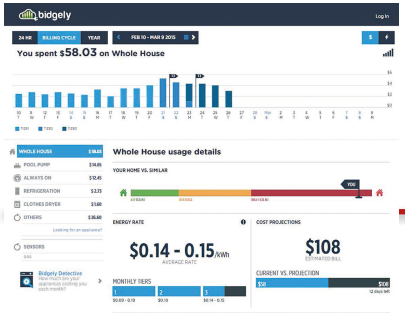

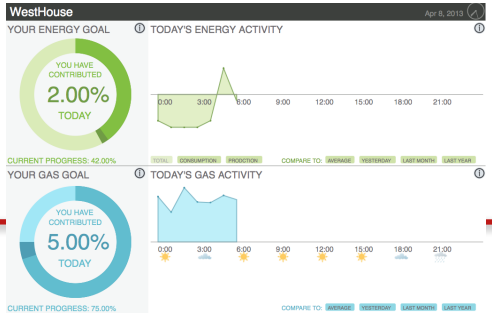

Personal Energy Analytics:

Successes, failures and challenges

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Human Centered Systems for Sustainable Living

SFU SCHOOL OF INTERACTIVE ARTS + TECHNOLOGY

Background

- Computer scientist
  - Information visualization, personal visual analytics
  - Information and computational systems for sustainable living
- My team:
  - Architects, engineers, computer scientists, designers, psychologists
- Our collaborators
  - Energy utilities, urban planners, green tech companies, building developers and designers, trades, community gardeners, social scientists....

Overview (and provocation)

- Chapter 1: Frame the problem
  - Energy, humans and behaviour
- Chapter 2: Data, feedback and design mismatches
- Chapter 3: The role NILM research [does, can, might] play
  - Discretionary use
  - Trust and agency

- Are we asking the right questions?
- Are we collecting (all) the right data?
- Are we operating under [correct, reasonable, effective] assumptions?

Overview (and provocation)

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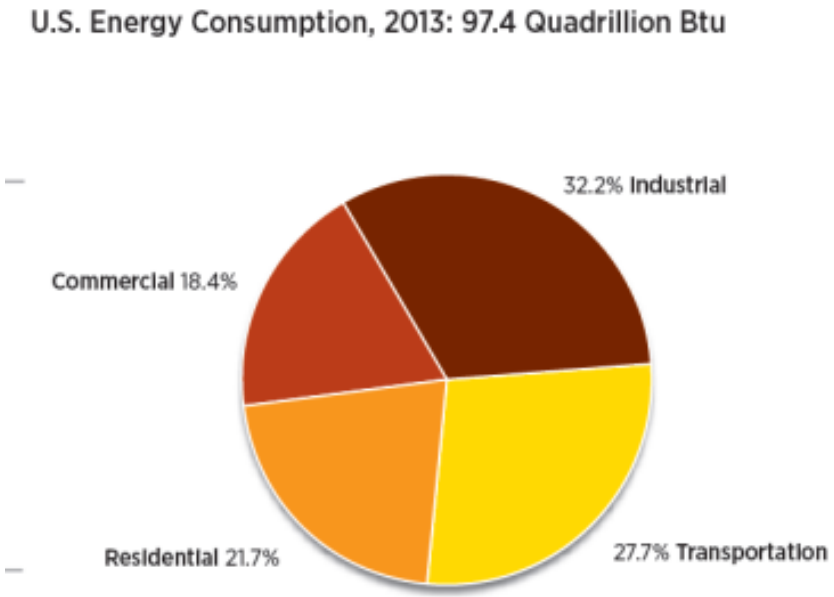
Buildings use significant energy

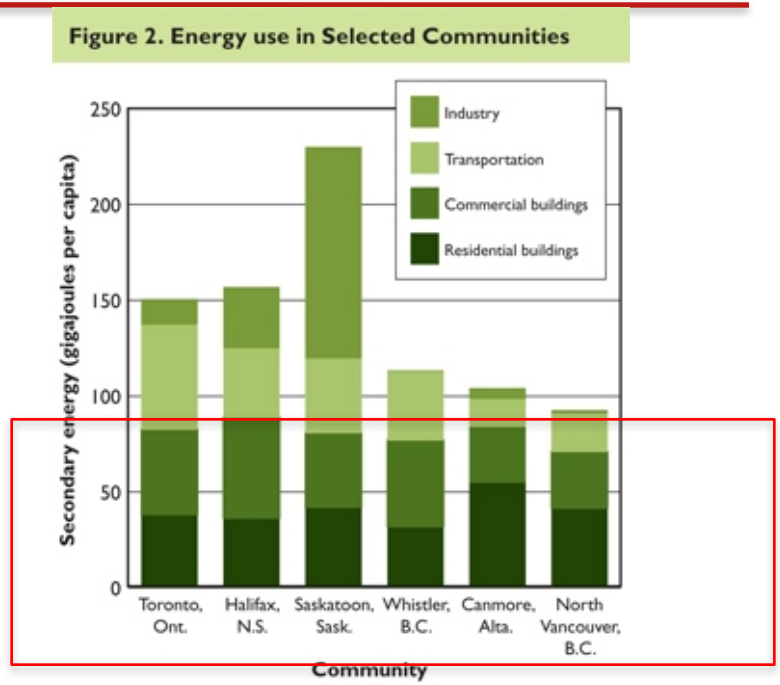
- Buildings in the US accounted for 40% energy consumption in 2013
  - ~22% residential



U.S. Department of Energy, Energy Information Administration

Buildings use significant energy

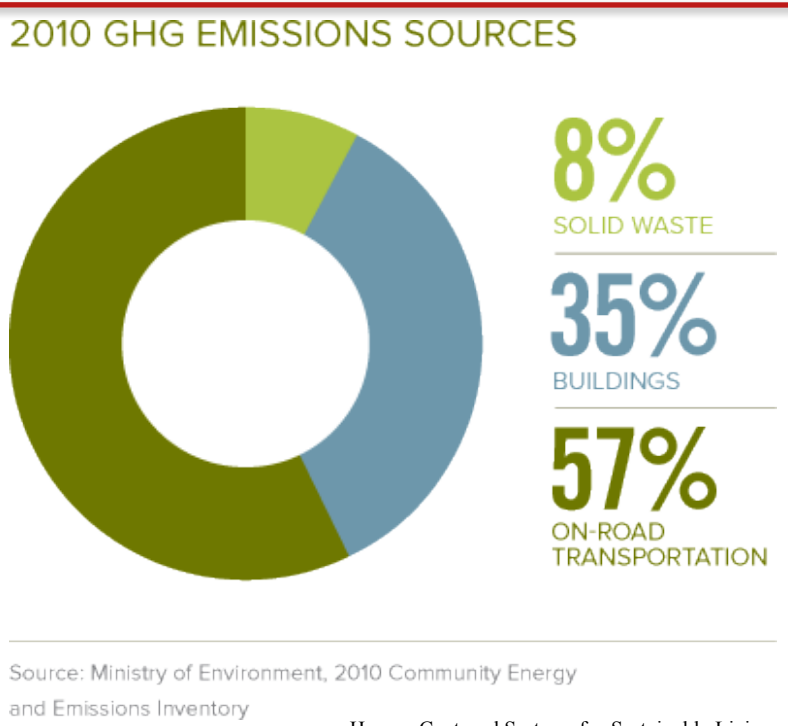
- Depending on the area, they are a primary consumer
  - Canadian study of community energy use, 2006



