Reflections of Ourselves

Sensing and Feedback to Inform Everyday Human Behavior

Human Computer Interaction Laboratory

@jonfroehlich

Assistant Professor Computer Science

UNIVERSITY OF MARYLAND

Let's **dance**.

I thought I could **dance**.

A process of self-discovery and reflection enabled by...

sensing feedback


you
sensing feedback

How can we use **sensing** and **feedback** to improve people's lives and the environment around them?


"**Persuasive technology** is any interactive computing system **designed to change people's attitudes** or **behaviors**"
-BJ Fogg, *Persuasive Technology*, 2002

Persuasive Technology

Savvy, persuasive mortgage broker guy
circa 2008

~~Persuasive~~ ~~Technology~~

Technology-mediated behavior change applications

Pedja Klasnja
Assistant Prof, iSchool
U. of Michigan

Jon Froehlich
Assistant Prof, CS
U. of Maryland

Eric Hekler
Assistant Prof, Health & Nutrition
Arizona State University

Matthew Buman
Assistant Prof, Health & Nutrition
Arizona State University

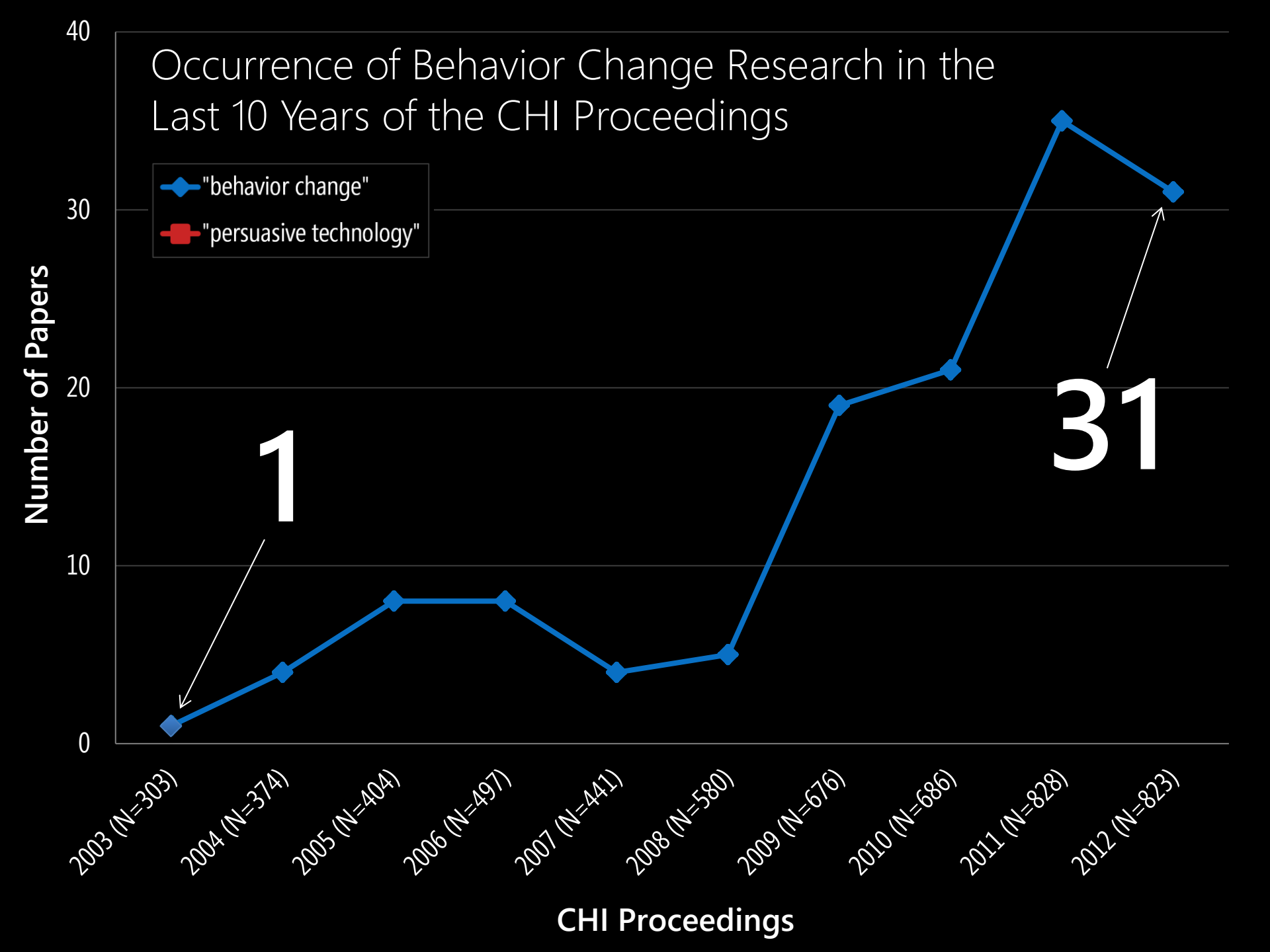
Encompasses:

