



### The Design and Evaluation of Prototype Eco-Feedback Displays for Fixture-Level Water Usage Data

Jon Froehlich<sup>1,2</sup>, Leah Findlater<sup>1,2</sup>, Marilyn Ostergren<sup>1</sup>, Solai Ramanathan<sup>1</sup>, Josh Peterson<sup>1</sup>, Inness Wragg<sup>1</sup>, Eric Larson<sup>1</sup>, Fabia Fu<sup>1</sup>, Mazhengmin Bai<sup>1</sup>, Shwetak N. Patel<sup>1</sup>, James A. Landay<sup>1</sup>







This talk is about eco-feedback displays for water usage in the home

#### **Todays Total Usage**

total | daily average



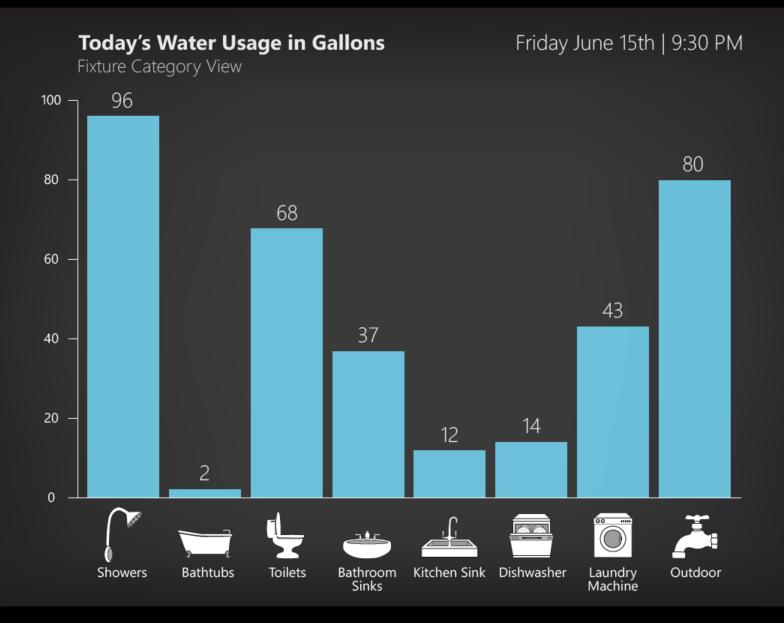
#### Friday June 15th | 9:33 PM

#### Today's Real-Time Water Usage

Fixture Category View



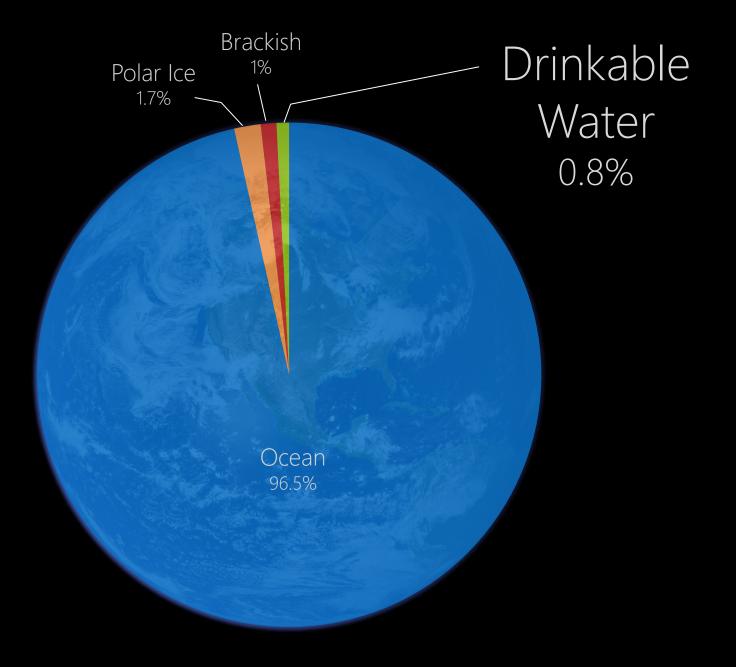
#### Friday June 15th | 9:30 PM



This talk is also about the design process for eco-feedback visualizations persuasive technology personal informatics quantified self But first, a quick primer on water

# two-thirds of the earth's surface is covered by water





[Glennon, Unquenchable: America's water crisis and what to do about it, 2009; Gleick, World Policy Journal, 2009]

### The amount of water on earth is not changing

# The amount of water on earth is not changing but its **location**, **quality** and **amount per person** is changing

## As the



### 's climate changes...



precipitation patterns

glacial and ice snowpack surface water availability

[Gleick, World Policy Journal, 2009]

# As populations O LOOM

per-capita water availability is declining

# water availability disproportionately felt in urban environments

[Barlow, 2007]

This places an enormous strain on drinkable water supplies

[Inman and Jeffery, 2006; Gleick et al., 2008 Vairavmoorthy, 2006]

# O e mano in 2010, water consumption rose to 938 billion gallons in beijing water supply = 576 billion gallons

[Guardian, Dec 2010]



### "china melting snow to meet freshwater demand"

[Guardian, Dec 2010]

lake mead expected to drop below intake pipes in next five years

[Bloomberg News, Feb 2009]

new sources of water more costly to extract

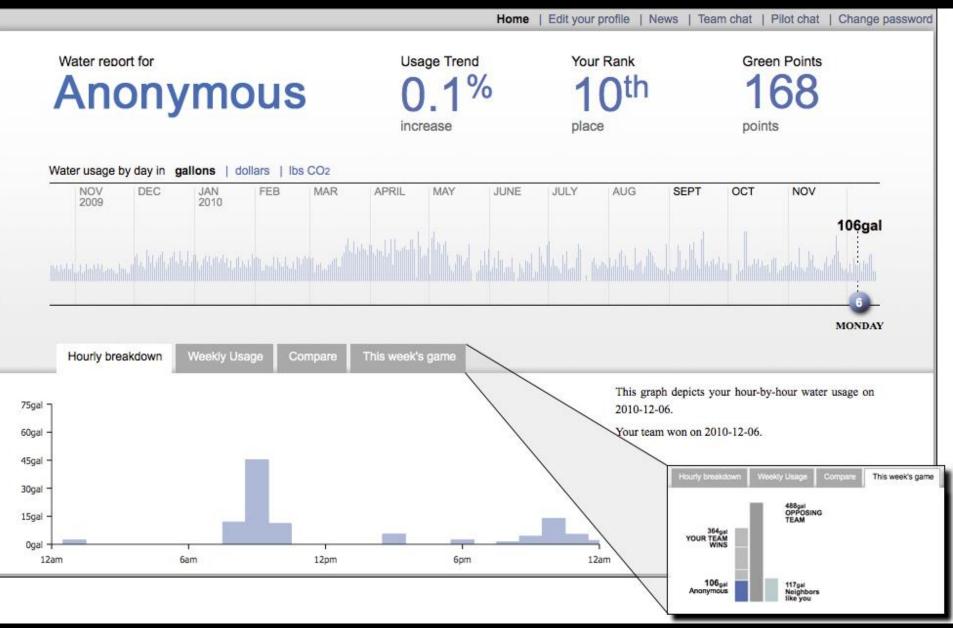
# water utilities governments shift focus

This is an area where HCI researchers and designers can help

# eco-feedback

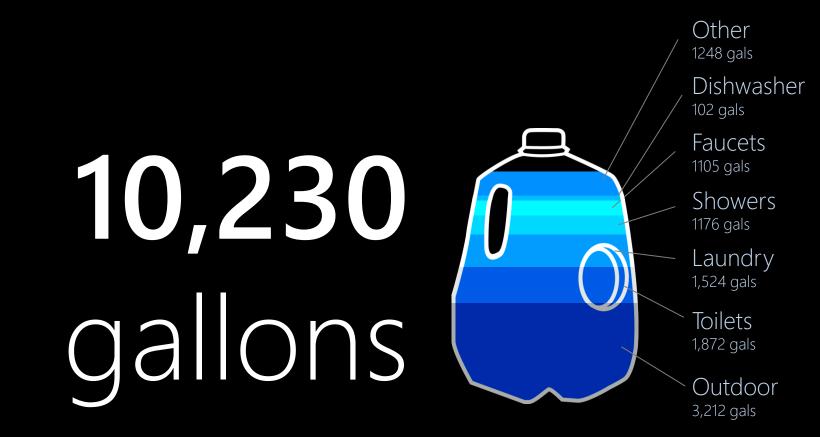
sensing and visualizing behavior to reduce environmental impact

### **Dubuque** Water Portal:



[Erickson et al., CHI 2012]





# waterbot

[Arroyo *et al.*, CHI 2005]

# showme

[Kappel & Grechenig, Persuasive 2009]

# upstream

### [Kuznetsov & Paulos, CHI 2010]

# waitek shower monitor



http://www.waitek.co.nz/

### **Point-of-Consumption** Eco-Feedback Displays



sensing and feedback unit co-located at fixture provides real-time feedback on water usage





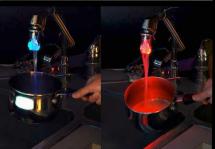


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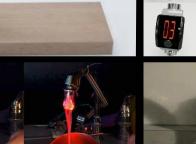


THE MORE WATER YOU SAVE, THE MORE CREATURES YOU CAN UNLOCK... THE MORE U



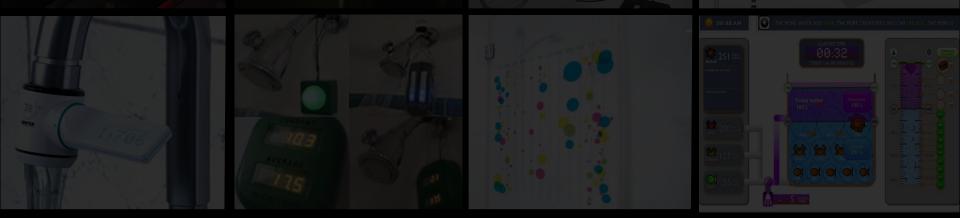








# Point-of-consumption feedback is the prevailing method for providing water usage feedback at the **fixture-level**





## **Showers** and **faucets** account for ~22% of water use in the average North American home



[Vickers, 2001]

# direct sensing

[Teague Labs, Arduino Water Meter, http://labs.teague.com/?p=722]

.2/1

2102

PVC SCH. 40 COUPLIN

# direct sensing

bath 6.5 gallons bathroom sink 1 4.2 gallons

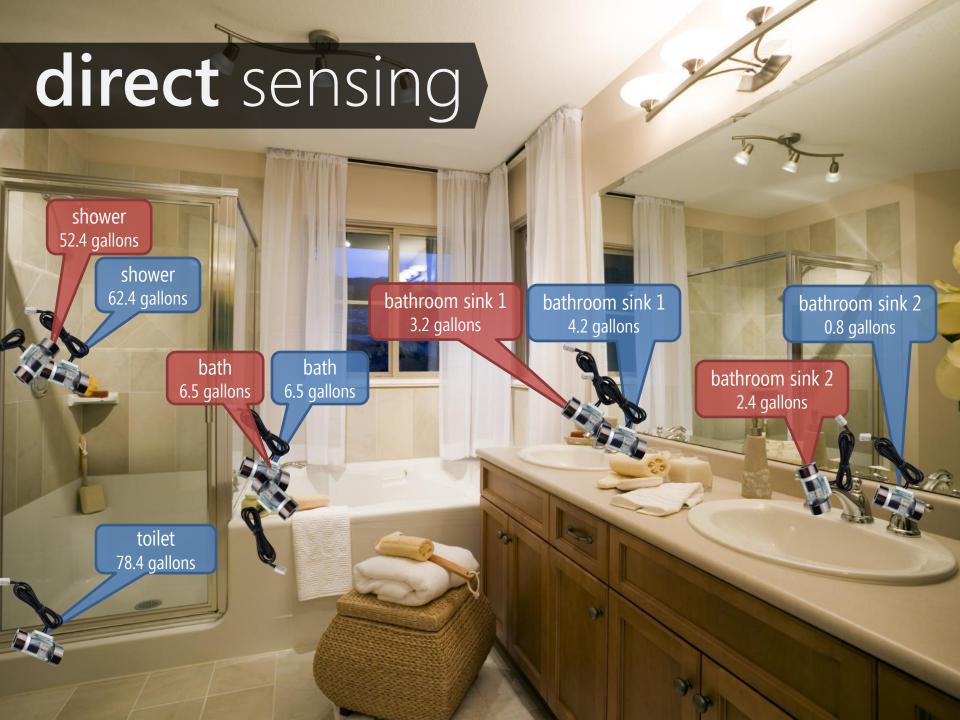
3)

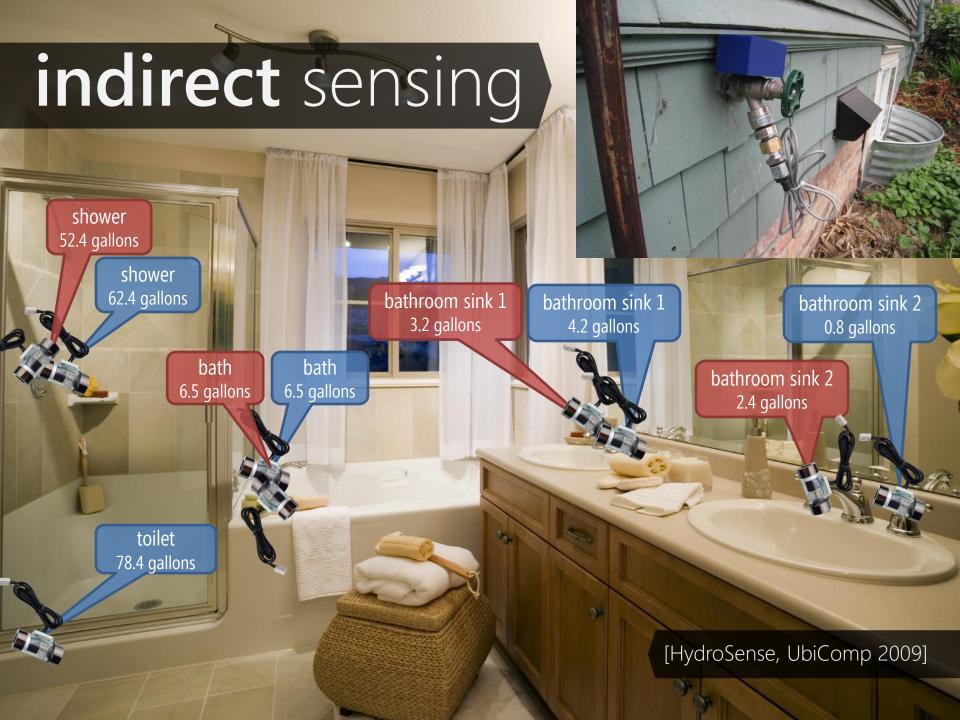
×.,

bathroom sink 2 0.8 gallons

toilet 78.4 gallons

shower 62.4 gallons





# indirect sensing

## A **single** sensor infers fixture-level usage for the entire home

[HydroSense, UbiComp 2009]

bathroom sink 1

# Emerging Water Sensing **Disaggregation** Methods Beal et al., mart Water Sys 2011 Compellet al. Ubicomp 2010 Crochich et al. UpiComp 2009 Froehich et al. Penasive 2011



### Flow tran analysis to assess wate

Analyzing flow traces from residential water meters enabled researchers to collect precise data about water use by individual fotures.