Narural Resources Canada, Energy resources, 2008

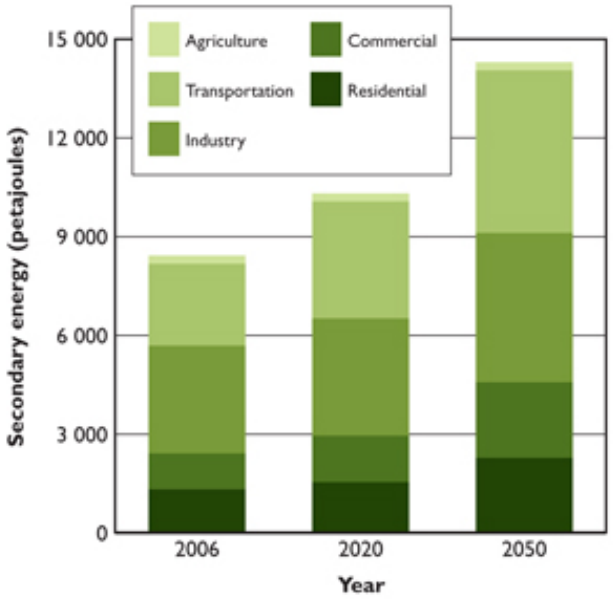
Emissions

- Even in BC, home of "clean energy", they generate significant GHGs



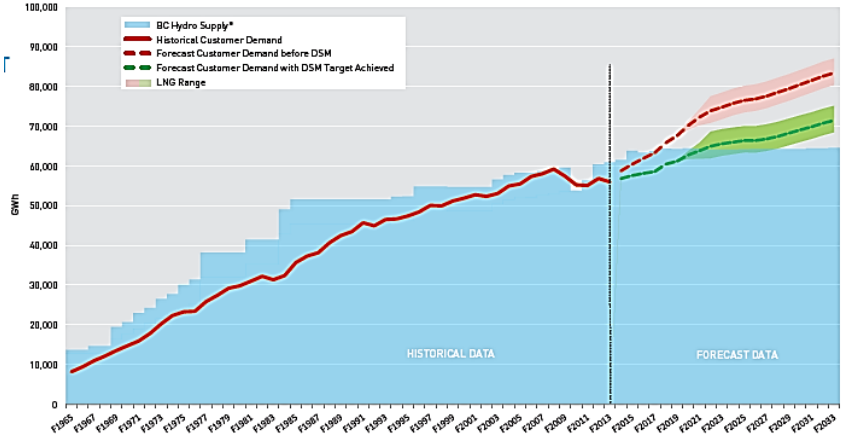
But that's not the scary part

Figure 3. Forecasted Growth in Community Energy Use



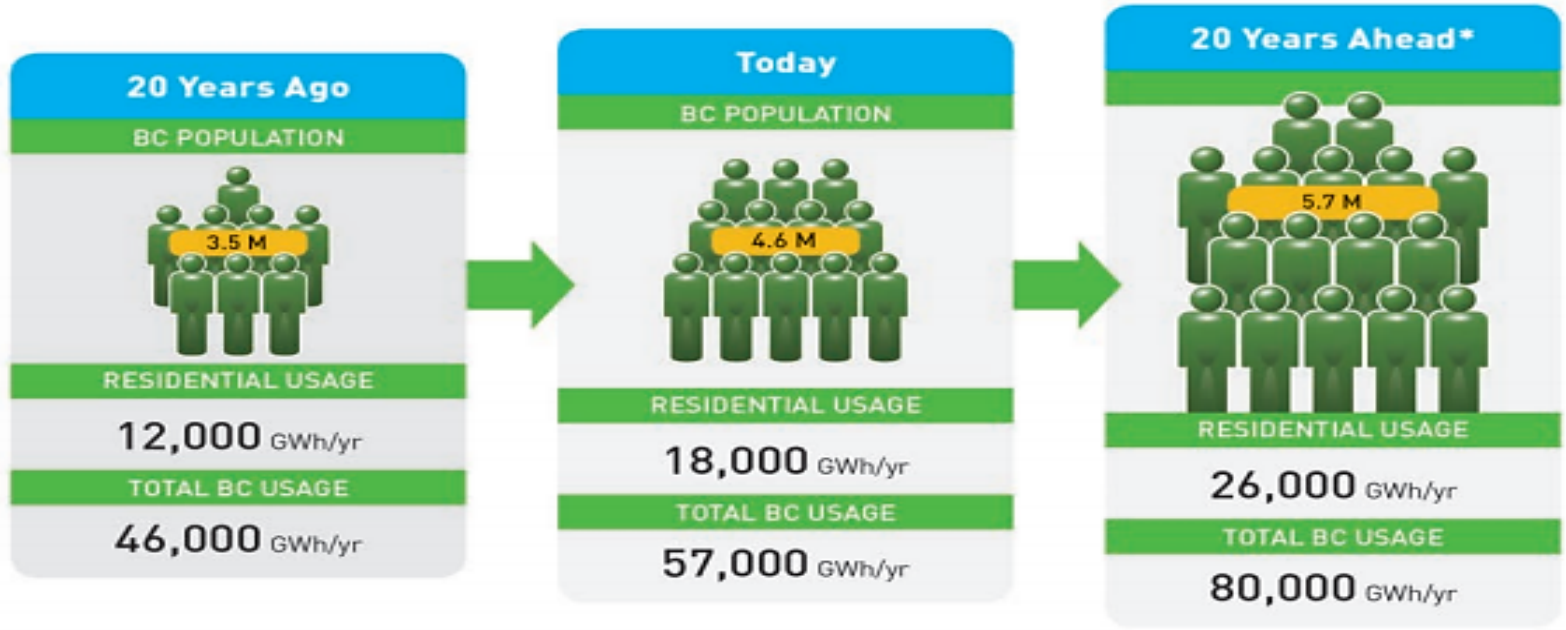
Natural Resources Canada, 2006

Electricity use is expected to increase by 40% over the next 20 years



BC Hydro PowerSmart, 2014

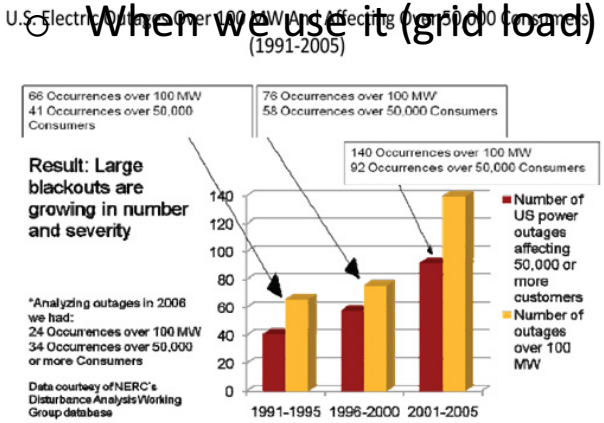
Residential electricity use is expected to outpace population growth by 2:1

