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

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dub design: use: build: UNIVERSITY of WASHINGTON

UNIVERSITY OF MARYLAND HCIL

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

Todays Total Usage

Friday June 15th | 9:33 PM

total | daily average

Bathroom Total: 81.2 | 108

Shower
Today 40
Avg 52

Toilet
Today 30
Avg 37

Bathroom Sink
Today 10
Avg 16

Bath
Today 1.2
Avg 3

Kitchen Total: 25 | 21

Kitchen Sink
Today 13
Avg 12

Dishwasher
Today 12
Avg 9

Laundry Total: 40.6 | 31

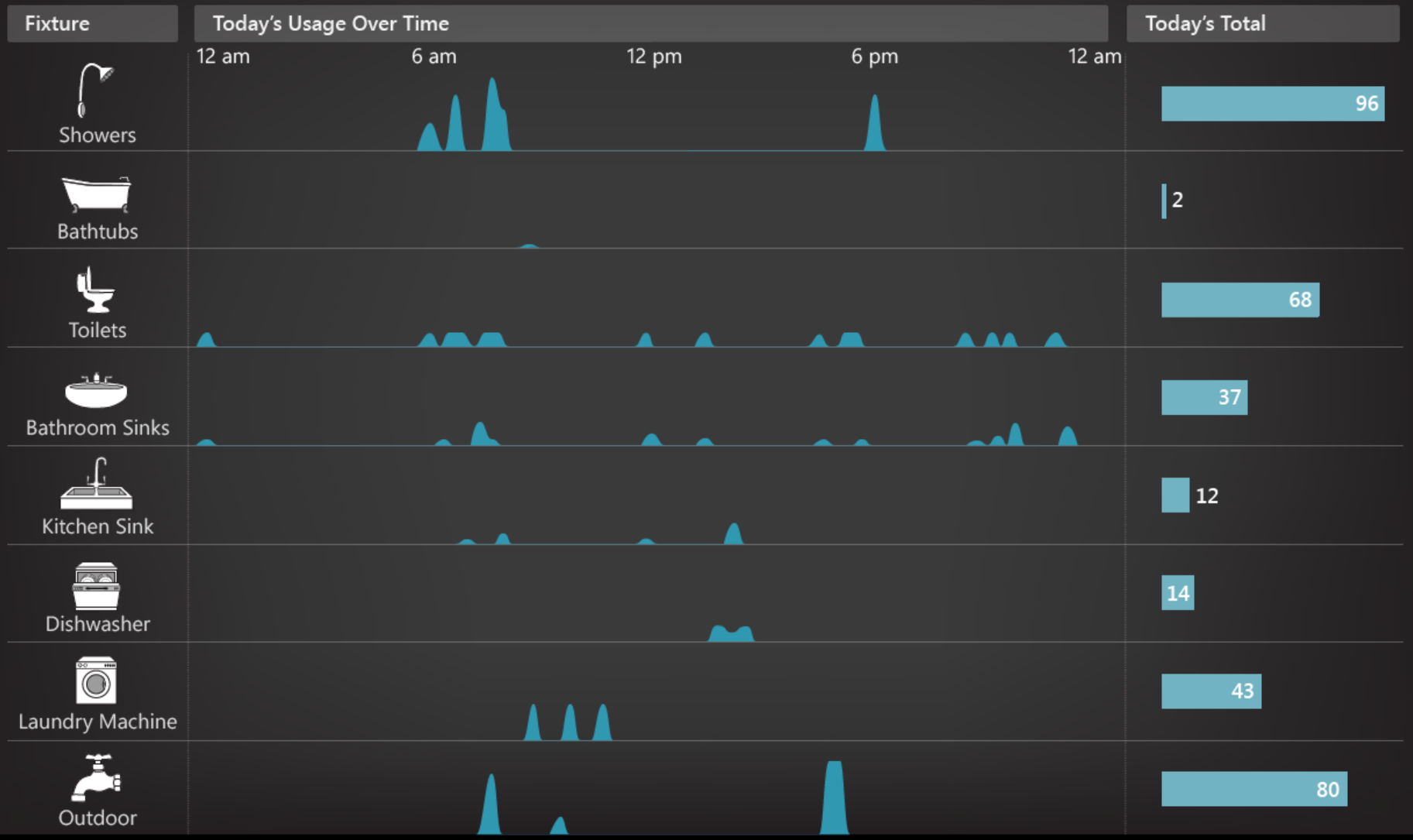
Laundry Machine
Today 40
Avg 30

Laundry Sink
Today 0.6
Avg 1

Today's Real-Time Water Usage

Fixture Category View

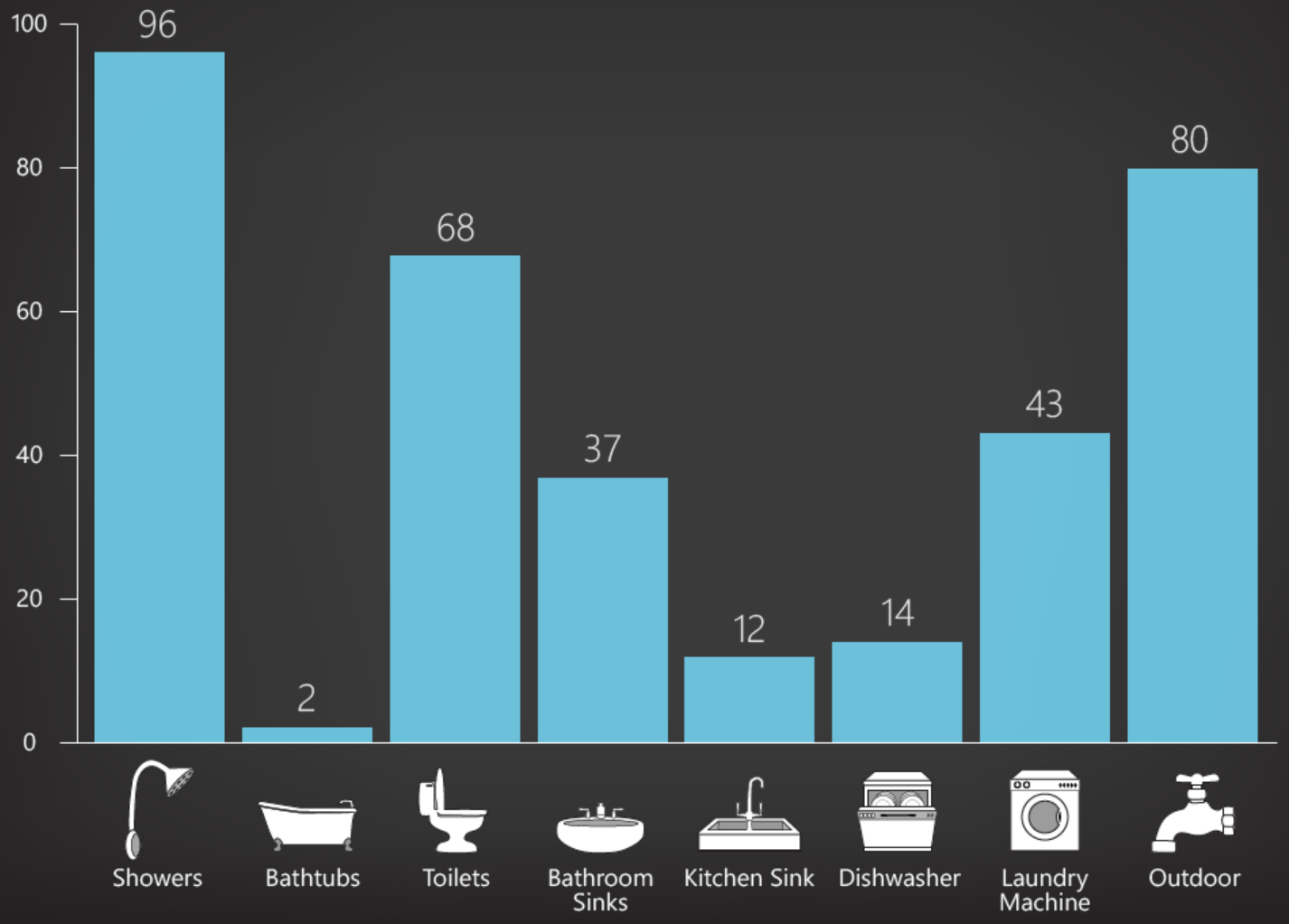
Friday June 15th | 9:30 PM



Today's Water Usage in Gallons

Fixture Category View

Friday June 15th | 9:30 PM

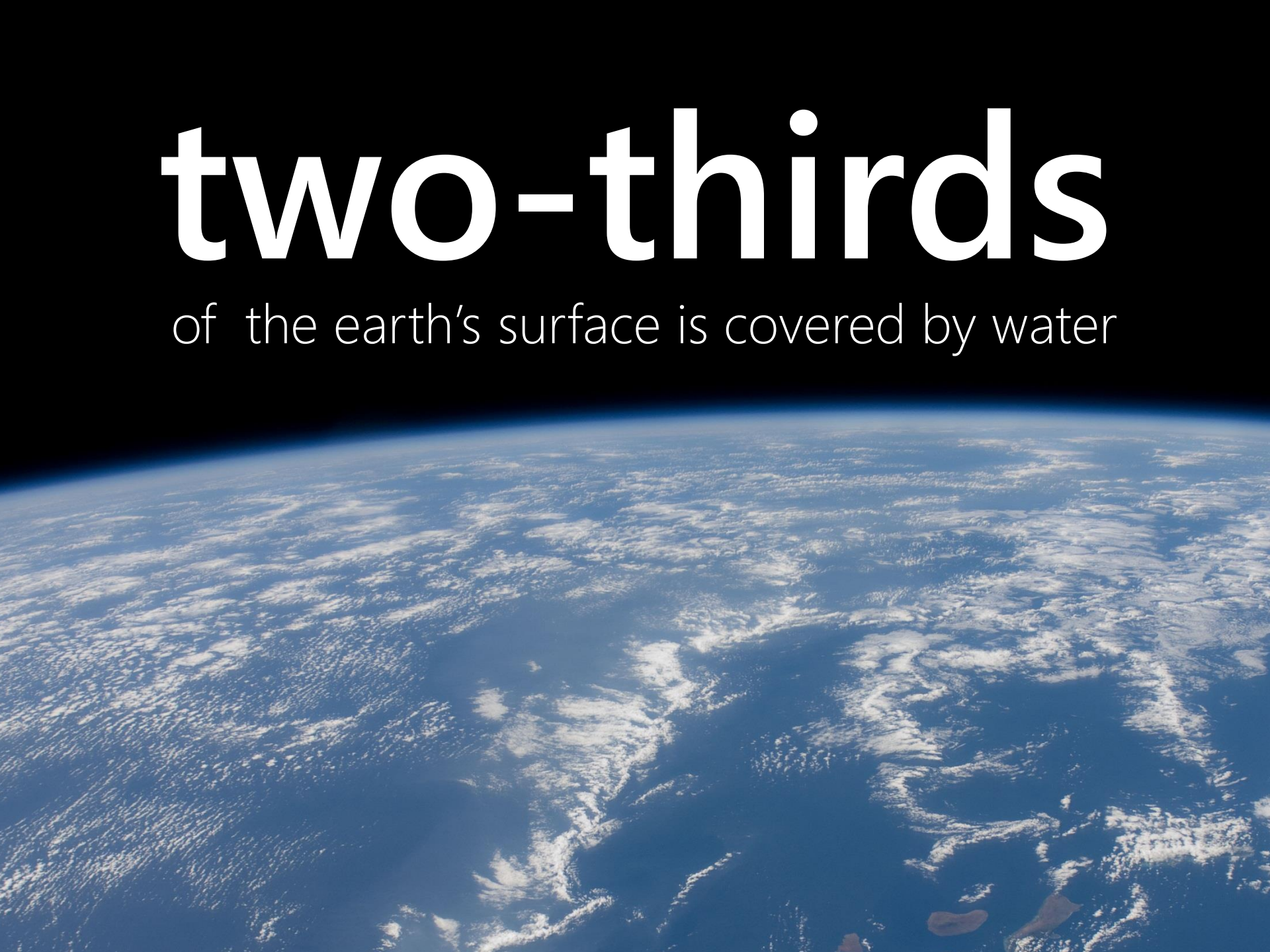


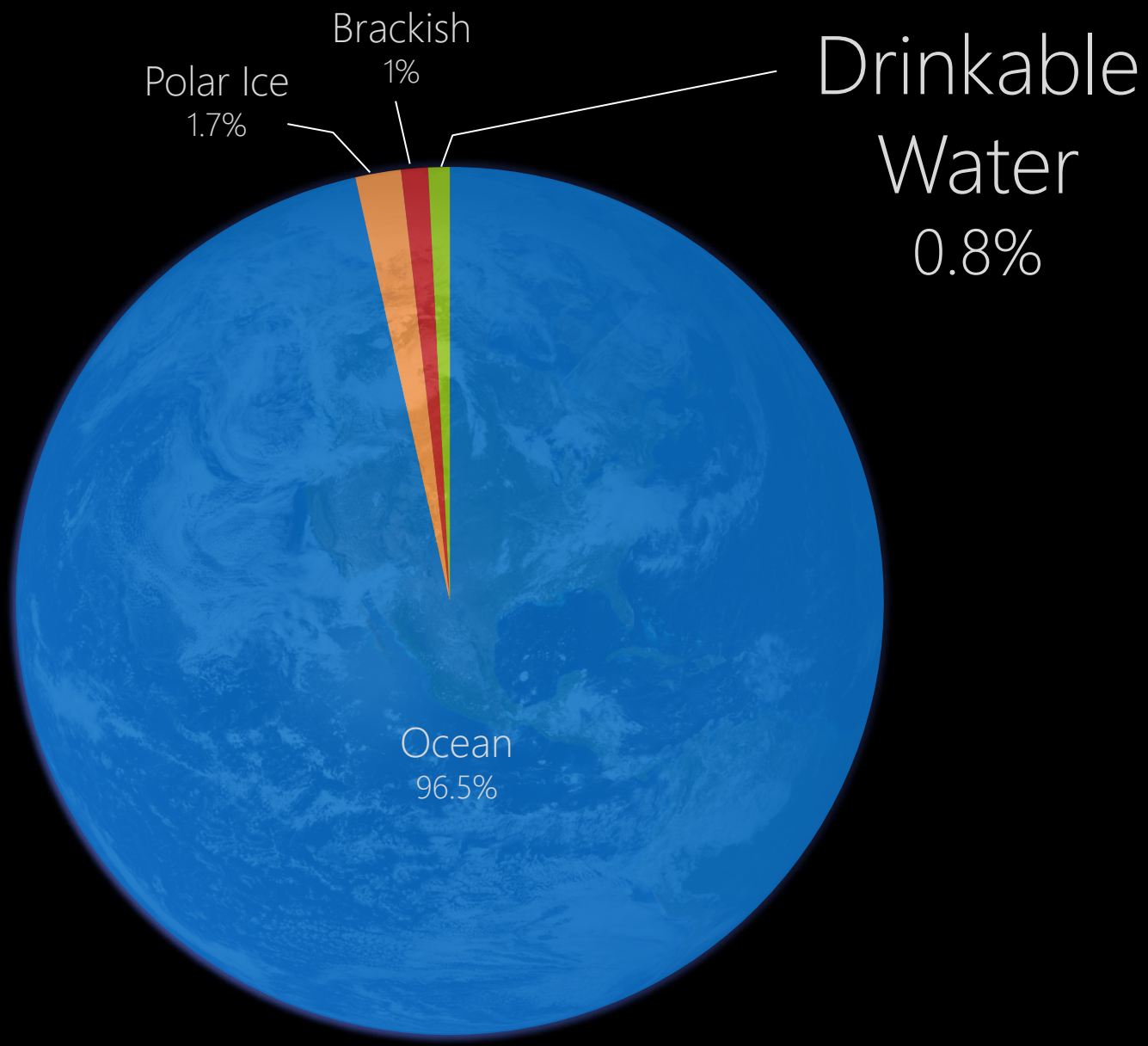
This talk is also about the design process for eco-feedback visualizations
persuasive technology
personal informatics
quantified self

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 grow
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]

growing demand

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]

[Bloomberg News, Feb 2009]


new sources of water
more costly to extract

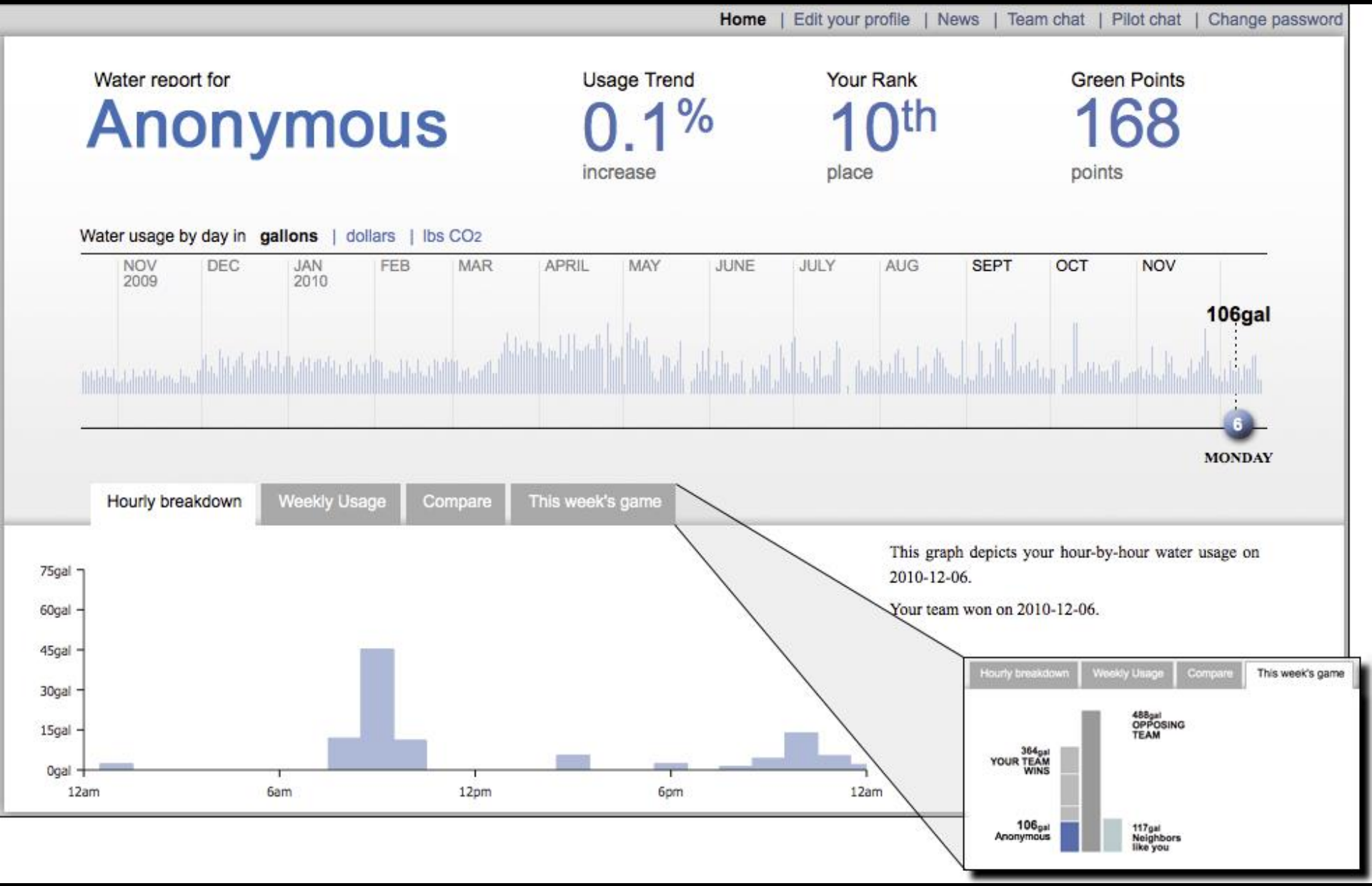

water utilities
governments
shift focus

This is an area where HCI researchers and designers can help

eco-feedback

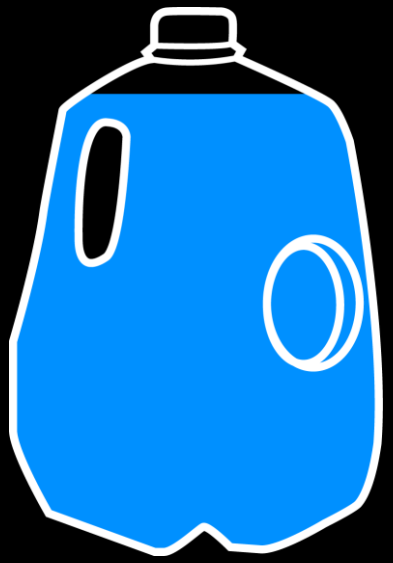
sensing and visualizing behavior to reduce environmental impact

Dubuque Water Portal:



[Erickson *et al.*, CHI 2012]

10,230
gallons



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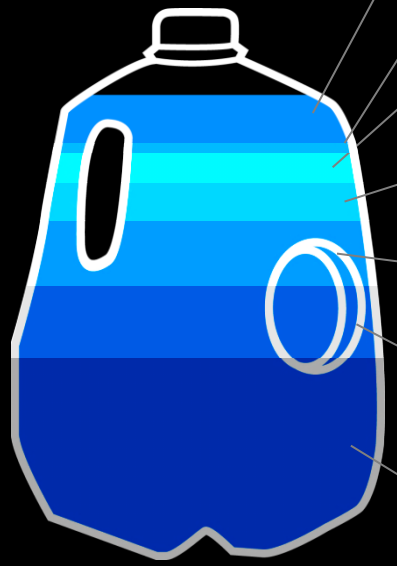


Other
1248 gals

Dishwasher
102 gals

Faucets
1105 gals

Showers
1176 gals

Laundry
1,524 gals

Toilets
1,872 gals

Outdoor
3,212 gals


waterbot
[Arroyo *et al.*, CHI 2005]


showme
[Kappel & Grechenig, Persuasive 2009]


upstream
[Kuznetsov & Paulos, CHI 2010]

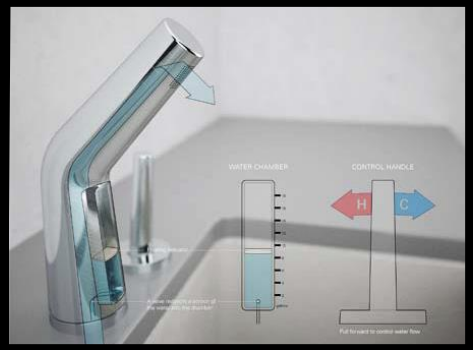
waitek shower monitor

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

Point-of-Consumption Eco-Feedback Displays

sensing and feedback
unit co-located at fixture

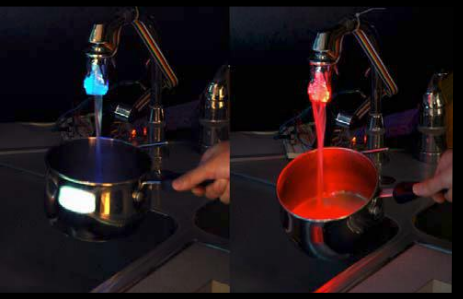
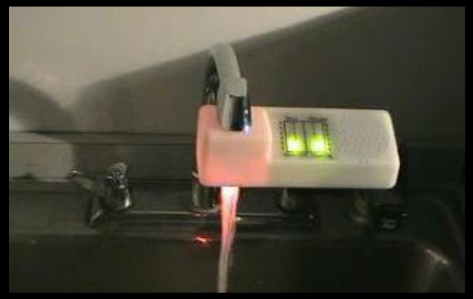
provides real-time
feedback on water usage