William Butler DeOreo, James Patrick Heaney, and Peter W. Mayor



#### Sensing from t Unobtrusive and

ABSTRACT

Deoreo et al. AMMA 1996

James Fogart Computer Science and E University of Wash Seattle, WA 9810 jfogarty@cs.washing

we deploy a small number of low-ce

we deploy a small number of low-cos-locations in a home's water distribu Rased on water usage patterns, we can in the home. To examine the feasibility we deployed real sensors into a real h Among other findings, we show that

microphone-based sensors that are

systematic noise sources can iden

88% of tailet flusher 72% of ha

Author Keywords

washer usage, 95% of dishwasher us

lasting ten seconds or longer. While th

what activities can be detected when an

our new approach represents a sweet

The home deployment of senso many new opportunities for hur

sensor-based systems to

One such opportunity motivating of

conds or longer, and 81% of

### The home deployment of sensor-based opportunities, particularly in the area of representatives, particularly in the area of systems to support aging in place by m activities of daily living. But existing a activity recognition are typically exp motall, or intrude into the living sy considers the feasibility of a new app into the home" via the existing infrastr we derive and model and the set of the set.

install self-calibrating system that provides is when, where, and how much water they see u

between what information is collected : ACM Classification Keywords H5.2. Information interfaces and presenta H1.2. Models and Principles: User/Machin INTRODUCTION AND MOTIVATION

constrict programming problem. We show through experiments on a three that such a system is indeed invalide and at minimize error in the water mange estimate. It accurates, were likely domestic flow-rate estimate term stability and a mess should error of 19 nonitoring activities of daily living [

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### NAWMS: Nonintrus

Younghun Kim Jonath Netwo University o kimyh.thor ABSTRACT

2 F09310/et al. UST 2006

Water is nuture's most precisus resources and mand is pushing from water supplies to the 1 renewability. New technological and social in enhances conservation and reduce waste are new ing consumers with fine-galaxie real-time indi-yielded benefits in conservation of power and 1 meeting the discontervation of power and 1 ending this philosophy to water conservation novel water monitoring system, NAWMS mpowers users. The goal of our work is to furnish users install self-calibrating system that provide

tem uses wireless vibration sensors attached thus, neither plumbing nor special expertise for its installation. By implementing a non-zonemous, and acluptive system using controltonsmous, and adaption system using commod we believe it is cost-effective and widely deploy. NAWMS makes use of the existing househol meter, which is considered accurate, but lacks a larity, and adds vibration sensers on individual to estimate the watter flow to each individual pressuing for manufacturing, installation, and a pressure of the sense of the set of the second

abilities requires calibration of these low or achieve a resonable level of accuracy. We a schaptive auto-calibration procedure, which doe a two phase linear programming and mi-matrix companying problem.

INTRODUCTION AND MOTIVATION In revolution, incomption multi monitory in the Effective methods for sensing and modeling hut in the physical world are a consistent of computing research and practice. Many con approaches have been developed, including rec

Author Keywords

Kin et al. Sen5152008

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#### HydroSens Single-Point Sensi Jon Froehlich<sup>1</sup>, Eric Larson<sup>2</sup>, Tim Ca Tim Campbell<sup>1</sup>, Eric Larson<sup>2</sup>, Gabe Co <sup>1</sup>Computer Scie

Mechanical Engine

(jfroehli@cs, eclarson@u, tcample

Recent work has examined infrastructure-med

as a practical, low-cost, and unobtuarve as sensing human activity in the physical world. It is based on the idea that human activities (e.g.

dishwasher, turning on a reading light, or walke

environment's existing infrastructures (e.g., a la electrical, and HVAC infrastructures). This po

sensor of pressure within a home's water in

HydroSense supports both identification of

individual water finites within a home (e.g., tolet, a kitchen sink, a particular shower) estimation of the amount of water being u fixince. We evaluate our approach using data

ten homes. Our algorithms successfully ide

events with 97.9% appregate accuracy and

events with 97.9% aggregate accuracy and water tisage with error rates that are cot empirical studies of traditional utility-sup meters. Our results both validate our approach a basis for future improvements.

Infrastructure-mediated sensing, activity sensi

ACM Classification Keywords

H5.2. Information Interfaces and Pre

ense, a low cost and easily-installed

doorway) can be sensed by their man

ABSTRACT

HuttoS

DUBI

{tcampbll, eclarson, s

(ADC), and a 433 MHz wureless transmitter, point whole-home water usage. We denn Author Keywords

Miscellaneous

General Terms Detign, Experin H1.7 Models and Principles: User Machine Syste

General Terms Algorithms, Experimentation, Measurement

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specific permission and er a fee DerComp 2010, September 16-29, 2010, Copenhagen, Denma Conventin 2010 ACM #78-1-60558-843-8-10-08, \$10.00

#### WATTR: A Metho Sensing of W

<sup>1</sup>Mechanical Engineering, <sup>2</sup>Elect UbiComp Lab, D

ABSTRACT We present WATTR, a novel self-powered moter second that unknew revidential worker protone imp both a powering and reming source. Consisting of harvesting circuit, precedencies second ultra-low-p it, piezoelectric sensor, ultra-low aller, 16-bir analog-to-digital apable of sampling home water pressure at 3 transmitting over 3 m when any water focture in the opened or closed. WATTR provides an alternative ton to the power intensive Bluetooth-based a in the HydroSence project by Froehlich et al. [2] i point while-adding where usings, we demonstrate as a viable self-powered sensor capable of monito transmitting water usage data without the use of a Unlike other water-based power harvester. WAT not waite water to power stuff. We discuss the implementation, and experimental verification WATTR device. Power Harveinne, Sentine, Water Conservation

ACM Classification Keywords H5 m. Information interfaces and presentation (e. ation, Measurement, Performa

#### INTRODUCTION In secent years, we have seen an astonishing increa

In meen years, we have seen an attaining more comparisonal and morage caphilines of co-systems. Unformately, hattey schooley h followed this same destable need A a coars mobile detects and buttery-powered withers see not often limited by their computational through promising absentative energy source. With

remaining to data capits of the object on it of part of this periods or characterises with paramet without the provided this not made or dimensionly provide or comparises advecting and it bear this notice and the full characterise the form page. To copy of or republish, to post on herves, or its polarithete to lass, requ matching assessments and at the

University of (jfroehli.eclarson, ifogarty. Abstract. We present the first long real-world water usage events in the sink, downstairs toilet). In order to wild, we deployed a ground truth sen and two apartments that directly me and appliances. We use this data to in constructing water usage activity i the design of a new probabilisticalgorithms in speech recognition.

James Fogarty

Computer Sc

<sup>2</sup> Electric

Mechni

show that with a single pressure sensitive laworld water usage at the fixture l category level with 96% accuracy. W increase to 94% and 98%. Finally, trained with fewer examples than a str

A Longitudinal Study

Real-World Water U

Jon Froehlich17, Eric Larson27, 1

1 Introduction

Low-cost and easy-to-install methods to have long been a focus of UbiComp rese activities of human life (e.g., bathing, has emerged as a particularly promising a [6, 8, 19]. In addition, these sensing sys granular consumption information for applications (e.g., [7]). In previous work based sensing solution that disaggregates

smart water systems & meter

#### SEQ residential end us C Beal, R A Stewart, T Huang, E Rey

8 Smart auto meter (5.0 (/ paller) 

Figure 2: Schematic flow of pro-wolse flow data. \*

19

Matheola

Activity Analysis Based on Low Sample Rate Smart Meters Feng Chen<sup>1</sup> Jing Da<sup>2</sup> Bingsheng Wang<sup>3</sup> Sambit Sahu<sup>4</sup> Mlind Naphade<sup>5</sup> Chang-Tien Lu<sup>8</sup> omputer Science Department, Virginia Tech 7054 Haycock Road Falls Church, VA

{"chenf, "claren89, "ctlu} @vt.edu

high accuracy on discovering washer and show

General Terms

1. INTRODUCTION

Keywords

Categories and Subject Descriptors

H 2.8 [Database Management] Database Applications

Algorithms, Deuga, Experimentation, Performance

Smart Meise, Low Sample Rate, Disaggregation, Classification, Hidden Mathov Model, Genssian Mixture Model.

1. INTRODUCTION Simulability and design of successful wheeledges law become upper and supports practy for case parts the suppredensed level of forcero densati - sume energy margin buildense patier softwy- to reave supports between the support of the support of the support of the support of the physical world has been possible with widersaid support of the support of the support of the support support of the support of the support of the support support of the support of the support of the support support of the support of the support of the support support of the support of the support of the support support of the support of the support of the support support of the support of the support of the support support of the support of the support of the support support of the support of the support of the support support of the support of the support of the support support of the support of the support of the support support of the support of the support of the support support of the support of the support of the support support of the support of the support of the support support of the support of the support of the support support of the support of the support of the support support of the support of the support of the support support of the support of the support of the support support of the support of the support of the support of the support support of the support of the support of the support of the support support of the support of

organizational collaboration among receively, industries, unbur planaey, and government. A lot of technology and search have

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17. August 21-34, 2011. San Diego, California, USA ghr 2011 ACM 978-1-4803-0815-711-06\_\$1000.

ABSTRACT

Chen et al. 100 2011

2.4.5 Watson Research Center, IBM 19 Skyline Drive Hawthome NY (jiddar, \*sambits, \*naphade) @us.ibm.com

nceatly focused on leveraging information from such digital nexts/ forward in increase advectant from out operations of objective of the large base party events ensemble advectant operation of the large base party operation is a single advectant operation of the large base of the large b

ABSTRACT ART: subjust indegraphics units consumption from user from the optical subgraphic network with homes accurate, a substantial independent on the advert subgraphic accurate orderes and approximate the sub-sub-subgraphic networks and advert substantial independent on the advert subgraphic constantial independent on the advert subgraphic accurate and an advert sub-sub-subgraphic resolution of a sub-stantial independent sub-sub-subgraphic resolutions and an advert sub-substantial independent on an advert substantial independent on the 100 km sub-stantiant independent subgraphic resolutions of the substantial formers of the substantial independent on the sub-tantiant independent independent on the substantial former in the substantial independent on the sub-stantiant independent independent on the sub-tantiant independent independent on the sub-stantiant independent on the substantiant independent independent in the substantiant independent on the sub-stantiant independent on the substantiant independent on the substantian deployed to serve over 300 pilot households in Dubuque, 1A Inservering activity-level consumption patterns have been identified meresting activity-level commution patterns have been identified, and the evaluation on both real and synthetic datasets has shown

sample: in dogs and note: instruments reperture. In this dogs and the second second second second second methods are set of the second larger inservish to essues realish dan ramanisan Howere physical environment may still fiftch the data transmission. However, hypotent environment may still fiftch the data transmission fit-despreption. If you had may excited a still of the data device in the size 15 minut march. D Diffusion of algung anger were transport, e.g. is show any space in stor erus marcha. D Lack of features, is sub-ing terms in the marcha how both transmission durate more forwards marcha how and expected design parts as example of our hard targets.

V Mier

Figure 1. An Example of Data and Disaggregated Activity To handle these challenges, we have designed a povel statistic mework for activity analysis on coarse granular max wat

End Use Analysis Approach 1. Sunshine Coast Brisbane 3. Ipswich 4. Gold Coast

Abstract

installation point. HydroSense identifies

template matching, a language mod Keywords: Water sensing, activity in

Figure 1: Regions examined in SECREUS. Inset: Location of SEC. an WHO-2011 Wate

T Based



sensing and visualizing behavior to reduce environmental impact

# What do we do with all this data?



# Key Questions

**What** are the key gaps in water usage understanding?

) What aspects of disaggregated data are potential users interested in and what sort of reactions do the visualizations provoke?

**How** might these visualizations impact behavior?

# Key Questions

1) What are the key gaps in water usage understanding?