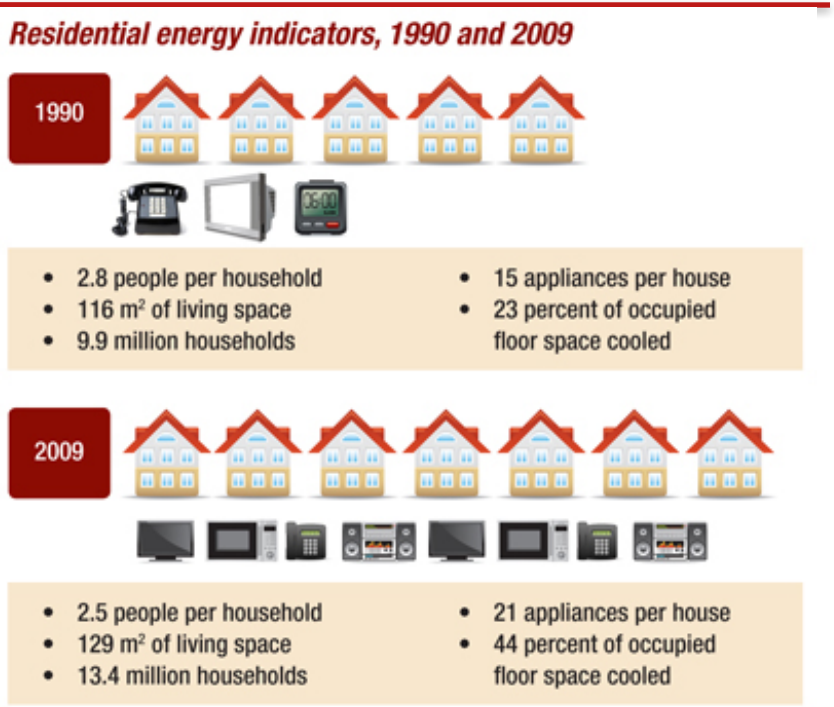


© BC Hydro

Increasing demand for energy

- Reducing residential energy use is an important strategy in reducing our environmental footprint
  - How much we use (consumption)
  - When we use it (grid load)

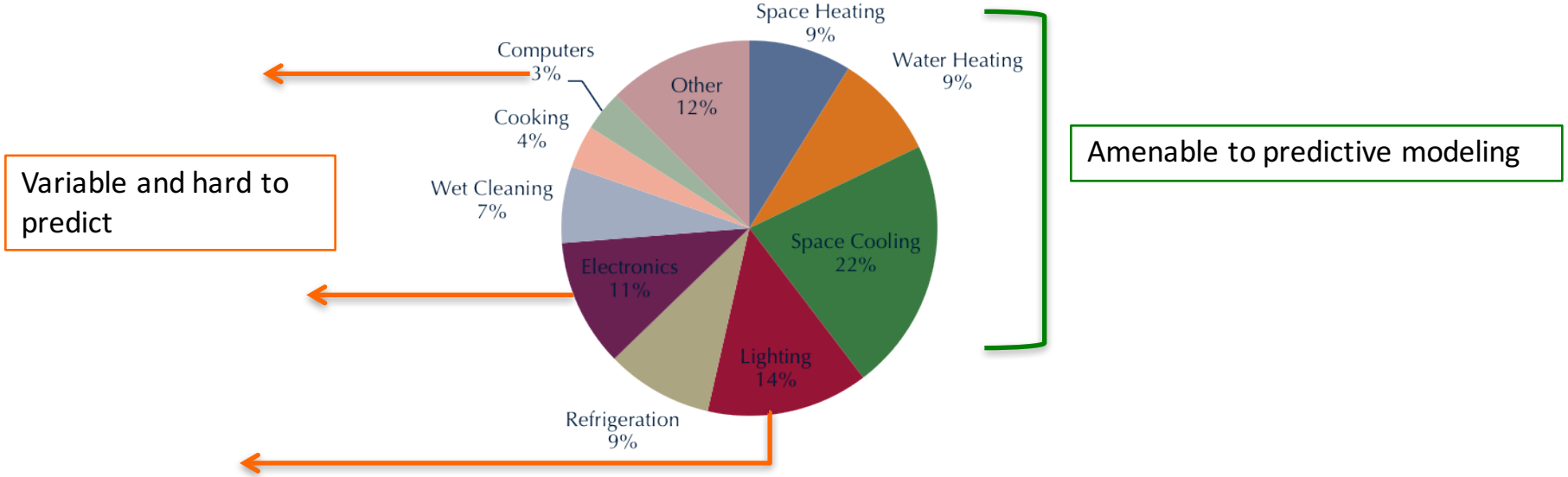




Natural Resources Canada, 2009

Quick context: where we use energy

Residential Consumption by End Use, USA 2010.



US DoE, Building Energy Data Book, Table 21.5, 2012.

The rational premise

- It's all about use (behaviour)
- So clearly, more information will help

Factors that impede conservation behaviour
Kashani, Bartram, Woodbury 2012

Painful lessons 2..200

It's not just about information deficit

- The wrong kind of awareness
- Numerous environmental behaviour models

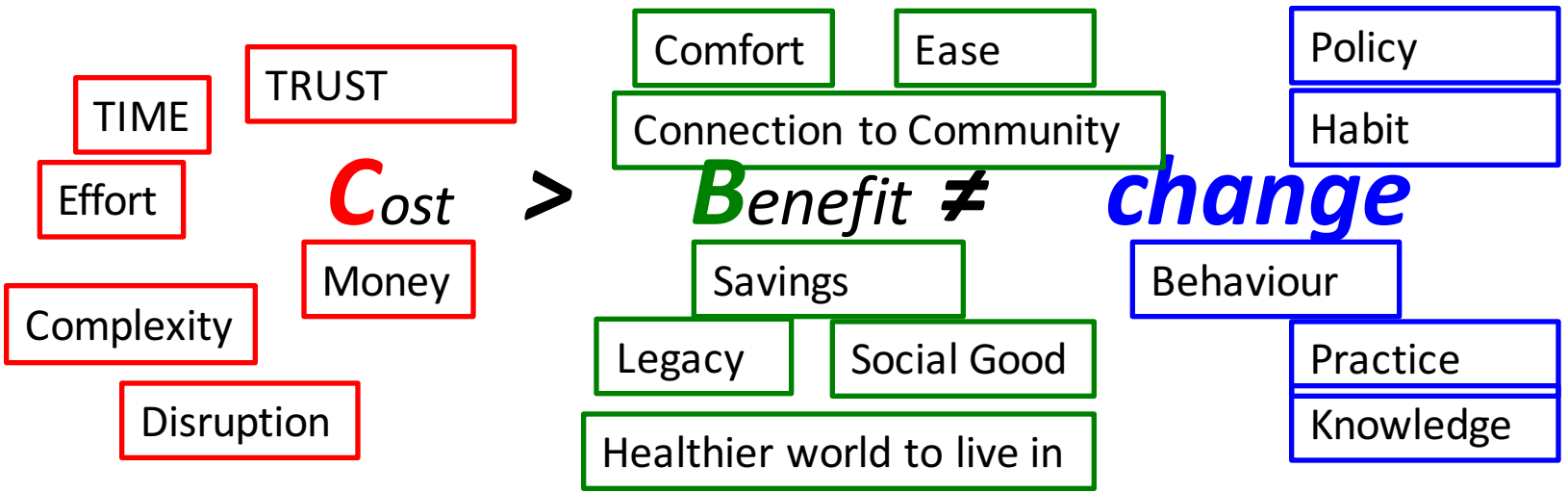
It's not just about adding more technology