WATER CHAMBER
CONTROL HANDLE
H
C

IN SIGHT MIND
see what you're wasting
WEEK
82
WEEK
327



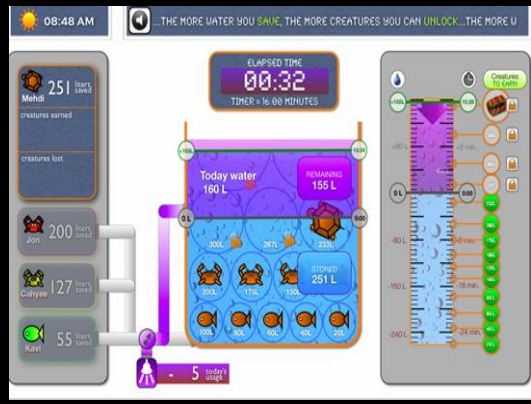

iSAVE
38
iSAVE
855

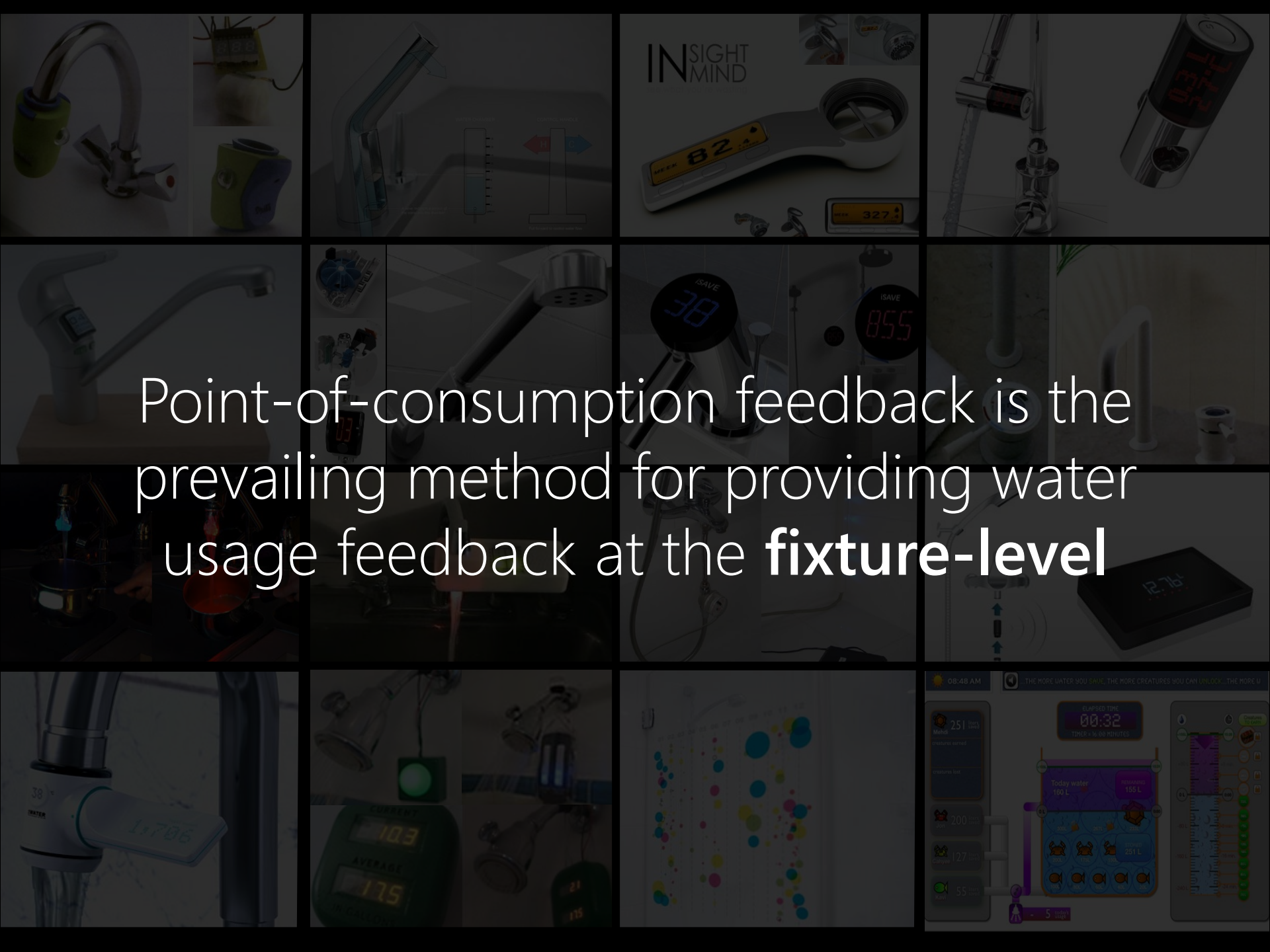





38
1.706

CURRENT
103
AVERAGE
175
IN GALLONS


08:48 AM
...THE MORE WATER YOU SAVE, THE MORE CREATURES YOU CAN UNLOCK...THE MORE U
ELAPSED TIME
00:32
TIMER = 16 00 MINUTES
Mehdi
251 liters saved
creatures earned
creatures lost
Today water
160 L
REMAINING
155 L
Jon
200 liters saved
Cahyee
127 liters saved
Kavi
55 liters saved
STORED
251 L
- 5 today's usage
Creatures To Collect



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

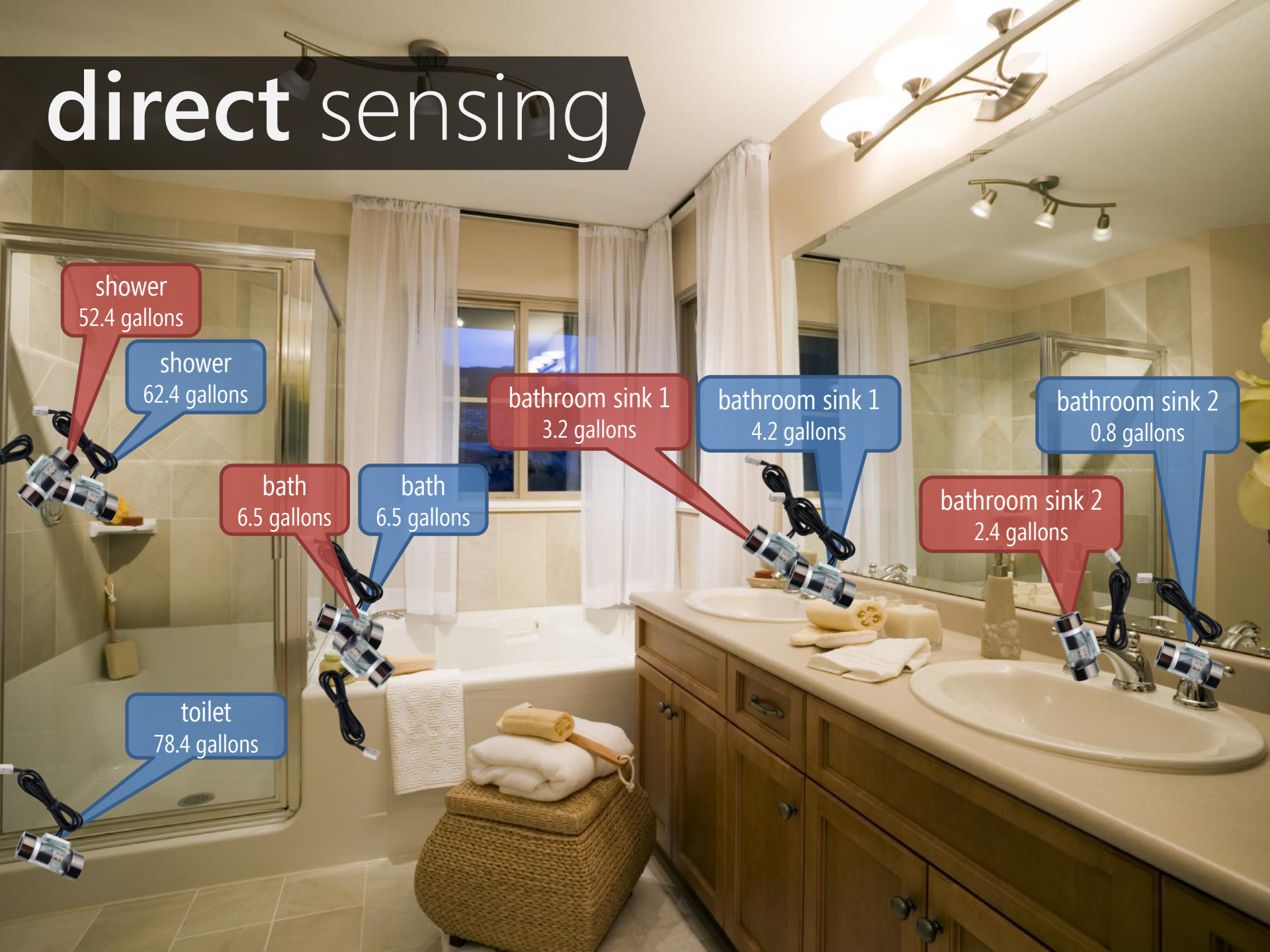
[Vickers, 2001]

direct sensing

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


direct sensing
shower
62.4 gallons
bath
6.5 gallons
toilet
78.4 gallons
bathroom sink 1
4.2 gallons
bathroom sink 2
0.8 gallons

direct sensing



indirect sensing

shower
52.4 gallons

shower
62.4 gallons

bath
6.5 gallons

bath
6.5 gallons

toilet
78.4 gallons

bathroom sink 1
3.2 gallons

bathroom sink 1
4.2 gallons

bathroom sink 2
2.4 gallons

bathroom sink 2
0.8 gallons

[HydroSense, UbiComp 2009]

indirect sensing

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

[HydroSense, UbiComp 2009]

Emerging Water Sensing **Disaggregation** Methods

DeOreo *et al.*, AWWA 1996

Fogarty *et al.*, UIST 2006

Kim *et al.*, SenSys 2008

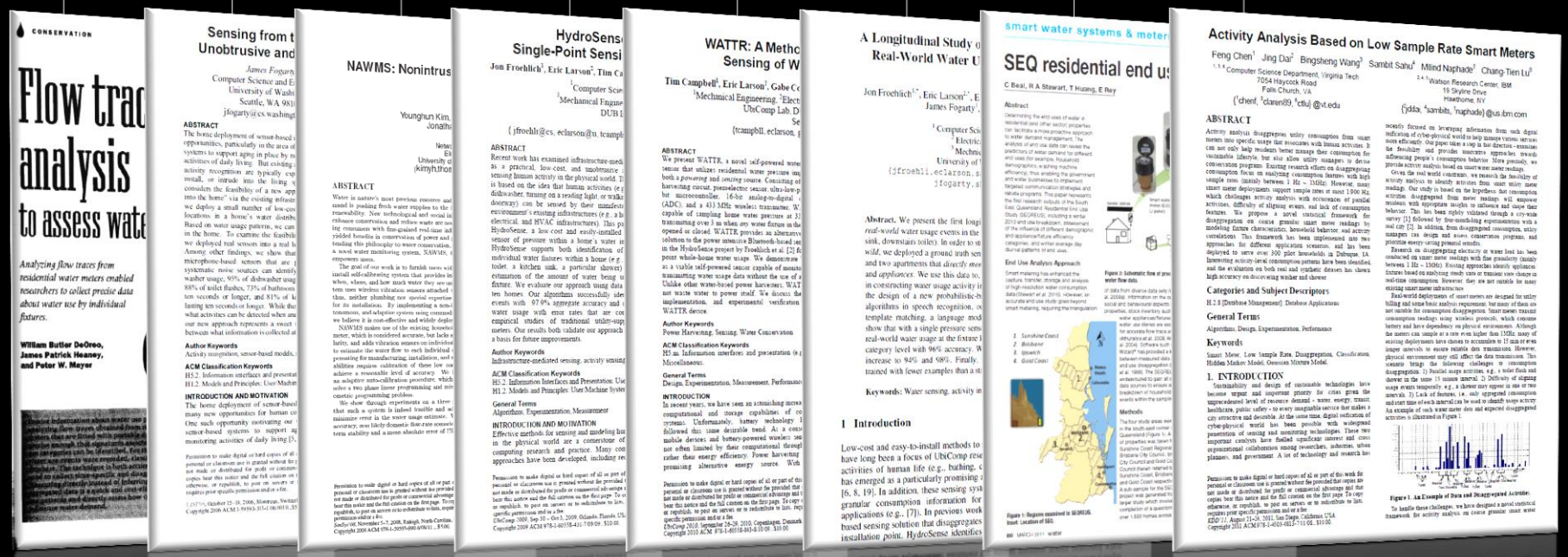
Froehlich *et al.*, UbiComp 2009

Campbell *et al.*, UbiComp 2010

Froehlich *et al.*, Pervasive 2011

Beal *et al.*, Smart Water Sys 2011

Chen *et al.*, KDD 2011



This data presents new, rich opportunities for...

eco-feedback

sensing and visualizing behavior to reduce environmental impact

What do we do with all this data?

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?

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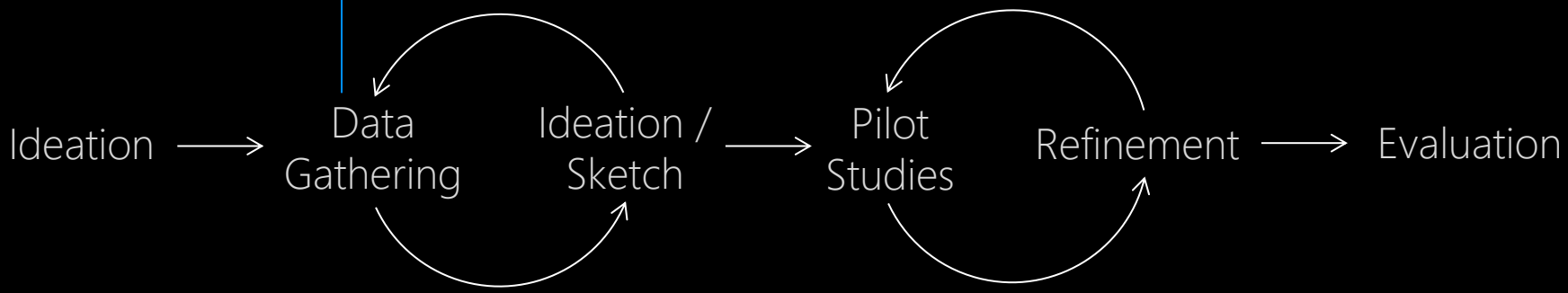
3. **How** might these visualizations impact behavior?

Two sets of designs:

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

2 **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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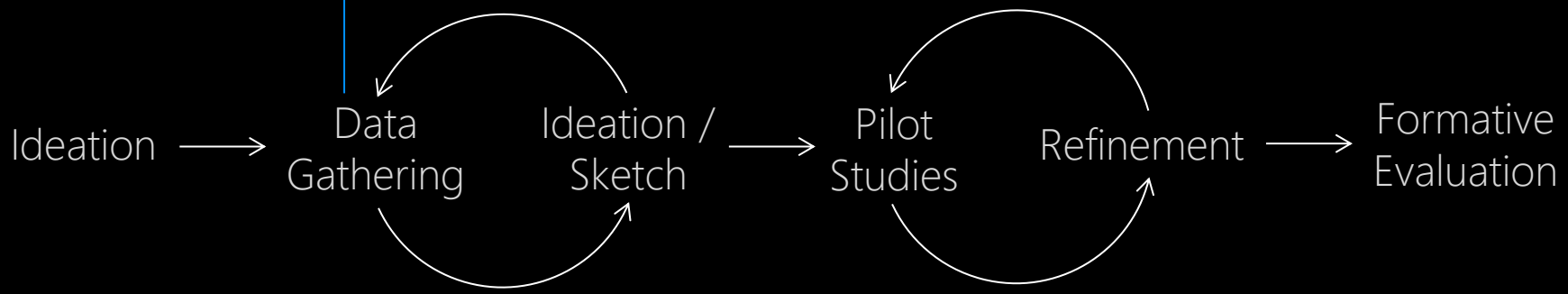

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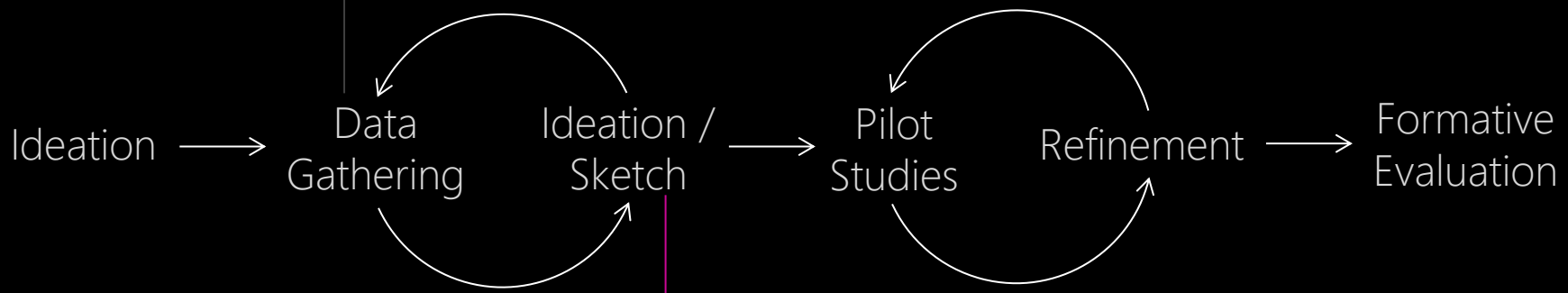


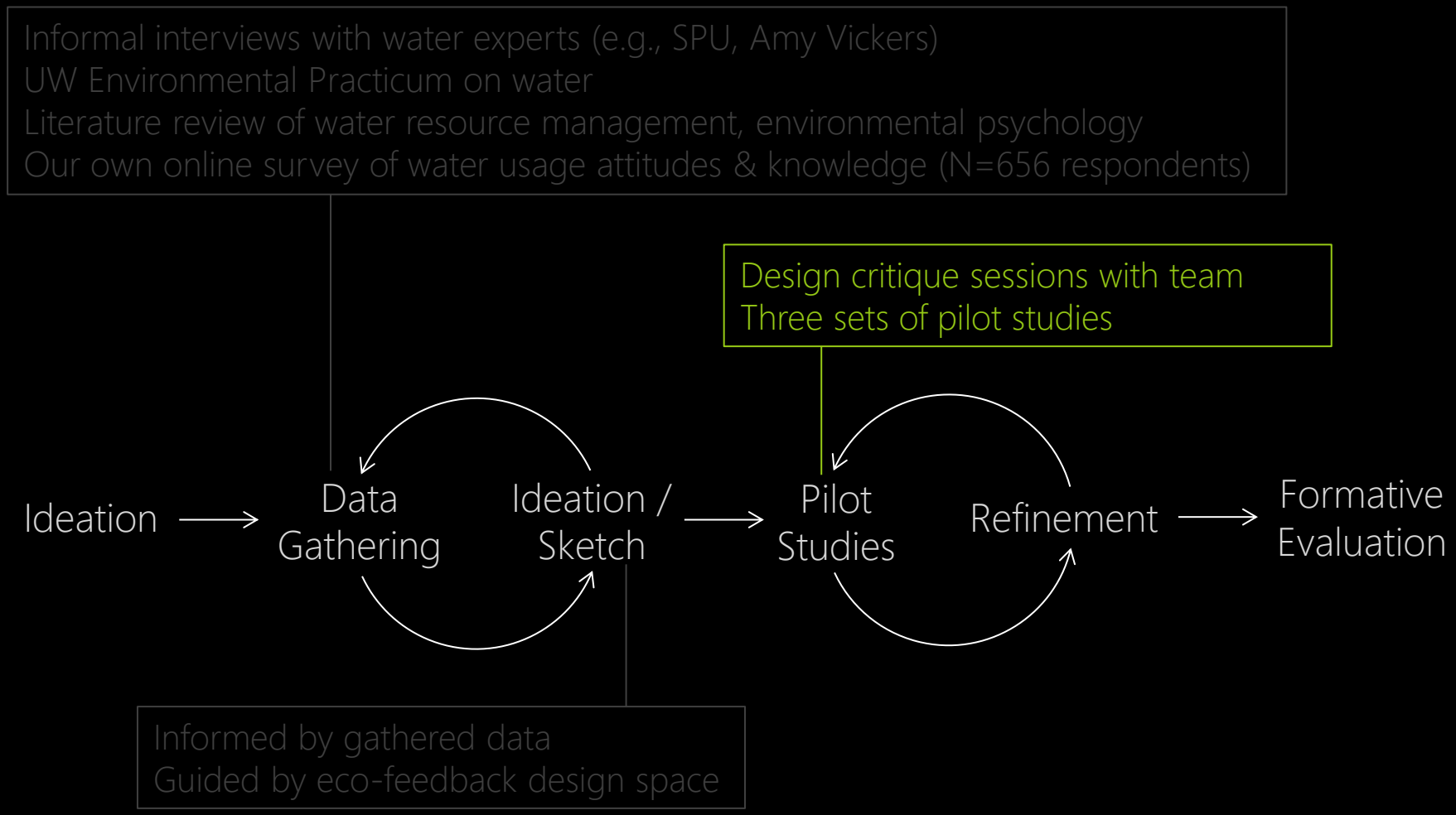
Informed by gathered data
Guided by eco-feedback design space

Iterative Design Process

Sketch

Lo-to-Mid Fidelity Mockup

Higher Fidelity Mockup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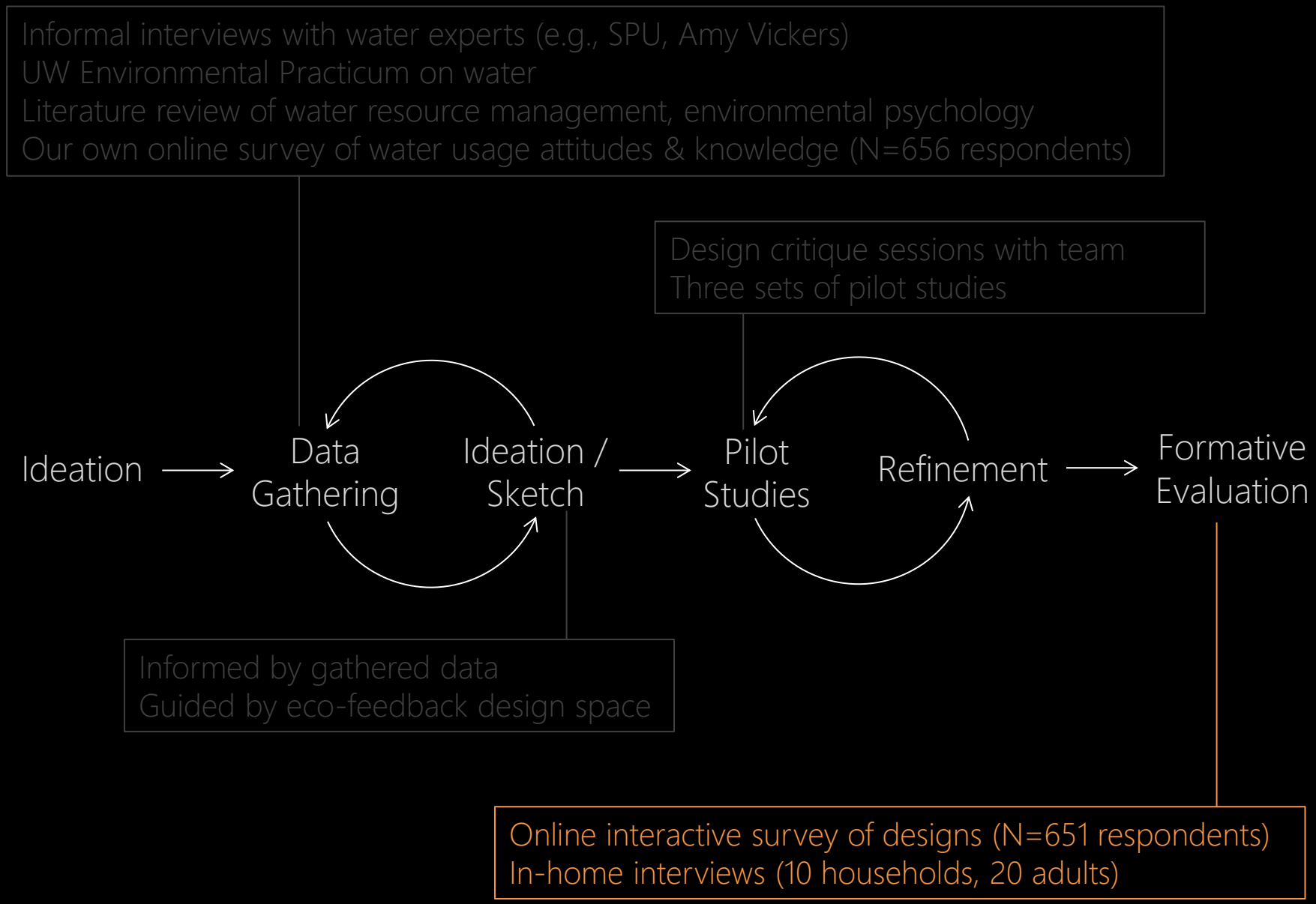
Design critique sessions with team
Three sets of pilot studies
Ideation
Data Gathering
Ideation / Sketch
Pilot Studies
Refinement
Formative Evaluation
Informed by gathered data
Guided by eco-feedback design space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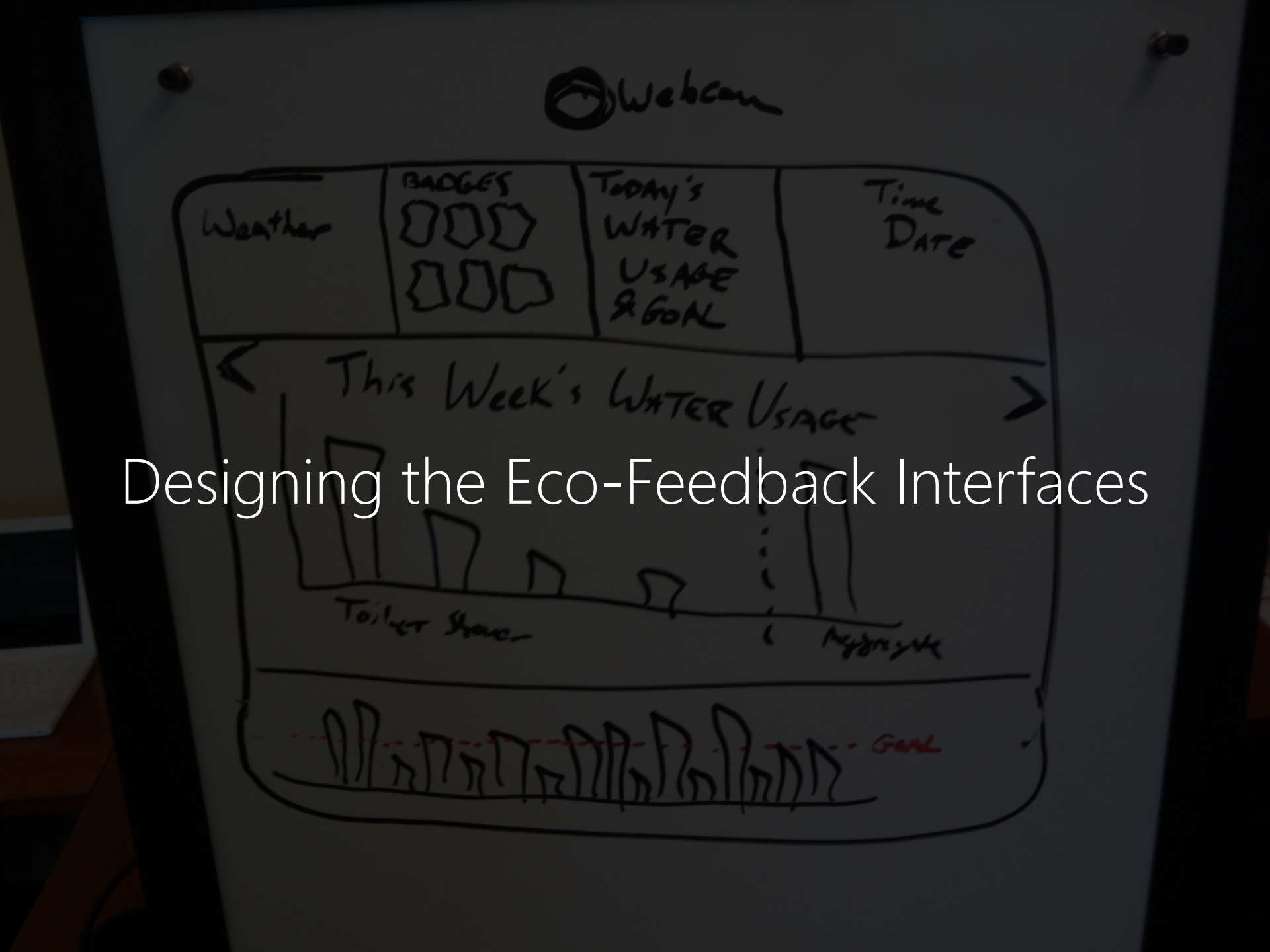
Three sets of pilot studies
Ideation
Data Gathering
Ideation / Sketch
Pilot Studies
Refinement
Formative Evaluation
Informed by gathered data
Guided by eco-feedback design space
Online interactive survey of designs (N=651 respondents)
In-home interviews (10 households, 20 adults)