- 2
- What aspects of disaggregated data are potential users interested in and what sort of reactions do the visualizations provoke?

**3** How might these visualizations impact behavior?

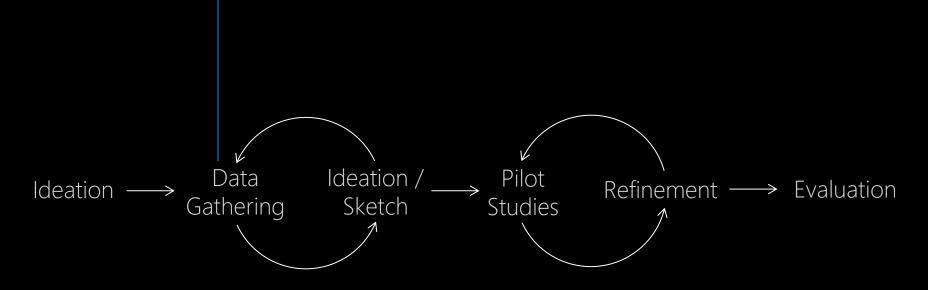
Two sets of designs:

# Design Dimensions

Isolate eco-feedback design dimensions in the context of water usage

# Design Probes

Meant to elicit reactions about how displays would fit within a household and investigate issues such as privacy, competition, family dynamics. Informal interviews with water experts (e.g., SPU, Amy Vickers) UW Environmental Practicum on water Literature review of water resource management, environmental psychology Our own online survey of water usage attitudes & knowledge (N=656 respondents)

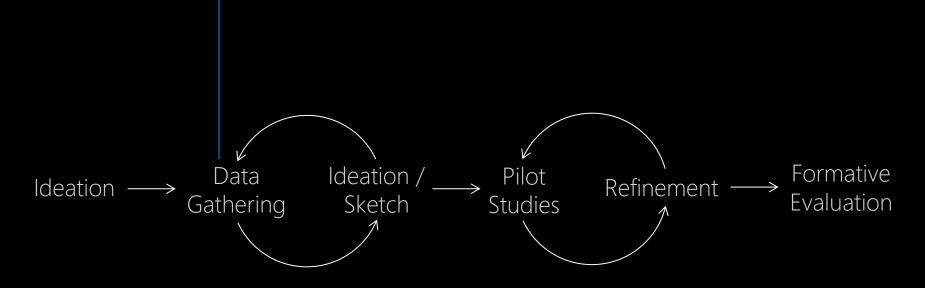


# Respondents (N=651) dramatically **underestimated** the amount of water used in common everyday activities.

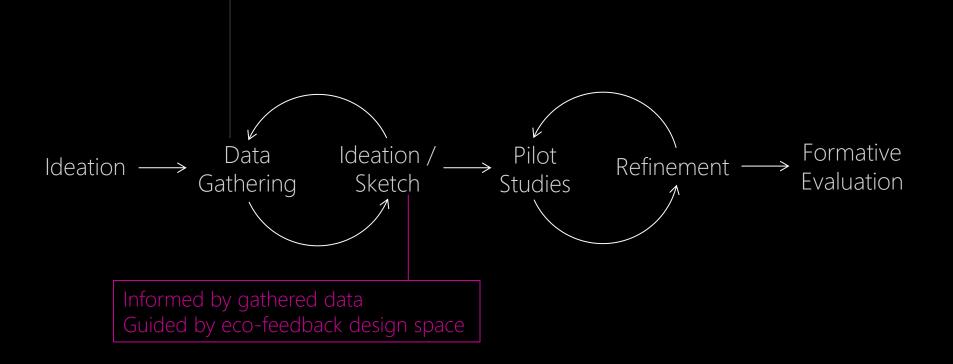
underestimate toilet : by 15% shower : by 30% bath : by 55% low-flow shower : by 60% outdoor yard watering : by 83% to 95%

[Froehlich, UW PhD Dissertation, 2011]

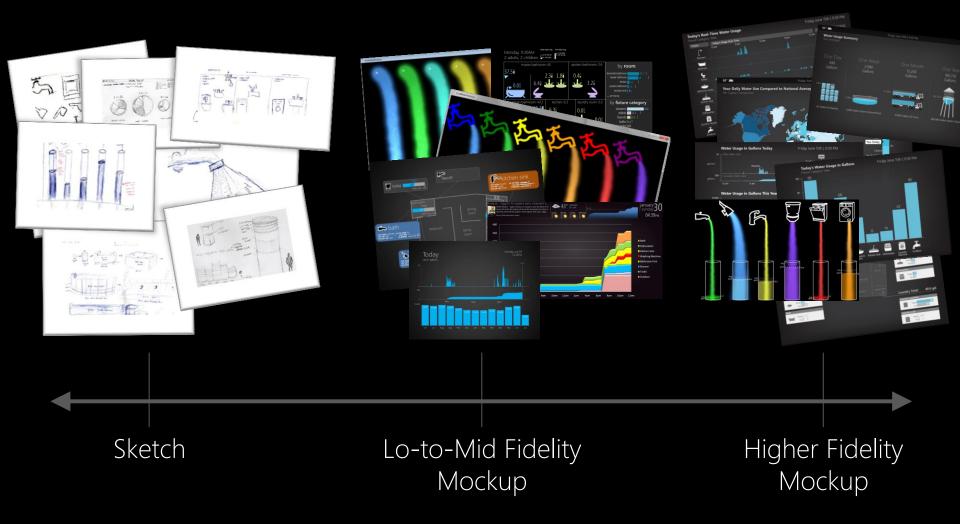
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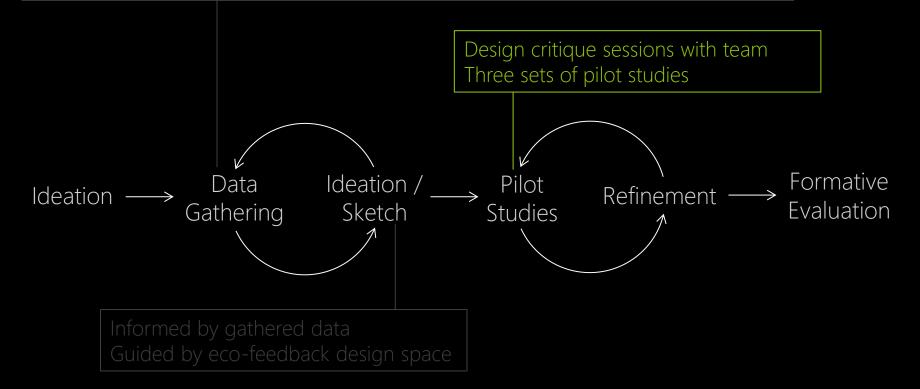
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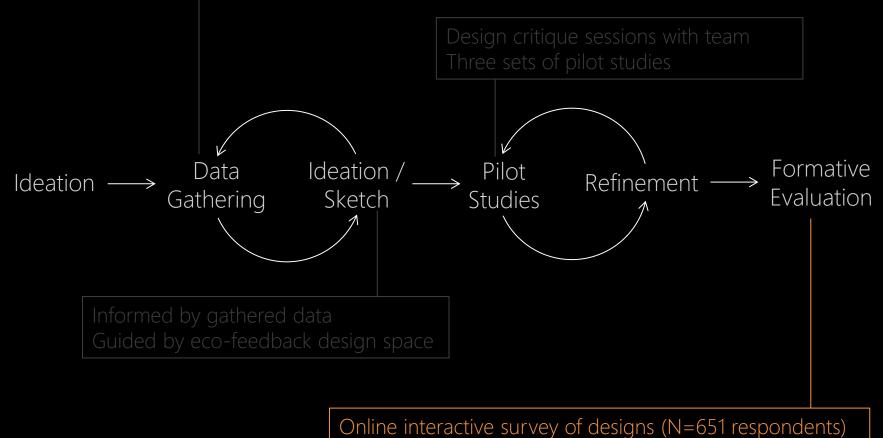
# Iterative Design Process



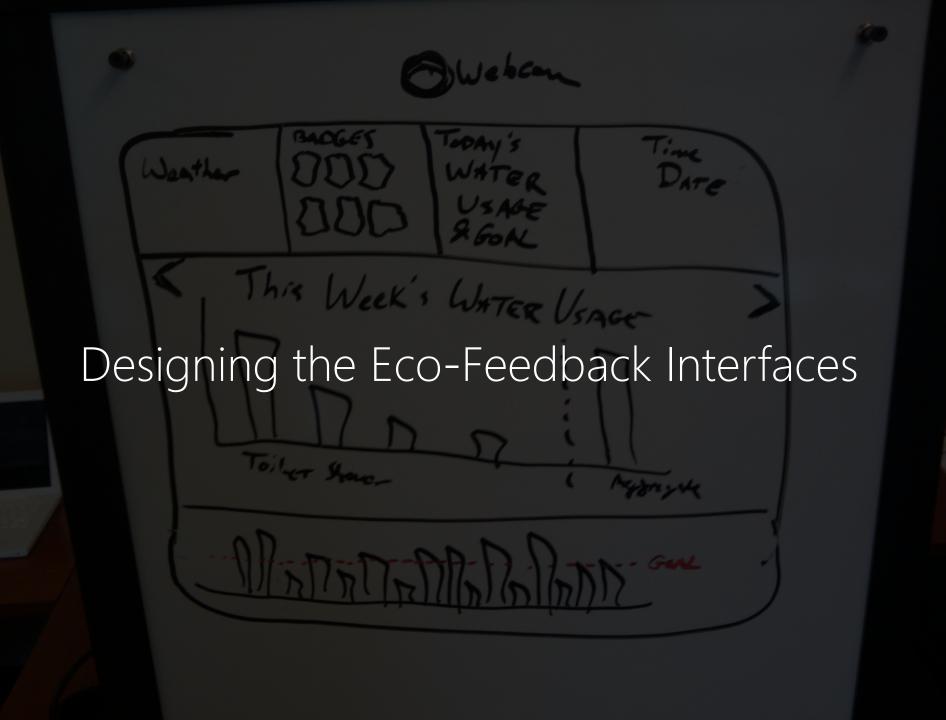
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In-home interviews (10 households, 20 adults)



How does one go about the process of designing interfaces for eco-feedback?

# **Eco-Feedback** Design Space

### **INFORMATION ACCESS**

undata	4		<b>_</b>	0
update frequency	real-time	monthly or	less	-
spatial proximity to behavior	co-located			remote
attentional demand	<b>↓</b> glanceable		high	► attention
effort to access	low			► high
NTERACTIV	ITY			
degree of interactivity	none			► high
interface customizability	none			► high
user additions	O user annotations		user c	O orrections
DISPLAY M	EDIUM			
manifestation	OO- webpage mobile phone ap	wearable	-	in-home display
ambience	▲ not-ambient			ambient
size	<b>▲</b> small			► large
Actionabii	LITY <b>/U</b> TILITY	/		
degree of actionability	<b>↓</b> low			→ high
decision support	O suggests actions	 suggests purchase decisions		anomaly alerts
personal- ization	no personalization	n hi	ighly pei	sonalized
information intent	Informs one action	n info	orms ma	→ ny actions
automation/ control	◄	system con	trols res	ource use

### **DATA REPRESENTATION**

aesthetic	◆ → pragmatic artistic
time window	
temporal grouping	<pre>≤sec by hour by day by week by month ≥year</pre>
data granularity	coarse-grain fine-grain
visual complexity	
primary visual encoding	
measurement unit	OOOOOO resource cost environmental activity time metaphor impact
	OOO temporal spatial categorical
data grouping	OOOOOOOOOOOOO

### **MOTIVATIONAL/PERSUASIVE STRATEGIES**

persuasive tactics from	persuasive tactics include:		
psychology and applied social psychology disciplines: persuasive design persuasive technology behavioral science/economics environmental psychology game design social marketing health behavior change	rewards punishment public commitment written commitment loss aversion kairos encouragement descriptive norms scarcity principle framing anchoring bias defaults	goal-setting narrative likeability reputation competition social proof authority emotional appeals door-in-face unlock features endowment effect collection building	

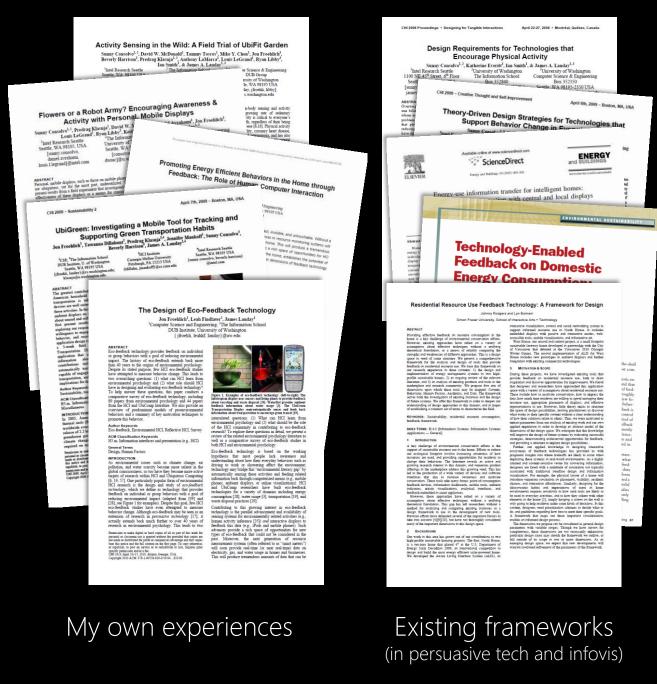
### **COMPARISON**

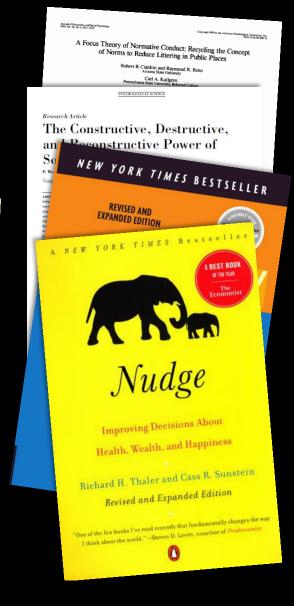
comparison target	O	O social	goal
comparison by time	<b>↓</b> past		► projected
social-comp. target	O geographically proximal	demographically similar	selected social network
goal-setting strategy	O self-set	system-set	externally-set
difficulty to reach comparison target	easy		hard
comparison var	iablesstatistic	computation	
<ul> <li>time window</li> <li>time granular</li> <li>data grouping</li> <li>data granular</li> <li>data granular</li> <li>measurement</li> </ul>	g O median O median O mode O ther	[hrly, daily, wkl over past [X] da this day type [v	st, last wk, mo, yr] y, monthly, yrly] ays veekday, weekend] k (e.g., mondays)