- data does not invoke action
- Poor computational models of human use
- Deep lack of understanding in how we use our homes

Where and **when** is as important as **what**

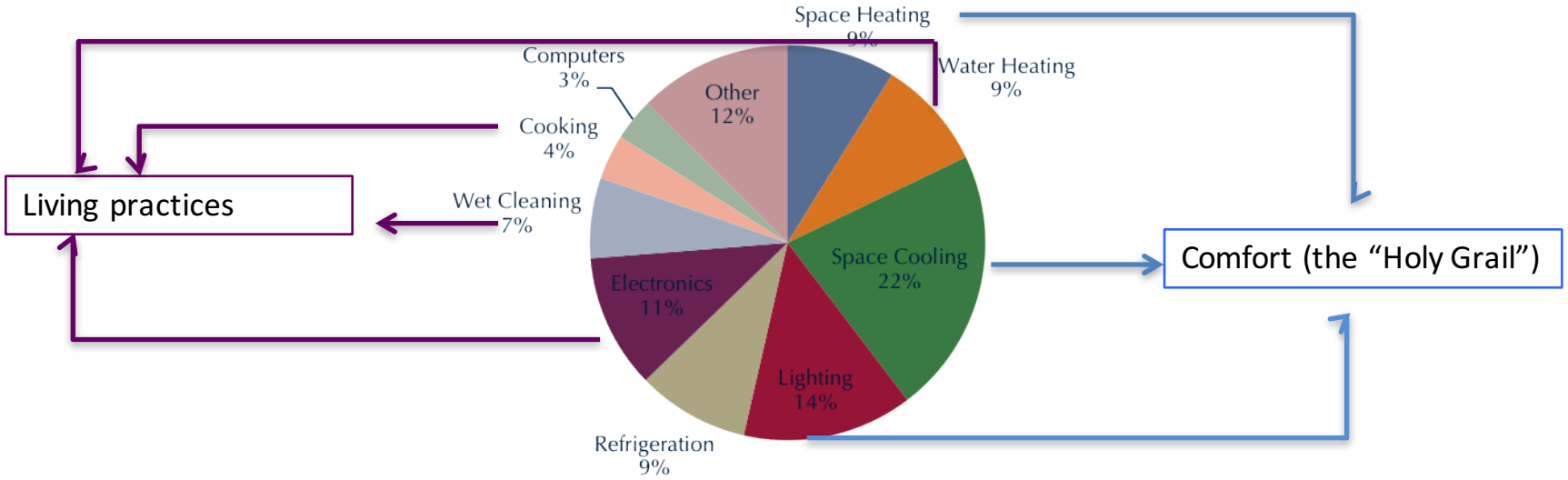
- supporting living practices

A simplistic model



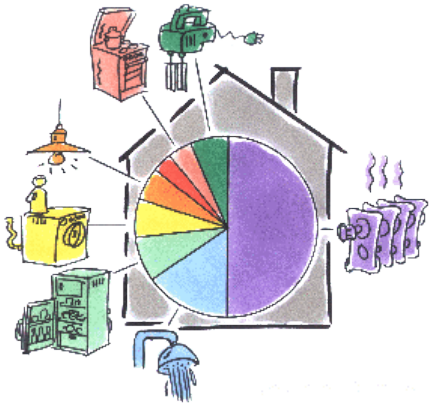
Quick context: why we use energy

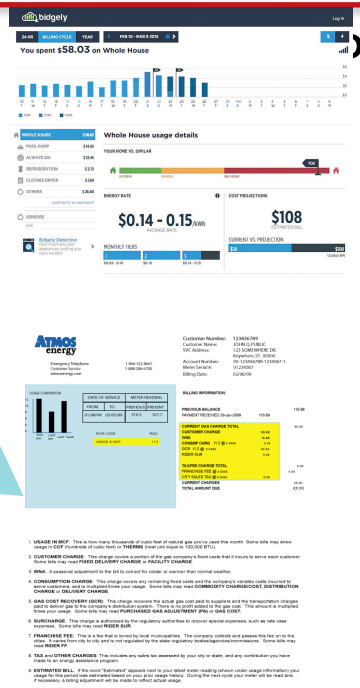
Residential Consumption by End Use, USA 2010.



US DoE, Building Energy Data Book, Table 21.5, 2012.