Designing the Eco-Feedback Interfaces



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

Eco-Feedback Design Space

Information Access

- **update frequency**: real-time — monthly or less — user poll
- **spatial proximity to behavior**: co-located — remote
- **attentional demand**: glanceable — high attention
- **effort to access**: low — high

Interactivity

- **degree of interactivity**: none — high
- **interface customizability**: none — high
- **user additions**: user annotations — user corrections

Display Medium

- **manifestation**: webpage — mobile phone app — wearable interface — custom display — in-home display
- **ambience**: not-ambient — ambient
- **size**: small — large

Actionability/Utility

- **degree of actionability**: low — high
- **decision support**: suggests actions — suggests purchase decisions — anomaly alerts
- **personalization**: no personalization — highly personalized
- **information intent**: Informs one action — informs many actions
- **automation/control**: no control — system controls resource use

Data Representation

- **aesthetic**: pragmatic — artistic
- **time window**: <hour — >year
- **temporal grouping**: ≤sec — by hour — by day — by week — by month — ≥year
- **data granularity**: coarse-grain — fine-grain
- **visual complexity**: simple — complex
- **primary visual encoding**: textual — graphical
- **measurement unit**: resource — cost — environmental impact — activity — time — metaphor
- **primary view**: temporal — spatial — categorical
- **data grouping**: by resource — by person — by time — by space — by activity — by consumption category

Motivational/Persuasive Strategies

persuasive tactics from psychology and applied social psychology disciplines:

- persuasive design
- persuasive technology
- behavioral science/economics
- environmental psychology
- game design
- social marketing
- health behavior change

persuasive tactics include:

- 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**: self — social — goal
- **comparison by time**: past — projected
- **social-comp. target**: geographically proximal — demographically similar — selected social network
- **goal-setting strategy**: self-set — system-set — externally-set
- **difficulty to reach comparison target**: easy — hard

comparison variables

- ☐ time window
- ☐ time granularity
- ☐ data grouping
- ☐ data granularity
- ☐ measurement unit

statistic

- ○ raw value
- ○ average
- ○ median
- ○ mode
- ○ other

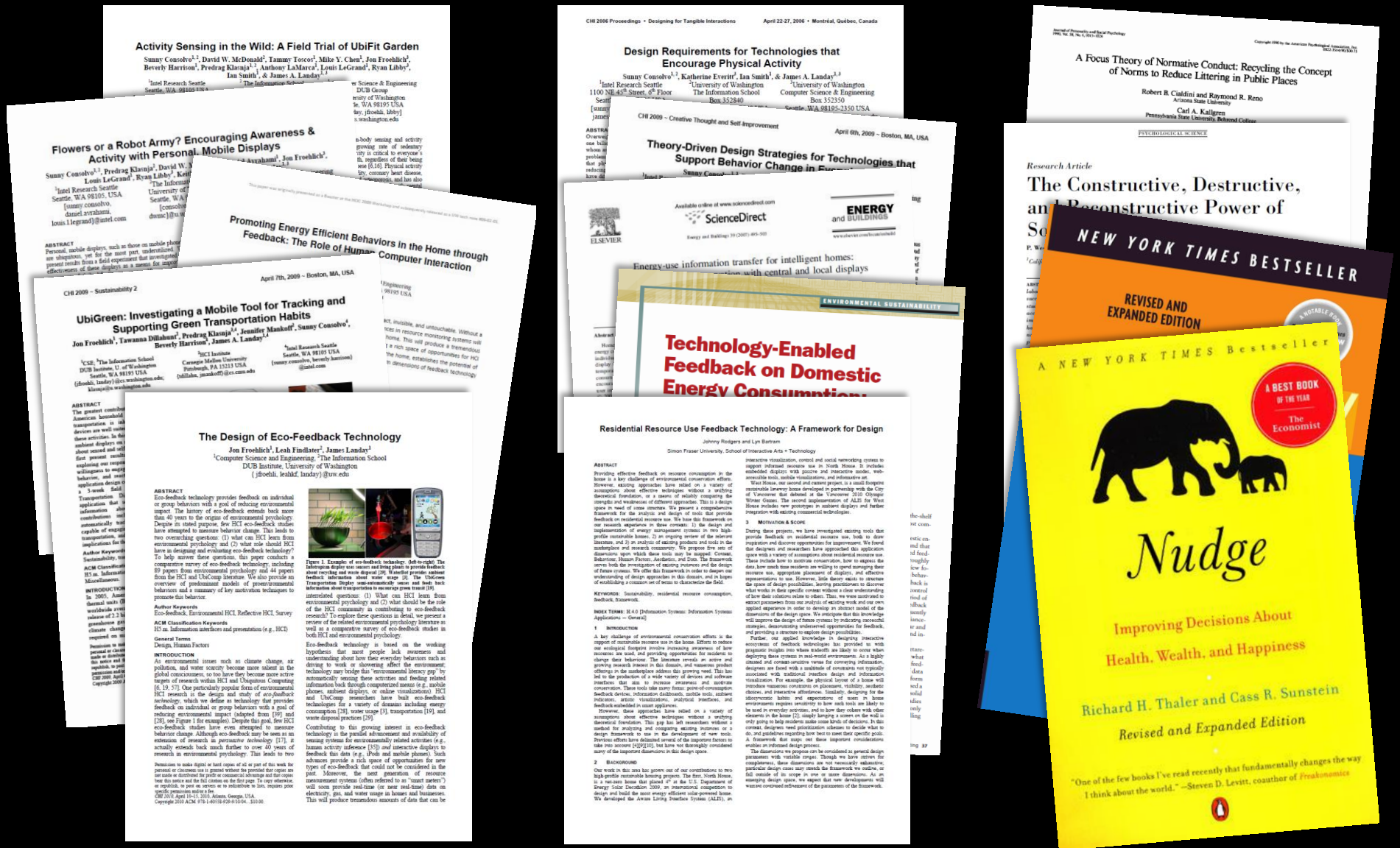
computation

- @ this time [yest, last wk, mo, yr]
- [hrly, daily, wkly, monthly, yrly]
- over past [X] days
- this day type [weekday, weekend]
- this day of week (e.g., mondays)

Social Aspects

- **target**: person — household — community — state — country
- **private/public**: private — public
- **data sharing**: none — everyone
- **social-comparison**: available — (see Comparison) — unavailable

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



My own experiences

Existing frameworks
(in persuasive tech and infovis)

Psychology
(particularly behavioral economics and environ. psych)


inputs (sensing)
support for user annotations
support for user corrections
social aspects
data representation
medium
persuasive tactics
push/pull
update frequency
user effort
location
alert/notification
information agenda
inputs models (themes)
Design for person/ design for household

Inputs (sensing)

- automated vs. self-report
- Data granularity
- user annotations
- user corrections

how do these things fit into any design space?

When I talk about the pros I talk about
- immediate
- simple
- educates
- constrained environment
- reason to care
- informs only one action

Models

what motivates us?

- Explicit encoding of behavior change theories
- Personalization
  - ↳ does system adapt to person based on sensed data or demographics
- Designer's agenda? ← to inform; to teach to change behavior
- Does person have reason to care

Social Aspects

- Design for person vs. design for household
- Social sharing of information over internet
- public or private display
- comparison to others ★

some overlap

Information Access

- Update frequency
- Push/pull
- Degree of interactivity
- Spatial proximity to behavior
- Approachability or learnability
  - ↳ how easy is interface to immediately understand
- Attentional Need
  - ~~Glanceability~~

attached ↔ independent

maybe this goes in data representation?

- ambient vs. non-ambient
- availability (highly available) ← effort to access

Data Representation

- views of data - historical view, by day, by room or fixture
- Grouping/clustering by time of day or by room or by fixture
- visual encoding of sensed data
  - ↳ textual, chart, icon, abstract
- simple ⟷ complex
- aesthetic
- Scale
- value type: relative/absolute

some overlap

some overlap

↑ Kosmo, presents spectrum of aesthetics

★ Comparison

- comparison to self
- comparison to others
- comparison to projected self
- comparison to a goal

Medium

- display medium: screen, orb, mobile, desktop, watch
- ambient vs. non-ambient (maybe this goes in Information Access)
- display size

Actionability

also, related is "utility" how much utility does user gain from tool

- degree of actionability
- maybe this is called perceptual affordance?
  - ↳ the thing I talked about @ BIEL 2010
- Decision support

maybe call this: motivational strategies? or behavioral science tool box

comparison might actually fit in here

Persuasive Toolbox

- projected future
  - ↳ project a trend to foreshadow where they will end up
- progress
- loss aversion
- goal-setting
- see word doc for more
- anticipation
- negative vs. positive feedback

- where would customizability go?
- What about perceived levels of trust?
- unintended positive reinforcement of visual relations
- role of information vs. role of persuasion

★ could also have group called Comparison & have comparison to others & comparison to self

★★ might have a few more specific things for home resource consumption feedback like "its fit into the home"

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data representation
information access
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inputs
the
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design space

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DESIGN SET 1: ISOLATING DESIGN DIMENSIONS

Design Dimensions Explored

① **Data** Granularity

② **Time** Granularity

③ **Measurement** Unit

④ **Comparison**

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


data representation
information access
display medium
comparison
actionability
motivational strategies
social
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inputs
the
eco-feedback
design space


data representation
information access
display medium
comparison
actionability
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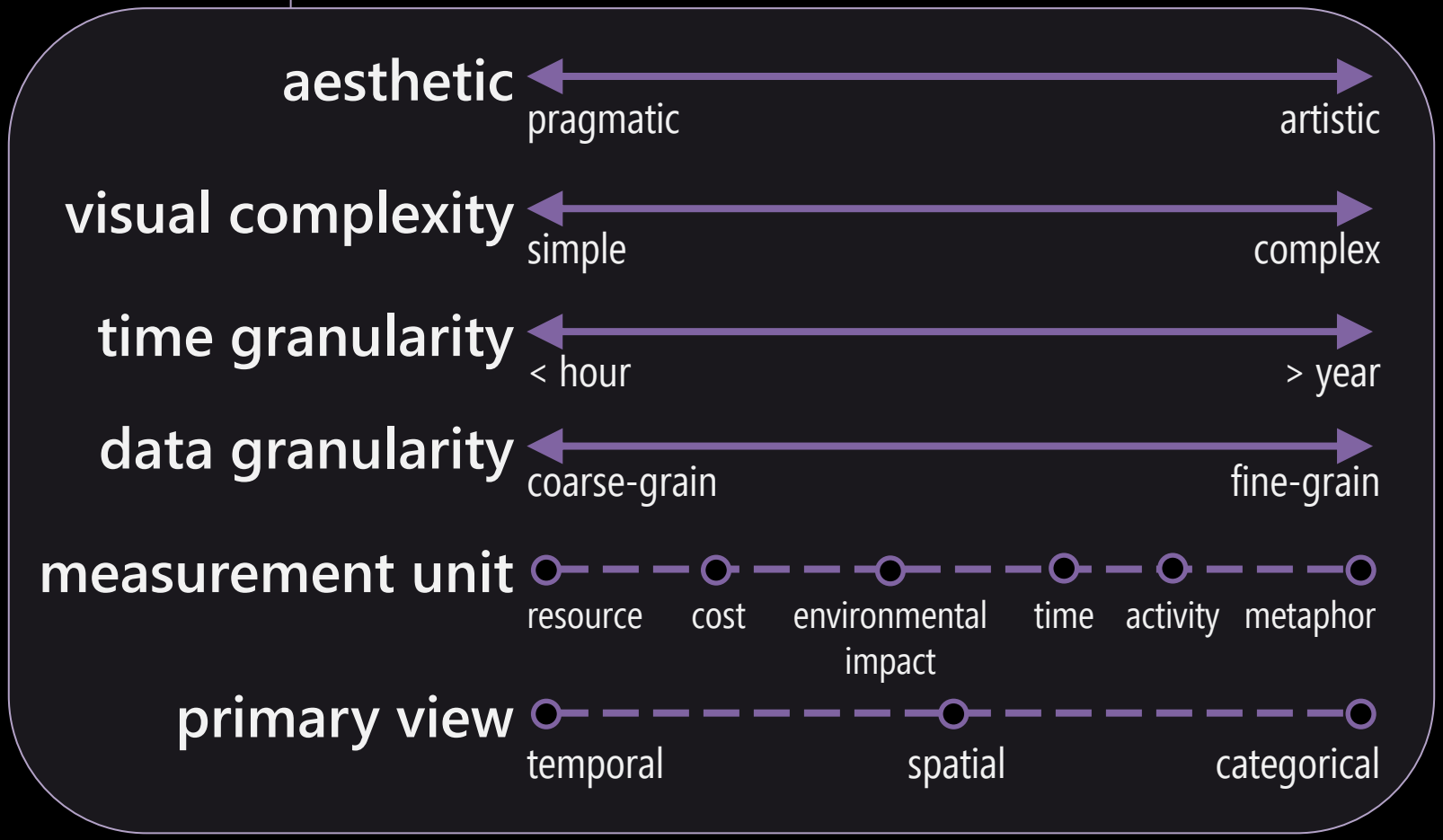
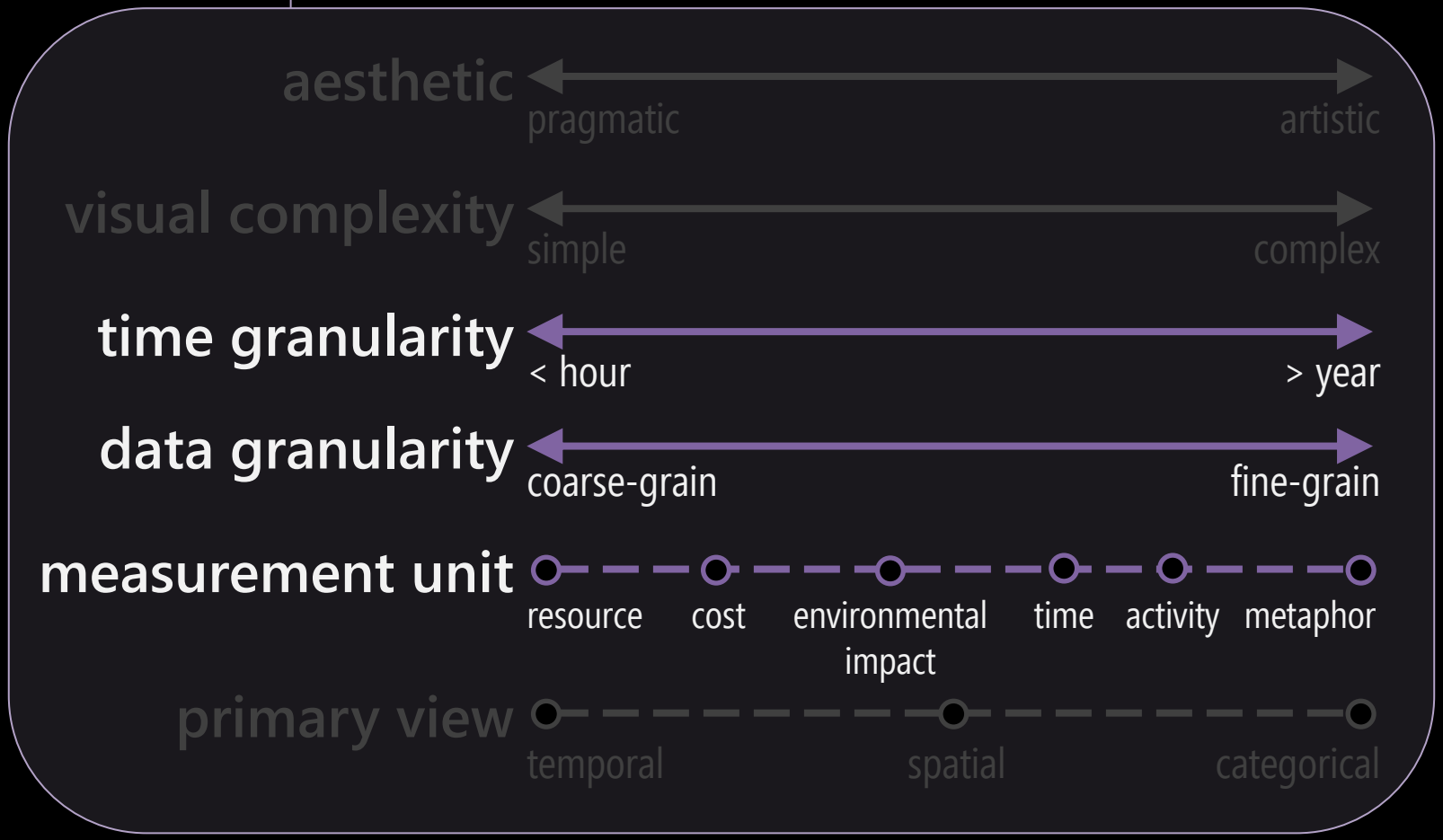
eco-feedback
design space

data representation

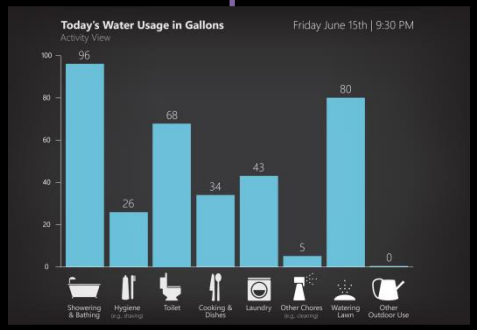


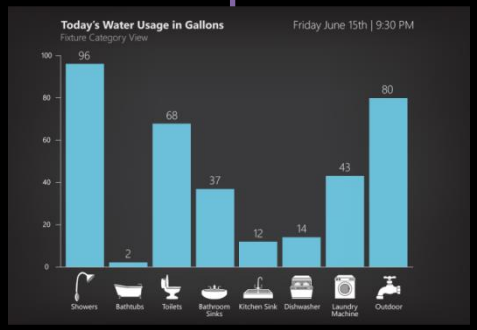
data representation

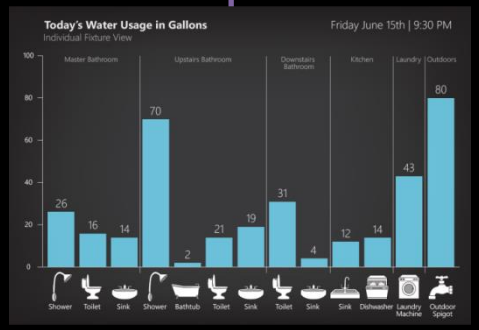


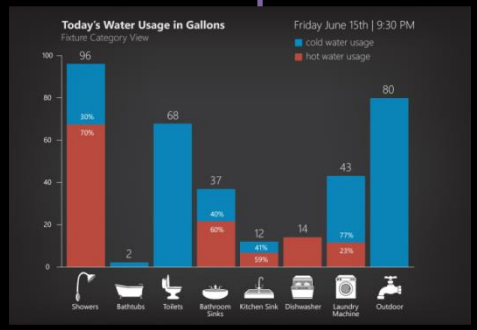
Data Granularity

coarse-grain ⟵ ≥neighbor-hood — home — room — activity — fixture category — fixture — ≤ valve ⟶ **fine-grain**