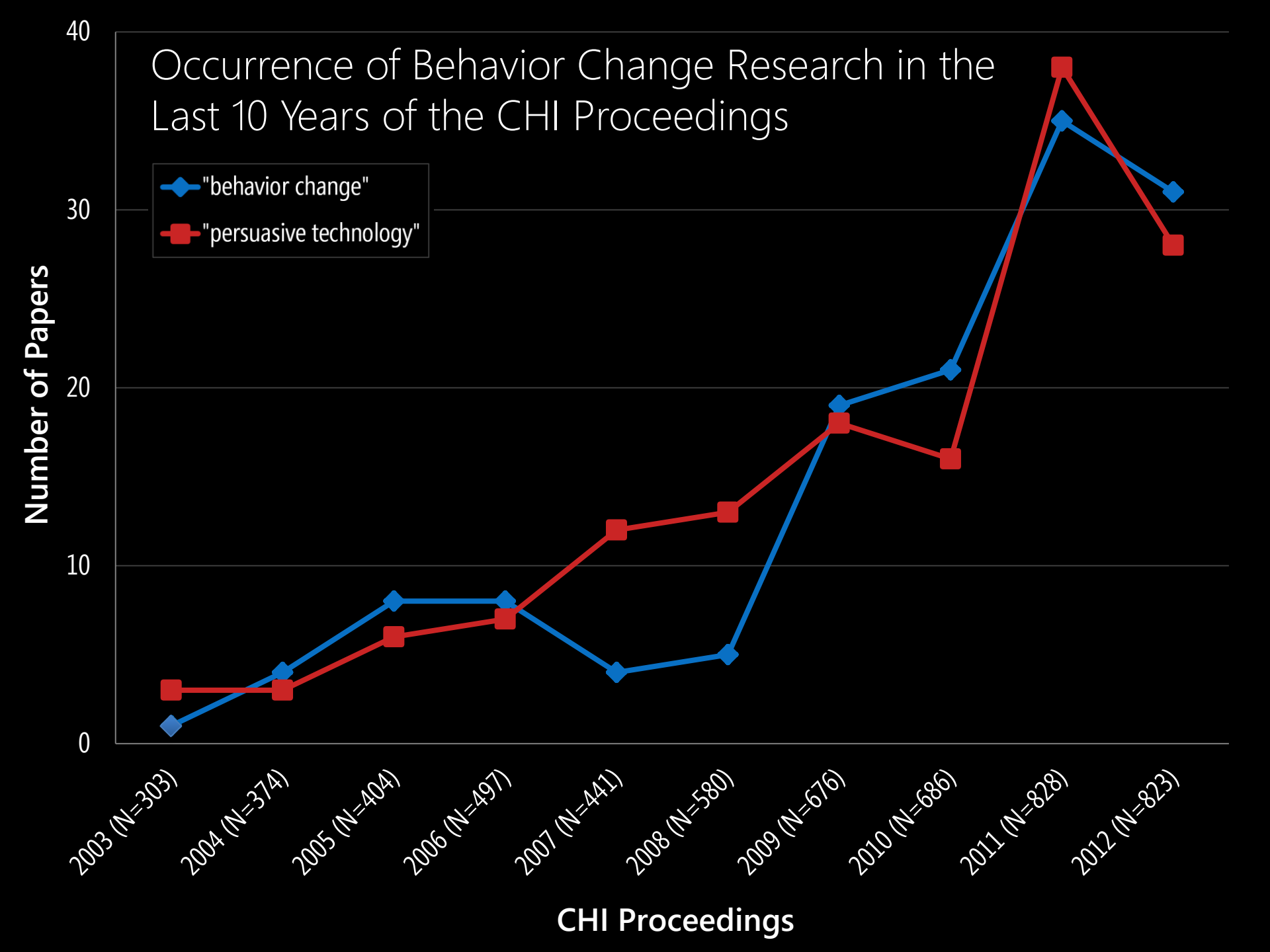
Quantified self

Personal informatics

Eco-feedback

...


Occurrence of Behavior Change Research in the Last 10 Years of the CHI Proceedings
"behavior change"
"persuasive technology"
Number of Papers
40
30
20
10
0
1
31
2003 (N=303)
2004 (N=374)
2005 (N=404)
2006 (N=497)
2007 (N=441)
2008 (N=580)
2009 (N=676)
2010 (N=686)
2011 (N=828)
2012 (N=823)
CHI Proceedings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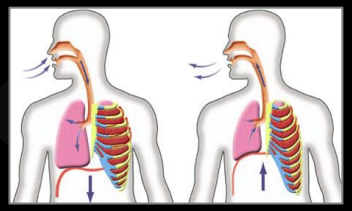
2012 (N=823)
CHI Proceedings

This is an incredibly interesting time to be working in this area.