### SOCIAL ASPECTS

target	<b>↓</b> person	household	community	state	country
private/ public	<b>↓</b> private				public
data sharing	<b>∢</b> none				everyone
social- comparison	-	(see	e Comparison)	u	– – – – O navailable

[Froehlich et al., HCIC2009; CHI2010; UW PhD Dissertation 2011]





Psychology (particularly behavioral economics and environ. psych)



MODELS Lund motivity 6 these things at this into design. INPUTS (SEASING) " Explicit encoding of behavior charge themes · automated the Self - report When I talk about the provs i talk about · personalization Lodges system adopt to person based on sensed data or · Trans granularity o jume donte " User onnotations demographics 1 simple · Designer's agenda? + + inter • Dark ansen 1 · User corrections n educatos a constrained environment · Does person have verifier to care \* reason to cove o informs only one SOCIAL ASPEUTS INFORMATION ACCESS " Desugn for person vs. design for horschold · Update frequency " Social Sharing of information over internet · push/pull · public or private display \* Degree of interactivity · Comparison to others \* · Spatial proximility to behavior / · Approachability or learnability is how easy is interface to immediatly understand & mybe thus your \* Attentional Needs Hysloreesbility room or by Exture in data representation " visual encoding of sensed data occumbrant vis icon analytext is testival, chart, iconve, abstract · availability ( with available ) & elibert to - ginple and complex of cale of cale of the complex of the cale of · COMPARISON + comparison to self I koson, presents spectrum of respective · comparison to others · compersion to projected self REDIVM · display med mi screen, orb, mobile, disktop, which a · ambient vs. non-ambient (maybe this goes in information Access) · comportson to a geal Agtariblity & also, related is much , display size PERSUASIVE TOOLBOX · degree of action 15/181 y too composison might · maybe this is called perceptual actually fit in here affordance? t the thing i talked about @ BIELE 2010 · projected future is project a trend to foreshedow where they will end up · Decision support , 1055 aversion · progress · where would customizebility 20 ? goal-setting unintended positive reinforcement of union 1 realitions . See word docr for more , orteripation "role of information us. role of personation · regative vs. positive feedback \* could also have group colled Comparison & have comparison to others & comparison to self \*\* might have a few more specific things for have resource consumption feedback like "it's fit into the

# **Eco-Feedback** Design Space

### **INFORMATION ACCESS**

undata	4		<b>_</b>	0
update frequency	real-time	monthly or	less	-
spatial proximity to behavior	co-located			remote
attentional demand	<b>↓</b> glanceable		high	► attention
effort to access	low			► high
NTERACTIV	ΙΤΥ			
degree of interactivity	none			► high
interface customizability	none			► high
user additions	O user annotations		user c	O orrections
DISPLAY M	EDIUM			
manifestation	OO- webpage mobile phone ap	wearable	-	in-home display
ambience	▲ not-ambient			ambient
size	<b>▲</b> small			► large
Actionabii	LITY <b>/U</b> TILITY	/		
degree of actionability	<b>↓</b> low			→ high
decision support	O suggests actions	 suggests purchase decisions		anomaly alerts
personal- ization	no personalization	n hi	ighly pei	sonalized
information intent	Informs one action	n info	orms ma	→ ny actions
automation/ control	◄	system con	trols res	ource use

### **DATA REPRESENTATION**

aesthetic	◆ → pragmatic artistic
time window	
temporal grouping	<pre>≤sec by hour by day by week by month ≥year</pre>
data granularity	coarse-grain fine-grain
visual complexity	
primary visual encoding	
measurement unit	OOOOOO resource cost environmental activity time metaphor impact
	OOO temporal spatial categorical
data grouping	OOOOOOOOOOOOO

### **MOTIVATIONAL/PERSUASIVE STRATEGIES**

persuasive tactics from	persuasive tactics include:		
psychology and applied social psychology disciplines: persuasive design persuasive technology behavioral science/economics environmental psychology game design social marketing health behavior change	rewards punishment public commitment written commitment loss aversion kairos encouragement descriptive norms scarcity principle framing anchoring bias defaults	goal-setting narrative likeability reputation competition social proof authority emotional appeals door-in-face unlock features endowment effect collection building	

### **COMPARISON**

comparison target	O	social	goal
comparison by time	<b>↓</b> past		► projected
social-comp. target	O geographically proximal	demographically similar	selected social network
goal-setting strategy	O self-set	system-set	externally-set
difficulty to reach comparison target	easy		hard
comparison var	iablesstatistic	computation	
<ul> <li>time window</li> <li>time granular</li> <li>data grouping</li> <li>data granular</li> <li>data granular</li> <li>measurement</li> </ul>	g O median O median O mode O ther	[hrly, daily, wkl over past [X] da this day type [v	st, last wk, mo, yr] y, monthly, yrly] ays veekday, weekend] k (e.g., mondays)

### SOCIAL ASPECTS

target	<b>↓</b> person	household	community	state	country
private/ public	<b>↓</b> private				public
data sharing	<b>∢</b> none				everyone
social- comparison	-	(see	e Comparison)	u	– – – – O navailable

[Froehlich et al., HCIC2009; CHI2010; UW PhD Dissertation 2011]



Two sets of designs:

## Design Dimensions

Isolate eco-feedback design dimensions in the context of water usage

### **Design Probes**

 Meant to elicit reactions about how displays would fit within a household and investigate issues such as privacy, competition, family dynamics.

# Design set 1: Isolating design dimensions Design Dimensions Explored

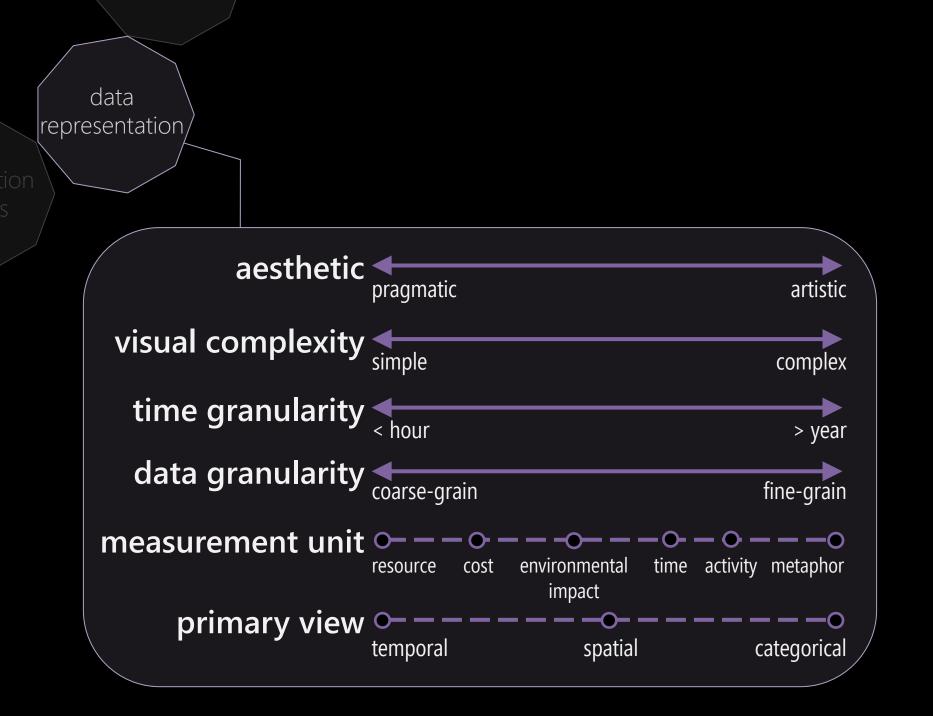
- 1 Data Granularity
- 2 Time Granularity
- 3 Measurement Unit

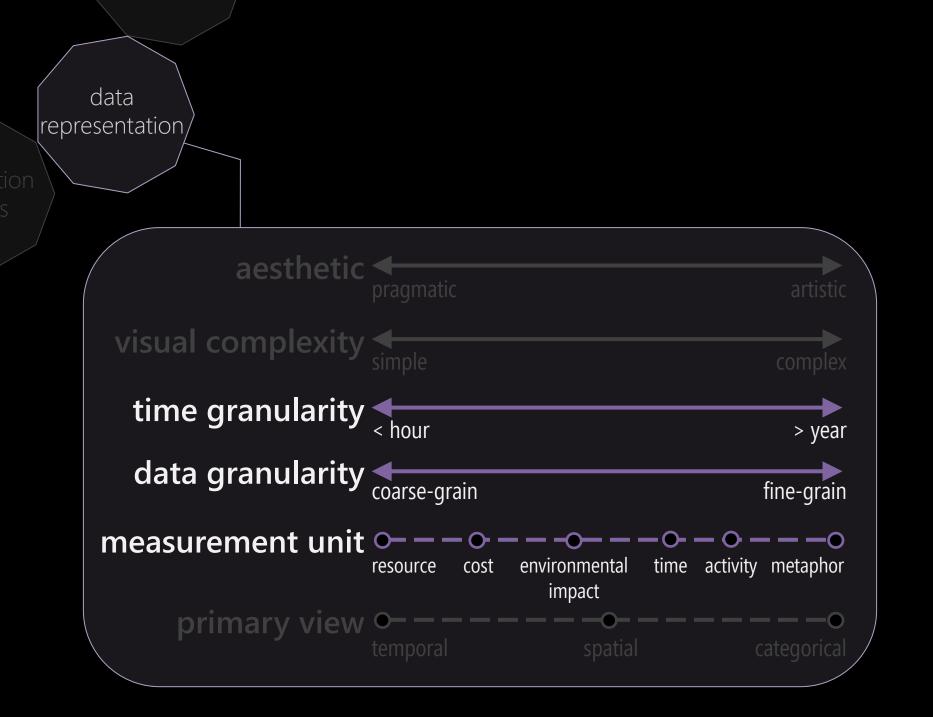
Part of "Data Representation" in the eco-feedback design space