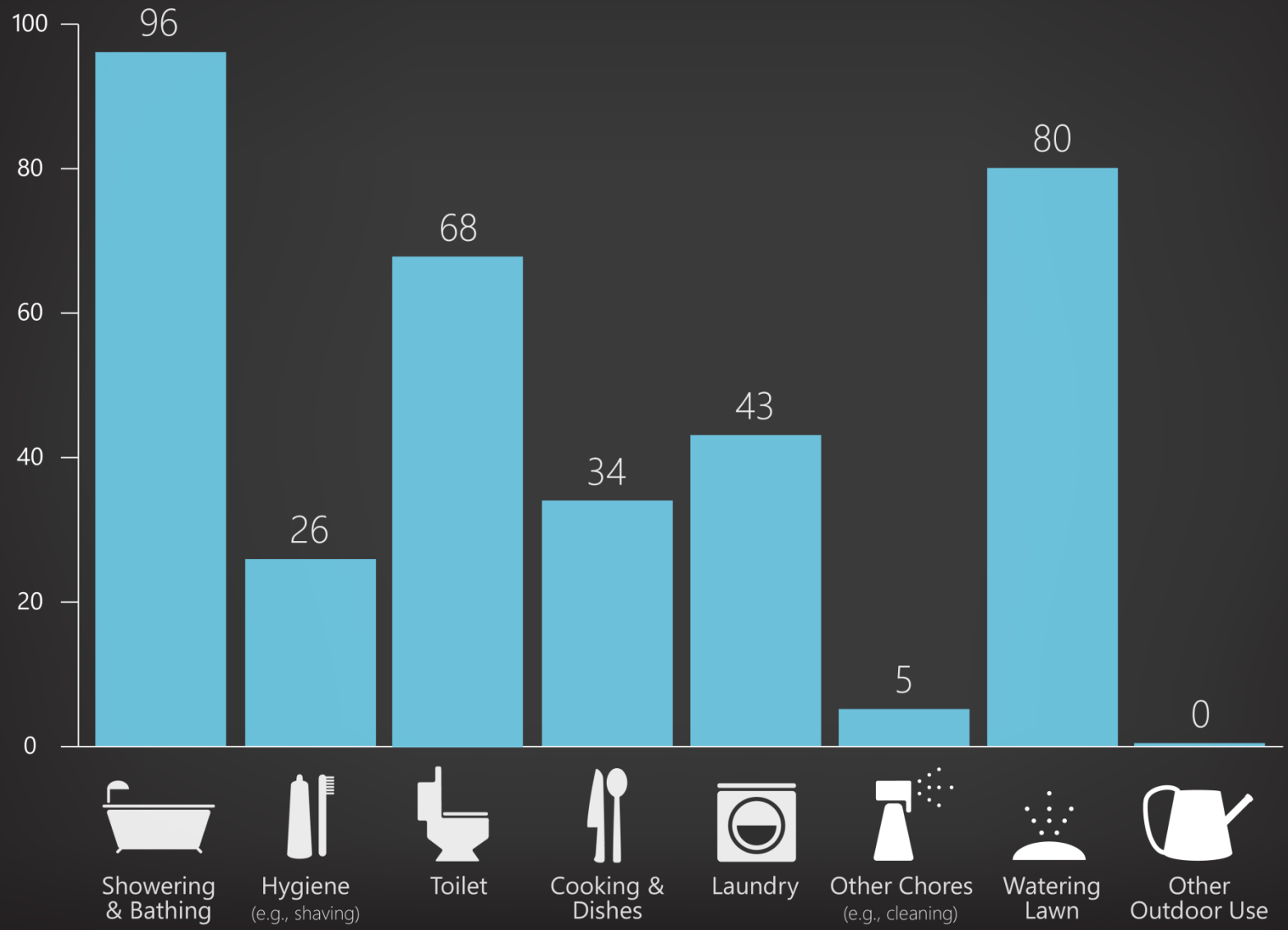




Today's Water Usage in Gallons

Activity View

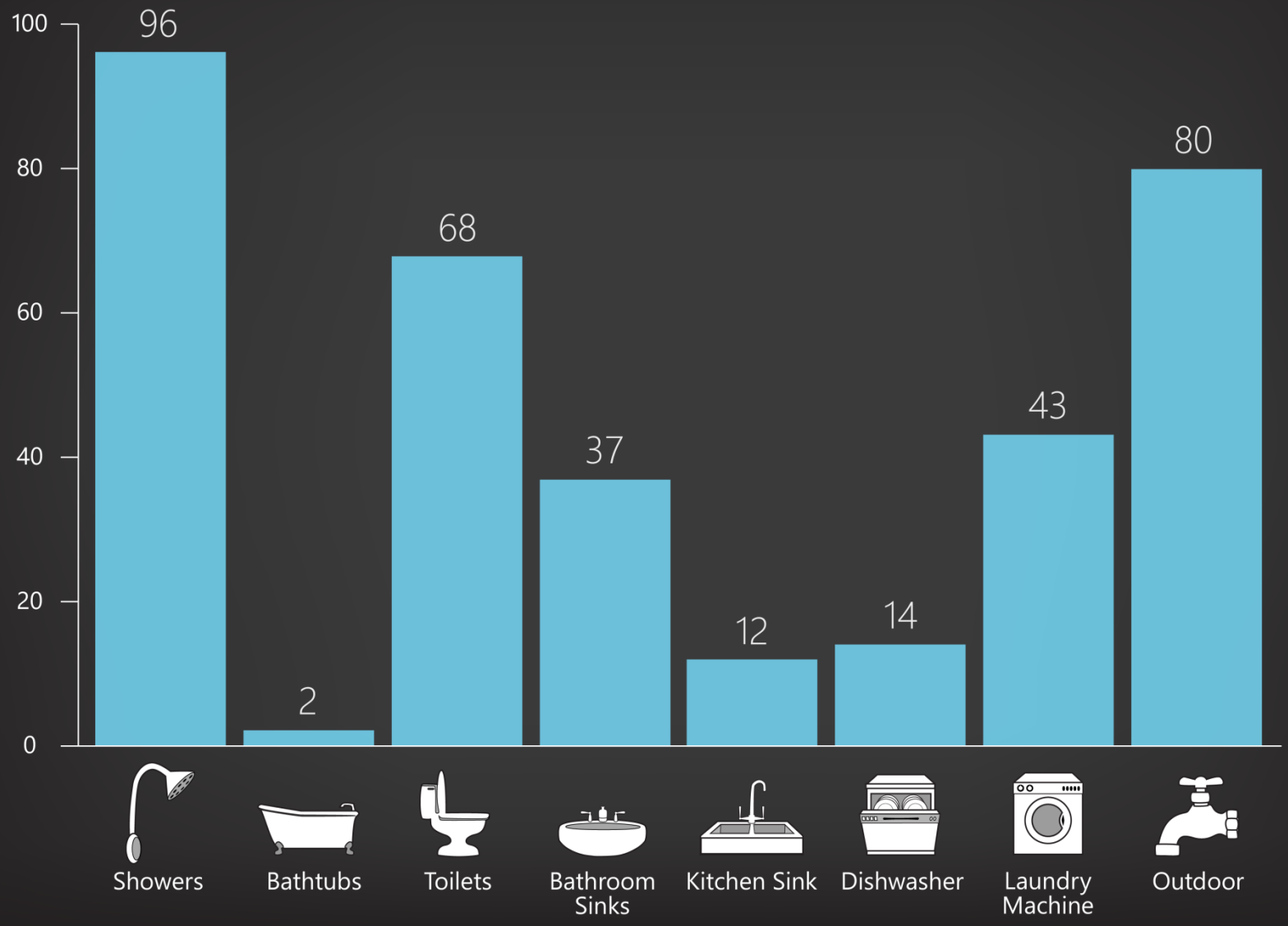
Friday June 15th | 9:30 PM



Today's Water Usage in Gallons

Fixture Category View

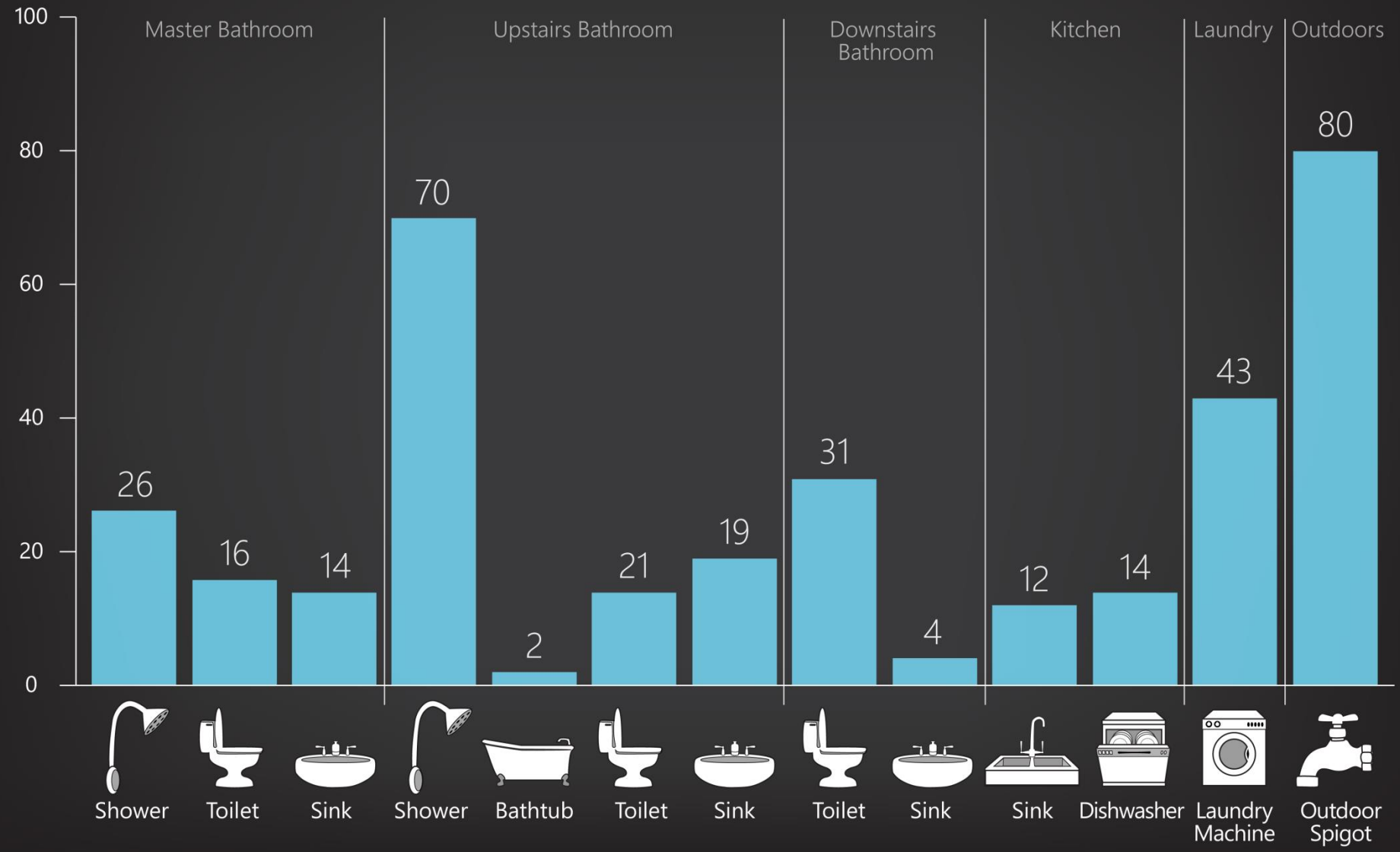
Friday June 15th | 9:30 PM



Today's Water Usage in Gallons

Individual Fixture View

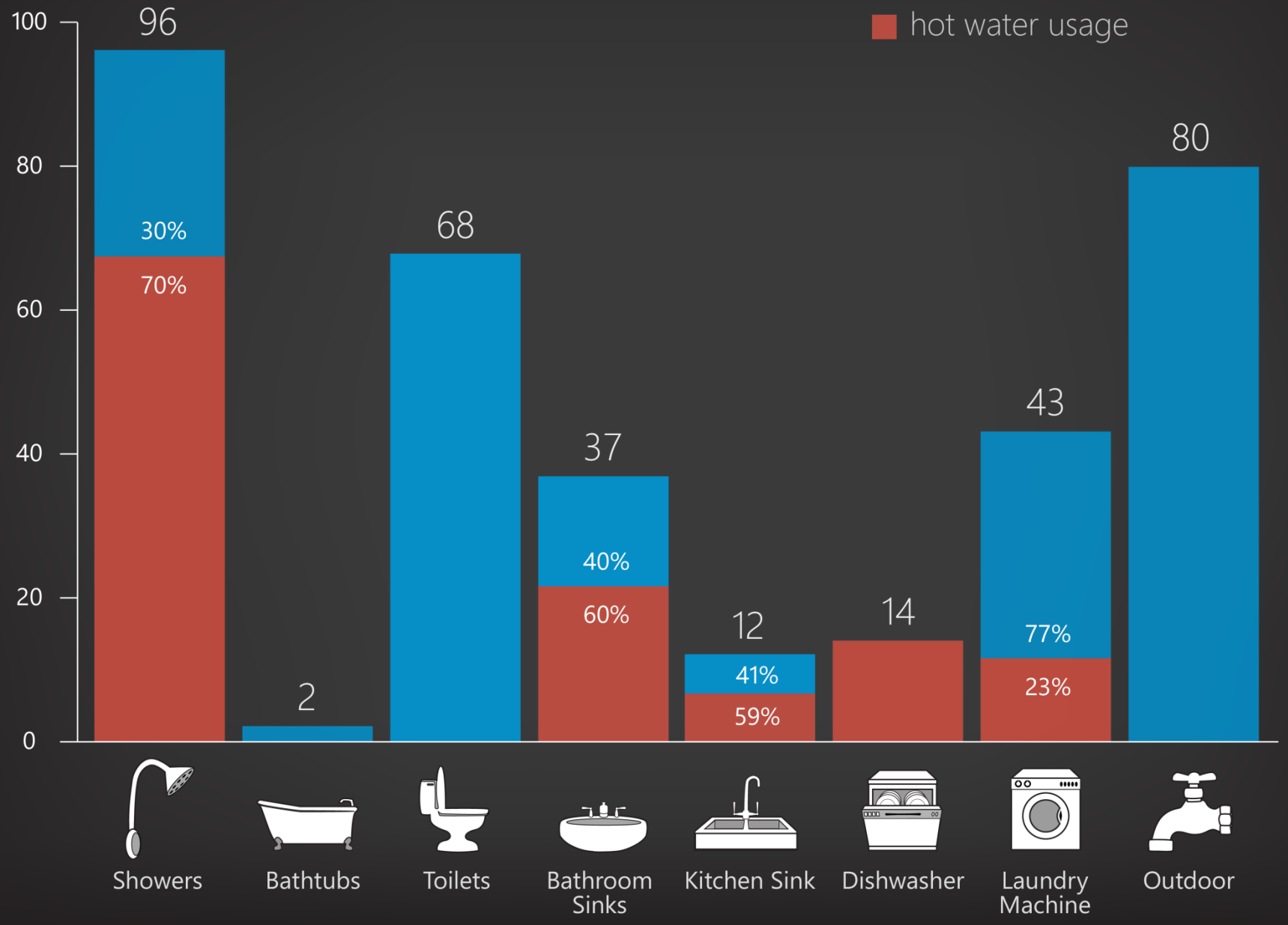
Friday June 15th | 9:30 PM



Today's Water Usage in Gallons

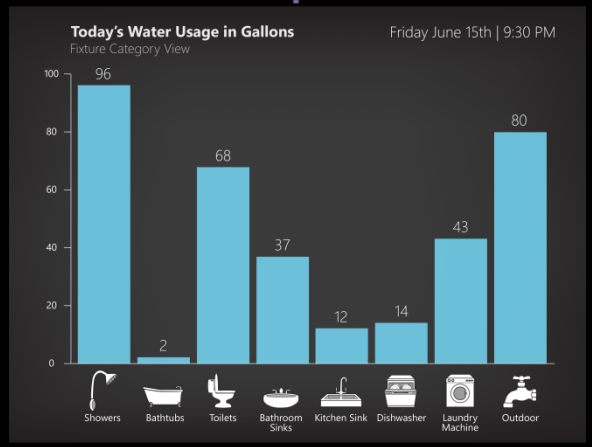
Fixture Category View: Hot vs Cold

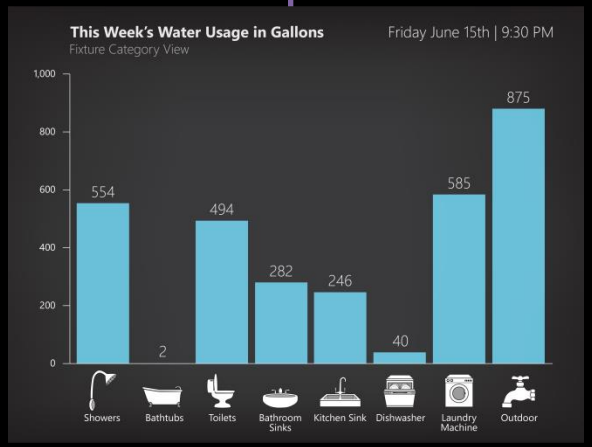
Friday June 15th | 9:30 PM

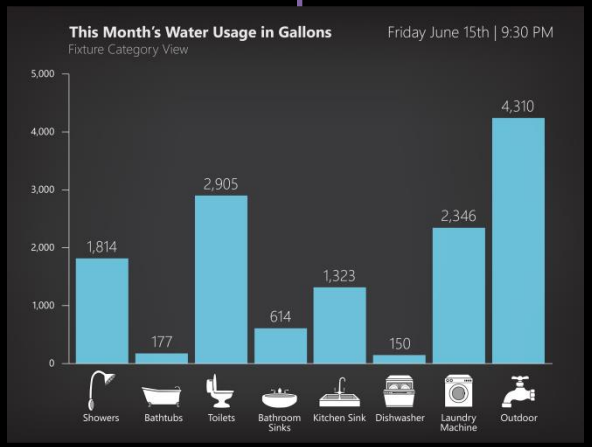


Time Granularity

≤ hour | day | week | month | ≥ year







Measurement Unit

resource — rate of consumption — cost — time — activity — metaphor

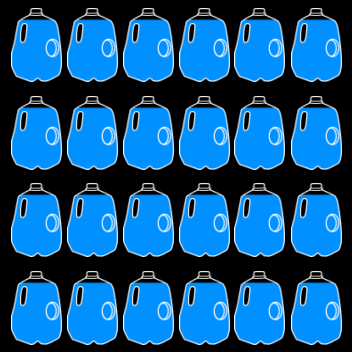
36 gallons of water

3 gpm

9 cents

12 minutes

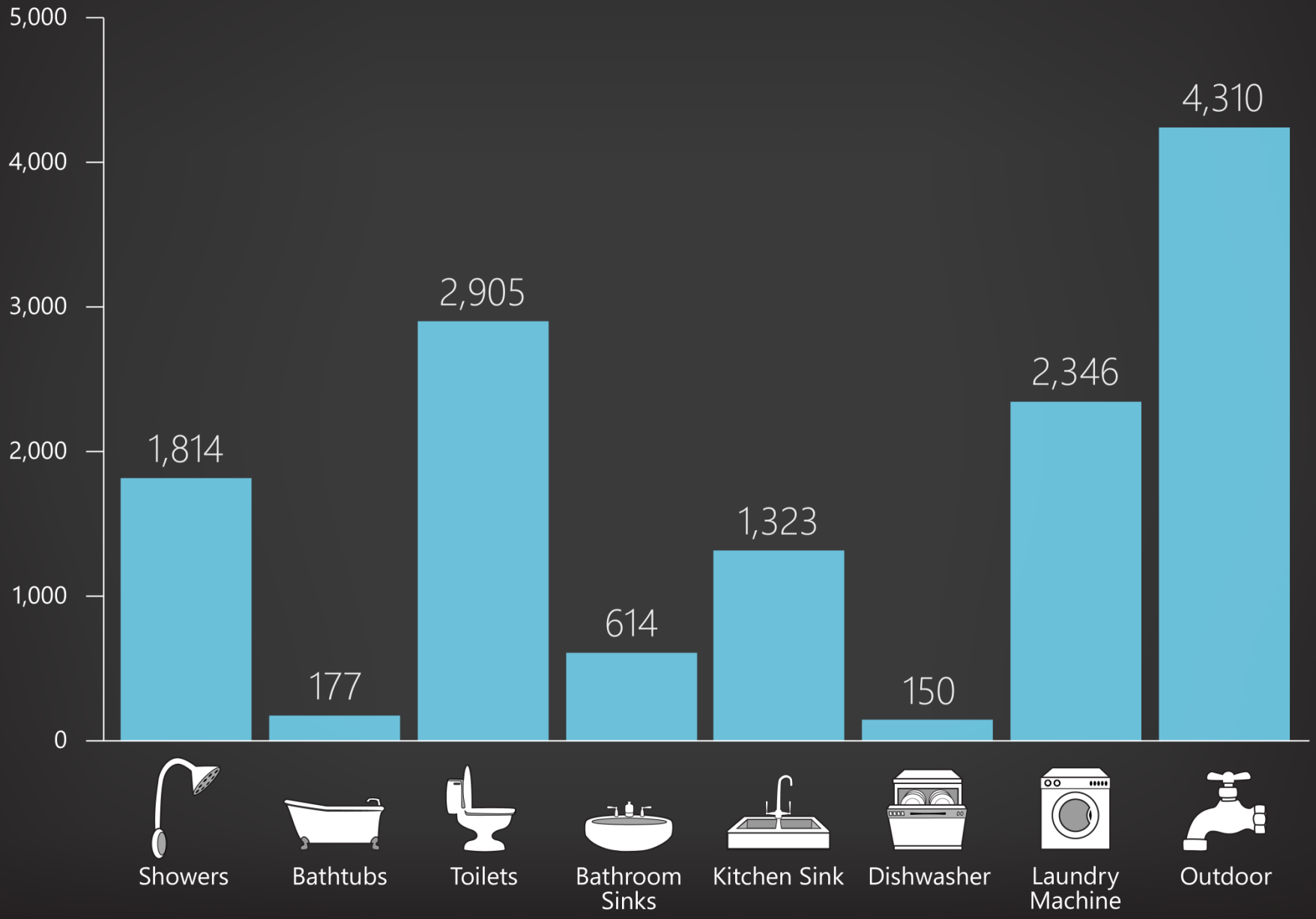
1 shower



This Month's Water Usage

Fixture Category View | In Gallons

Friday June 15th | 9:30 PM

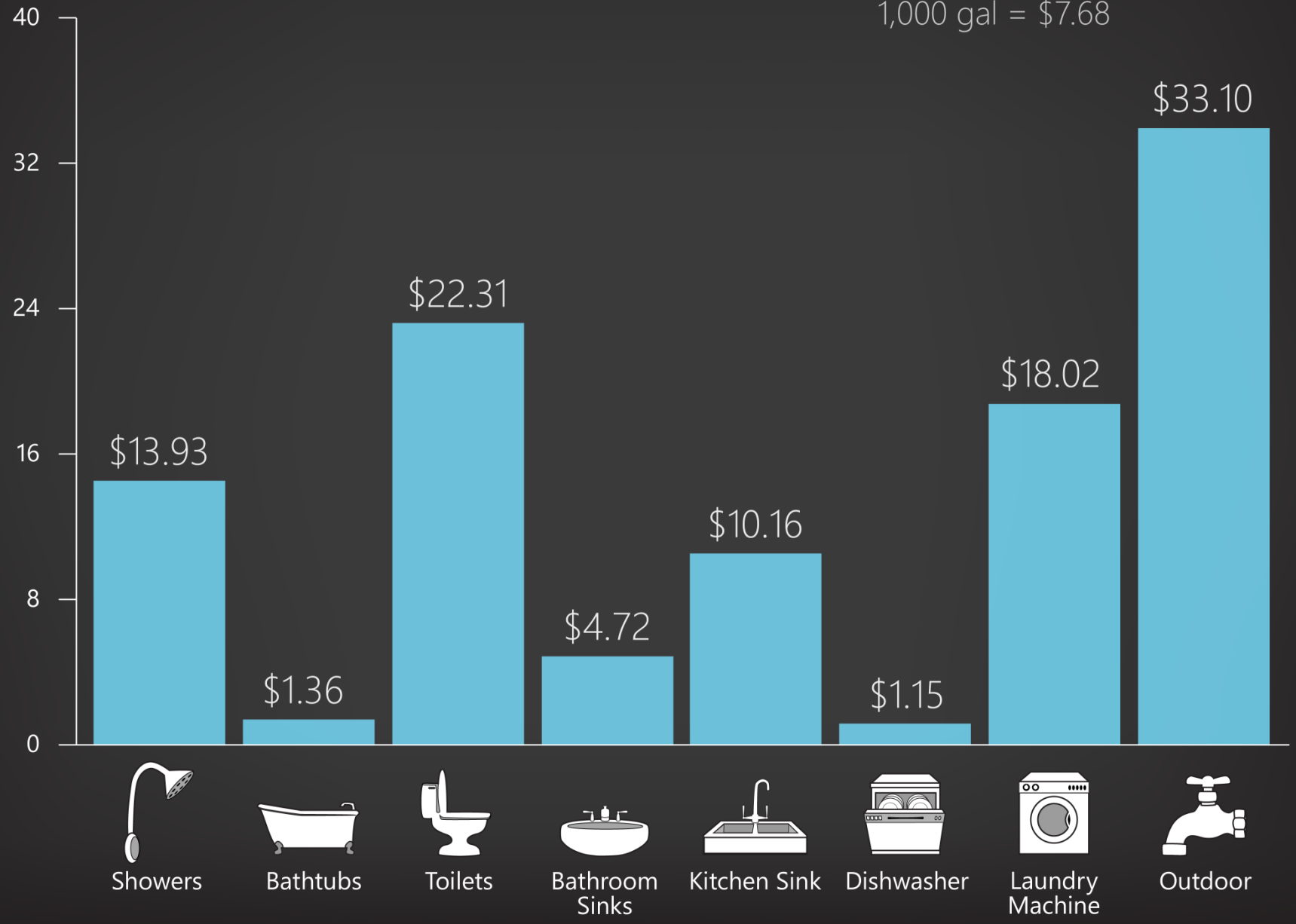


This Month's Water Usage

Fixture Category View | In Dollars

Friday June 15th | 9:30 PM

Your Current Water Rate:
1,000 gal = $7.68

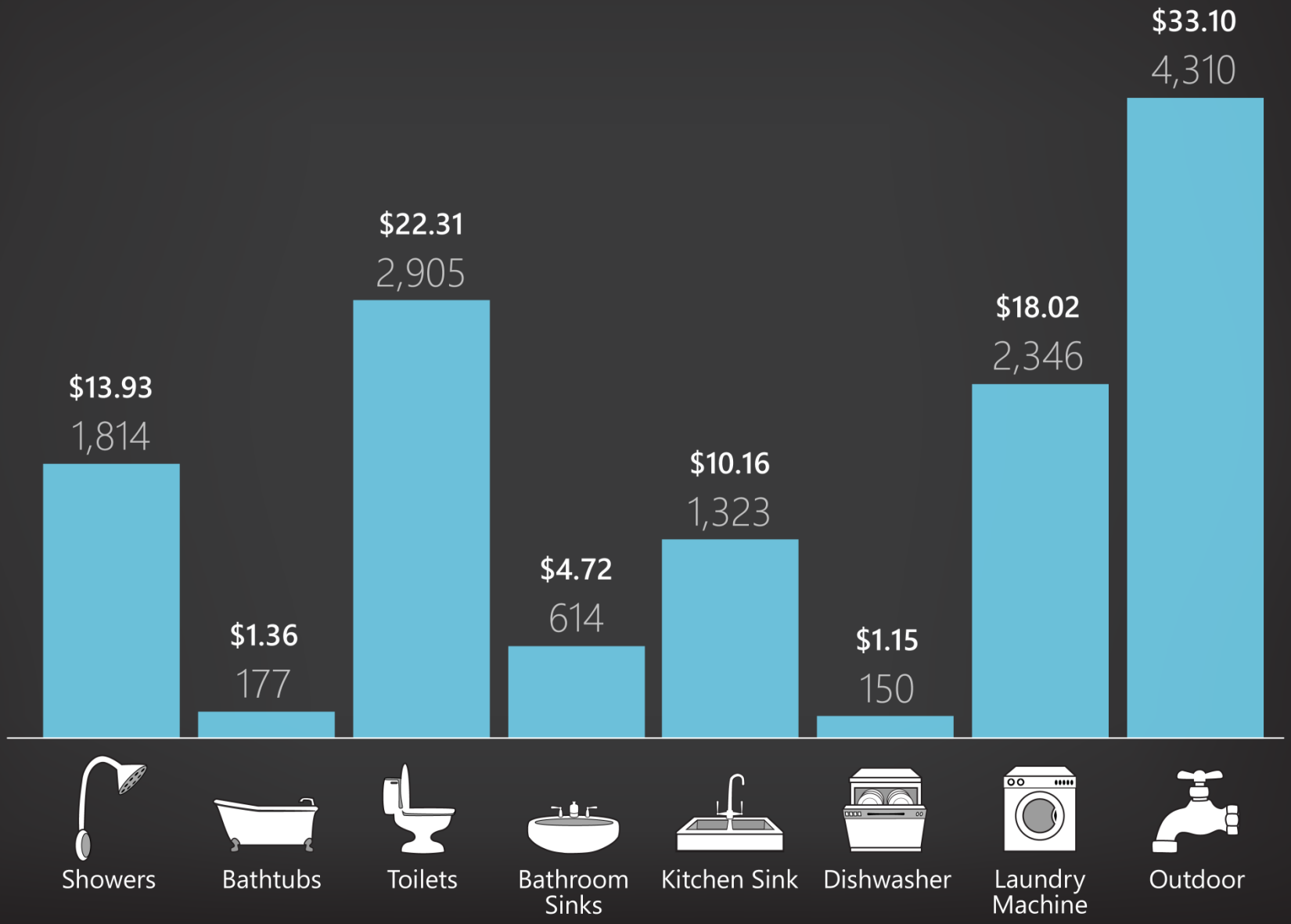


This Month's Water Usage

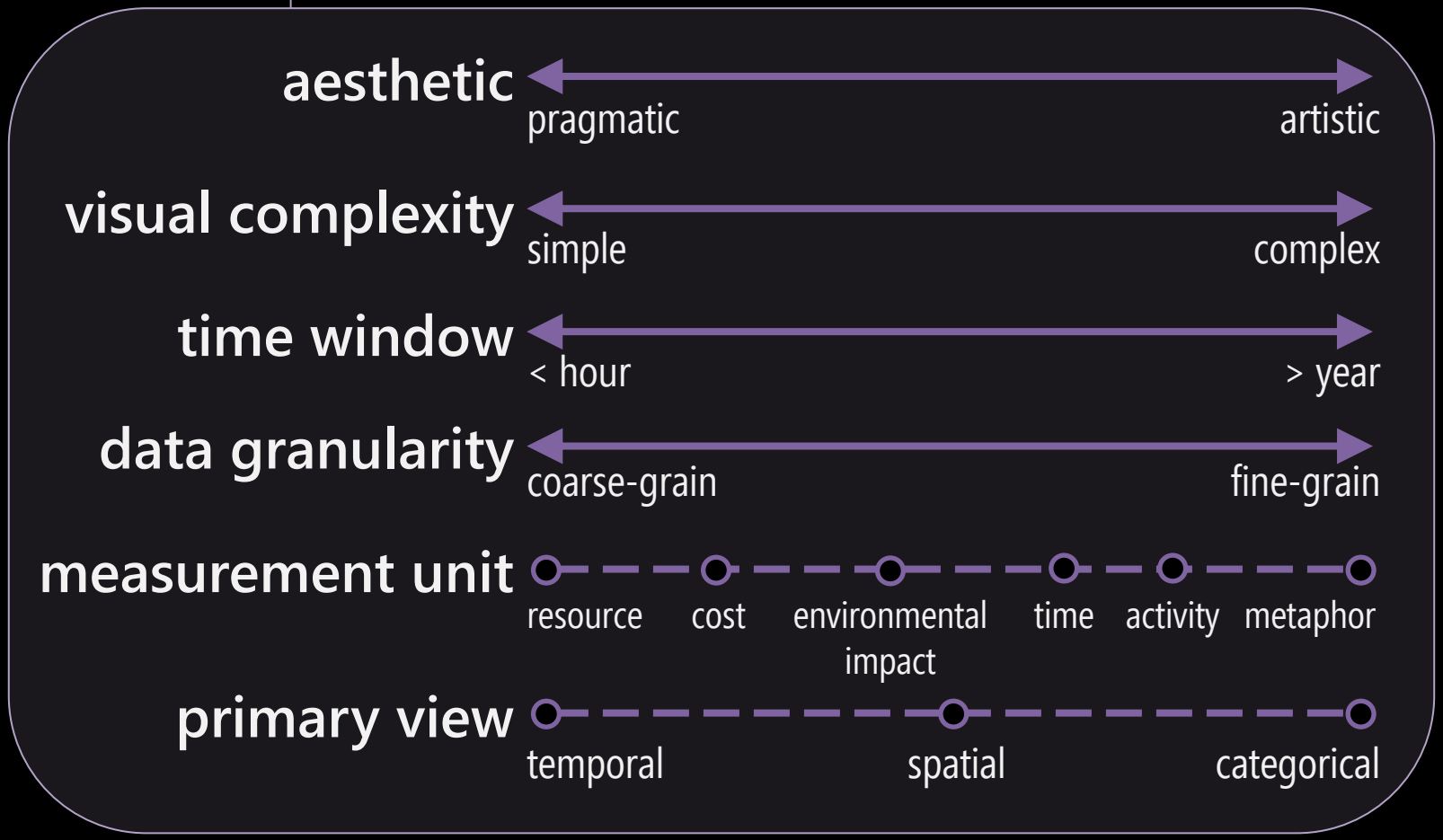
Fixture Category View | In Dollars & Gallons