People have trouble understanding their use

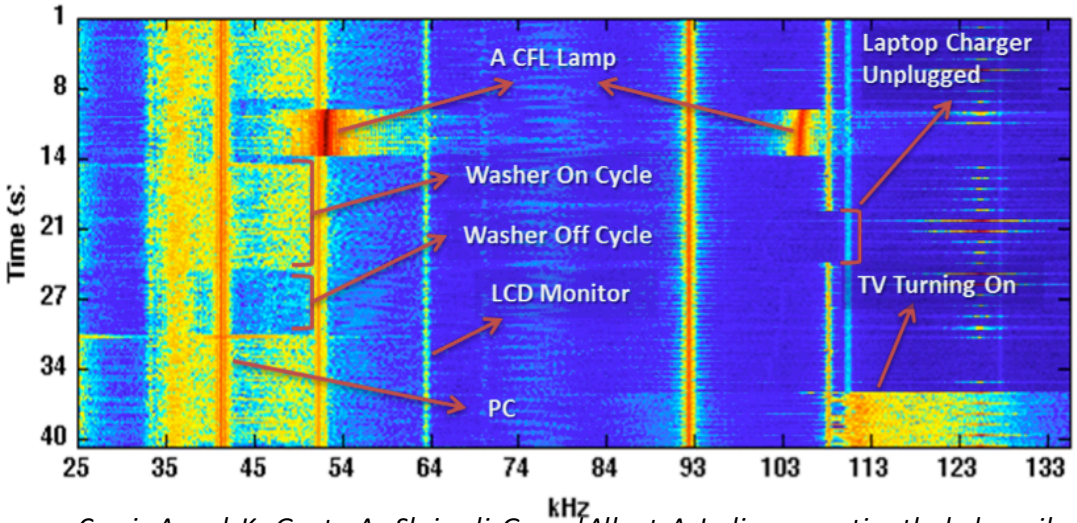




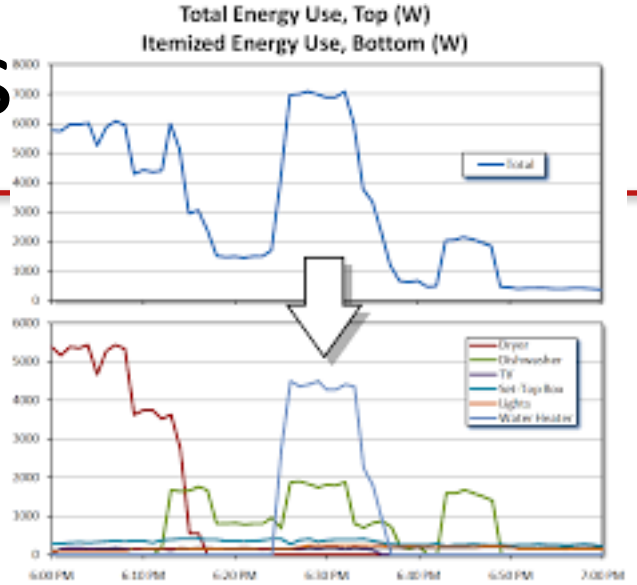
Poor energy literacy

The magic of analytics

- Monitoring energy use



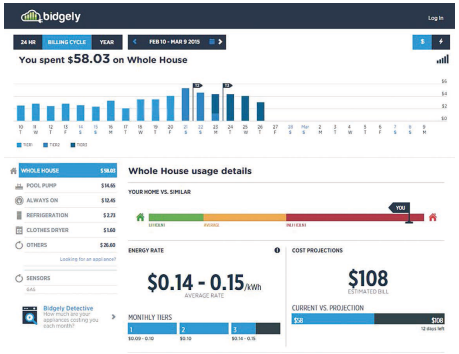
Carrie Armel, K., Gupta, A., Shrimali, G., and Albert, A. Is disaggregation the holy grail of energy efficiency? The case of electricity. Energy Policy 52, (2012), 213–234



Christensen et al. NILM Applications for the Energy-Efficient Home. US DoE, 2012

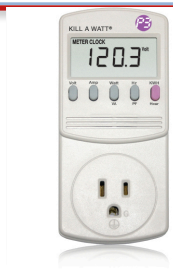
Eco-feedback approaches

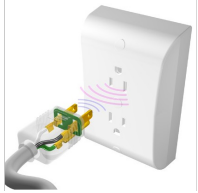
- Aggregate reporting



- Combined (HEMS)

- Detail POC





Results from the field

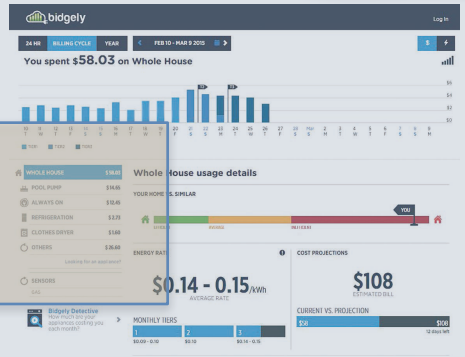
- Aggregate reporting is insufficiently rich
- Retrospective reporting does not inform behaviour

- While initial response shows high change (15%), rates drop off quickly

- Social comparison is effective

Eco-feedback approaches

Dashboards/Portals — In-Home Displays — Ambient Displays



Mobile

Detail

Aggregate

Standard feedback for the extra-informed resident

www.ge.com

What is a user?

- Consumer of energy
- Decision maker about allocation of resources
- Consumer of information?
- Interacts with artifacts and technology
- *Resident/householder/inhabitant*

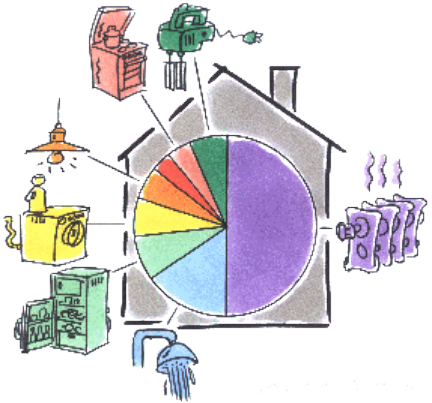
More data ≠ more efficiency …..

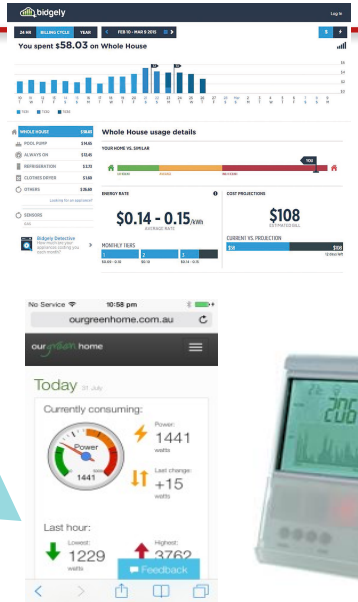
?

It's a program on conserving energy

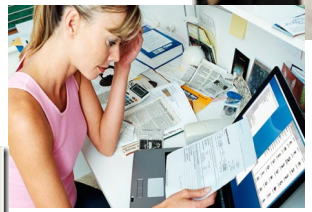
People have trouble changing their use

Daily activities

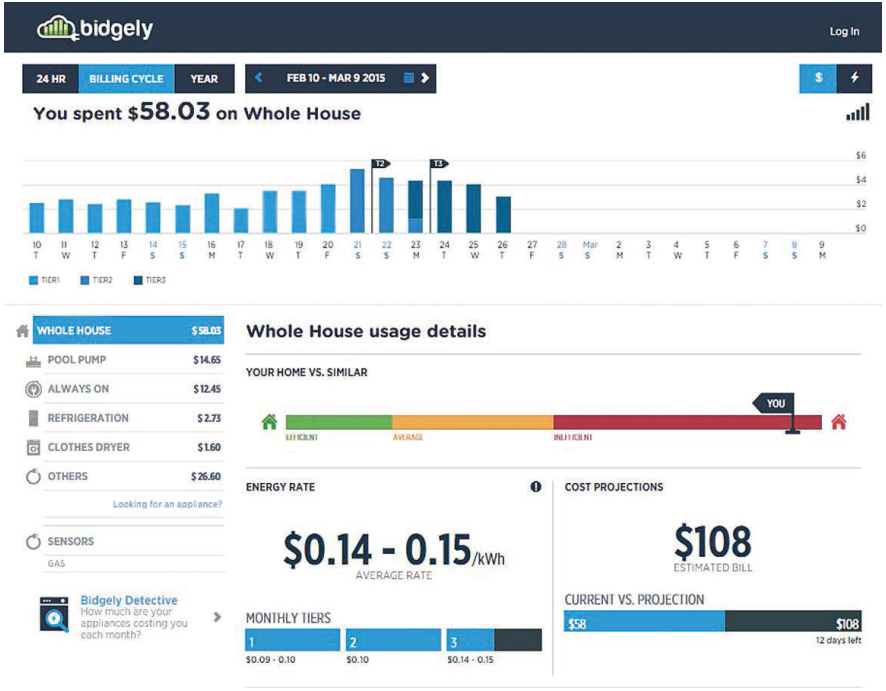




Poor energy literacy



What's the issue?