**4** Comparison

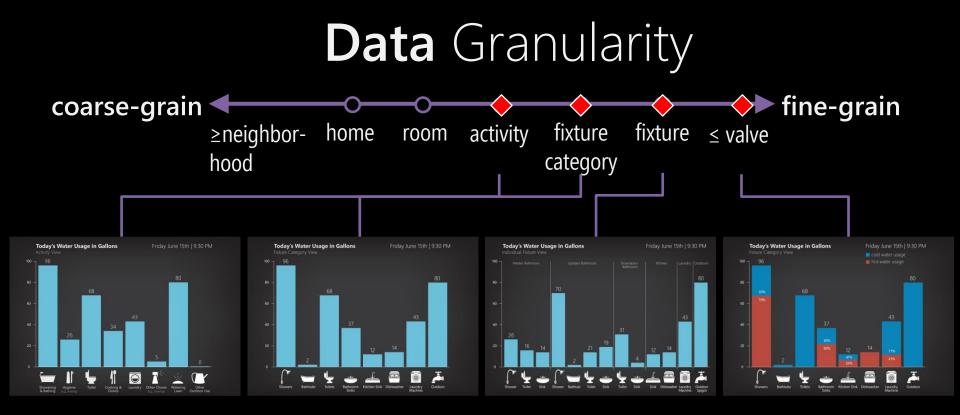


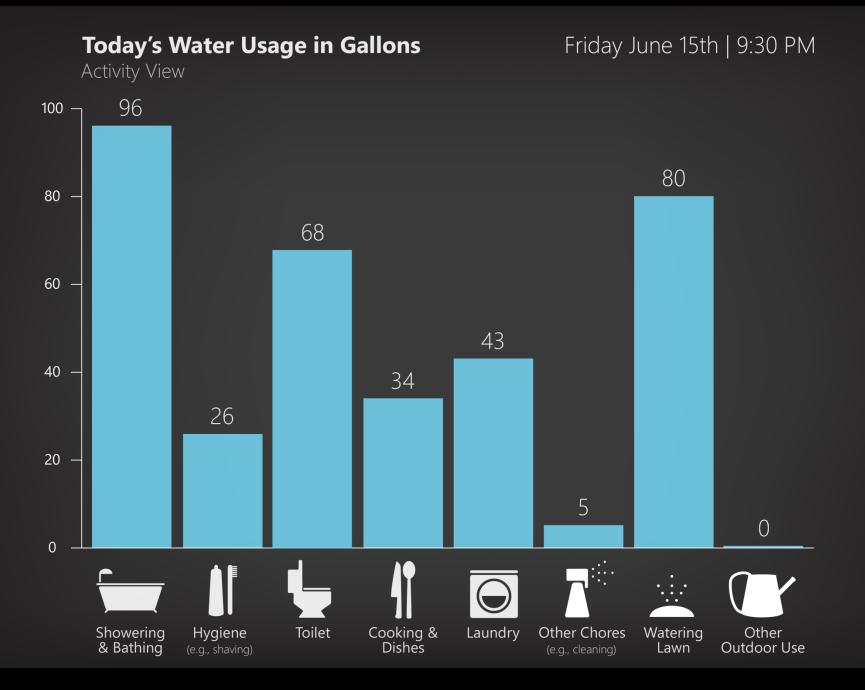






### **DESIGN SET 1: ISOLATING DESIGN DIMENSIONS**

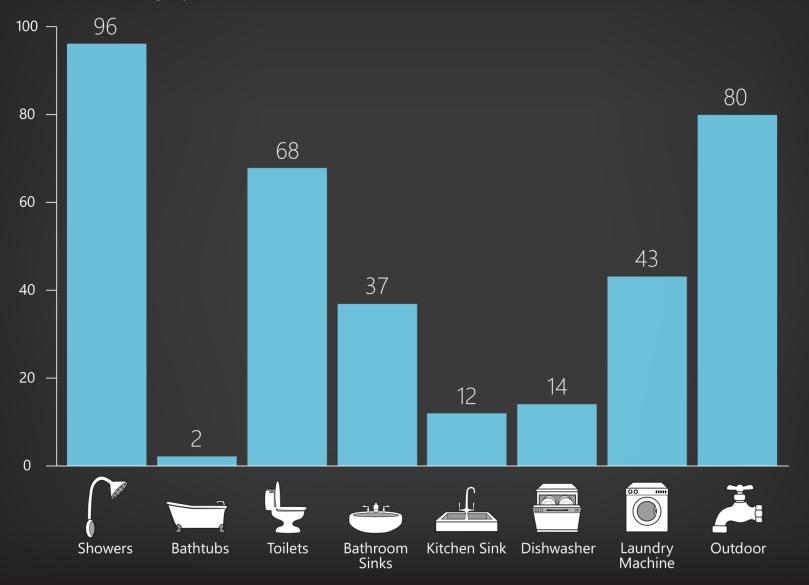




### Today's Water Usage in Gallons

Fixture Category View

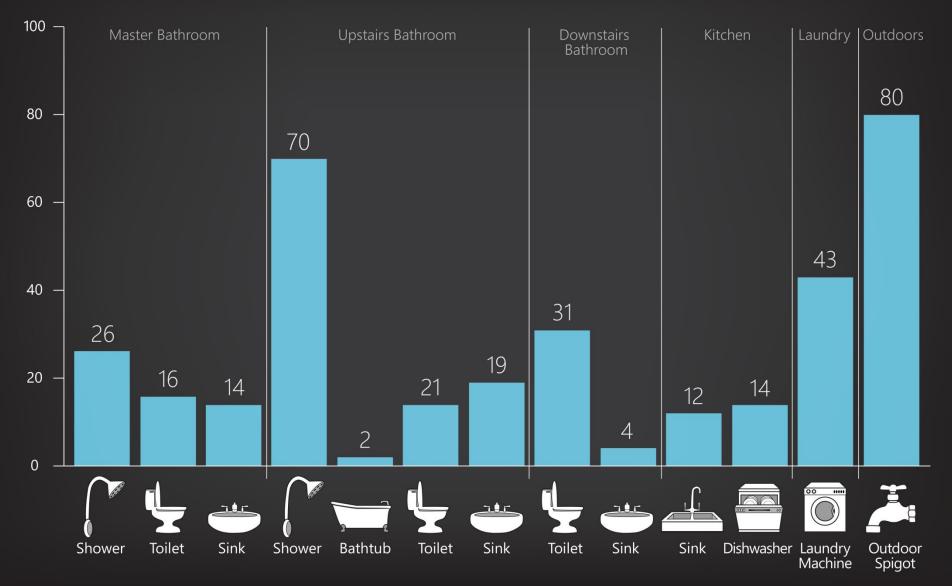
Friday June 15th | 9:30 PM

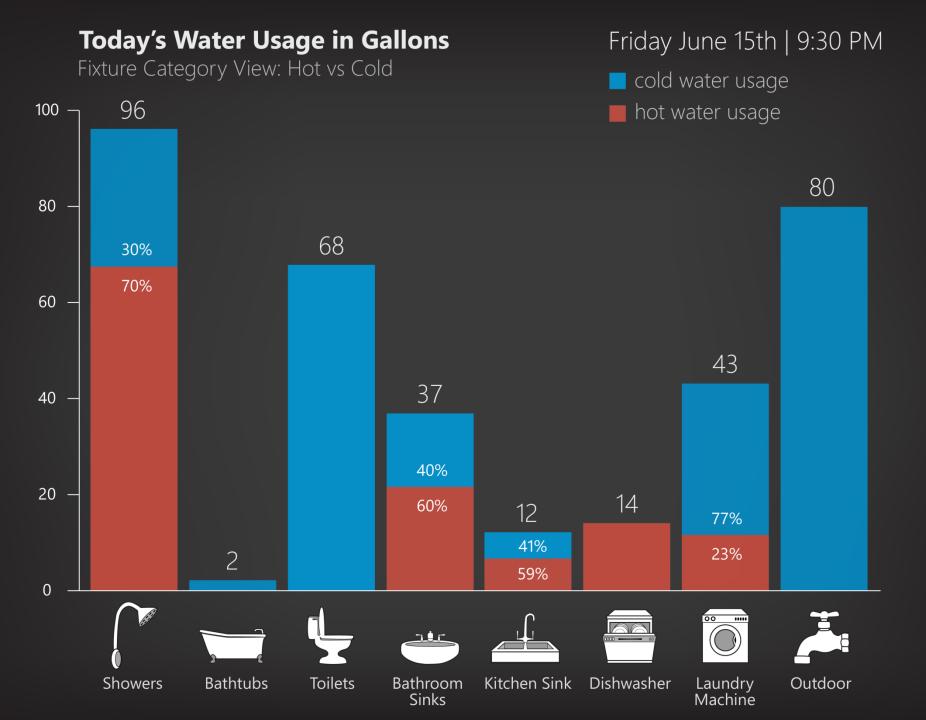


### Today's Water Usage in Gallons

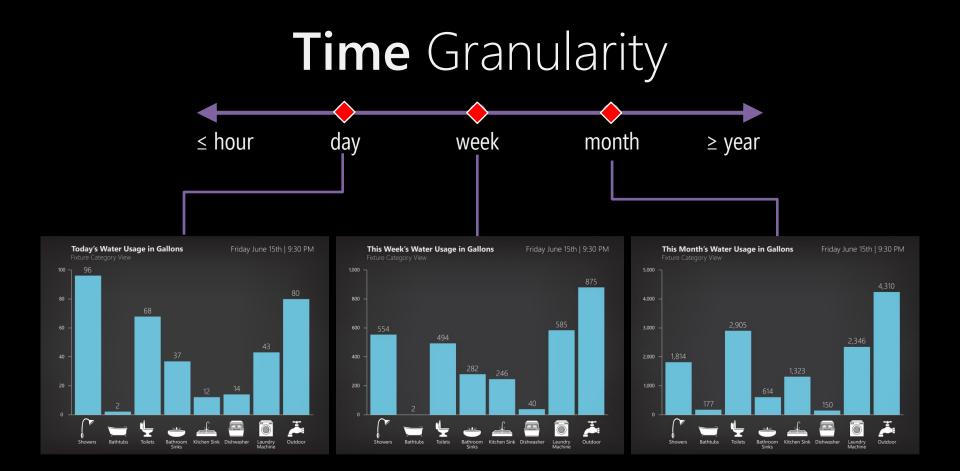
### Friday June 15th | 9:30 PM

Individual Fixture View

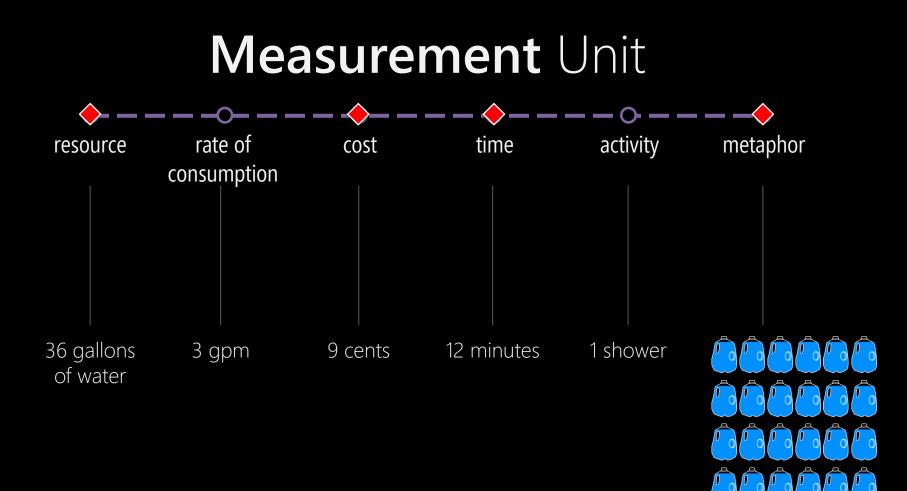




#### **DESIGN SET 1: ISOLATING DESIGN DIMENSIONS**



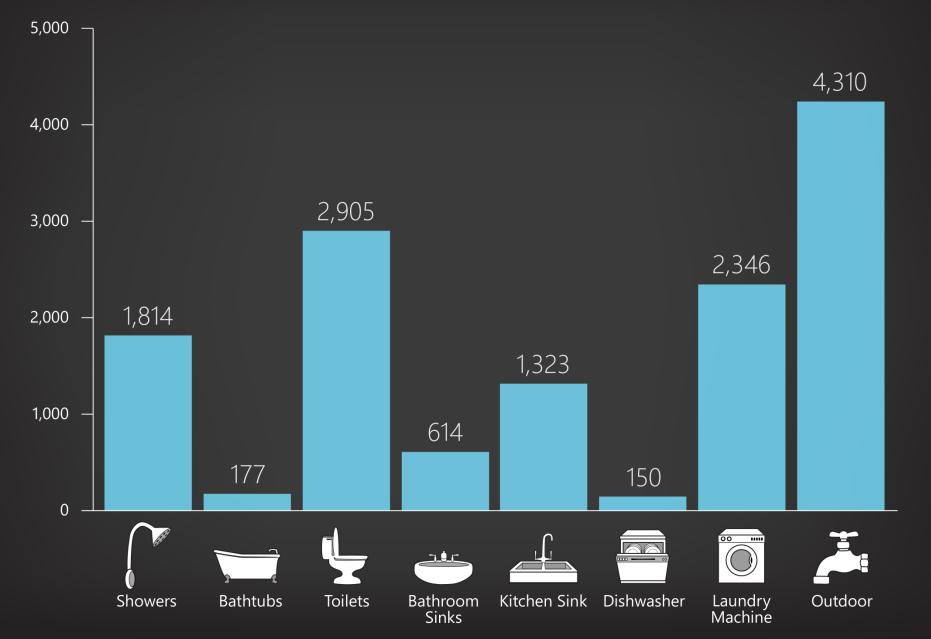
**DESIGN SET 1: ISOLATING DESIGN DIMENSIONS** 



