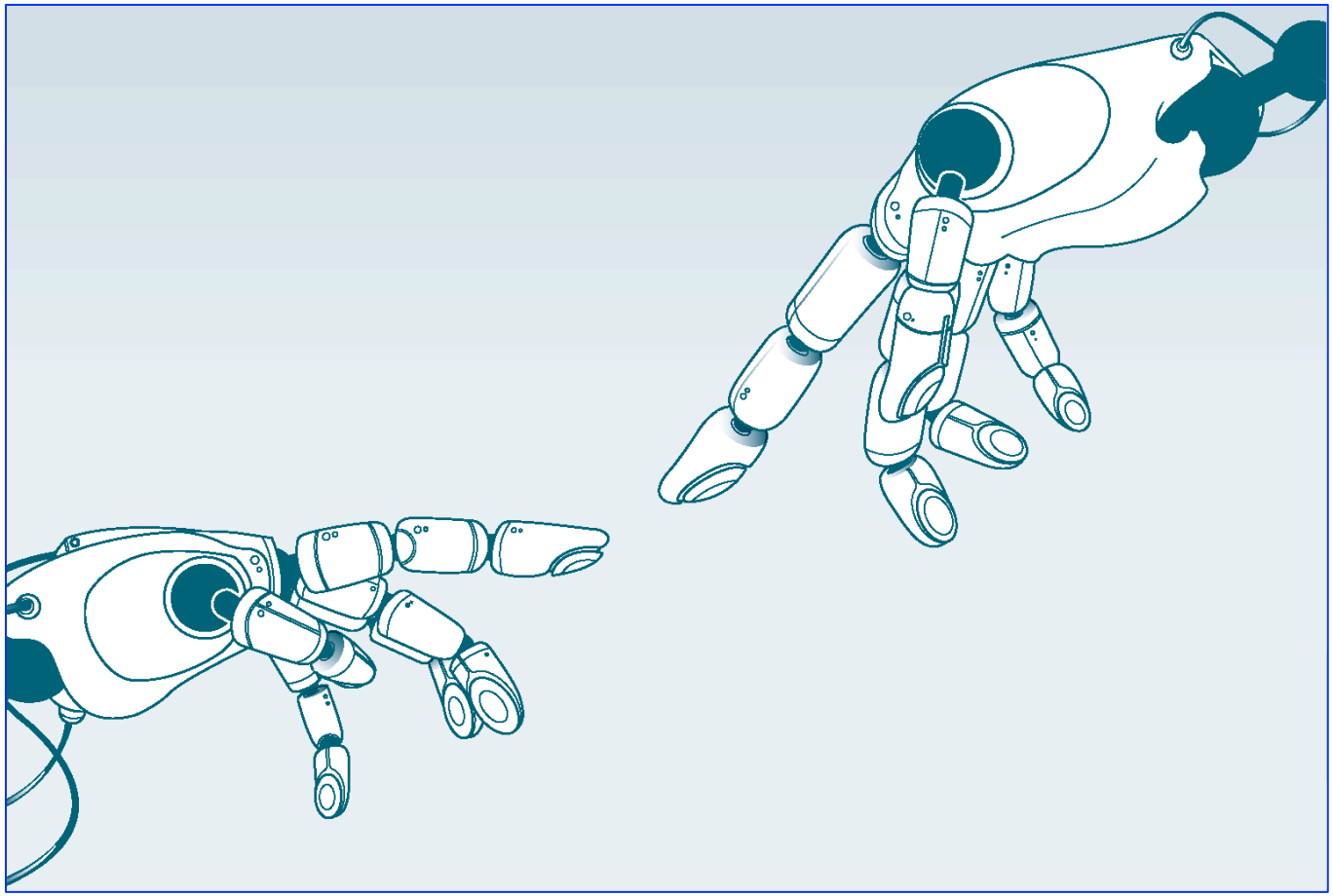
Growth of Devices With Standby Power and Network Connections



Devices with standby power

Devices with network connections

Much of the growth in information flows will occur between machines



Implications

- The "Internet of Things" is actually the "Internet of Energy-Using Things"
  - Many new things will be supplying information: windows, streets, and suitcases
  - We need to make sure that the energy is used wisely
  - We need to develop network devices so efficient that they can happily operate on ambient energy sources: light, heat, motion, and air movement
- Network-related energy will be much, much larger than standby