What are we missing?

- Engineering approaches are task- or data-driven
- Misaligned design
  - People don't use energy as a goal [Strengers]
  - Making which invisible visible ?
- Traditional infovis principles support only a small portion of the space
  - new ways of thinking about the problem
  - Expanding dimensions of personal visualization [Huang et al 2015]

Factors : Cognitive

- Knowledge (What does “understand” mean?)
  - Conceptual models and analytical reasoning (👍)
    - When do I spend more energy?
    - How much energy do my appliances take?
  - **Situational awareness**
    - What is using energy right now, and why?
  - **Operational knowledge (actionable)** **
    - What can I do about it [now]?

Factors : Behavioural

- Engagement and Motivation (What makes people behave differently?)
  - Extrinsic
    - Financial incentives (rebates) or disincentives (rate hikes tied to usage)
  - Intrinsic
    - Internal satisfaction in meeting goals
    - contributing to common good
  - Normative
    - social comparisons
    - shared goals
- Humans are not rational actors

Factors : effort

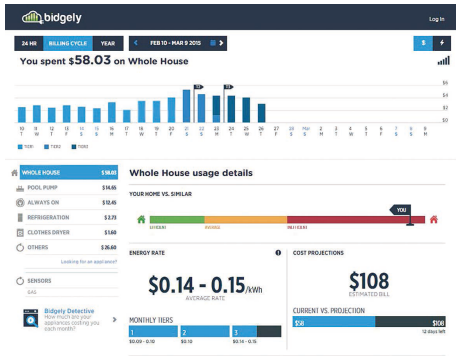
- Information access (How accessible is the feedback?)
  - Effort to find information
  - Ease of interpretation
    - What does that red light mean?
  - Appropriate context
    - Type of knowledge to support

Design dimensions for eco-feedback

- Data
  - Mental model and scope (what's a kWh?)
  - Additional: derived, personal, actions and consequence
- Reasoning and behaviour
  - Knowledge type, motivation
- Context
  - Temporal, spatial and binding
- Effort
  - Attentional demand, interaction cost
- Communicative scope
  - Affect, ecological fit

Eco-feedback approaches

Dashboards/Portals



Mobile

- Designed for analysis and reflection
- High effort
- Low engagement
- Resident as energy manager
- Financial and engineering models
- Partly actionable?
  - No context of use
  - Reduced learning

Eco-feedback approaches

In-Home Displays

- Persistent, lower effort (with caveats….)
- Situational awareness
- Data sparse
- Specific detail (POC)
- Actionable
  - (POCs) operational insights
  - misleading
- Poor ecological and aesthetic fit

Eco-feedback approaches

Ambient Displays

EnergyOrb, Ambient Inc, 2014

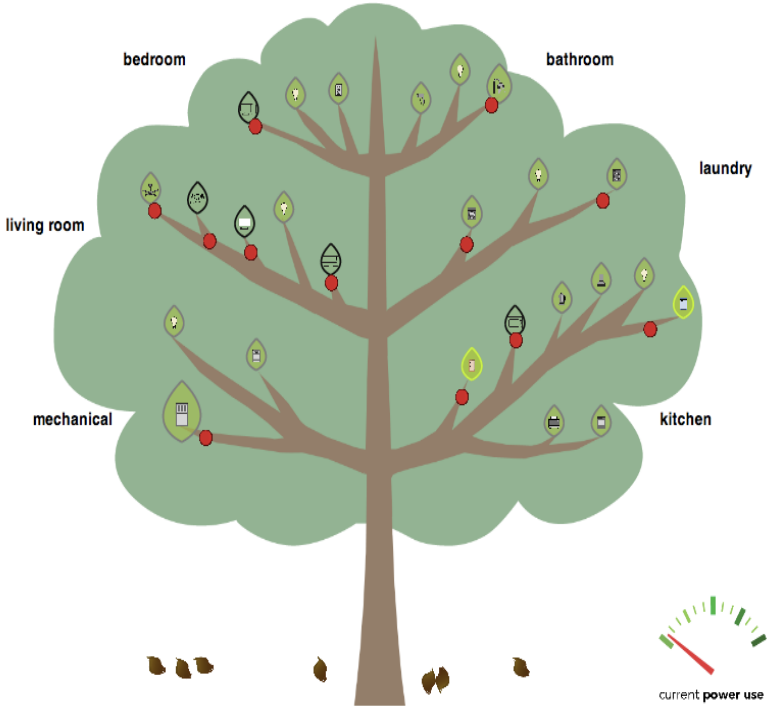
Wattson SolarMonitor, Smart Home Energy Inc, 2014

- Low detail (hazy)
- unintrusive
- Situational awareness
- Data sparse
- Reportedly engaging
- ambiguous
- Can be tuned to design sensibilities
  - People will use them ?
- Idiosyncratic, novelty item

Power-Aware Cord, Energy Design Studio, 2010

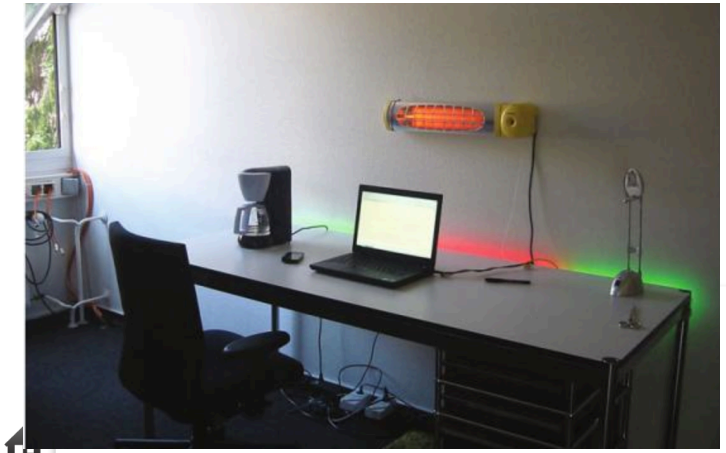
Design Challenges for eco-feedback techniques

- Match the data model to what people are doing
  - New types of data
  - Data collection
- Provide multiple reference systems
  - *visaphors*
  - Cost
  - GHGs
  - Equivalences (“4 laundry cycles”)
- Meaningful norms
  - Personal goals and achievable thresholds
  - Social framing



Right data

- Example:
  - Point of choice vs point of consumption
    - [Eves]
  - Discretionary ??
    - What/why is user doing?
  - Action hints