#### This Month's Water Usage

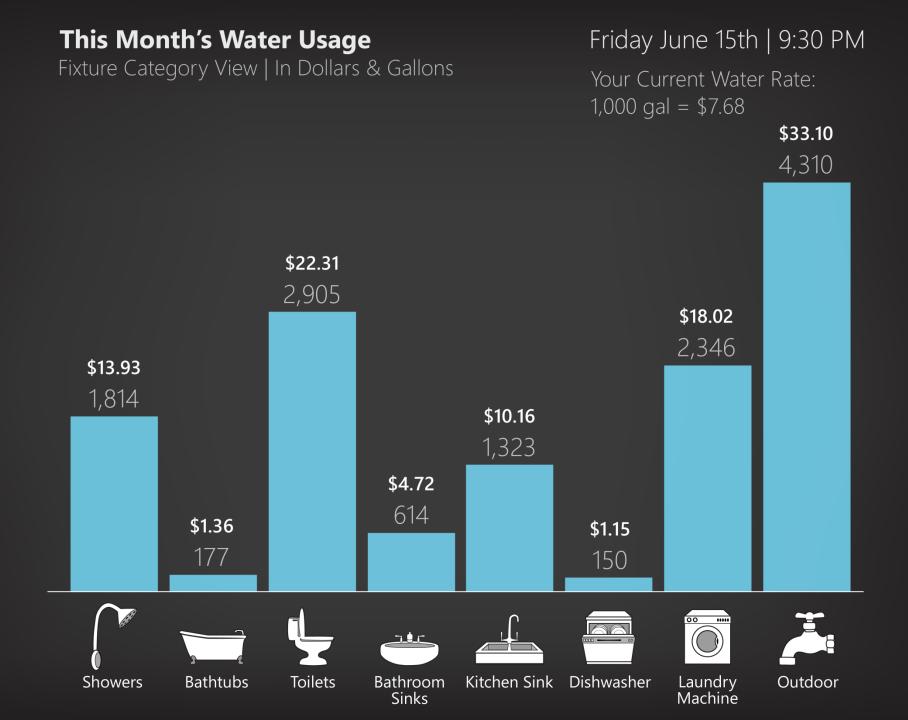
Fixture Category View | In Gallons

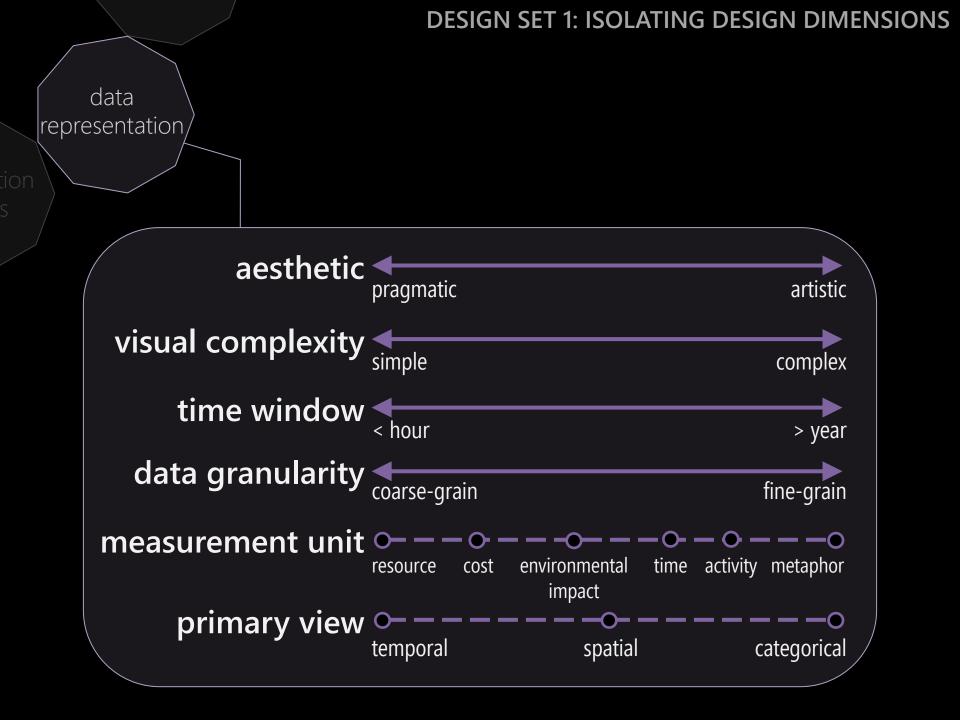
#### Friday June 15th | 9:30 PM









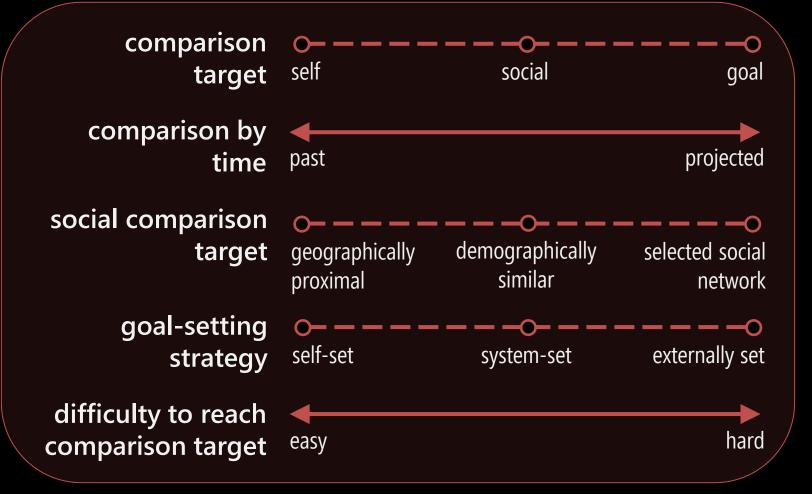


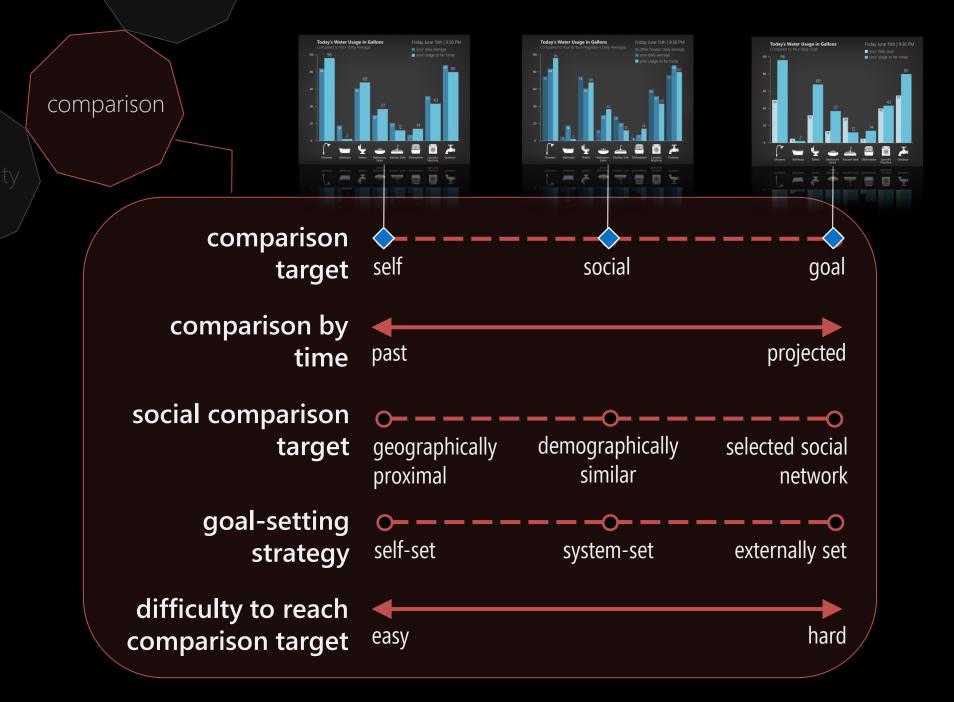


#### DESIGN SET 1: ISOLATING DESIGN DIMENSIONS

#### **DESIGN SET 1: ISOLATING DESIGN DIMENSIONS**

comparison





# Design set 1: Isolating design dimensions Design Dimensions Explored



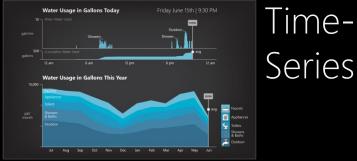
Two sets of designs:

- **1** Design Dimensions
  - Isolate eco-feedback design dimensions in the context of water usage

### **7** Design Probes

 Meant to elicit reactions about how displays would fit within a household and investigate issues such as privacy, competition, family dynamics.

# **DESIGN SET 2: DESIGN PROBES** Design Probes Explored

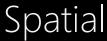






### Aquatic Eco-system



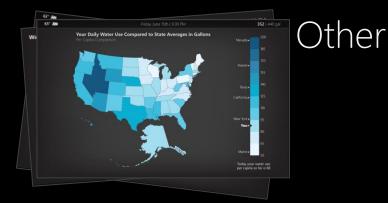




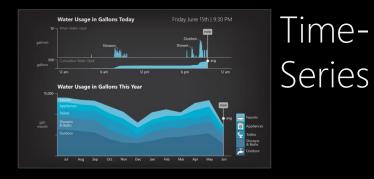








# Design set 2: Design probes Design Probes Explored









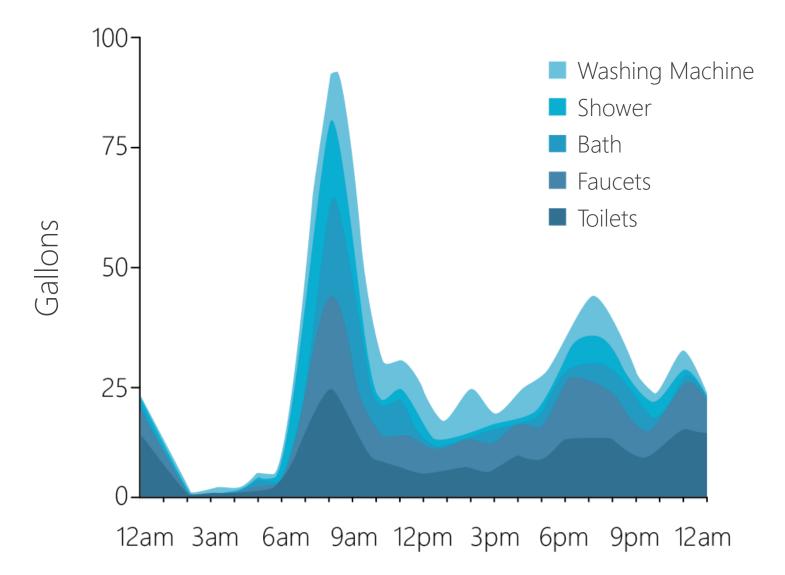






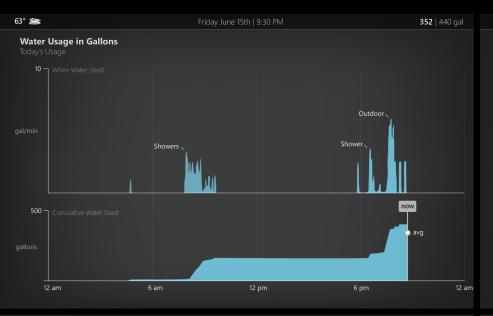


# Daily Patterns of Water Usage



[Adapted from Butler, Building and Environment, 1993]

### design set 2: design probes **Time-Series** Views

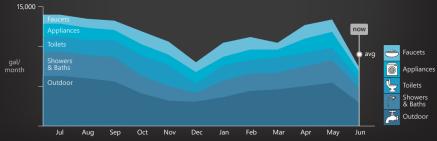


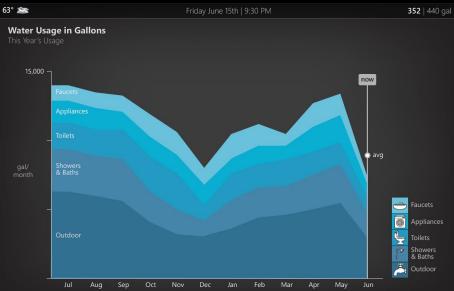
Water Usage in Gallon<u>s Today</u>

Friday June 15th | 9:30 PM



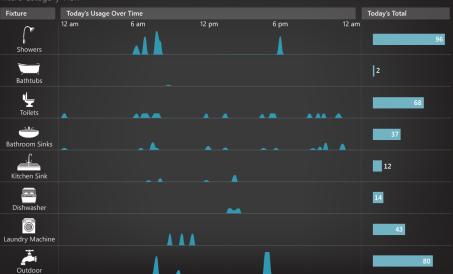






#### Today's Real-Time Water Usage

ure Category View



Friday June 15th | 9:30 PM

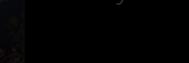
# **DESIGN SET 2: DESIGN PROBES** Design Probes Explored















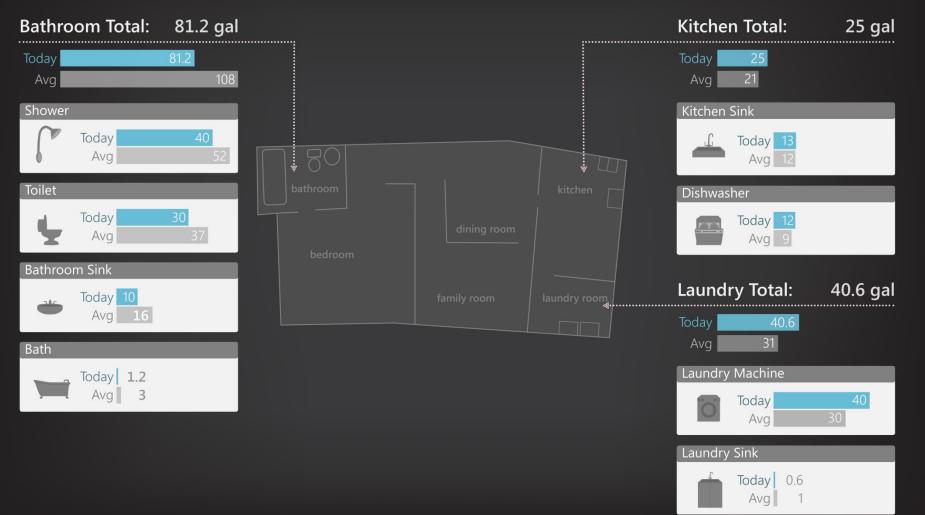




## DESIGN SET 2: DESIGN PROBES Spatial View

#### Today's Water Usage in Gallons

Room View



Friday June 15th | 9:30 PM

# Design set 2: Design probes Design Probes Explored













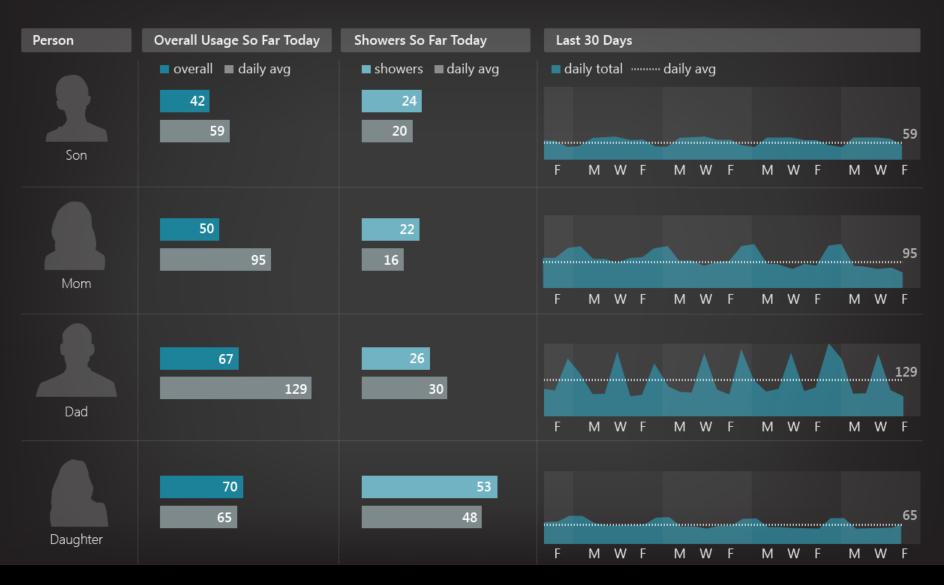




# **Per-Occupant** View

#### **Personal Usage Totals**

Friday June 15th | 9:30 PM



# Design set 2: Design probes Design Probes Explored









### Aquatic Eco-system









#### **DESIGN SET 2: DESIGN PROBES**

# Aquatic Ecosystem Design Influences



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88	9.xxx2
5 <sup>JRL</sup>	6 MND
	-