sensing

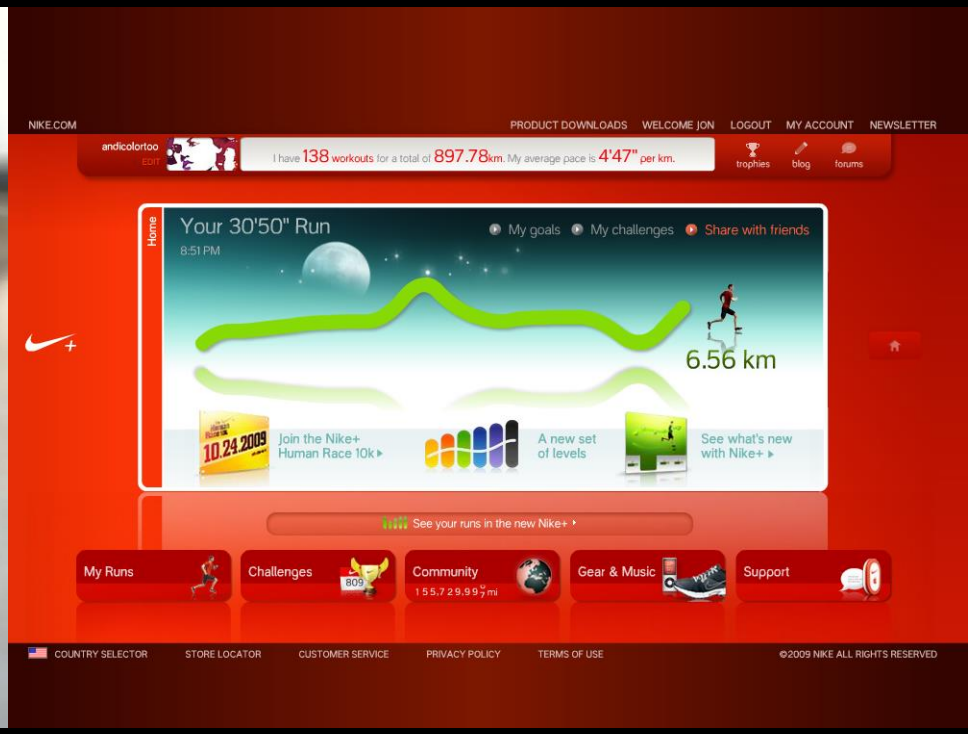
Human Activities

Biometric Data



feedback

Nike+ Running Monitor

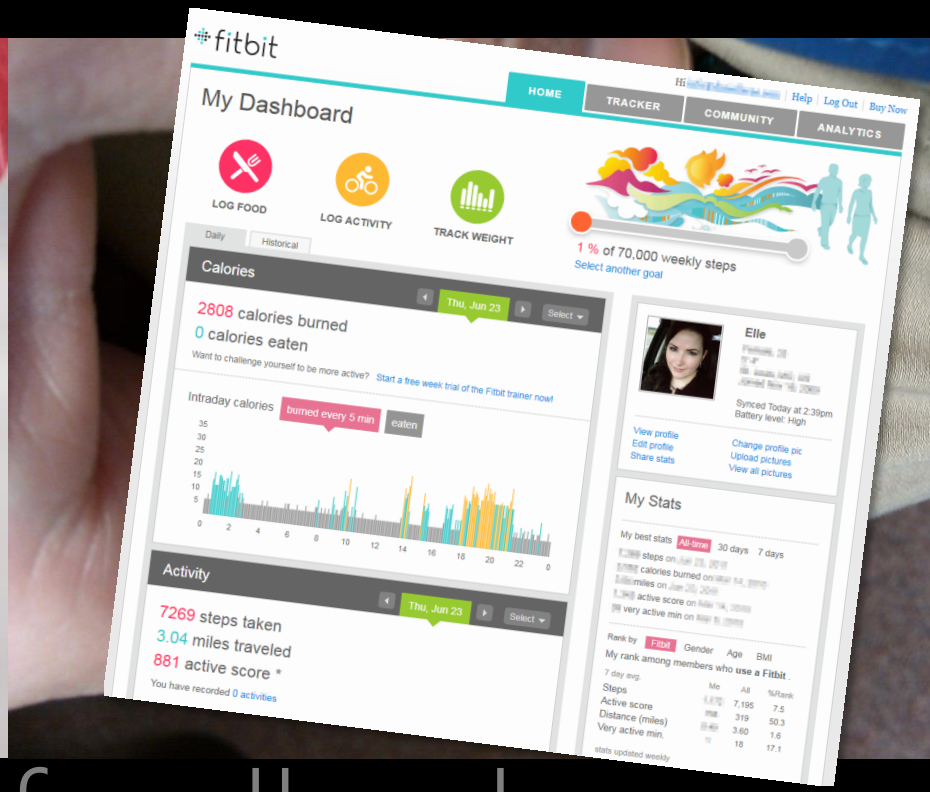


sensingfeedback

Fitbit Activity Level Tracker

sensingfeedback

Fitbit Activity Level Tracker

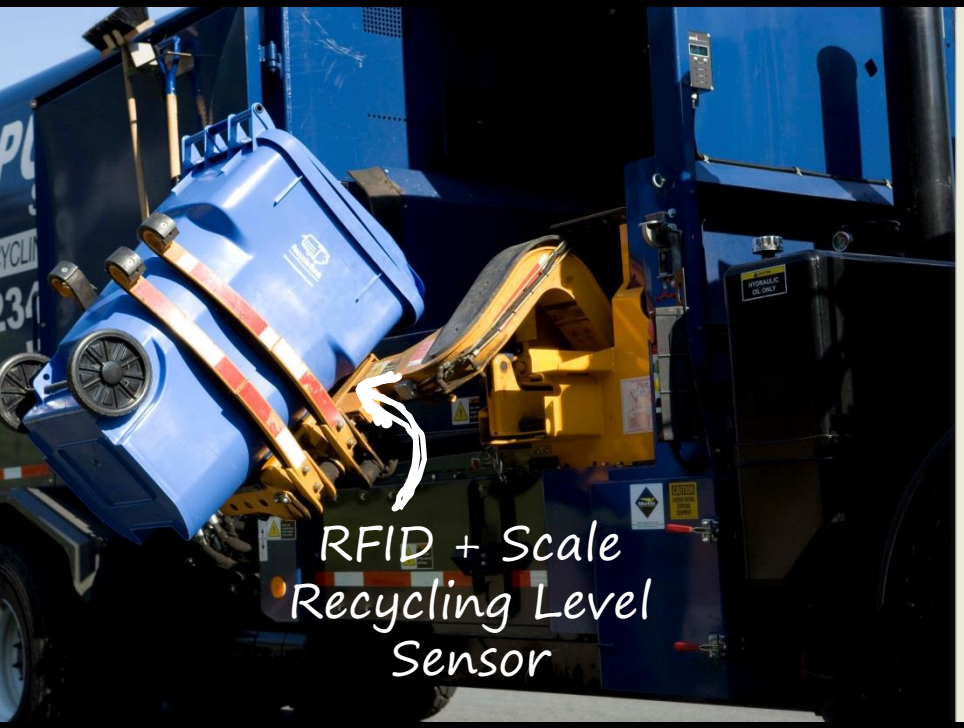


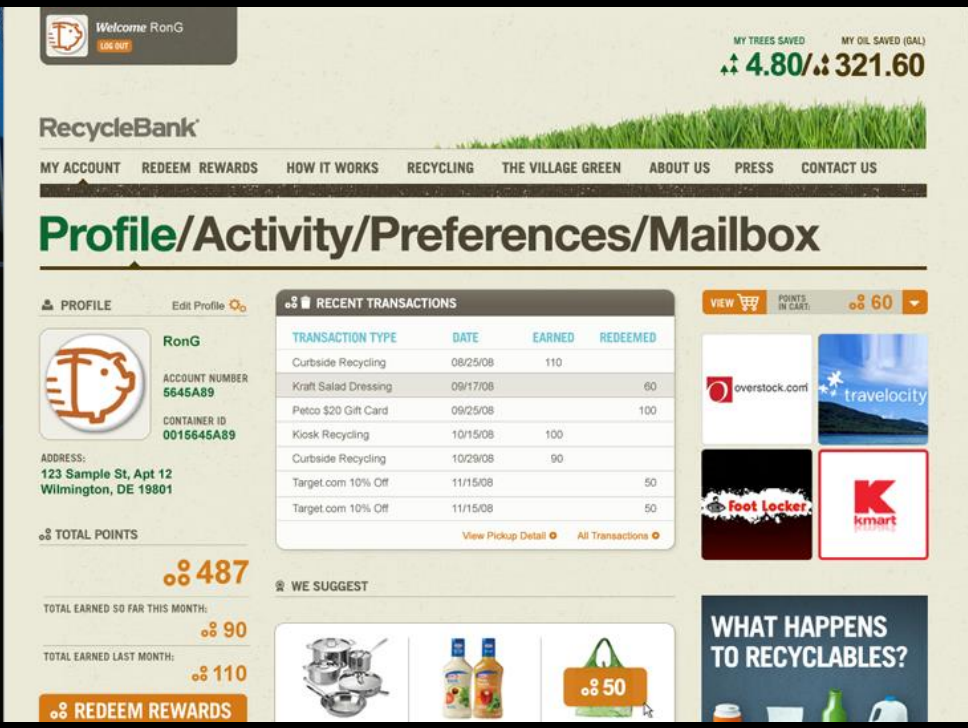
sensingfeedback

Zeo Sleep Coach

sensingfeedback

Recyclebank Recycling Tracker





sensingfeedback


And this is just the **beginning**.

Overarching Questions

1. What **behaviors** to **sense?**
2. What aspects to **visualize**?
3. How should we approach & structure the **design process**?

Overarching Questions

① What **behaviors** to **sense?** And how? And Why?

② What aspects to **visualize**? And how? And Why?

③ How should we approach & structure the **design process**?

These are far from solved questions!

Health

Motivations for **healthy behavior** may **differ** from motivations for **proenvironmental behavior**

In particular, I will focus on **sensing** and **feedback** systems for residential water usage