Friday June 15th | 9:30 PM

Your Current Water Rate:
1,000 gal = $7.68



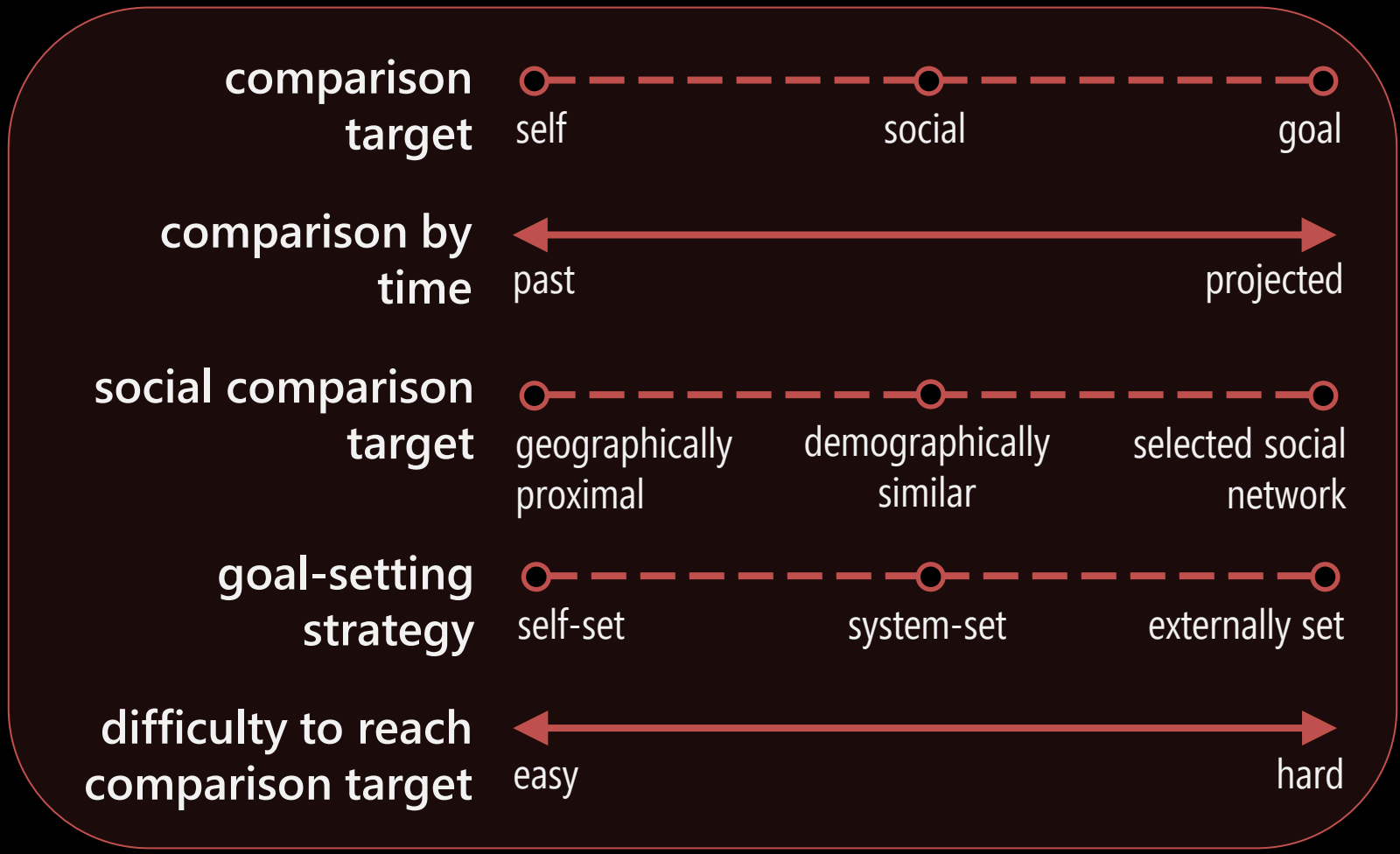
data representation



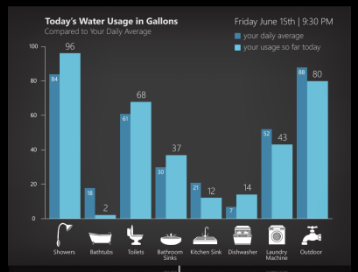
DESIGN SET 1: ISOLATING DESIGN DIMENSIONS

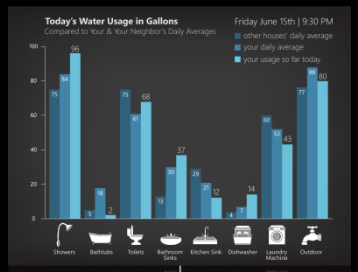
comparison

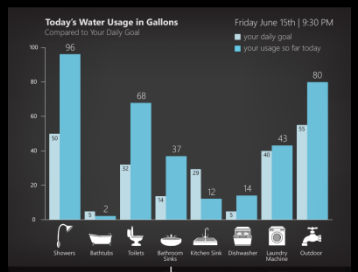
ty



comparison







comparison target

self — social — goal

comparison by time

past — projected

social comparison target

geographically proximal — demographically similar — selected social network

goal-setting strategy

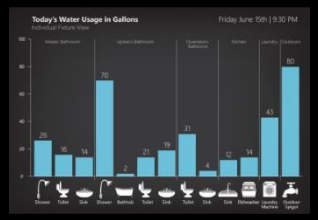
self-set — system-set — externally set

difficulty to reach comparison target

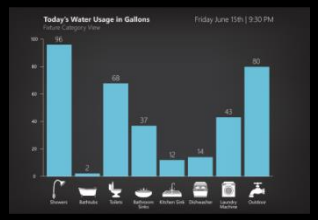
easy — hard

Design Dimensions Explored

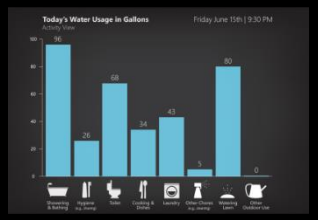
Data Granularity



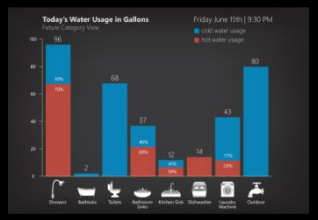
Individual Fixture



Fixture Category

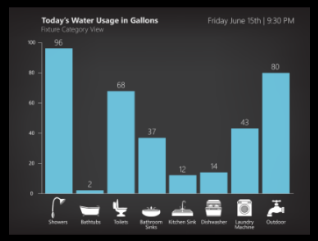


Activity

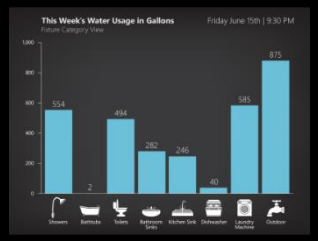


Hot and Cold

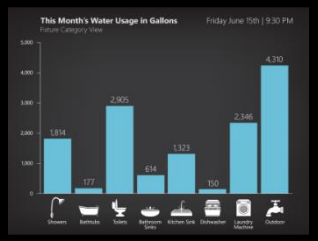
Time Granularity



So Far Today

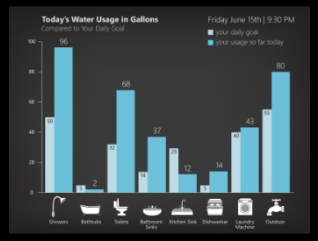


So Far This Week

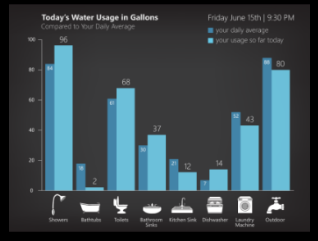


So Far This Month

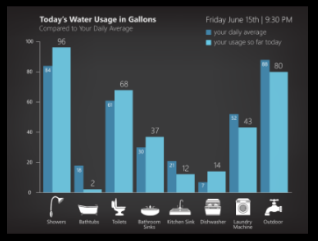
Comparison



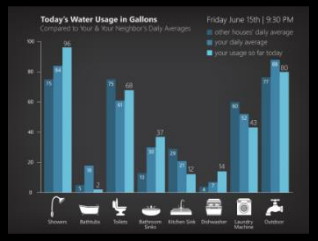
Self Comparison



To Others

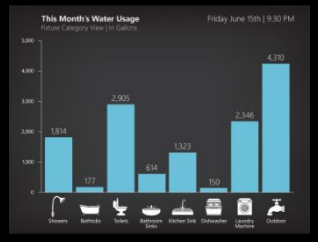


To A Goal



Social/Self

Measurement Unit



In Gallons

In Dollars

Dollars / Gallons

Including Sewage

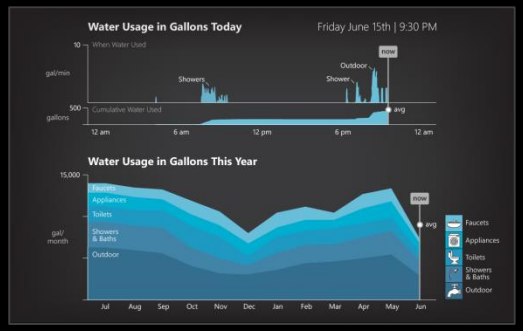
Two sets of designs:

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

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

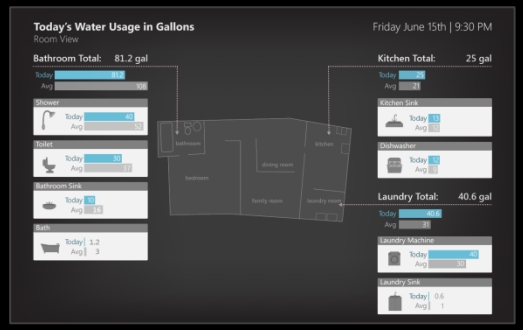
DESIGN SET 2: DESIGN PROBES

Design Probes Explored

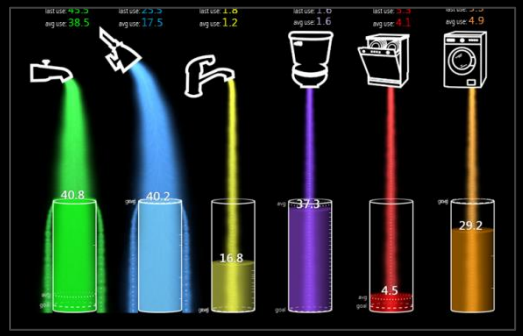


Time-Series

Aquatic Eco-system

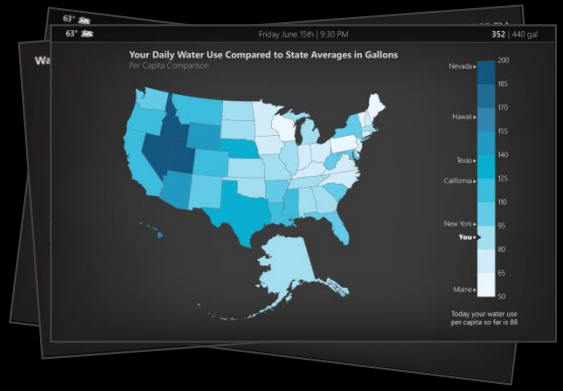


Spatial



Rainflow

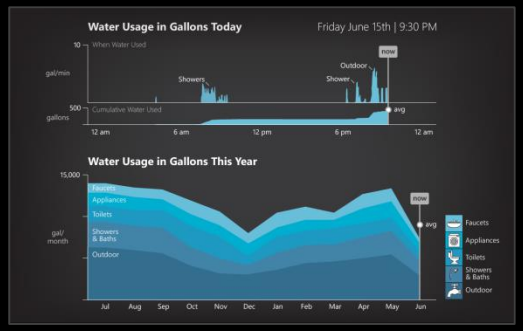
Per-Occupant



Other

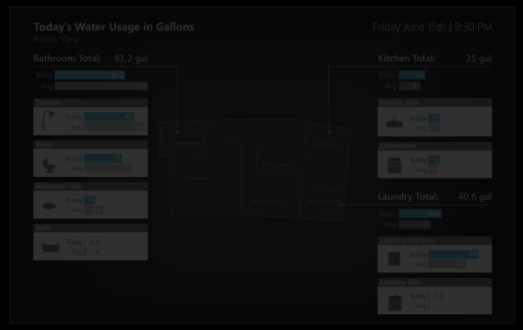
DESIGN SET 2: DESIGN PROBES

Design Probes Explored



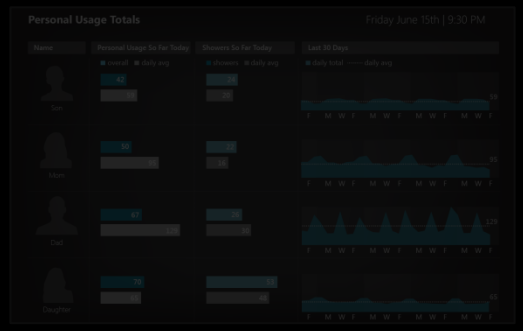
Time-Series

Aquatic Eco-system

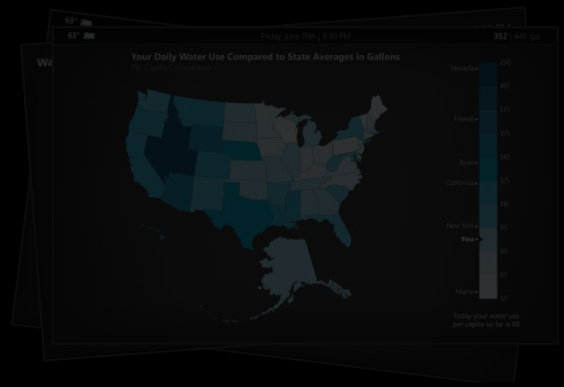


Spatial

Rainflow

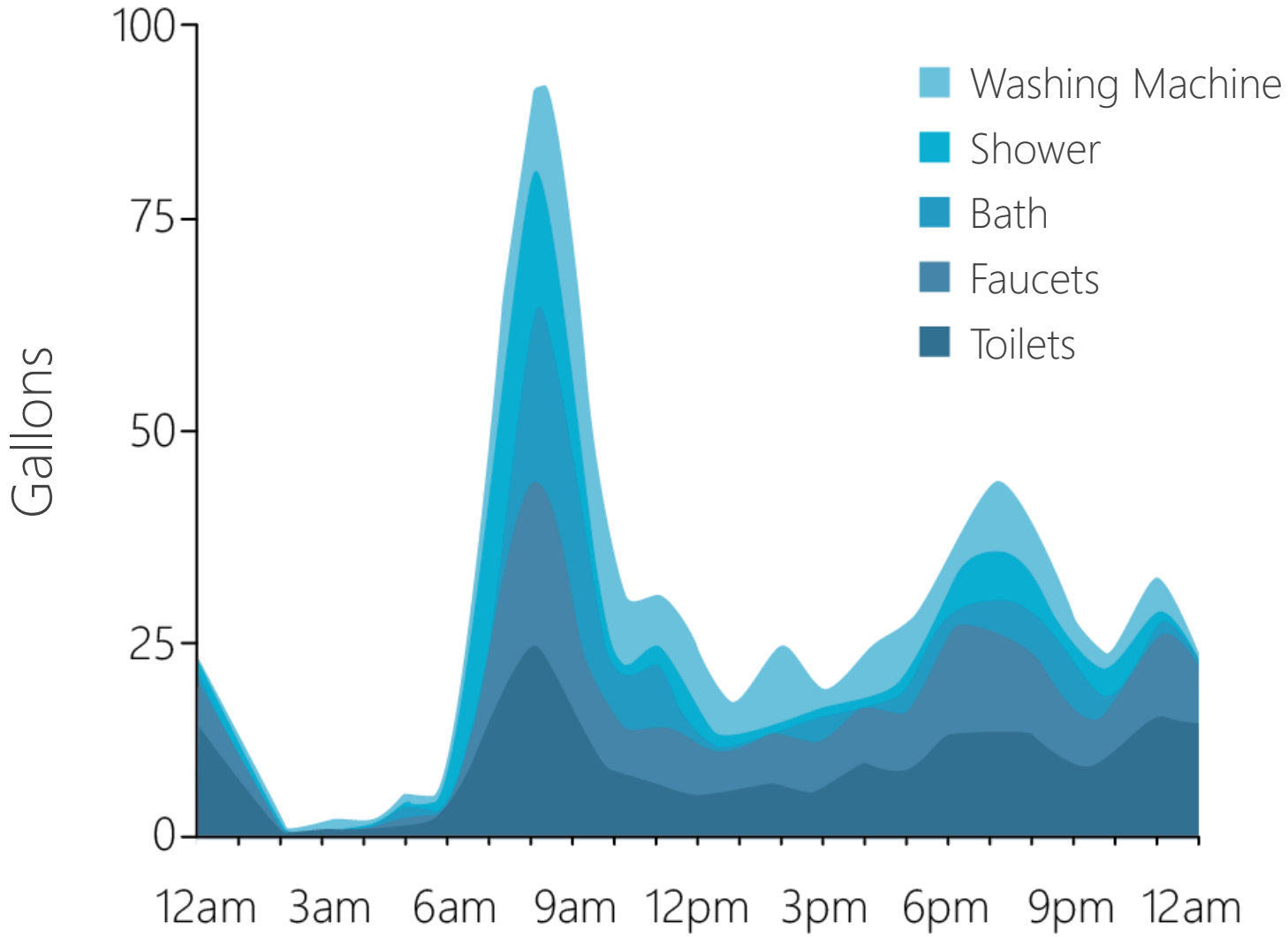


Per-Occupant



Other

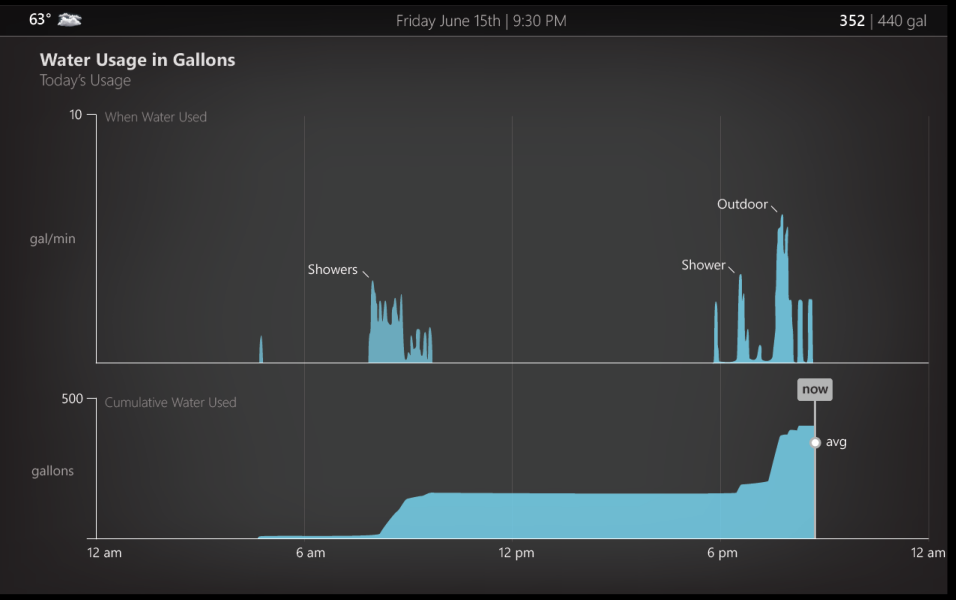
Daily Patterns of Water Usage

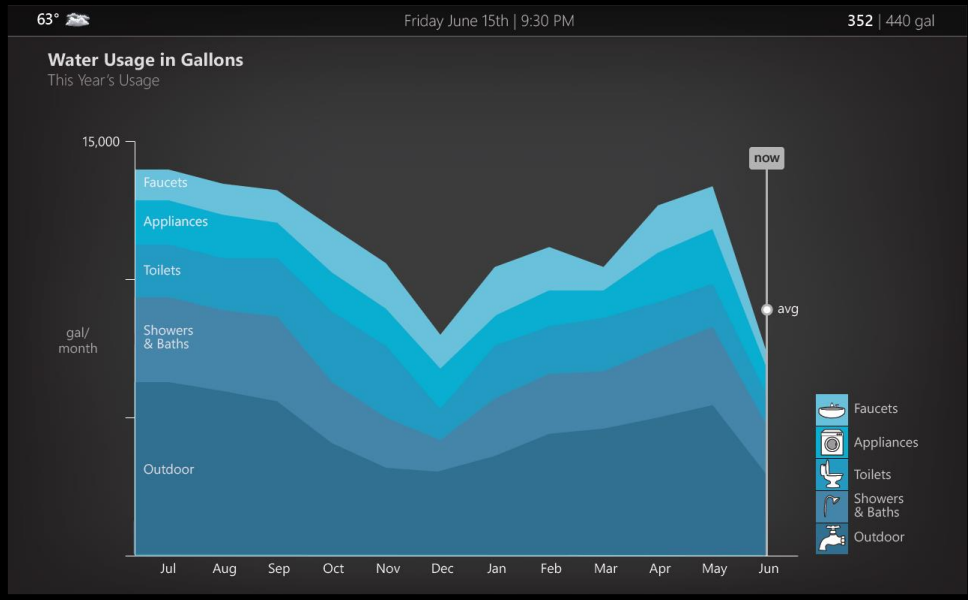


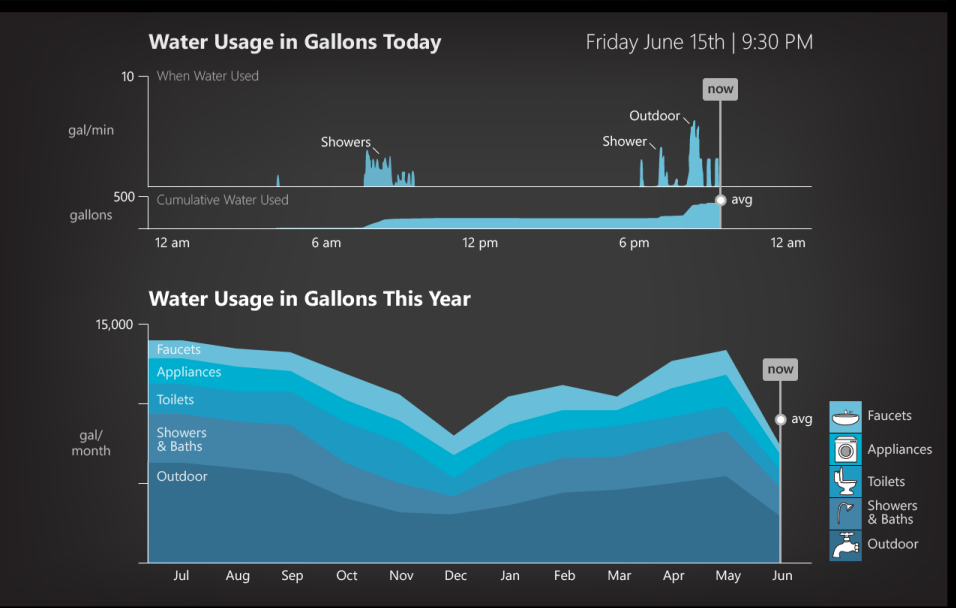
[Adapted from Butler, Building and Environment, 1993]