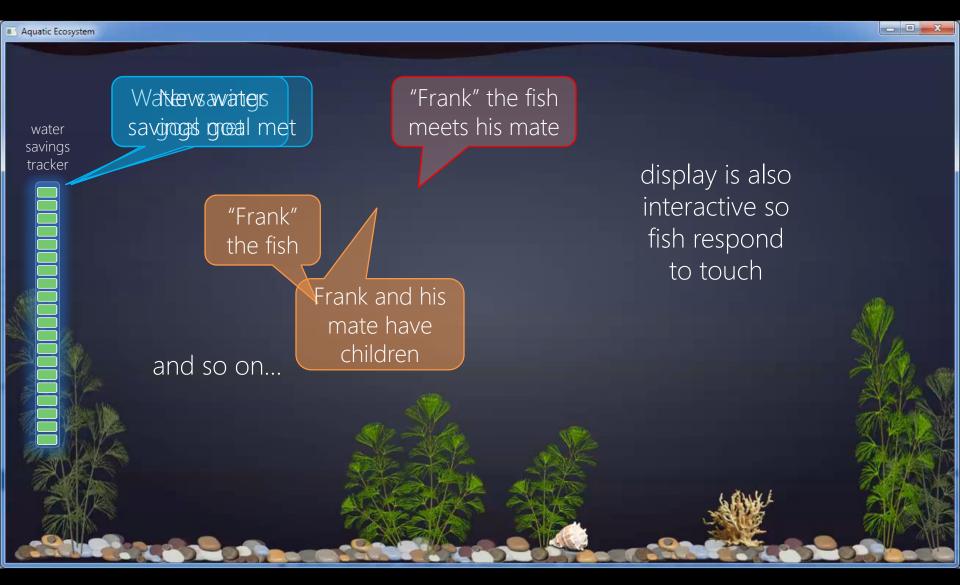
**ubifit** Consolvo *et al.,* CHI2008

Consolvo *et al.,* UbiComp2008



# ubigreen Froehlich *et al.,* CHI 2009

## design set 2: design probes Aquatic Ecosystem View



# Design set 2: Design probes Design Probes Explored

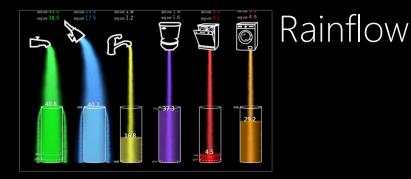








#### Aquatic Eco-system

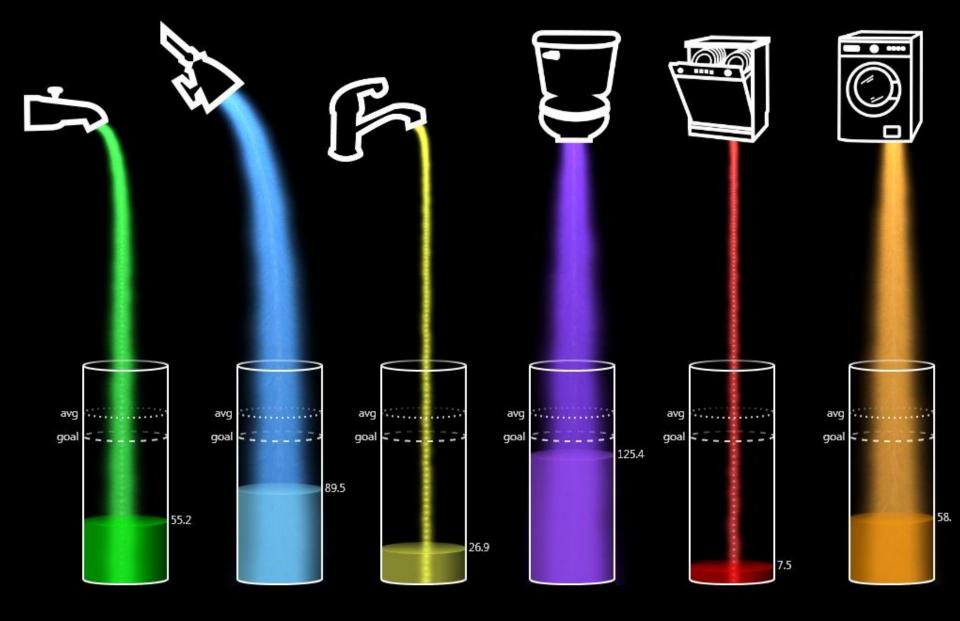




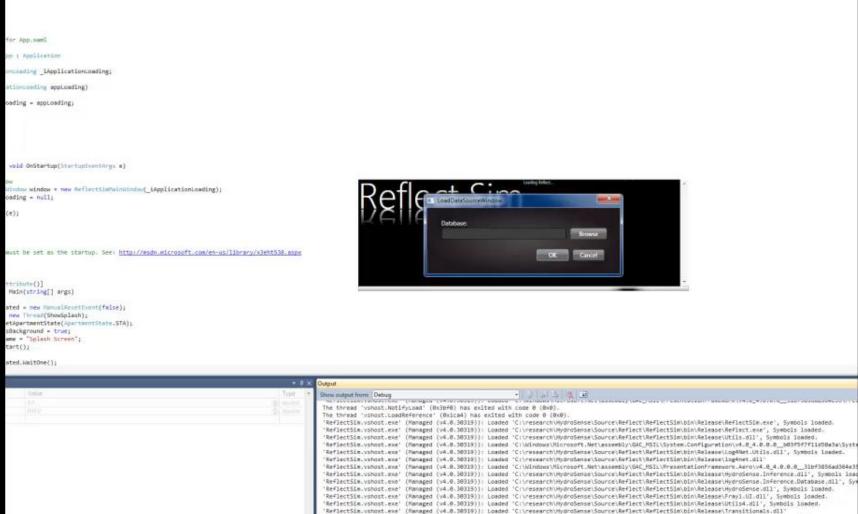
Per-Occupant



## design set 2: design probes **Rainflow** View



# **Rainflow** View Movie



Netactsim.vmnost.exe (newsped (vw.0.2013)): Loaded ':'Uresearch/Wydrobenes/isurce/kerisctsim.ton/aises/irransitjonais.dl)
'ReflectSim.vshost.exe' (Nanaged (v4.0.30319): Loaded 'L'Uresearch/WydroSense/Source/ReflectSim/bin/aiseas/Krm.Roogawrt.HelperTrinity.dl)
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# Design set 2: Design probes Design Probes Explored

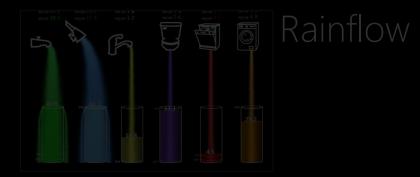








#### Aquatic Eco-system

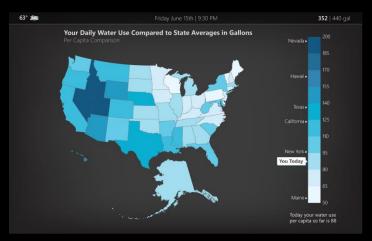




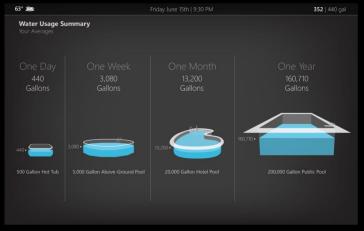




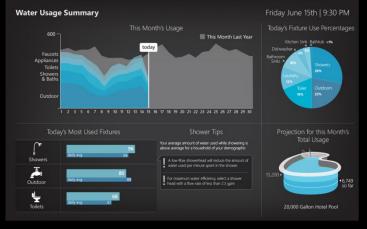
## Design set 2: Design Probes Other Design Probes



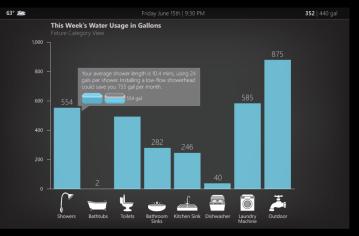
Geographic Comparisons



Metaphorical Unit Designs



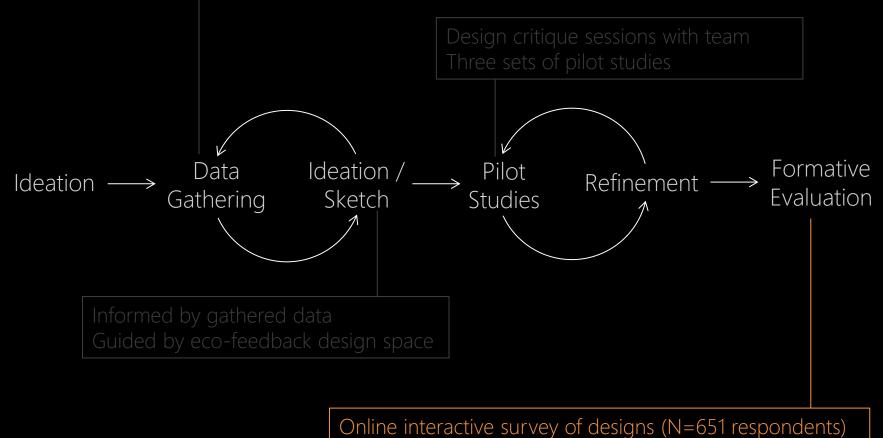
Dashboards



Recommendations

# Evaluation

Informal interviews with water experts (e.g., SPU, Amy Vickers) UW Environmental Practicum on water Literature review of water resource management, environmental psychology Our own online survey of water usage attitudes & knowledge (N=656 respondents)



In-home interviews (10 households, 20 adults)

# **Online** Survey

ii, my name is Jon Froehlich and I'm a graduate student at the University of Washington. The survey you are about to take is for my PhD dissertation on water usage information systems. Your responses will help inform the design of future water conservation programs.

#### Water Feedback Evaluation Survey **Consent Form**



#### RESEARCHERS' STATEMENT

We are asking you to be in a research study. The purpose of this consent form is to give you the information you will need to help you decide whether to be in the study or not. Please read the form carefully. You may ask questions about the purpose of the research, the possible risks and benefits, your rights as a volunteer, and anything else about the research or this form that is not clear by emailing jfroehli@uw.edu. After reading this form, you can decide if you want to be in the study or not. This process is called "informed consent." You can print a copy of this form for your records.

appreciate you taking the time to fill out this survey

Jon E. Froehlich

PhD Candidate University of Washington

#### PURPOSE OF THE STUDY

We are studying how computer displays (interfaces) can help inform people about their energy, water, and gas usage in the home.

#### STUDY PROCEDURES

To participate in this study, you simply need to fill out the forthcoming online survey. Please try to answer each question carefully and honestly. The survey should take between 20-35 minutes to complete. At the end of the survey, we will ask you for your email address. You do not need to provide this information. Those respondents that do supply their email addresses will be entered in a raffle to win a \$100 gift certificate to Amazon.com. We will not use your email for any other purpose or give out you email address to anyone for any reason.



#### RISKS STRESS OR DISCOMEORT

We do not expect any risks, stresses, or discomforts as a result of this research

#### BENEFITS OF THE STUDY

Although you may not directly benefit from this study, we hope that the findings of this study will help to develop new technology that will help the environment.

#### OTHER INFORMATION

Taking part in this study is voluntary. You can stop filling out the survey at any time. Information about you is anonymous. The information you provide is not linked to your name.

#### SUBJECTS STATEMENT

This study has been explained to me. I volunteer to take part in this research. If I have questions later about the research, I can email one of the researchers listed above. If I have questions about my rights as a research subject, I can call the University of Washington Human Subjects Division at (206) 543-0098.

The survey should take between 20-35 minutes to fill out. If you would like to go back to a previous page once you start the survey, please do not hit the "back" button on your browser, instead, use the "back" button located at the bottom of each survey page.

By clicking 'Yes' below, you consent to take part in this study. \*

## Recruitment

Online postings and word-of-mouth

#### Survey Design

- 63 questions (10 optional) Ο
- Question and answer order  $\bigcirc$ randomized when possible

#### **Collected Data**

- 712 completed surveys (651 from US or Canada)
- Nearly 6,000 qualitative responses Ο

-

#### ← → C O edu.surveygizmo.com/s3/632637/CHI2012-WaterFeedbackSurveyDemo

#### Water Feedback Evaluation Survey

Introduction

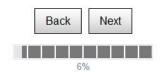


Most people receive information on their water usage from a monthly or bi-monthly bill. We are working on a new type of system that can **immediately show people how much water they are using** at each fixture in their home. This information could be viewed, for example, on a mobile phone, on a laptop, a digital picture frame, or on an in-home touchscreen display.