Design Challenges for eco-feedback techniques

- Expand context

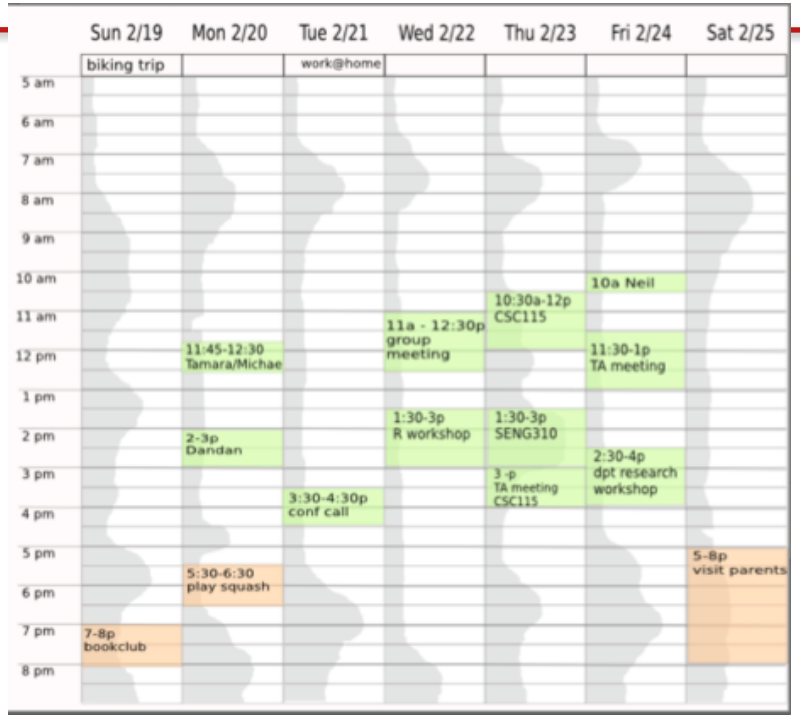
- Task/information models are incomplete
  - Analysis : **explicit** information task
  - Awareness: **implicit** relation (cooking dinner)
    - tighter mappings between activity and outcome
    - Reduced effort

- FRAMING and integration
  - Provide feedback in existing information landscape
  - Support sufficient external information

Context is not just extra information

Mashups and Framing

Reduce effort
Support "why" questions
Persistent awareness



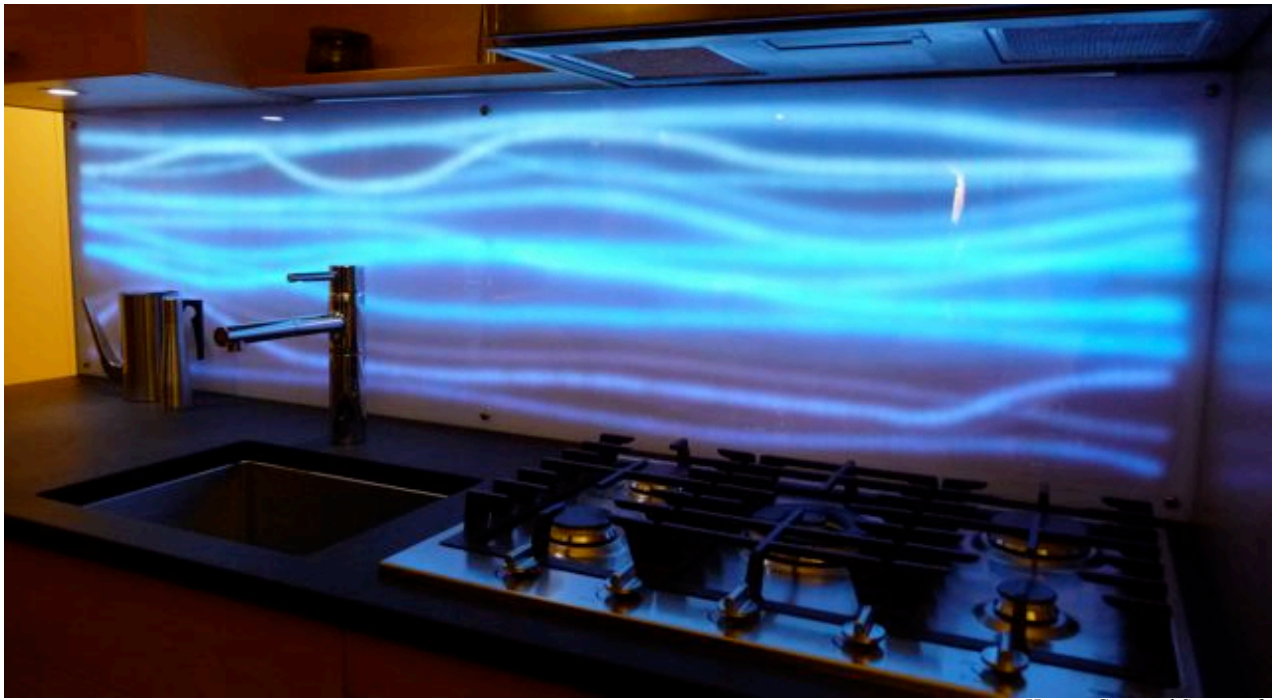
Huang et al. Calvis, InfoVis 2014.

Design Challenges for eco-feedback techniques

- Enhance Communicative Scope
- Engagement, interest and motivation

- Aesthetics and **affect**
  - "Communicate a concern, rather than show data" [Kosara 2007]
  - Enhance experience, promote engagement
    - Amplify learning
- May (should) change data model!

Data themselves change the message: affect?



Design Challenges for eco-feedback techniques

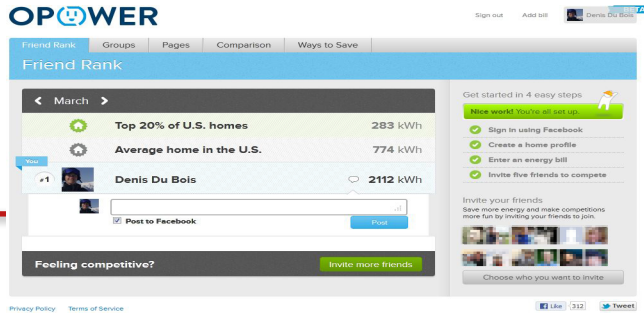
- ecological fit and appropriate data

Design Challenges for eco-feedback

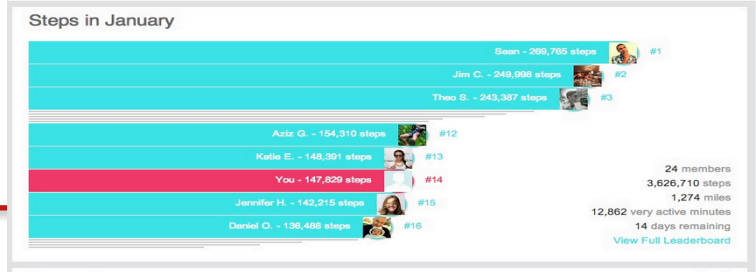
- Functional aesthetics and ecological fit
  - Design sensibility of the home
- Encoding must be adaptive
  - Light
  - Viewing distance
  - Activity
  - Additional Function
- Proxemics [Greenberg]
- Opportunistic display

Social framing

- increasingly used by organisations
  - Issues of norming and activation
- Variations on a theme ?
  - budget rather than activities
  - Privacy , community and trust
  - Common ground



Share and compare



Internet of Things –> Awareness of Activity –> Sharing –> Better Health, Share This, 2014

Social agency

- People like me?
- Comparison
- Joint goals
- Joint agency: documentation, tracking and enlisting
  - Walk to school program (BAST)
  - Localised decisions
- Social media, GPS
- District Energy management systems
  - Donate/share discretionary energy?