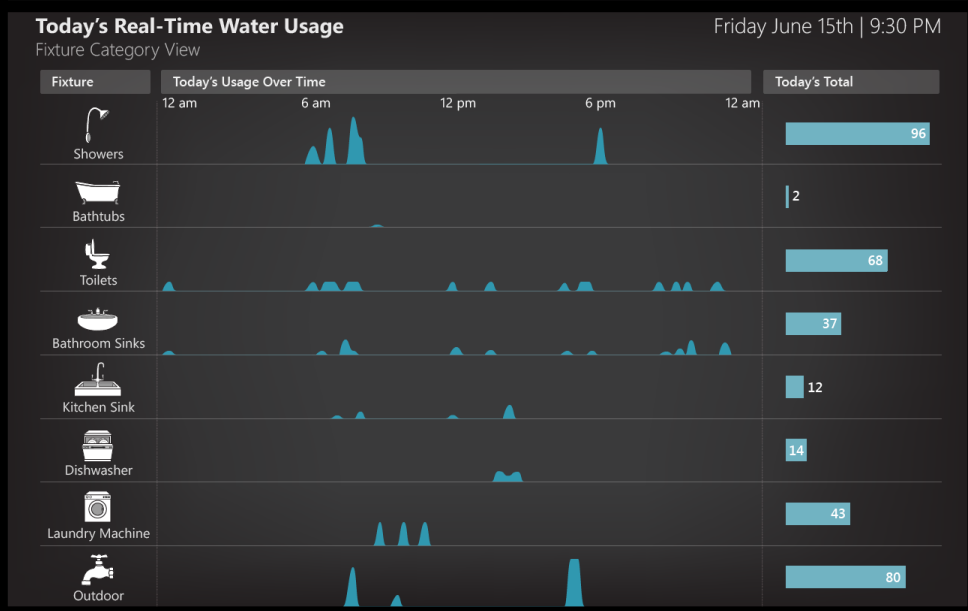
DESIGN SET 2: DESIGN PROBES

Time-Series Views



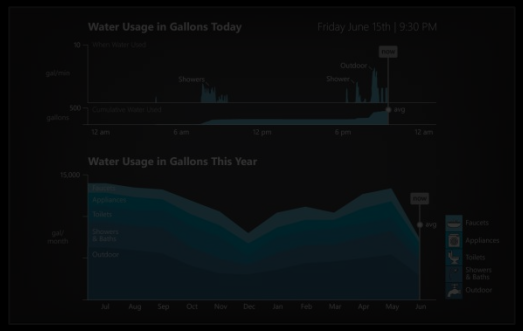






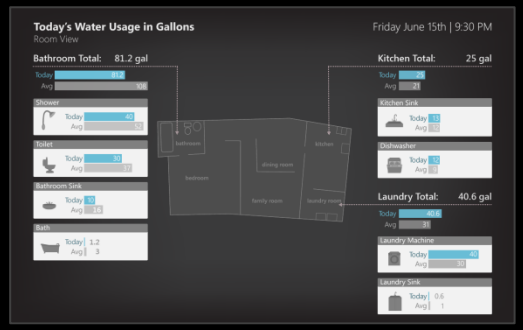
DESIGN SET 2: DESIGN PROBES

Design Probes Explored

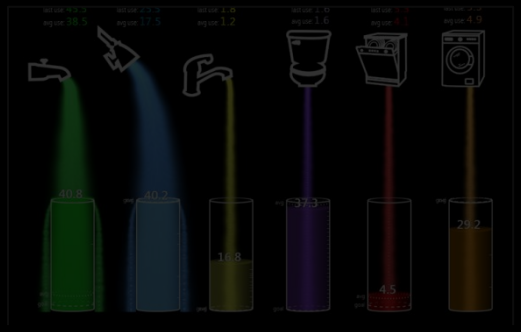


Time-Series

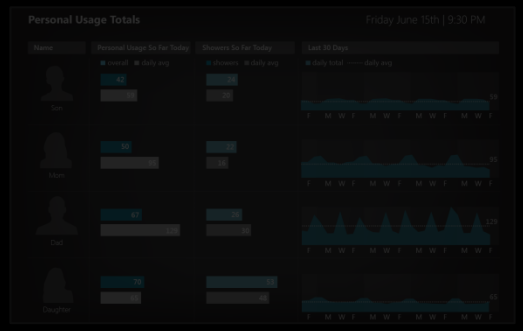
Aquatic Eco-system



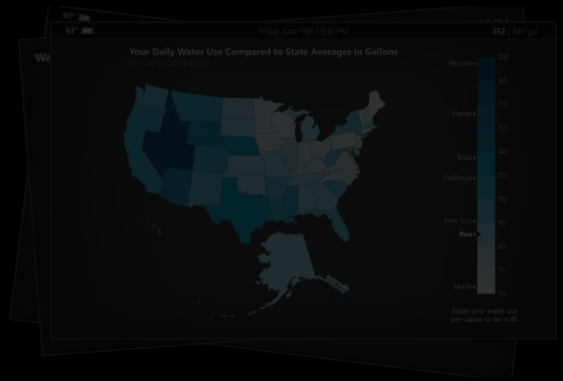
Spatial



Rainflow



Per-Occupant



Other

Spatial View

Today's Water Usage in Gallons

Room View

Friday June 15th | 9:30 PM

Bathroom Total: 81.2 gal

Today 81.2
Avg 108

Shower
Today 40
Avg 52

Toilet
Today 30
Avg 37

Bathroom Sink
Today 10
Avg 16

Bath
Today 1.2
Avg 3

Kitchen Total: 25 gal

Today 25
Avg 21

Kitchen Sink
Today 13
Avg 12

Dishwasher
Today 12
Avg 9

Laundry Total: 40.6 gal

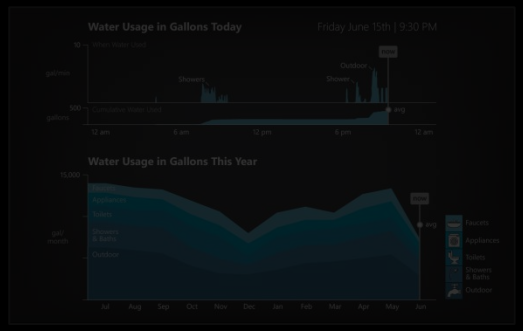
Today 40.6
Avg 31

Laundry Machine
Today 40
Avg 30

Laundry Sink
Today 0.6
Avg 1

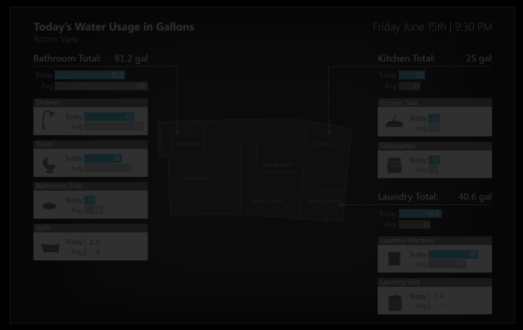
DESIGN SET 2: DESIGN PROBES

Design Probes Explored

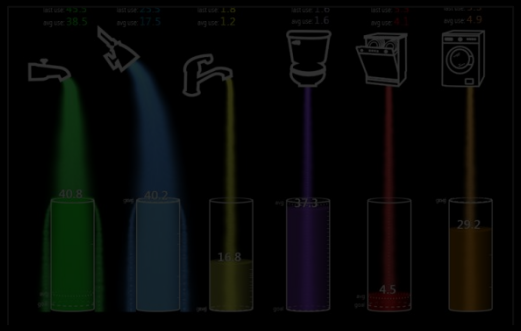


Time-Series

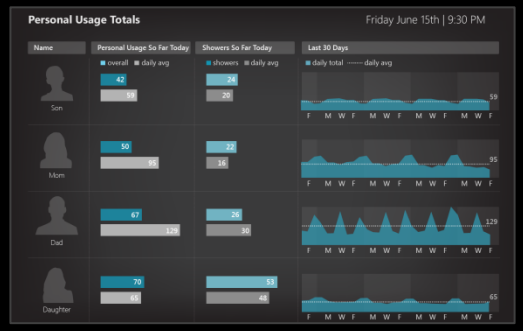
Aquatic Eco-system



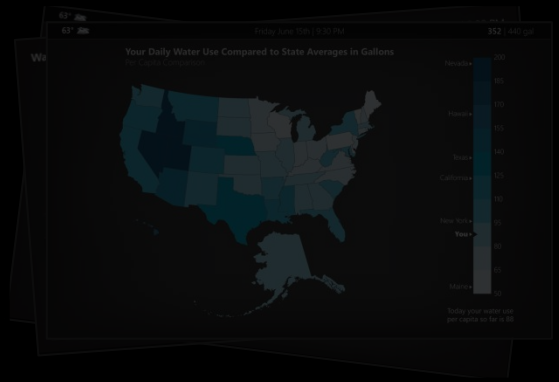
Spatial



Rainflow



Per-Occupant



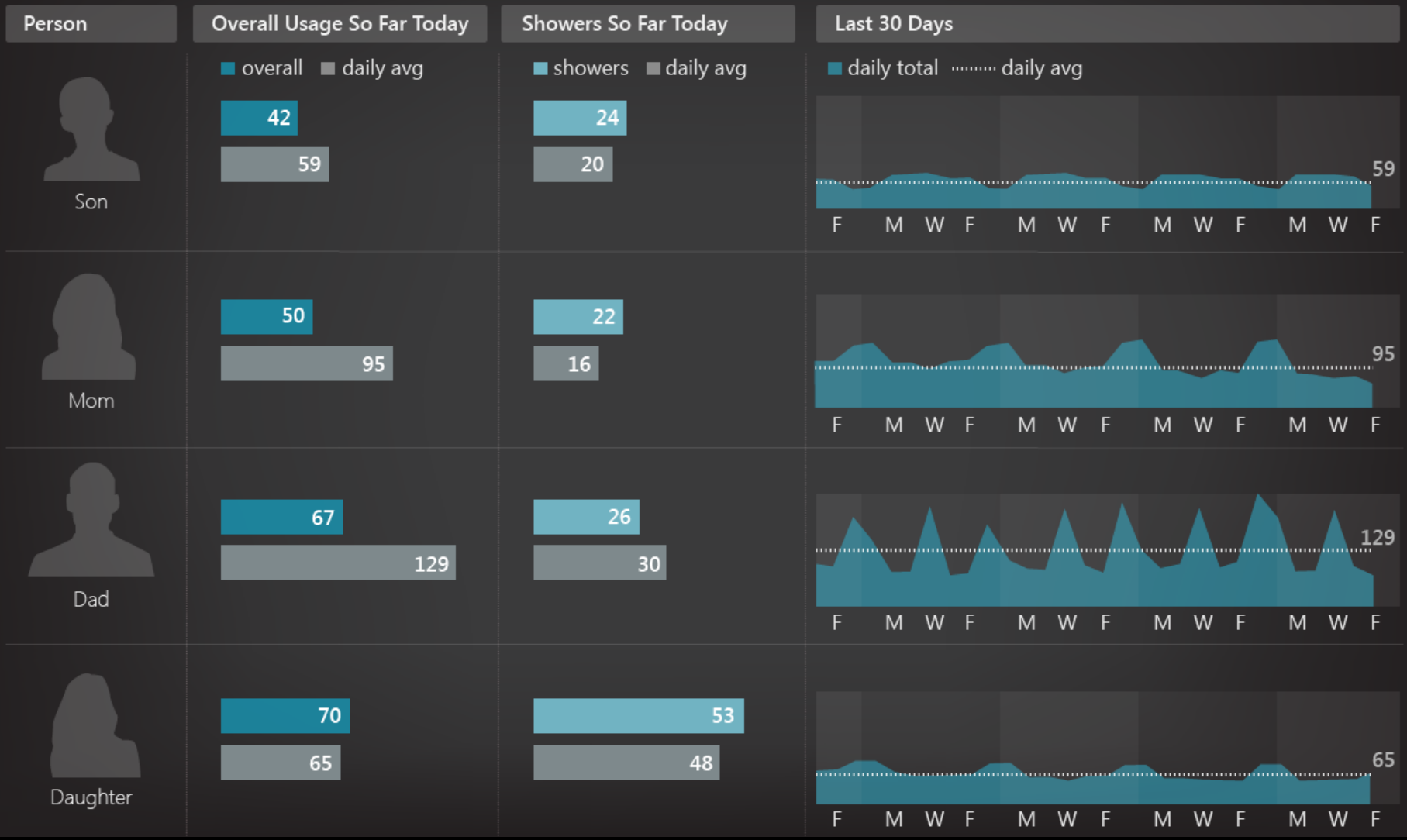
Other

DESIGN SET 2: DESIGN PROBES

Per-Occupant View

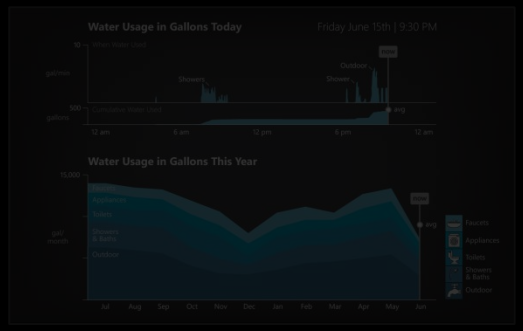
Personal Usage Totals

Friday June 15th | 9:30 PM



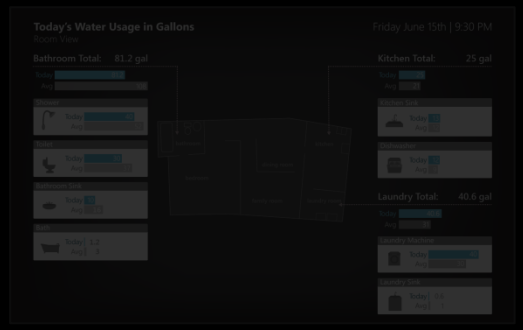
DESIGN SET 2: DESIGN PROBES

Design Probes Explored

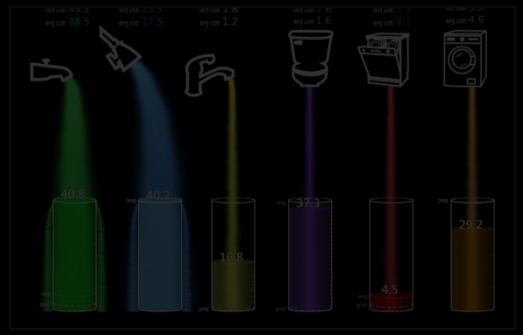


Time-Series

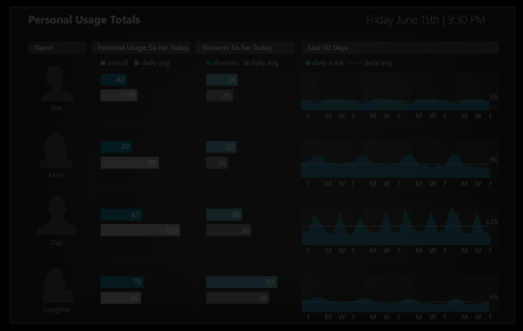
Aquatic Eco-system



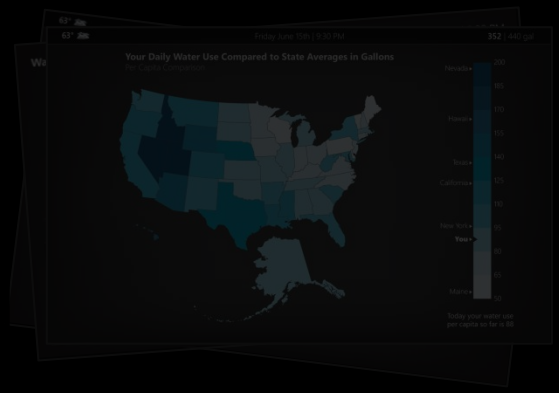
Spatial



Rainflow



Per-Occupant



Other

Aquatic Ecosystem Design Influences

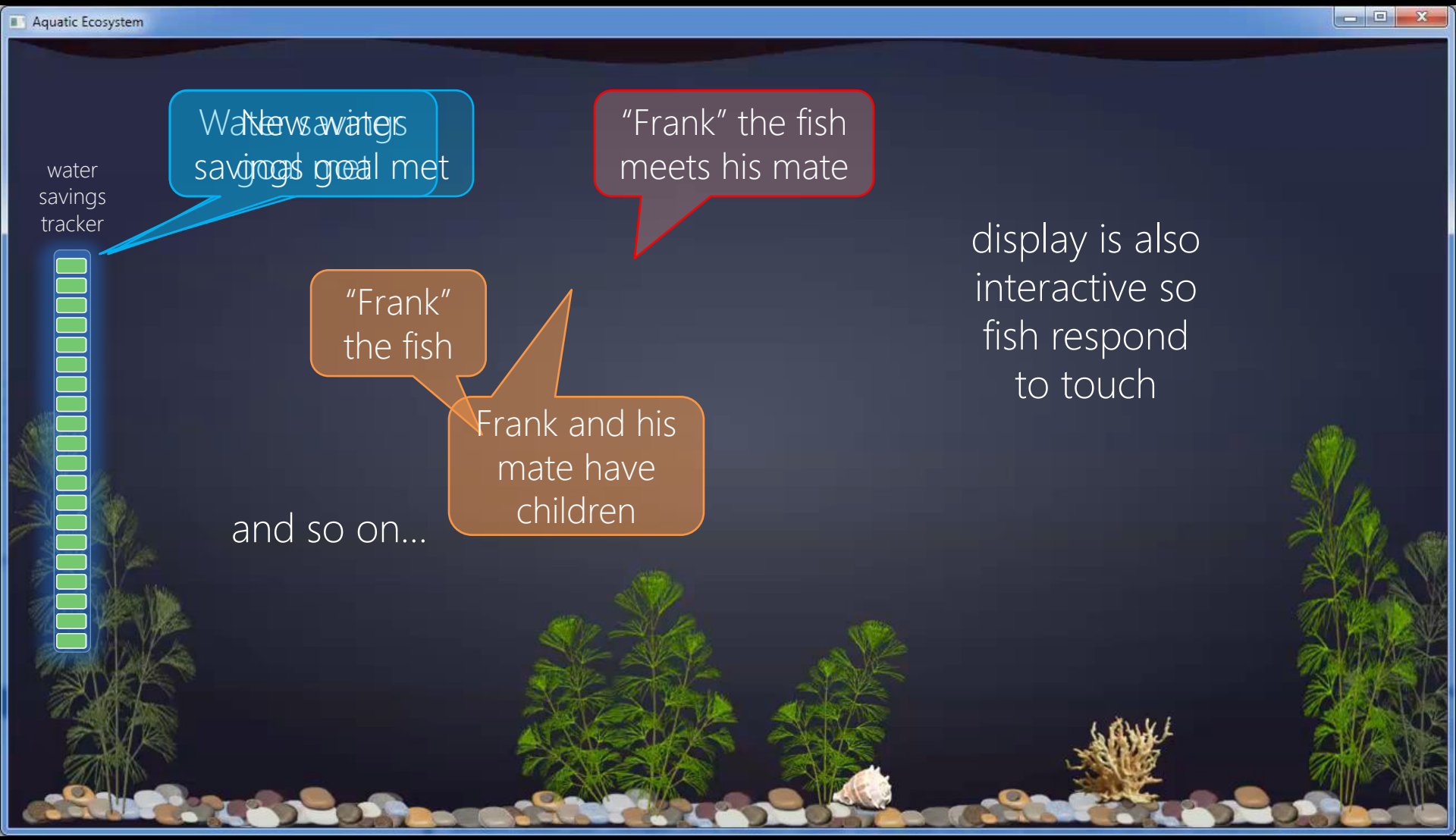
ubifit

Consolvo *et al.*, CHI2008
Consolvo *et al.*, UbiComp2008

ubigreen

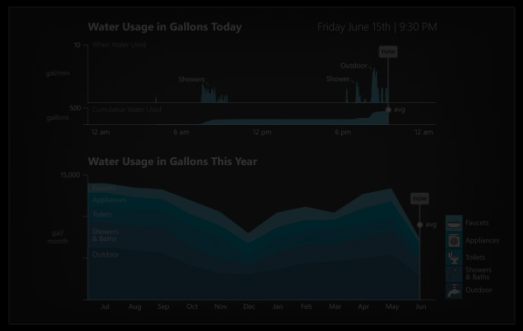
Froehlich *et al.*, CHI 2009

Aquatic Ecosystem View



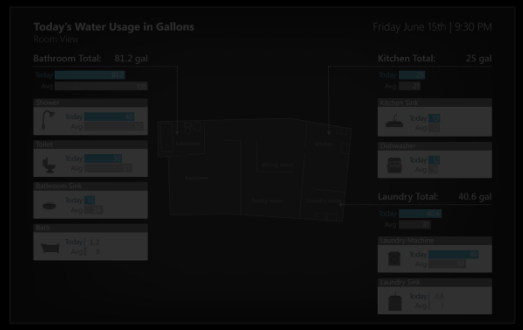
DESIGN SET 2: DESIGN PROBES

Design Probes Explored

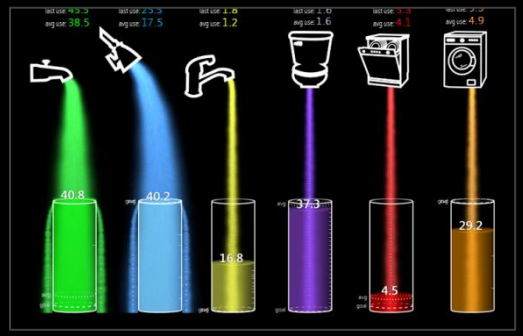


Time-Series

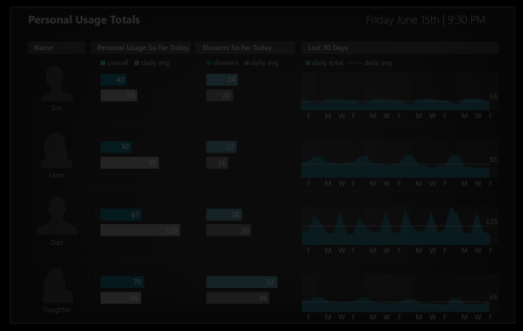
Aquatic Eco-system



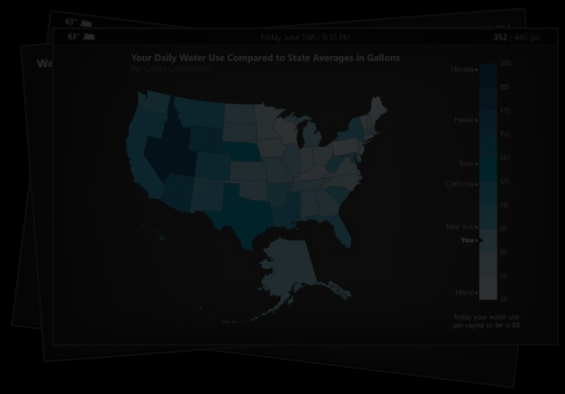
Spatial



Rainflow



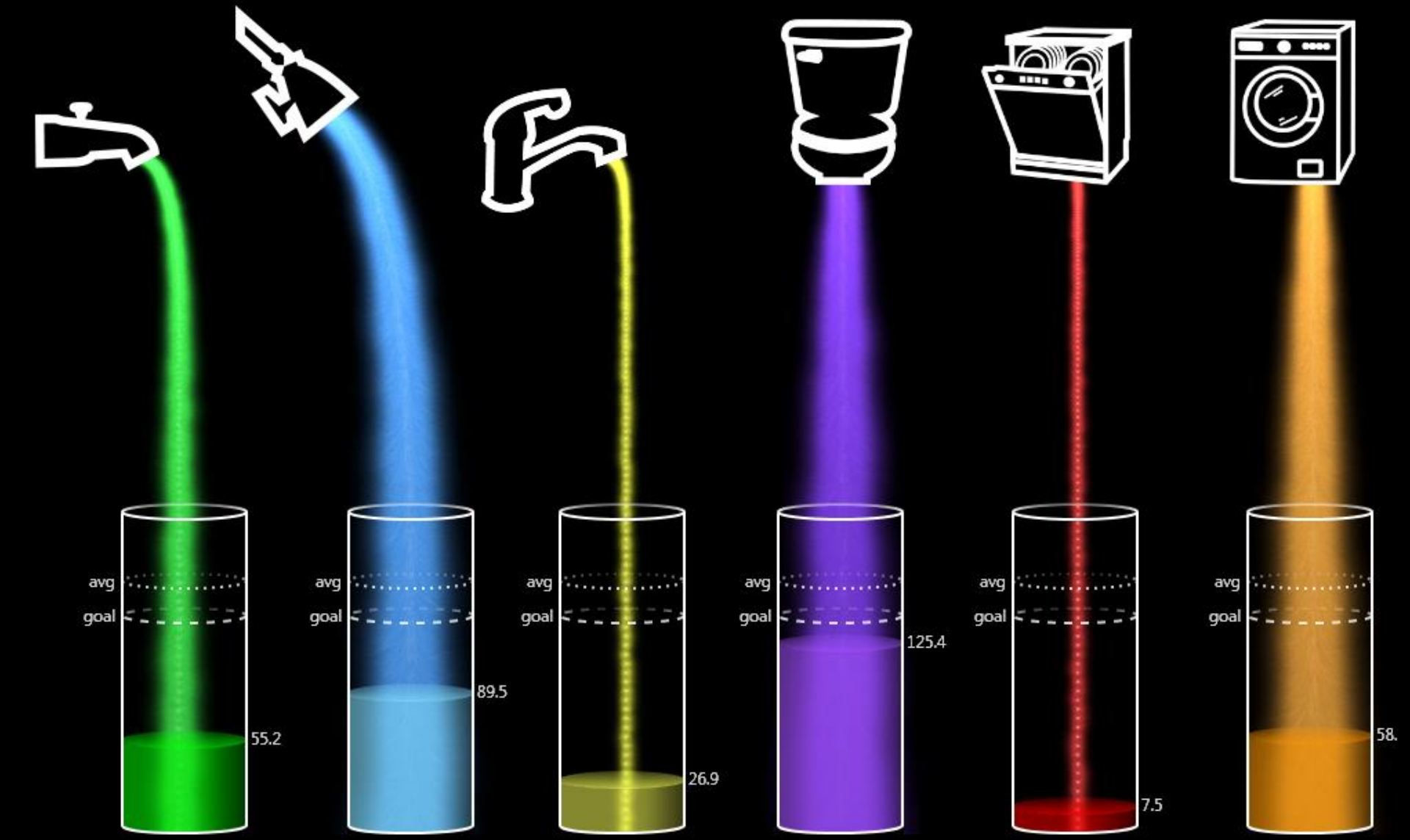
Per-Occupant



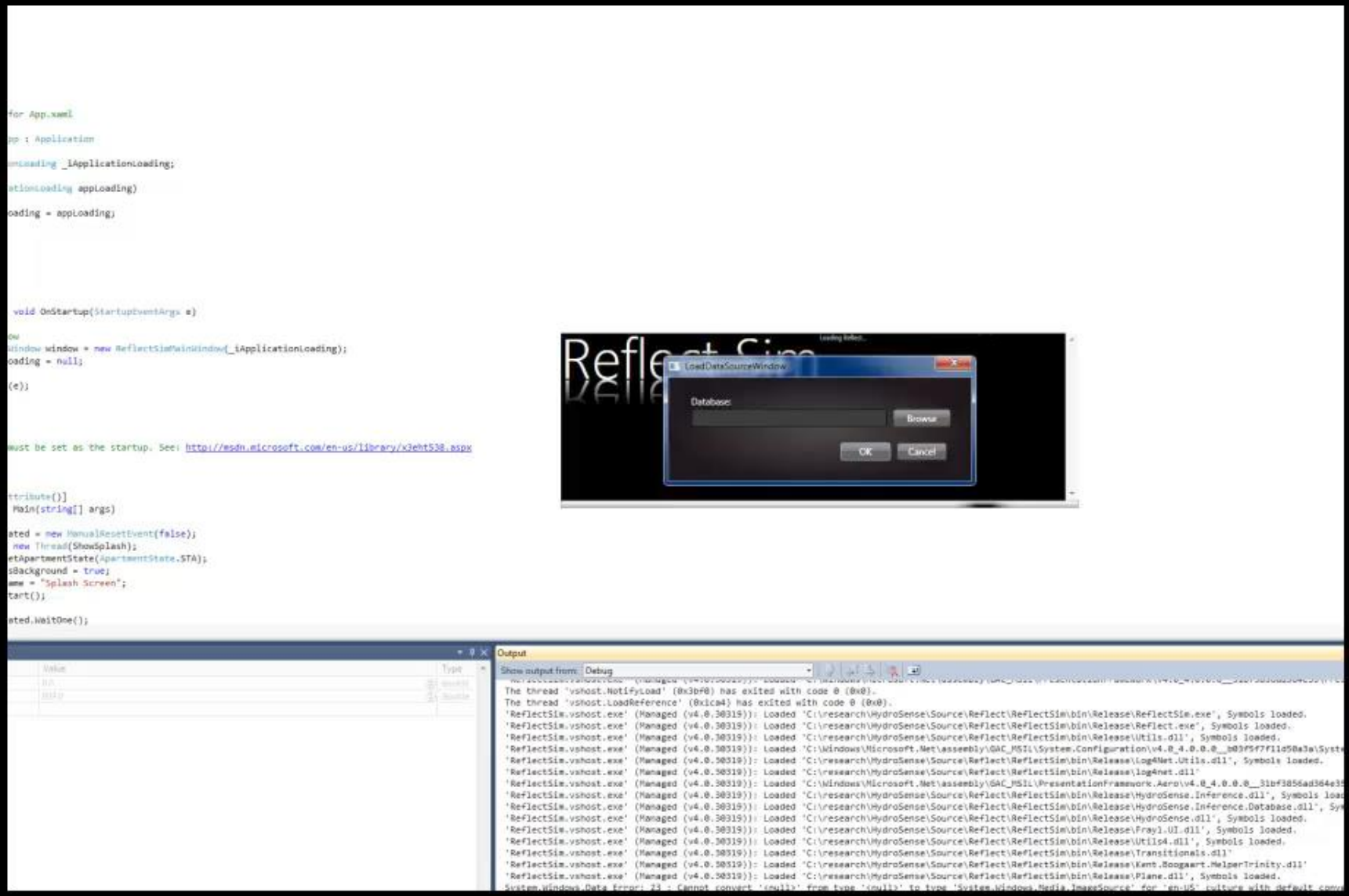
Other

DESIGN SET 2: DESIGN PROBES

Rainflow View

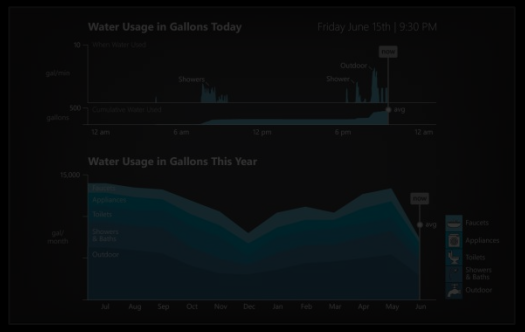


Rainflow View Movie



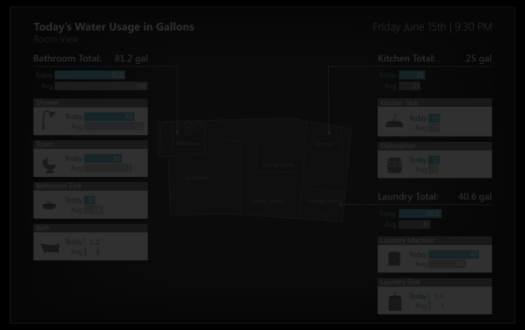
DESIGN SET 2: DESIGN PROBES

Design Probes Explored

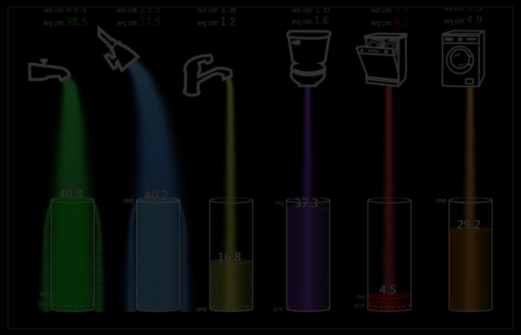


Time-Series

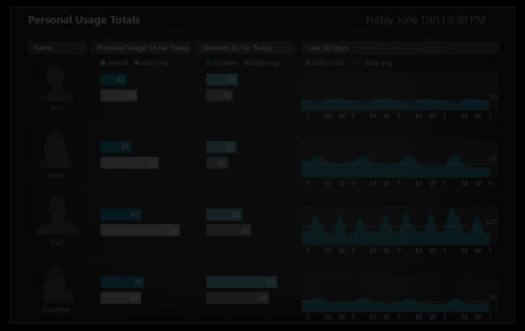
Aquatic Eco-system



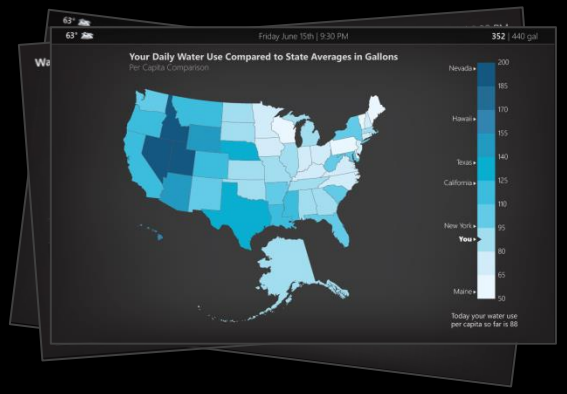
Spatial



Rainflow



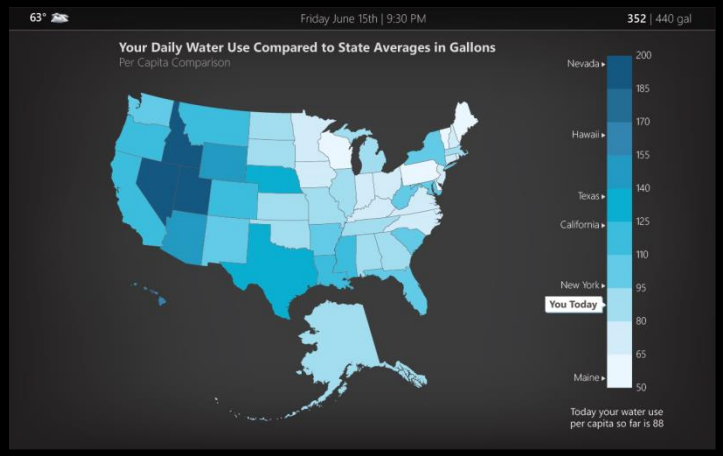
Per-Occupant



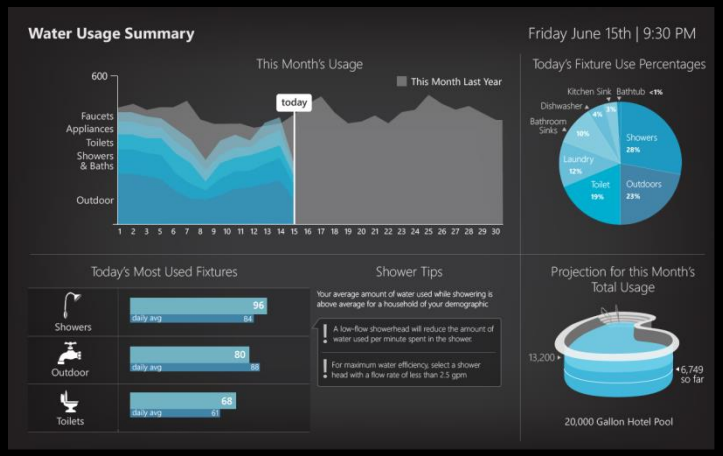
Other

DESIGN SET 2: DESIGN PROBES

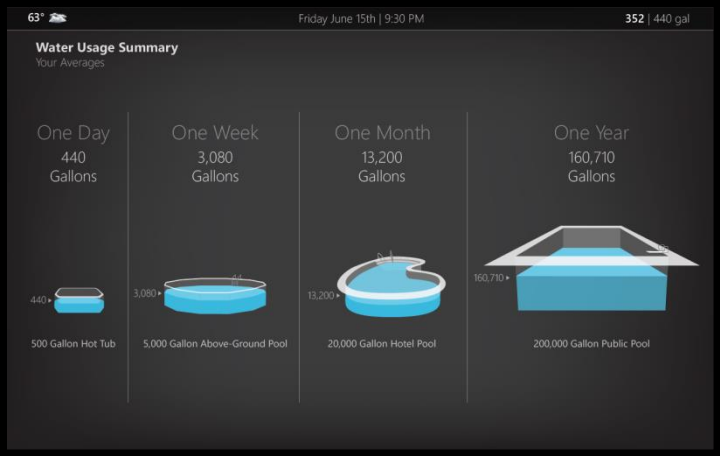
Other Design Probes



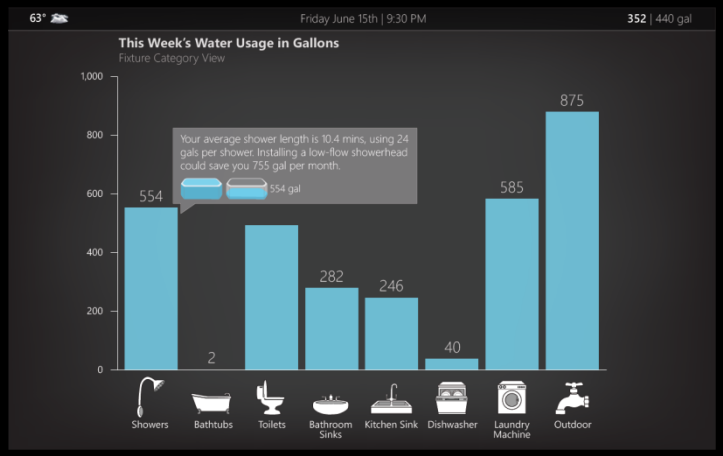
Geographic Comparisons



Dashboards

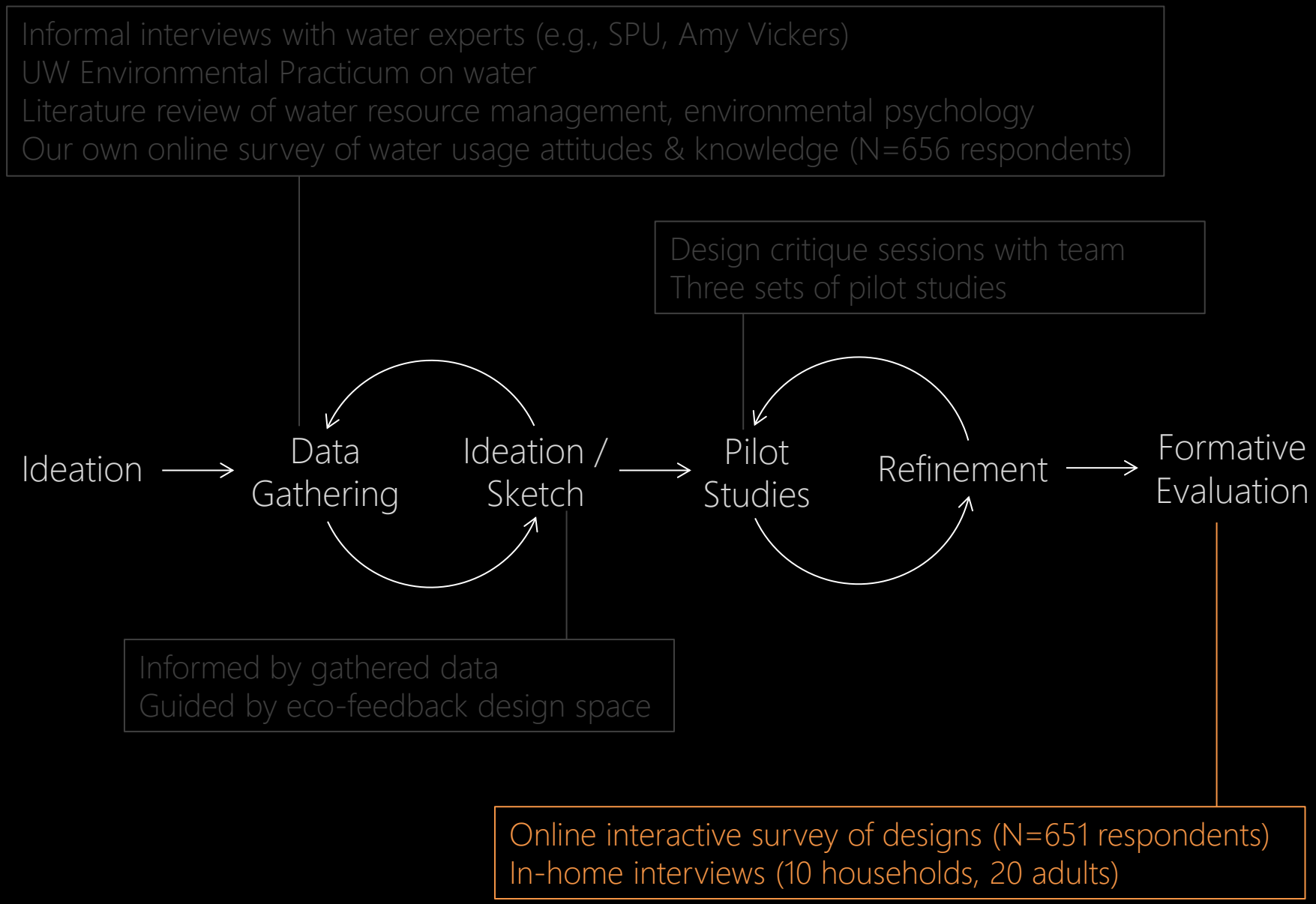


Metaphorical Unit Designs



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)
Design critique sessions with team
Three sets of pilot studies
Ideation
Data Gathering
Ideation / Sketch
Pilot Studies
Refinement
Formative Evaluation
Informed by gathered data
Guided by eco-feedback design space