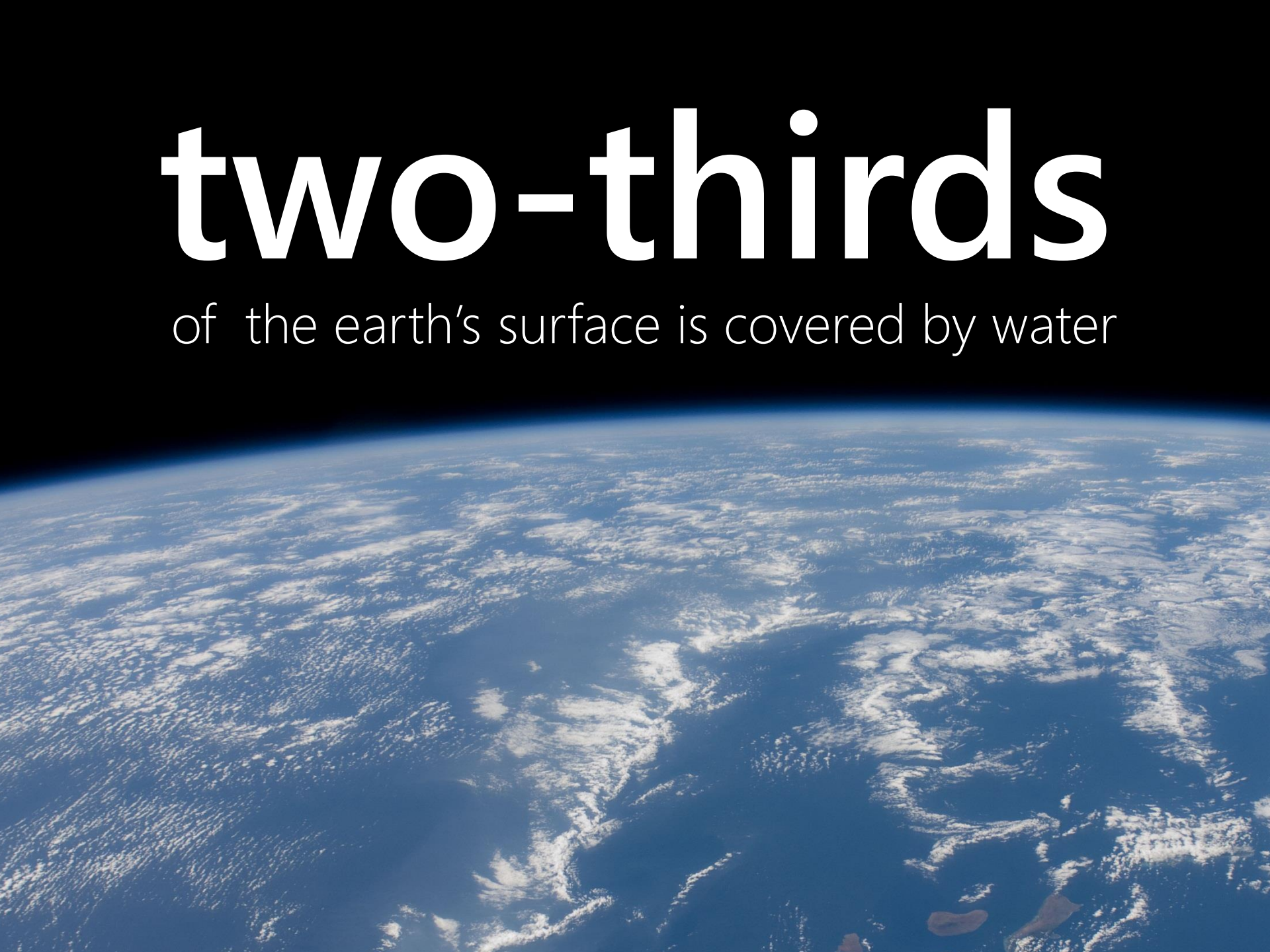
why **water?**

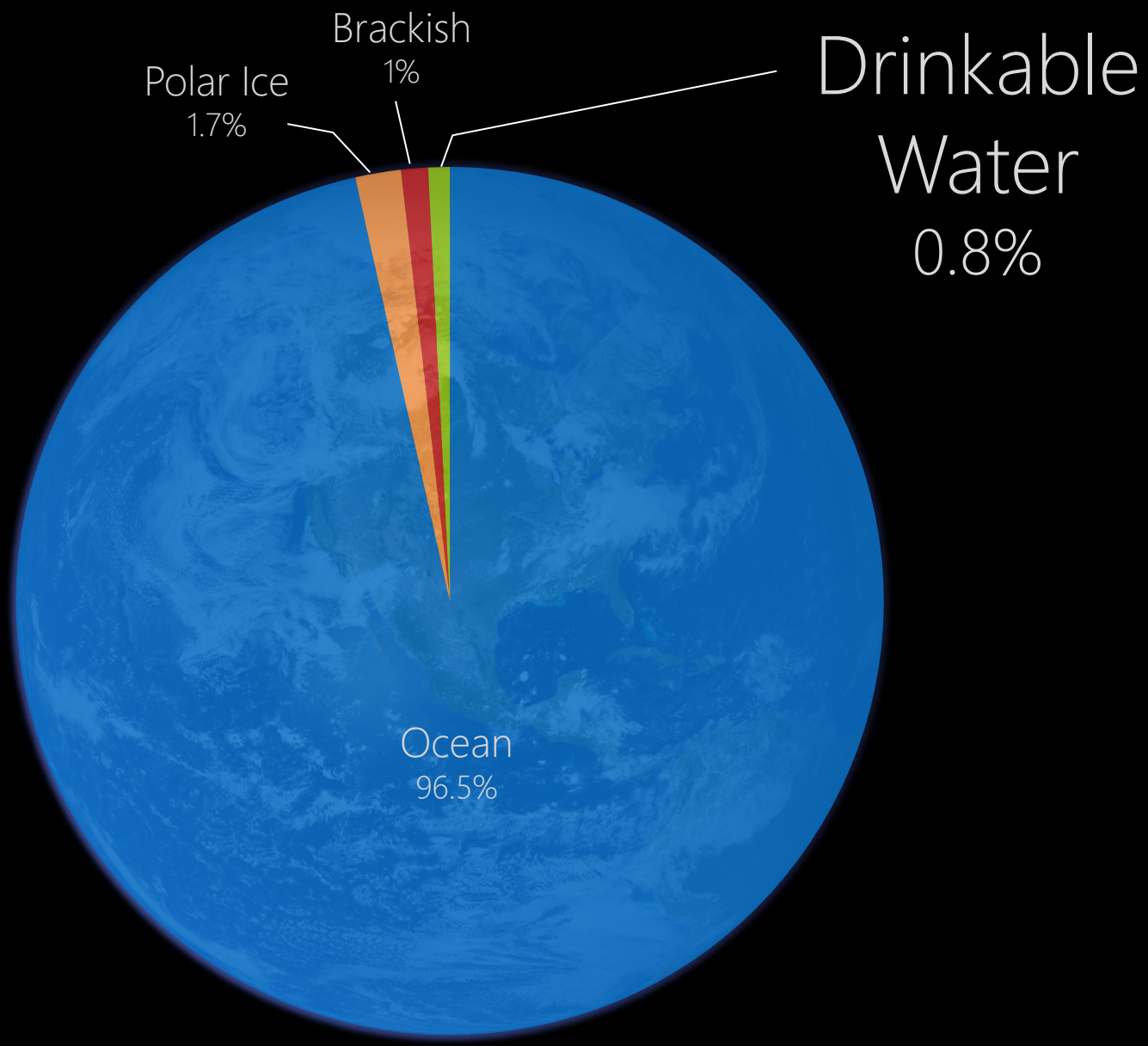
cheap
difficult to transport
usage often creates waste
fundamental ingredient of life
not energy

though water infrastructure
requires lots of energy to run

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]


number of people in
urban environments
surpassed the number of people in
rural areas
[Barlow, 2007]

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

Looking at current sensing and feedback systems for water...

water sensing

Municipal Services Statement

City of Tempe
P.O. Box 29617
Phoenix, AZ 85038-9617
480-350-8361
480-350-8400 (TDD)

0000127520000000010068700154711 8

LINDER HOLLINQUEST
7450 S KENWOOD DR
TEMPE AZ 85283-4921

Mark if address change requested on reverse side

Account Number: 100687-00154711
Utility Amount Due: 127.52
Voluntary Donation: 1.00
Total + Voluntary Donation: 128.52
Date Due: 1/8/2007
Enter Amount Paid:

Make checks payable to the City of Tempe.

PLEASE FOLD BEFORE TEARING

Return the top portion of this statement with your payment.

Keep the bottom portion of this statement for your records.

See reverse side for important information.

Account Number: 100687-00154711
Current meter reading: 16507
Billing period: 12/2006
Previous meter reading: 16305
Service Address: 7450 S KENWOOD LN
Meter read date: 11/20/2006
Gallons delivered: 20,200
Days of service: 27

Account Activity

Date	Description	Amount
	Payments Received Thank You	100.00
12/12	Water Quality Fee	0.13
12/12	Tempe City Tax	0.61
12/12	State Tax	2.15
12/12	Sewer Service Charge	7.28

Date	Description	Amount
12/12	Water Consumption	20.11
12/12	Water Service Charge	13.99
12/12	1% Delinquent Fee	0.40
12/12	Sewer Charge	11.48
12/12	Residential Refuse	17.41

The due date on this ... applies ONLY to current charges.
... Discover payments accepted, call 480-350-8361

Date Due: 1/8/2007

Previous Balance	Payments	Credits	Net Due	Late Charges	+ Other Debits	=Utility Amount Due
153.96	100.00	0.00	53.96	73.56	0.00	127.52