In this survey, we'll explore different ways of visually displaying water usage information. Unless otherwise noted, each design is based on an average North American household of four people with two adults and two teenagers.

First, though, we need to ask some demographic questions.



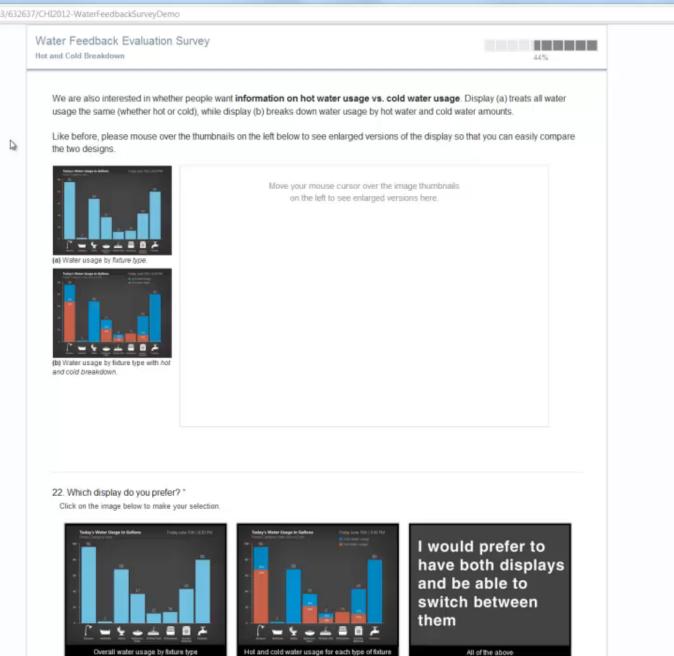


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# In-Home Interviews



# Recruitment

- o Online postings and word-of-mouth
- o Specifically recruited families

### **Interview Method**

- o Semi-structured with two researchers
- o 90-minutes, 3-phases
- o Data coded by two researchers into themes

## Participants

- o 10 households (20 adults)
- o 11 female/9 male
- Diff. socio-economic backgrounds & occupations
- o 18 had college degrees

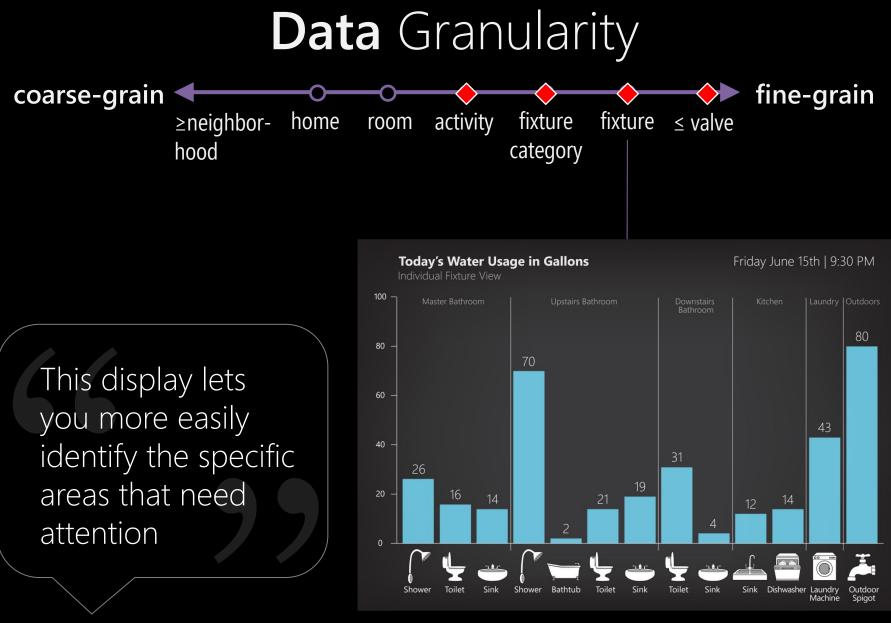




For both the survey and interviews, **90%** of participants indicated an interest in **conserving water** 

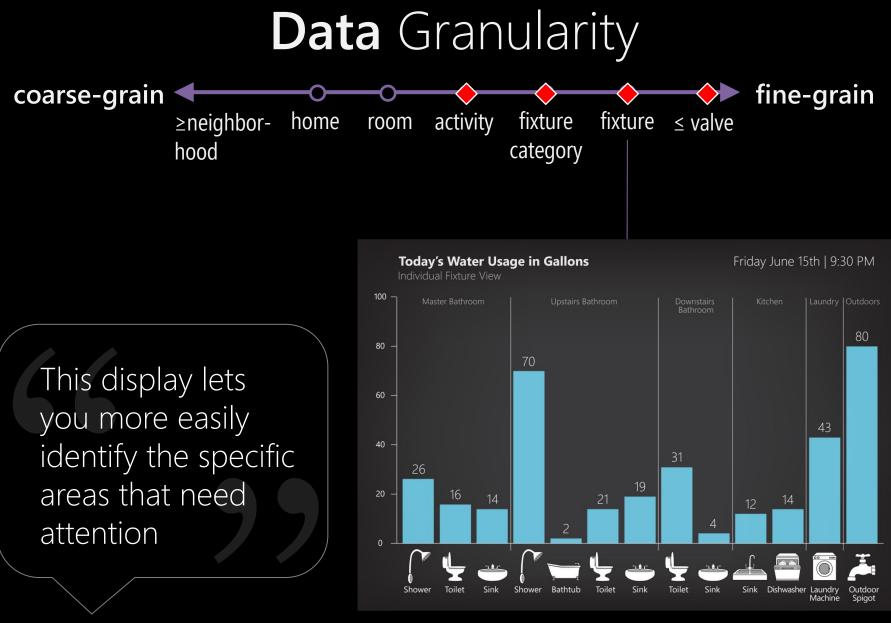
# Average morning shower uses 400 gallons of water

# Findings



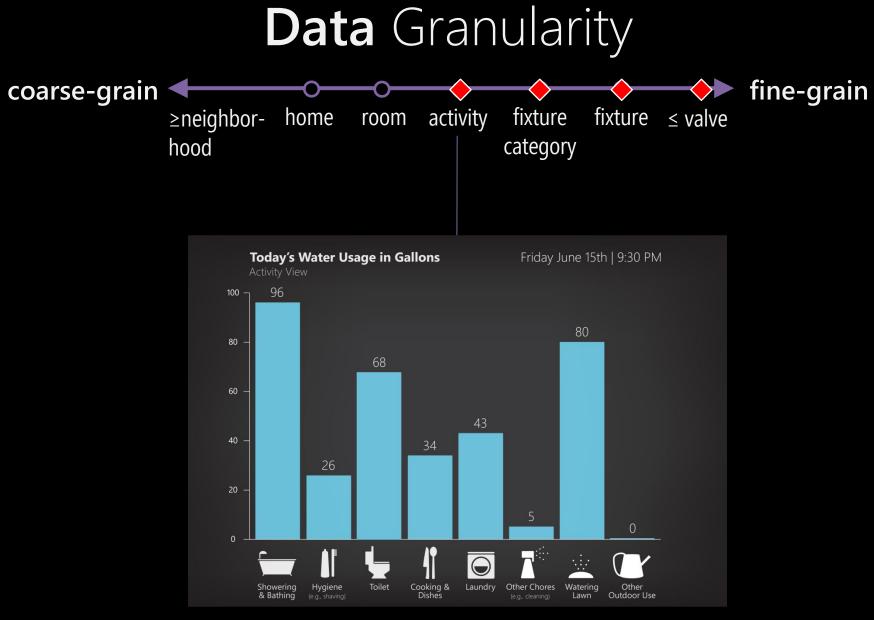
Majority preferred the Individual Fixture Display

R536



Majority preferred the Individual Fixture Display

R536



20% preferred the Activity Display

#### Measurement Unit



71% of respondents preferred to see both gallons and cost

Seeing the gallon amount triggers the 'save the environment' impulse to conserve, while the dollar amount is helpful because almost everyone is motivated by money to some extent

R143

I don't think very well in 'thousands of gallons', but \$20 I can understand. That's a case of beer down the drain, if you will

#### Time Granularity



Majority of respondents wanted ability to switch between different time granularities

**Comparisons** were the most uniformly desired pieces of information of all the dimensions

#### Self-comparison was most preferred



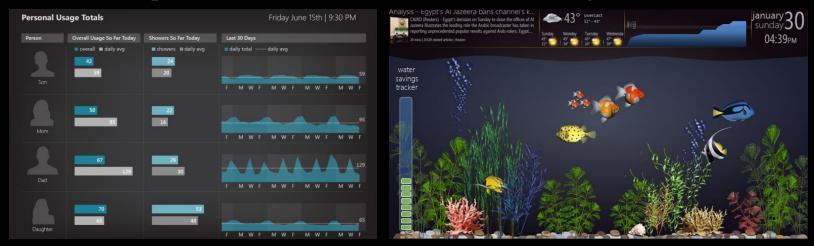
	JAKE 2/6/10
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JANE 4-12-09-	
JAKE 2/20/09	
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TAKE 1-27-00

#### **Emergent** Themes

- (1) Competition and Cooperation
- 2 Accountability and Blame
- 3 Playfulness and Functionality
- (4) Sense of **Privacy**
- **(5) Display** Placement

#### **Competition** and Cooperation



You can compare usage to others, and create friendly competition

R220

It pits the family members against each other rather than encouraging collaboration

[It] sets up a 'competitive' environment that we are trying not to create in our household R485

#### Accountability and Blame



It holds each individual accountable for water usage

R354

There's no reason to add an element of 'blame' to conservation efforts within a family

Would seem to lead to plenty of arguments about usage

R98

#### Playfulness and Functionality



I like the idea of getting rewards for saving water

18.2

It's like unlocking badges in Foursquare. No matter how trivial it can be to make a fish appear on this screen, you still want to do it

14.1

It doesn't appeal to me as much. I don't do Foursquare. This distracts me a little bit and it doesn't make me think about my usage

#### Useful as an educational tool?



#### Privacy Spectrum



It's incredibly invasive. And other people's water consumption is not my business.

Water usage for many purposes can be very personal, and shouldn't be automatically shared

#### Privacy Spectrum



### **Display** Location Preferences





### If we placed the display here, the kids couldn't see it.

## **Display** Location Preferences



near thermostat

kitchen



high traffic areas



accessible when needed



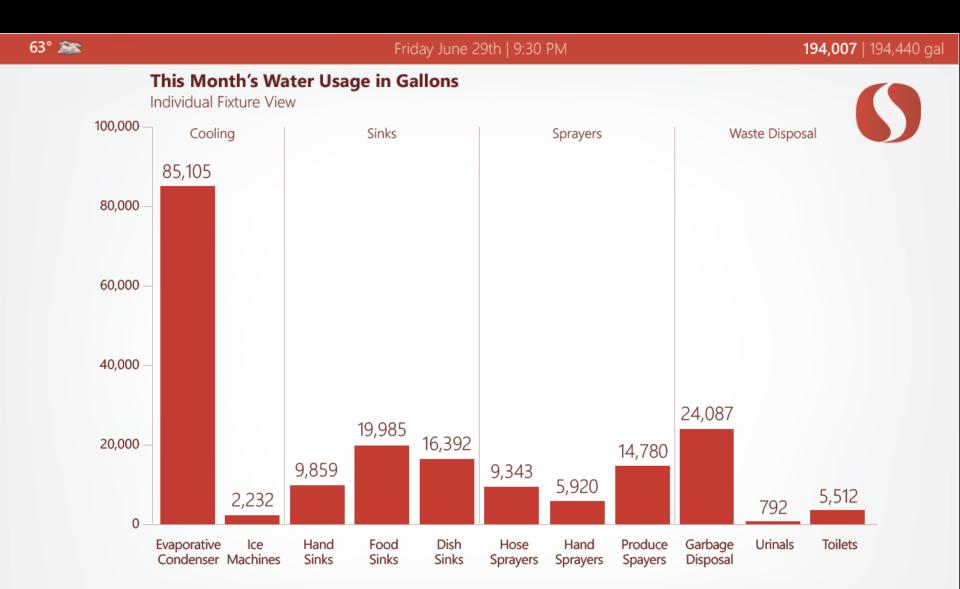
#### **Primary** Contributions

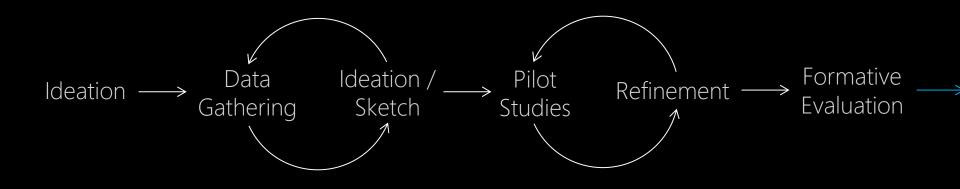
- 1 First work to design and evaluate feedback visualizations for disaggregated water data
- 2 An iterative design roadmap for others working in the space of eco-feedback or other behavior change technologies



Sensing and feedback for water **quality** not just consumption







#### **Closing** Thought

Eco-feedback displays do not just visualize consumption, they document household activities

#### The Eco-Feedback Team!



#### Acknowledgements:

Seattle Public Utilities: Ray Hoffman, Director; Al Diettemann, Water Conservation Expert; Bob Alpers Amy Vickers, Water Conservation Expert Austin Polebitski, Assistant Professor of Civil and Environmental Engineering, UMass

Austin Polebilski, Assistant Professor of Civil and Environmental Engineering, O

David Hsu, Assistant Professor City and Regional Planning, UPenn

Sara Sheridan for her early design work

# Questions?

#### @jonfroehlich