Changing Boundaries

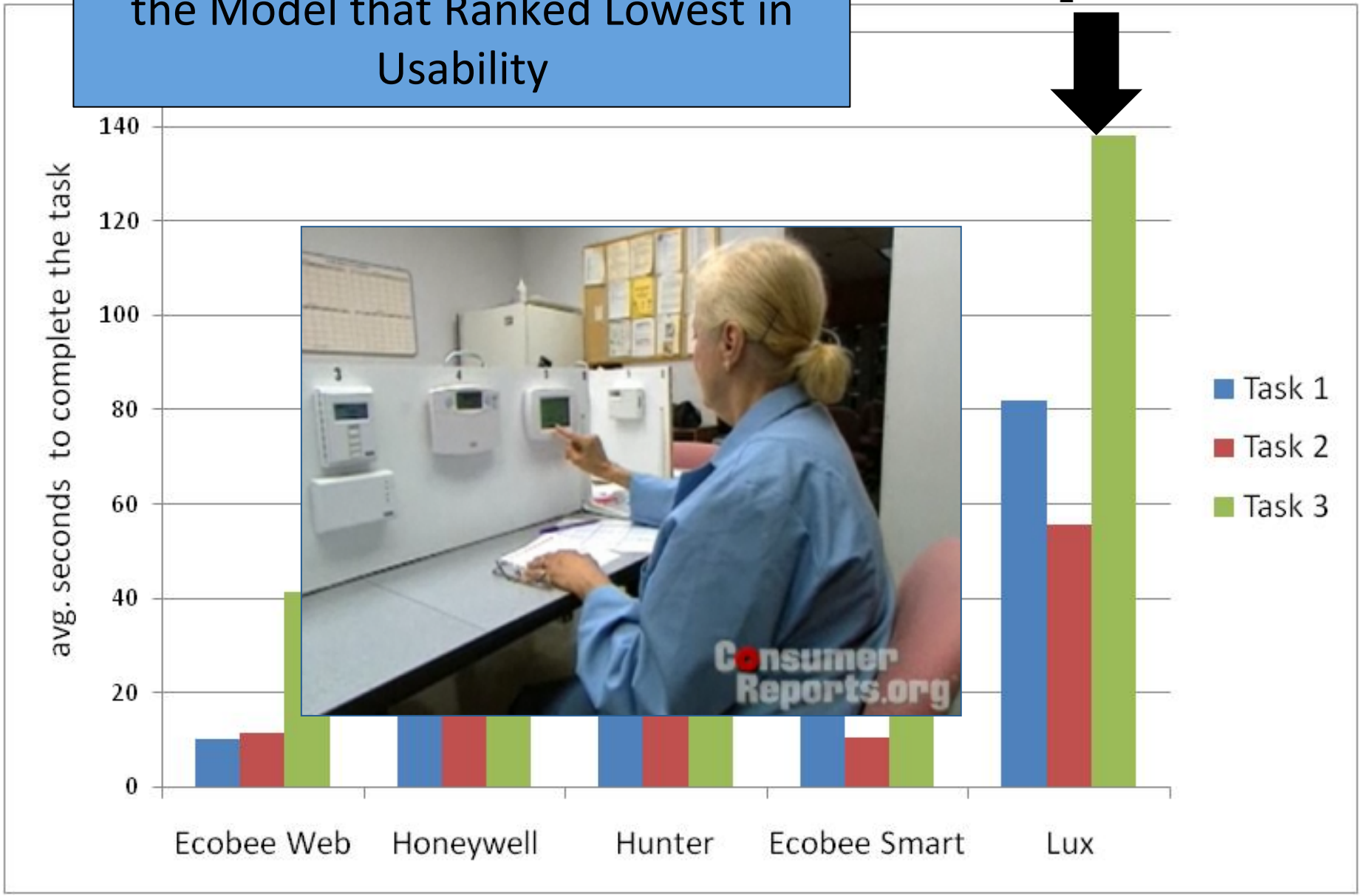
- Usability
  - Considers the user as part of the product
- DC Power
  - A new form of electricity
- Internet of Things
  - An information revolution dragging energy use with it

Three Examples Illustrating the New Boundaries of Energy Efficiency

- Usability of products
- DC power through USB and Ethernet
- Observations:
  - Near-zero energy buildings won't occur without the active collaboration of the occupants
  - Proliferation of smaller appliances, where energy growth continues
  - We need to promote greater integration of renewables – "modest PV" in existing buildings, not separate from efficiency
  - Energy consumption of one product depends on its relationship to another product

Consumer Reports Recommended the Model that Ranked Lowest in Usability

Consumer Reports



Six Lighting Controls