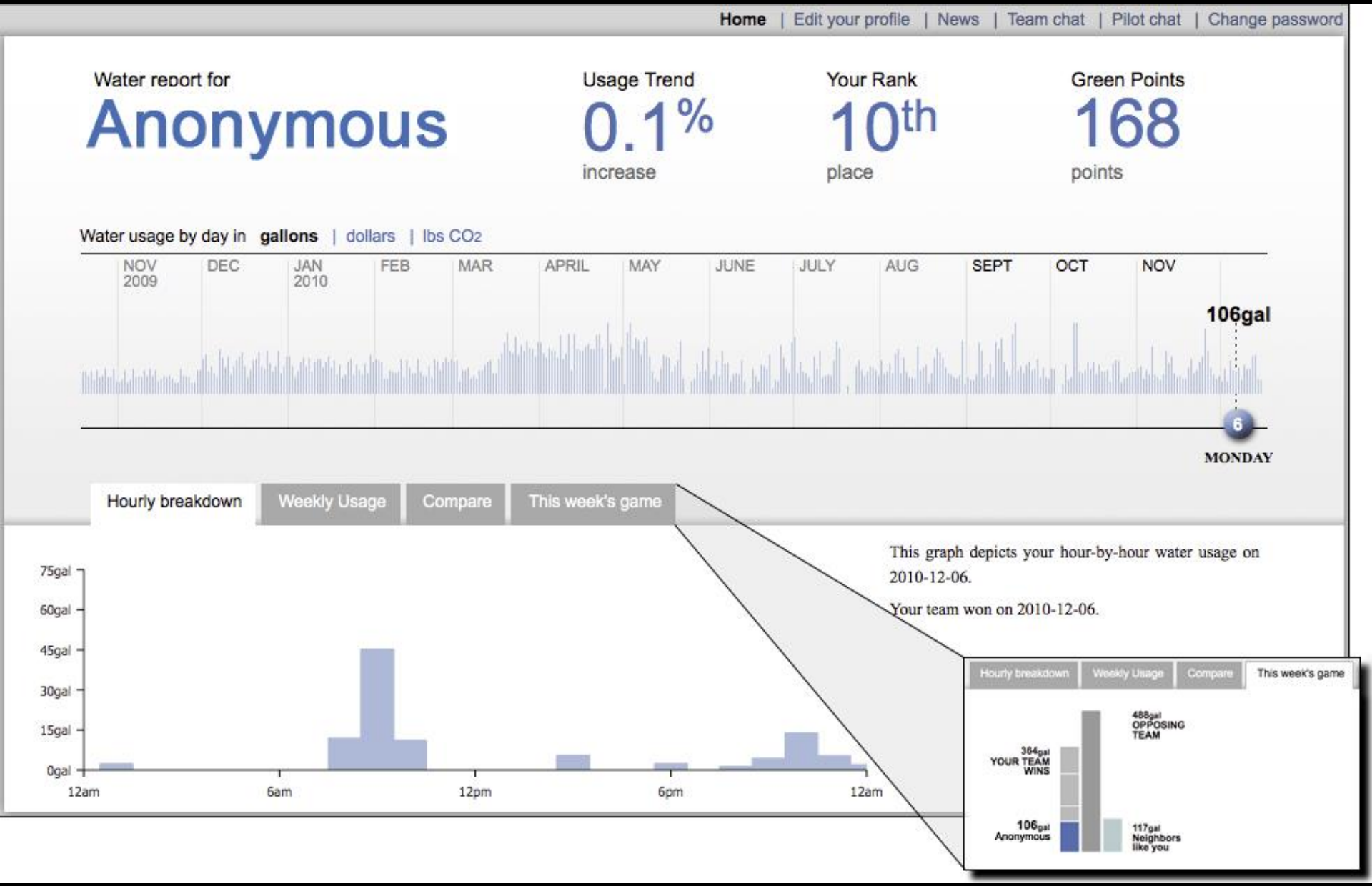
+ Voluntary Donation	= Total Including Voluntary Donation
1.00	128.52

Year to Date Voluntary Donation Thank You: 0.00

Help to Others voluntary donation program makes it easier to help neighbors in need. Help to Others supports essential human service programs for children, families and seniors. If you do not wish to contribute to this program, simply pay only the "Utility Amount Due."

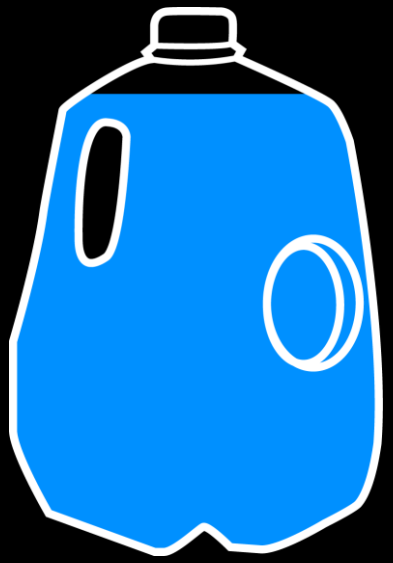
water feedback

Dubuque Water Portal:



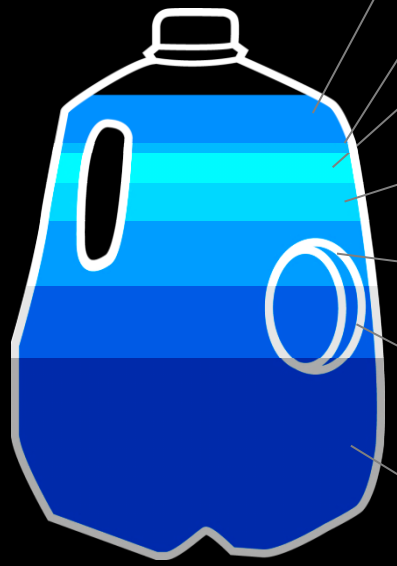
[Erickson *et al.*, CHI 2012]

10,230
gallons




SAFEWAY
SAVE MORE AT SAFEWAY
GROCERY
SFWY PRTZLE STICK
RegPrice 1.79
CardSav .29
1.50 B
BLKBERY PRES
SFY CANOLA OIL
CEREAL PNT BUTTER
CHILI SAUCE SWT
CHF-B PIZZA
LK GRLC SCE
REFRIG/FROZEN
LUC CHEESE
RegPrice 6.79
SPINACH ARTICHOKE
RegPrice 3.79
3S CRWN VEG RSTD
RegPrice 3.79
2@2.50 SFWY SEL MEDALL FC
RegPrice 7.58
MARGARINE
GEN MERCHANDIS
#SFY BENEHIST TAB
BAKED GOODS
LD COSMIC BROWNIES
1.29 B
OROWEAT RYE
3.14 B
CUSTARD PIE 9IN
4.99 B
RegPrice 5.99
CardSav 1.00
CHOC CREAM PIE
4.99 B
RegPrice 5.99
CardSav 1.00
**** TAX
6.76 BAL
144.25
VF MC XXXXXXXXX
144.25
.00
CHANGE
TOTAL SAVINGS 16.97
NUMBER OF ITEMS = 35
SAFEWAY
SAVE MORE AT SAFEWAY
Month: April 2006
Total Food Units: 1527
Total Price:
$642