Online interactive survey of designs (N=651 respondents)
In-home interviews (10 households, 20 adults)

Online Survey

Water Feedback Evaluation Survey

Consent Form

0%

Hi, 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.

I appreciate you taking the time to fill out this survey,

Jon E. Froehlich
PhD Candidate
University of Washington

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.

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 DISCOMFORT
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.

SUBJECT'S 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. *

Yes

Recruitment

- Online postings and word-of-mouth

Survey Design

- 63 questions (10 optional)
- Question and answer order randomized when possible

Collected Data

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

Water Feedback Evalu ×

edu.surveygizmo.com/s3/632637/CHI2012-WaterFeedbackSurveyDemo

Water Feedback Evaluation Survey

Introduction

6%

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.

Back Next

6%

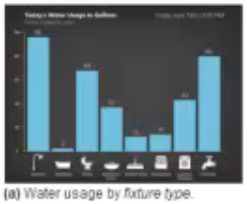
Water Feedback Evaluation Survey

Hot and Cold Breakdown

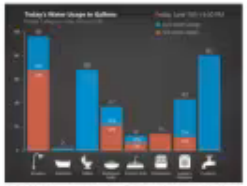
44%

We are also interested in whether people want **information on hot water usage vs. cold water usage**. Display (a) treats all water usage the same (whether hot or cold), while display (b) breaks down water usage by hot water and cold water amounts.

Like before, please mouse over the thumbnails on the left below to see enlarged versions of the display so that you can easily compare the two designs.



(a) Water usage by *fixture type*.

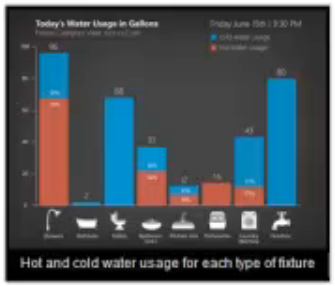


(b) Water usage by fixture type with *hot and cold breakdown*.

Move your mouse cursor over the image thumbnails on the left to see enlarged versions here.

22. Which display do you prefer? *

Click on the image below to make your selection.



I would prefer to have both displays and be able to switch between them

All of the above

In-Home Interviews

Recruitment

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

Interview Method

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

Participants

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





CLAUSING





Daily average consumption by fixture for the month of May
69.3 gallons
of water consumed per day on average
Weekly consumption pattern for the month of May
average consumption for this day of the week
average daily consumption
M T W T F S S

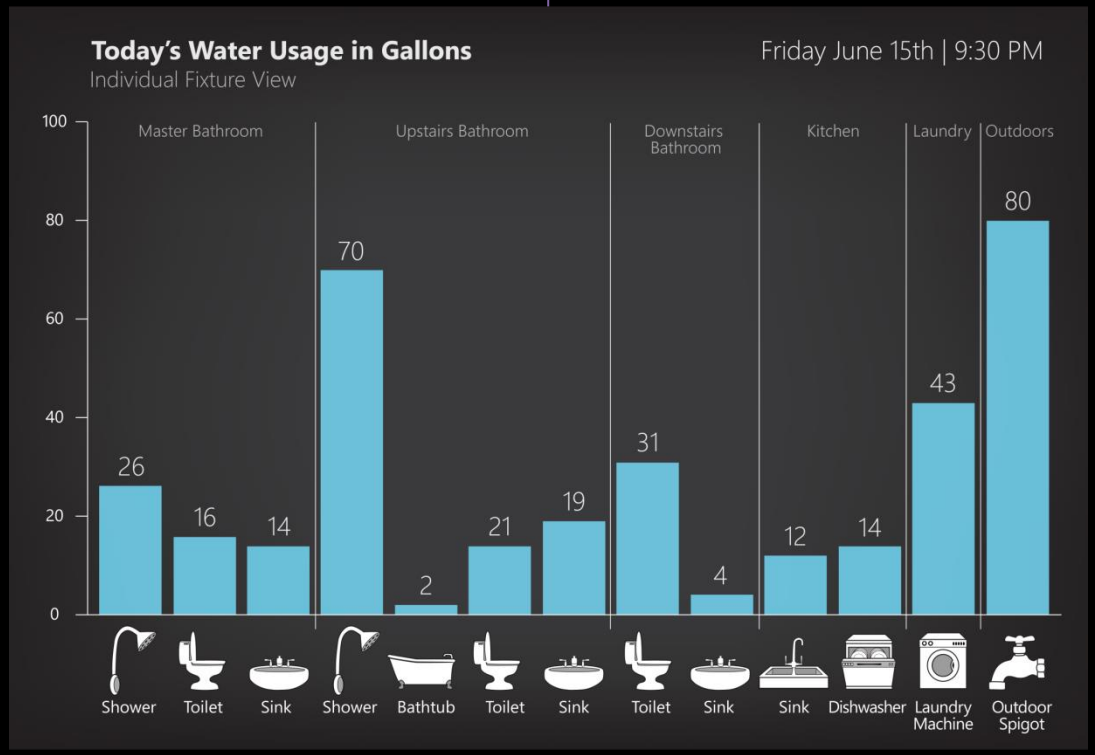
For both the survey and interviews, **90%** of participants indicated an interest in **conserving water**

Average morning shower uses 400 gallons of water

Findings

Data Granularity

coarse-grain ≥neighbor-hood | home | room | activity | fixture category | fixture | ≤ valve **fine-grain**



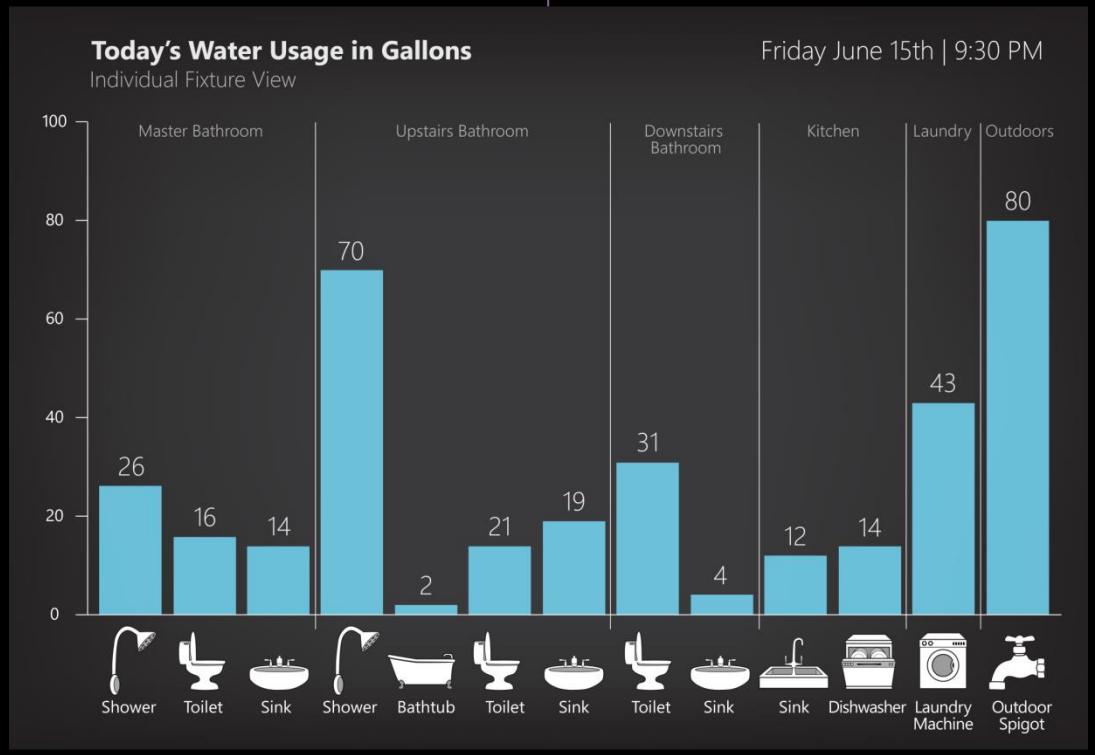
"This display lets you more easily identify the specific areas that need attention"

R536

Majority preferred the *Individual Fixture Display*

Data Granularity

coarse-grain ≥neighbor-hood | home | room | activity | fixture category | fixture | ≤ valve **fine-grain**



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R536

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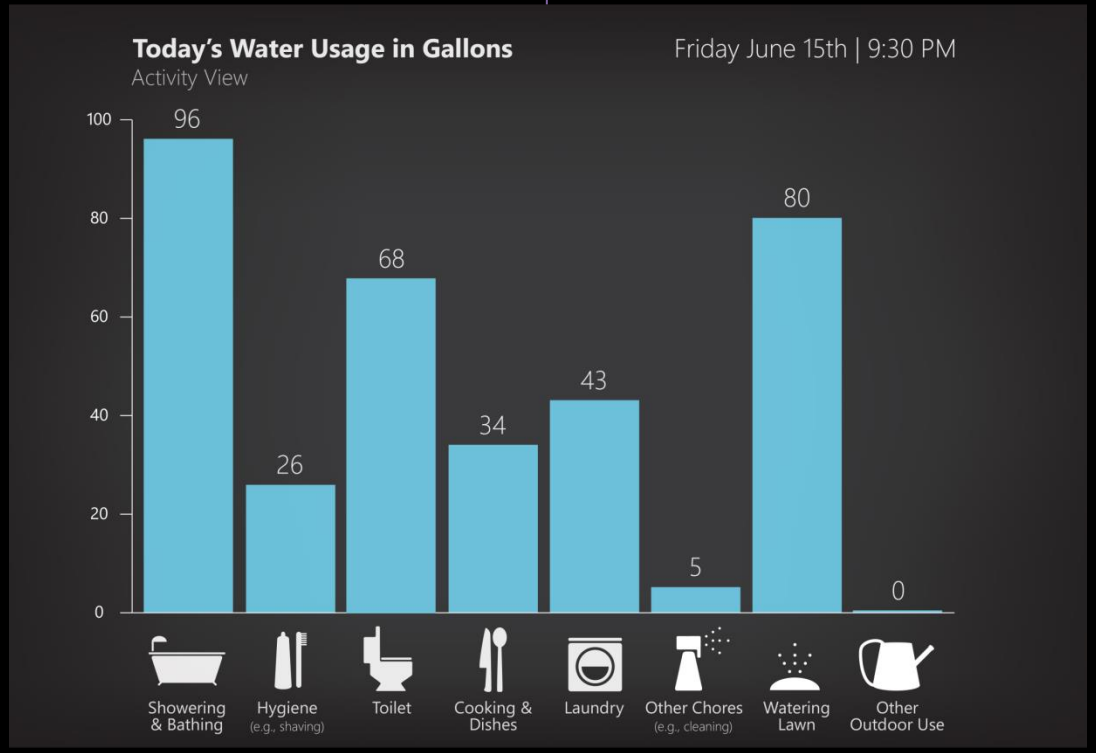
coarse-grain ≥neighbor-hood | home | room | activity | fixture category | fixture | ≤ valve **fine-grain**