What is meaningful?

- What kinds of questions do people ask?
  - How am I doing wrt to “people like me”? My neighbourhood? My goal?
  - **What can I do about it?**
- Equivalences and experiential framing are key to engagement (but we don’t know the right ones…)
  - A distance of 14 Harry Potter CDs
  - 3 days where my child cannot play outside
- (How) could I live with “something like this” ?

How does NILM fit into this space?

- Extending the traditional scope of residential energy analytics

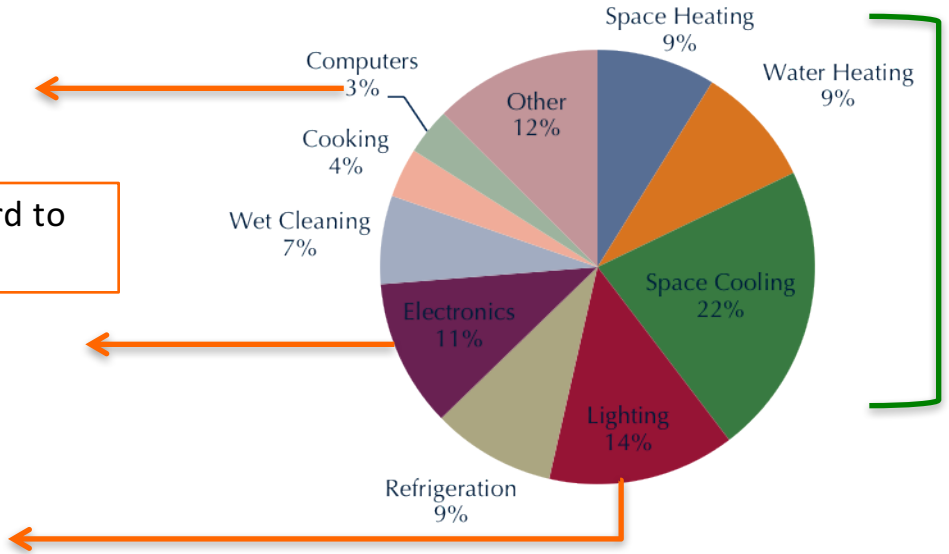
- Considering the entire information landscape of energy use
  - Recommender systems
  - Underpinning automation decisions
  - Informing building design applications and tools
- Expand richness of social schema

Non-intrusive Load Monitoring

- Load?
  - Simple consumption data insufficiently informative
  - Actions rather than appliances
  - Discretionary load
- Efficiency
  - Optimum deployment of resources
- Distributed implications
  - Generation as well as consumption
  - Local store vs. grid use

Track and characterise the critical data

Residential Consumption by End Use, USA 2010.



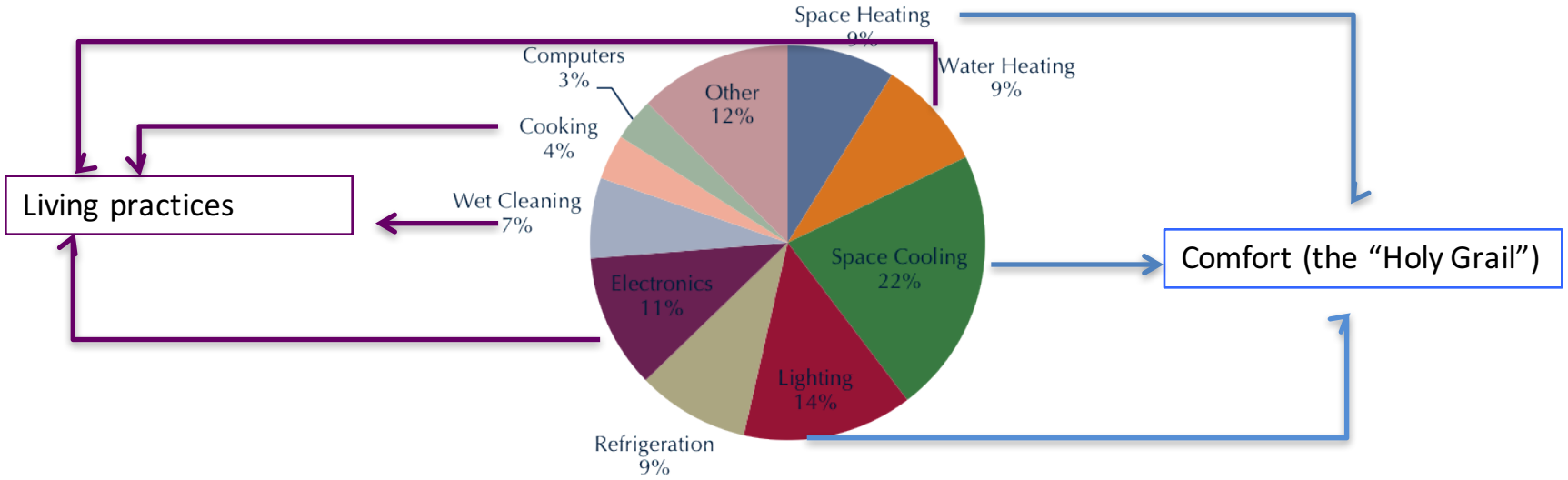
Variable and hard to predict

Amenable to predictive modeling

US DoE, Building Energy Data Book, Table 21.5, 2012.

Consider better models of user behaviour and *discretionary* use

Residential Consumption by End Use, USA 2010.



US DoE, Building Energy Data Book, Table 21.5, 2012.

Non-intrusive Load Monitoring

- Non-intrusive ?
  - Great privacy concerns
  - TRUST not simply privacy
- Agency, control and access
  - Where do the data sit?
  - Who owns them? Controls access? Gets to release interpretation?
  - Perceived benefit vs. perceived risk

Non-intrusive Load Monitoring

- Non-intrusive (Single Household)? Load Monitoring
  - More sophisticated comparison schema
  - Determinants of similarity
  - Normalized metrics
  - social media integration
- Measure “real” effect of social comparisons
  - Competition vs coordination vs collaboration
  - Social energy sharing?

Wrap it up

- NILM forms part of a larger initiative to use data to change behaviour
  - Insufficient understanding of the human factors
  - Sparse capture of relevant data
- Great potential to change/increase value to households
  - Influence policy and practice of energy utilities and building management
  - Requires richer data models, algorithms and application
- Engage with larger research community around dimensions

Thank you

- NSERC
- City of Vancouver
- Pacific Institute of Climate Solutions
- BC Hydro
- Government of Canada
- MITACS

?

- ….and many creative students.