10,230 gallons



Other
1248 gals

Dishwasher
102 gals

Faucets
1105 gals

Showers
1176 gals

Laundry
1,524 gals

Toilets
1,872 gals

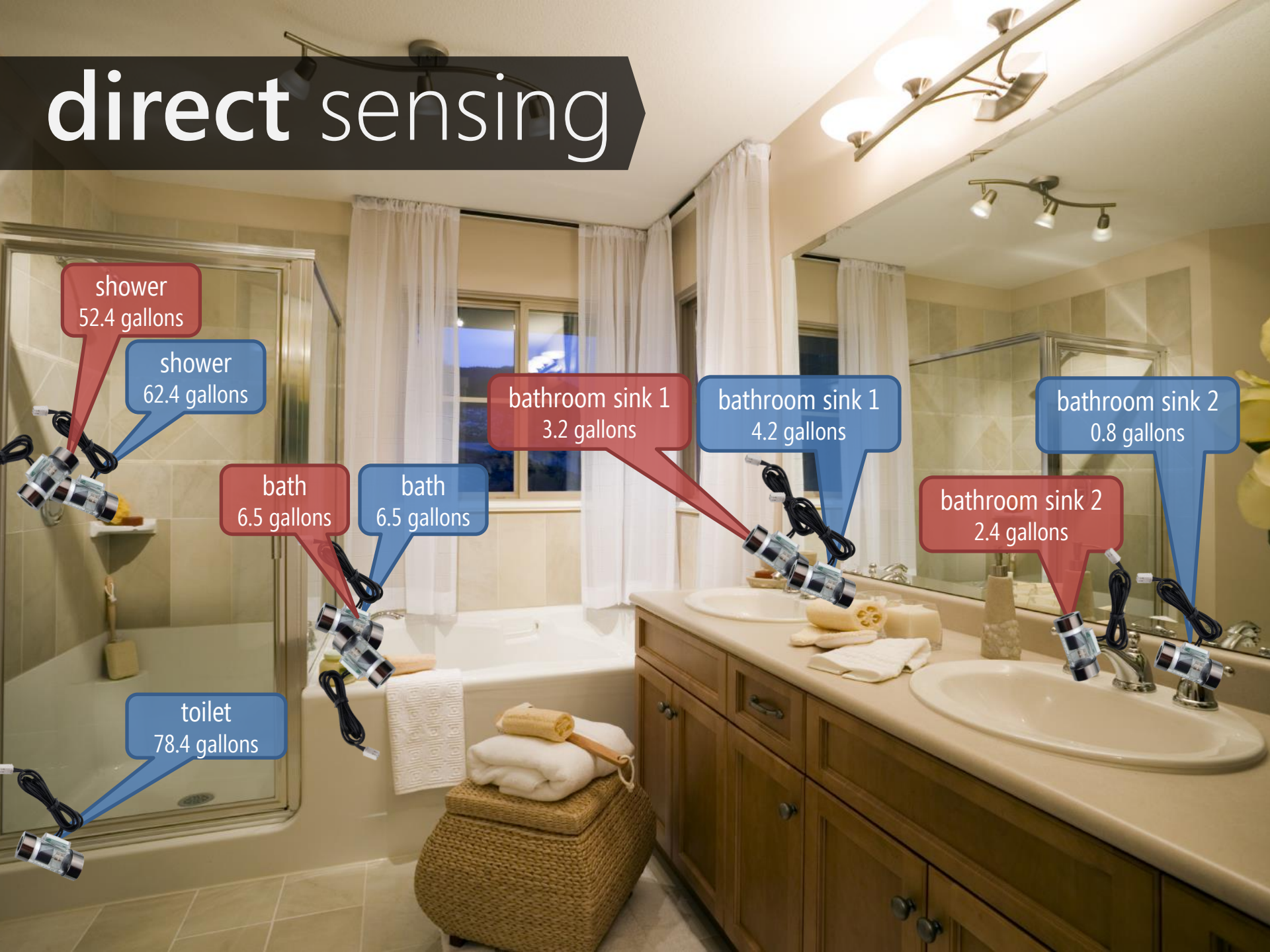
Outdoor
3,212 gals

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

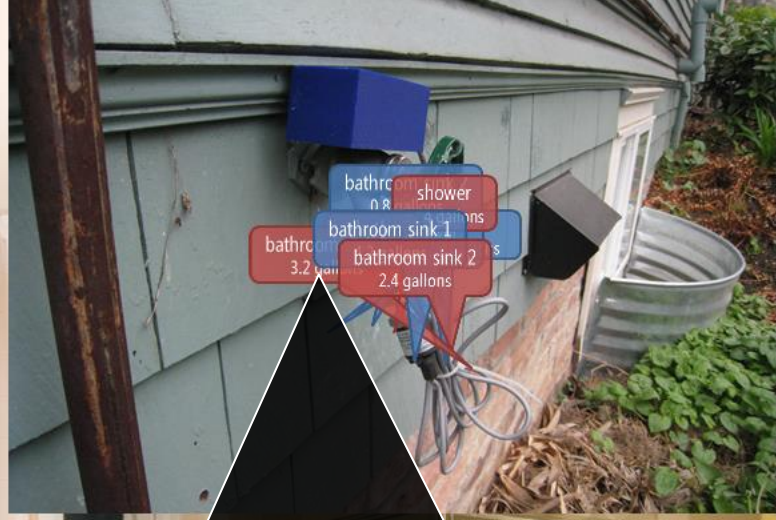
bathroom sink 1
4.2 gallons

bathroom sink 2
2.4 gallons

bathroom sink 2
0.8 gallons

[HydroSense, UbiComp 2009]

indirect sensing



HydroSense attempts to infer fixture-level usage for the entire home from a **single** point.