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

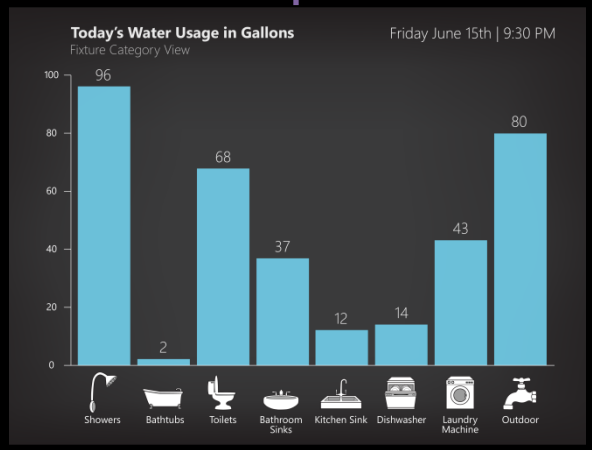
R143

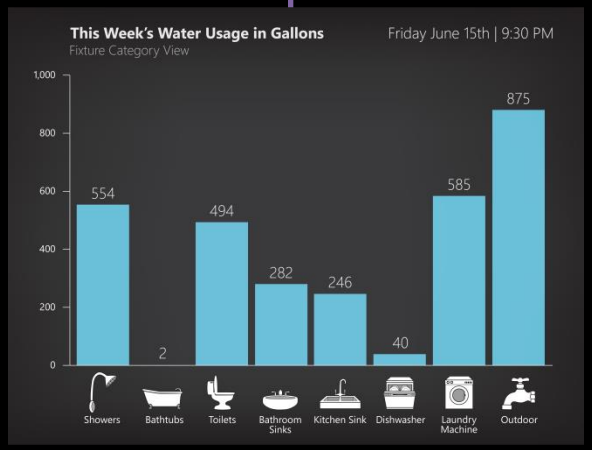
> I don't think very well in 'thousands of gallons', but $20 I can understand. That's a case of beer down the drain, if you will

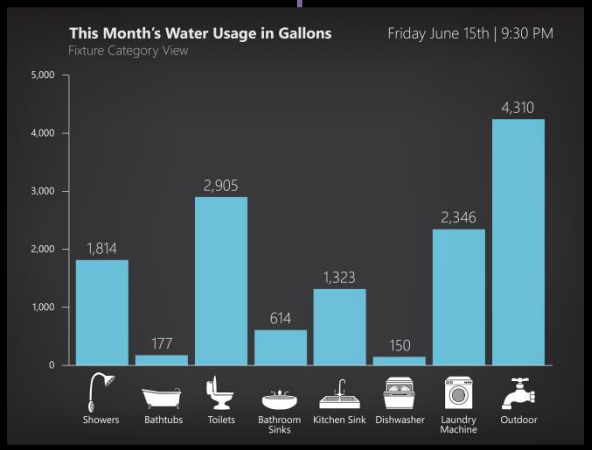
R48

Time Granularity

≤ hour | day | week | month | ≥ year





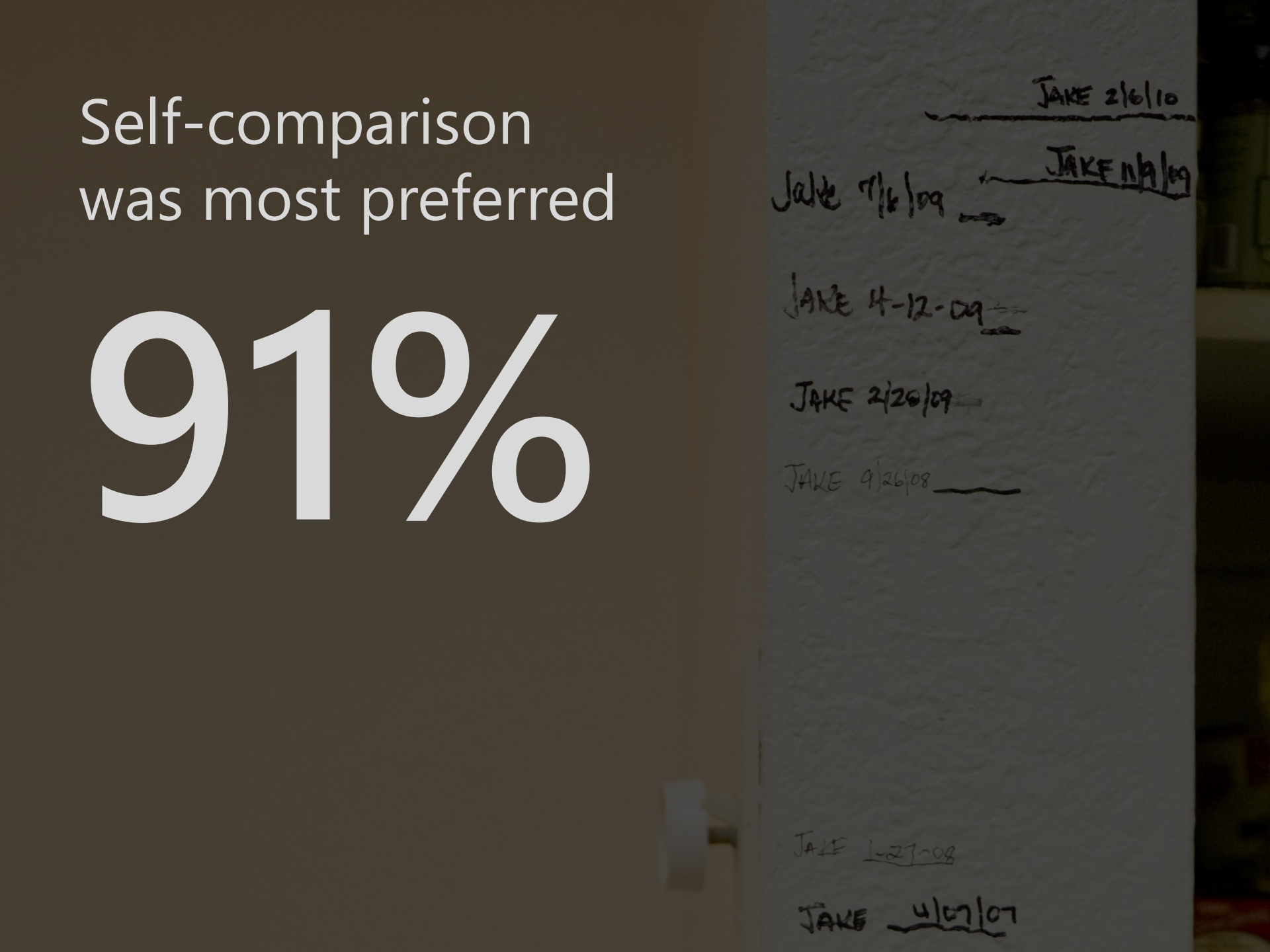


Majority of respondents wanted ability to switch between different time granularities


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

Self-comparison
was most preferred

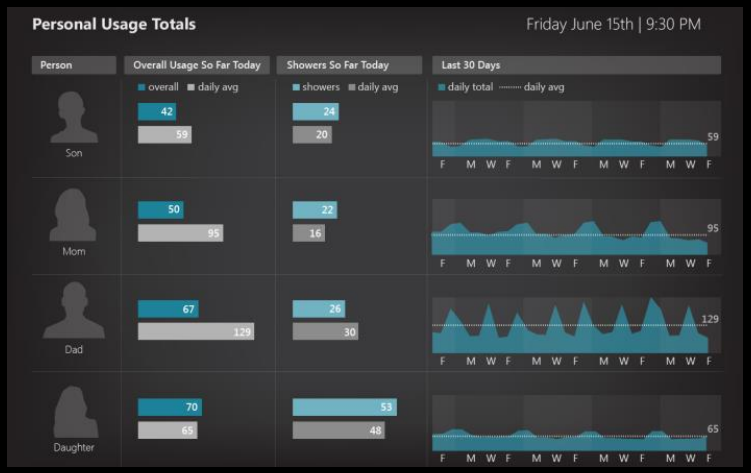
91%



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

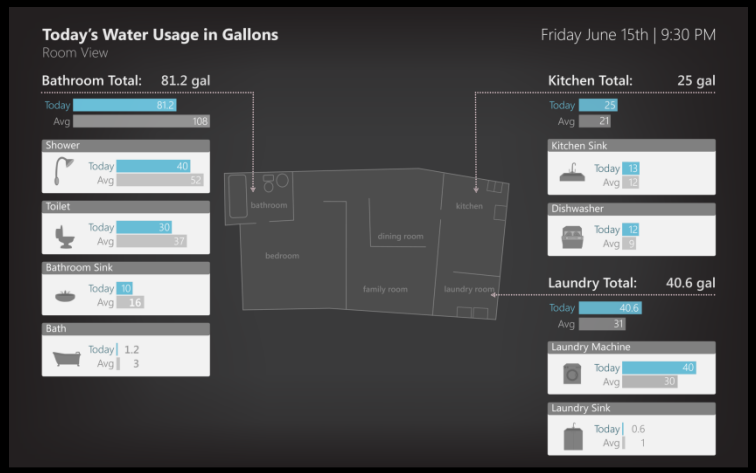
> It pits the family members against each other rather than encouraging collaboration

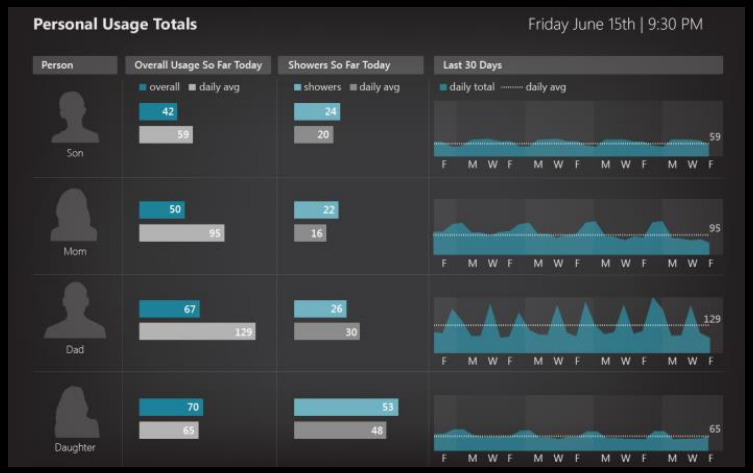
R485

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

R493

Accountability and Blame





"It holds each individual accountable for water usage"

R354

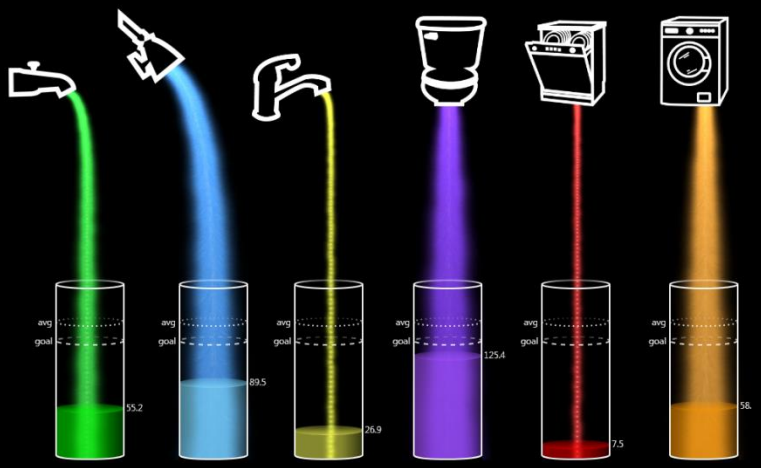
"There's no reason to add an element of 'blame' to conservation efforts within a family"

R98

"Would seem to lead to plenty of arguments about usage

R144

Playfulness and Functionality



"I like the idea of getting rewards for saving water"

I8.2

"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"

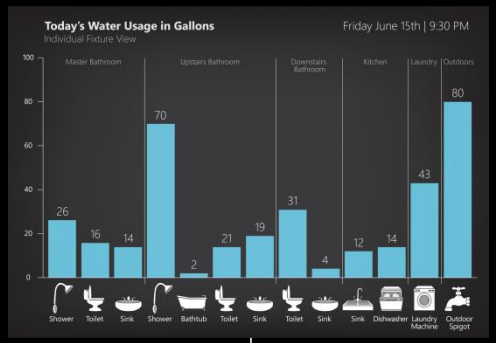
I4.1

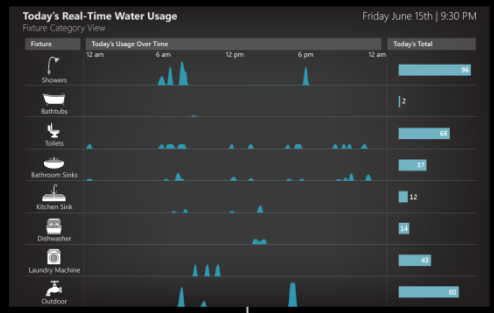
"It doesn't appeal to me as much. I don't do Foursquare. This distracts me a little bit and it doesn't make me think about my usage"

I4.2

Useful as an educational tool?

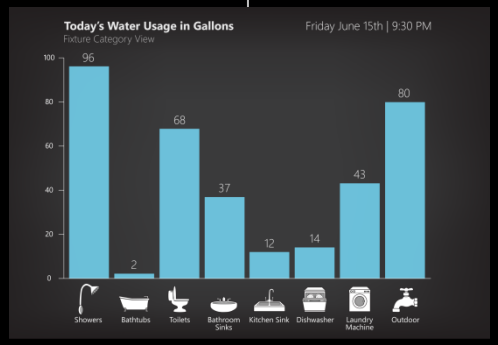
Privacy Spectrum

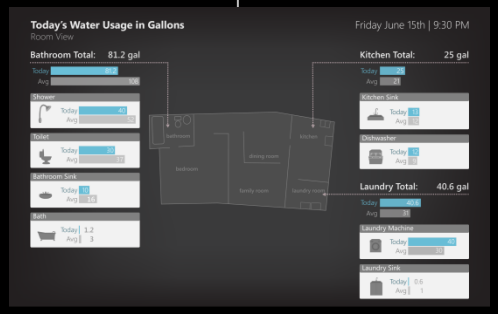




Least Invasive

Most Invasive





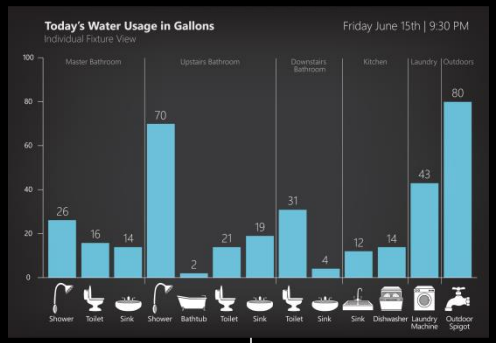
“It’s incredibly invasive. And other people’s water consumption is not my business.”

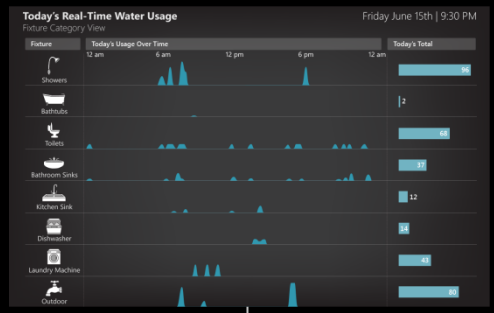
R25

“Water usage for many purposes can be very personal, and shouldn’t be automatically shared”

R25

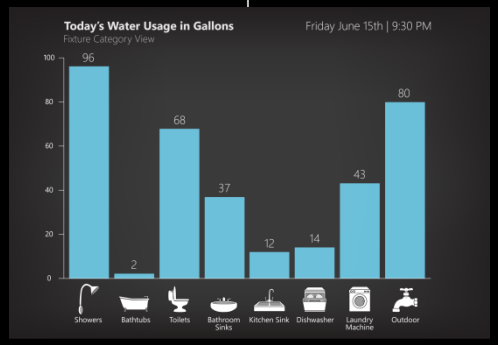
Privacy Spectrum

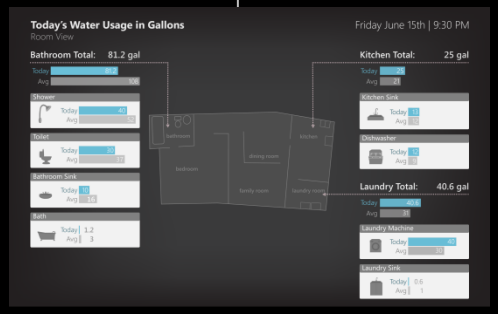




Least Invasive

Most Invasive





Display Location Preferences

“If we placed the display here, the kids couldn’t see it.”

I2.1

Display Location Preferences

kitchen

near thermostat

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

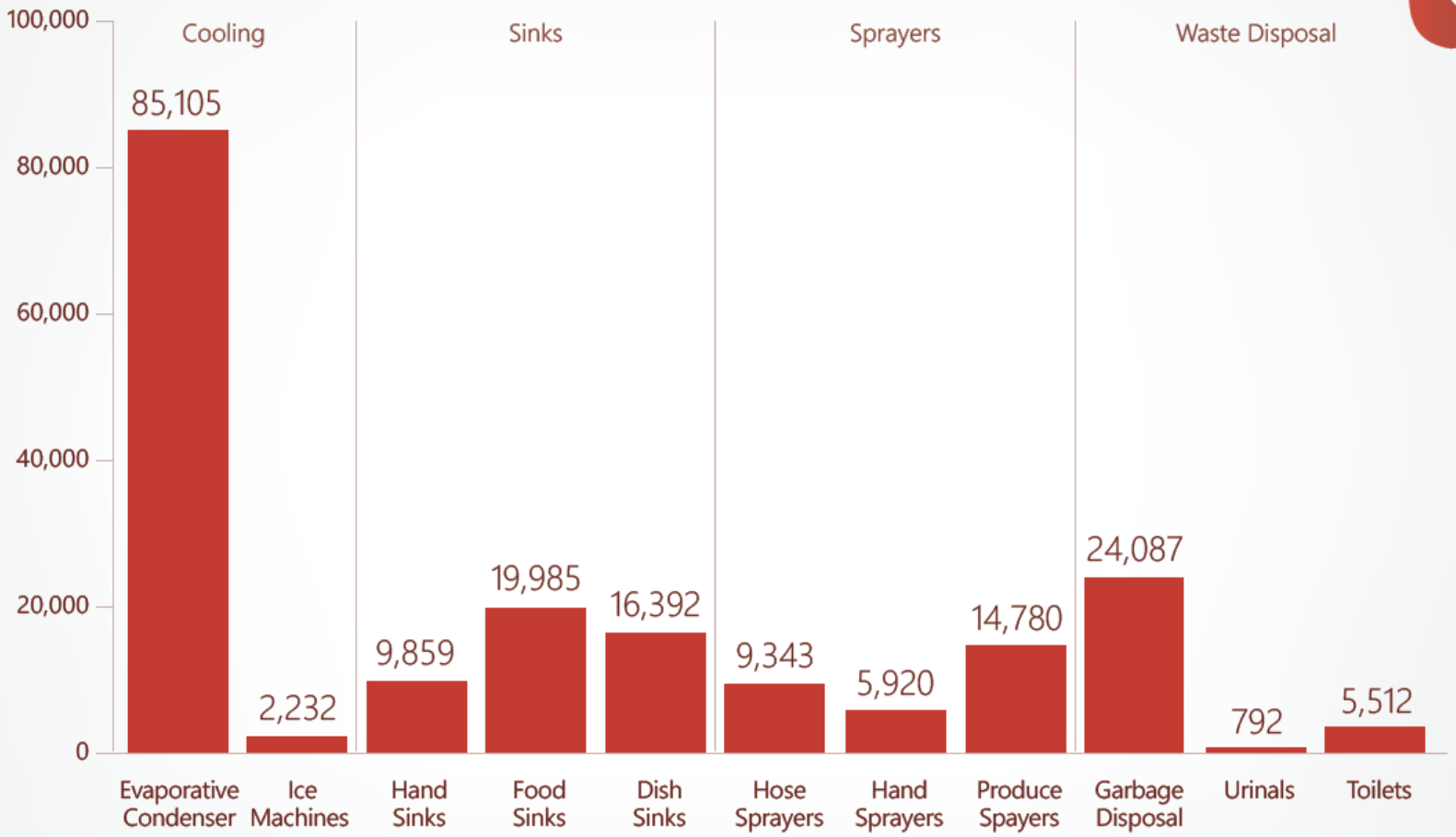
Sensing and feedback for water **quality** not just consumption

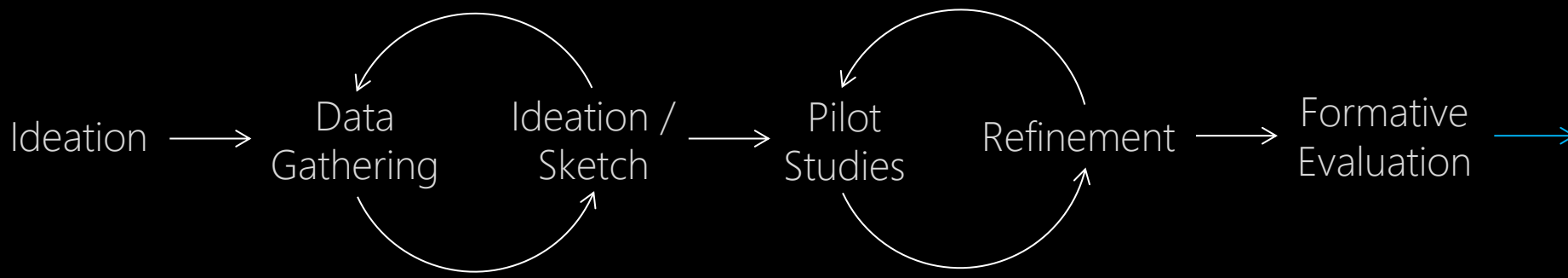
Today's Water Usage in Gallons

Individual Fixture View

This Month's Water Usage in Gallons

Individual Fixture View

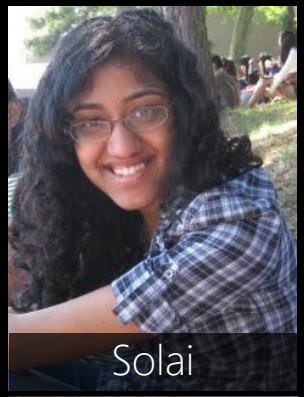


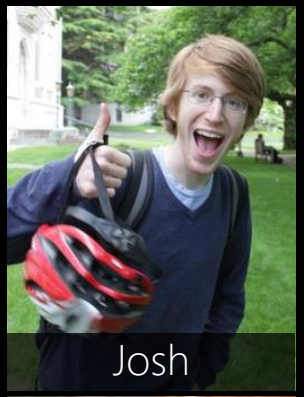

Ideation
Data Gathering
Ideation / Sketch
Pilot Studies
Refinement
Formative Evaluation

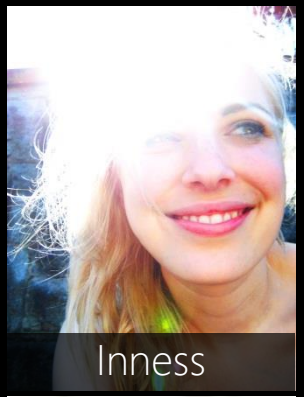
Closing Thought

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

The **Eco-Feedback** Team!


Solai

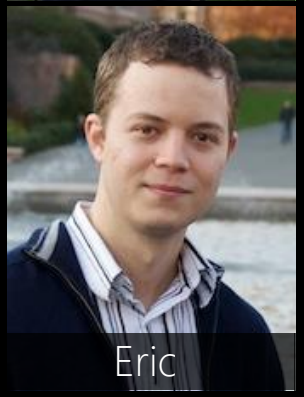

Josh


Inness


Fabia


Mazhengmin


Marilyn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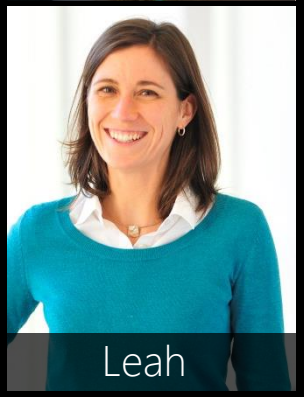
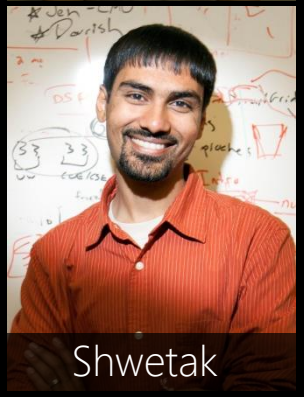

Leah


Shwetak


James

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Questions?

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