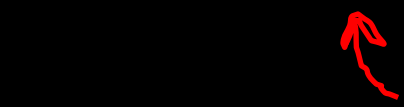
[HydroSense, UbiComp 2009]

This data presents new, rich opportunities for...

eco-feedback

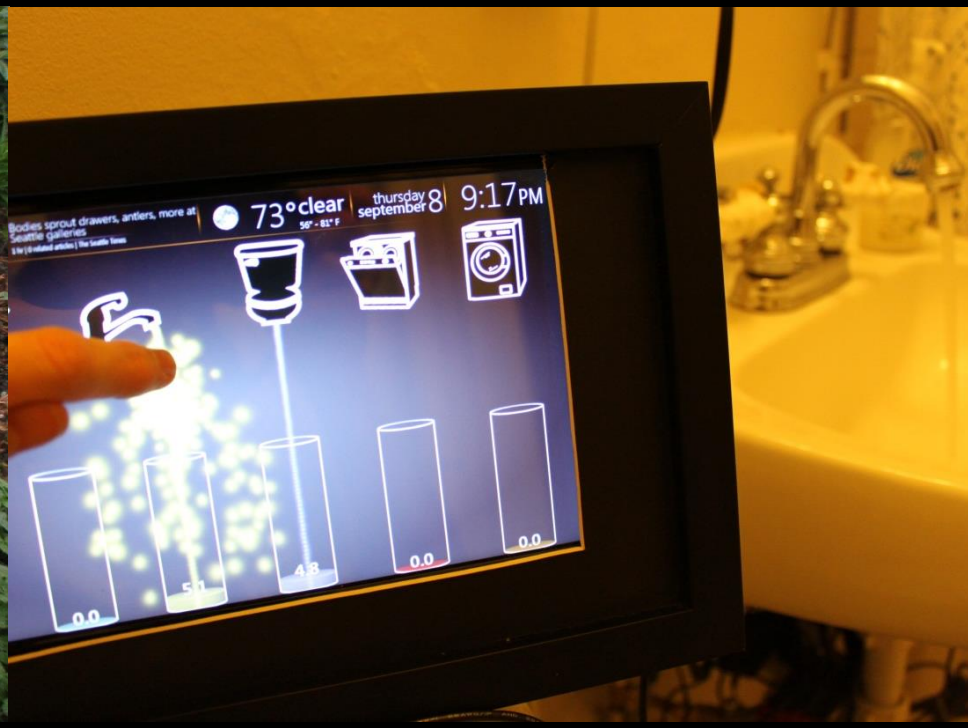
sensing and visualizing behavior to reduce environmental impact

What do we do with **all this data**?



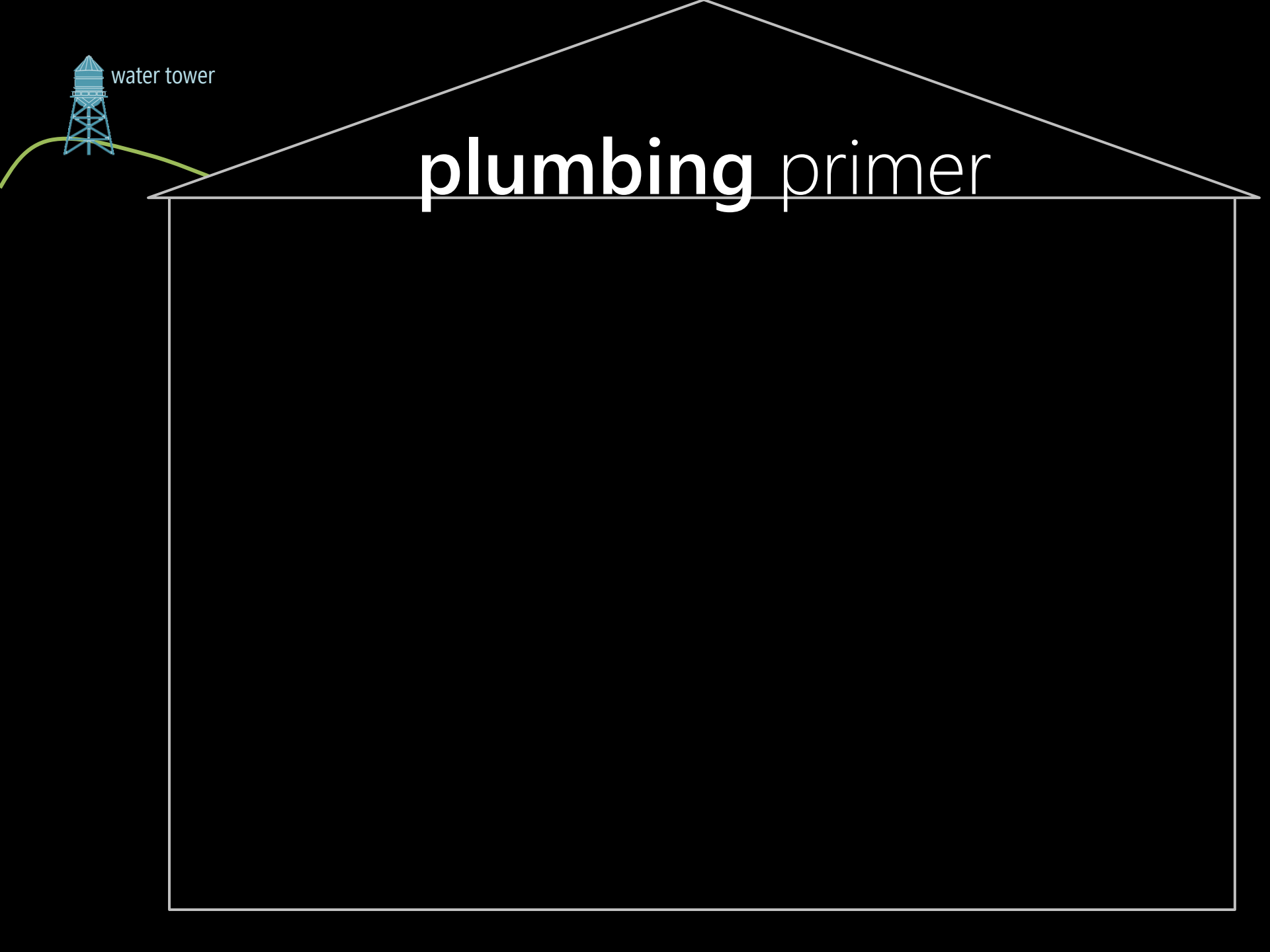
How should we approach this design process?

HydroSense + **Reflect**$_2$O

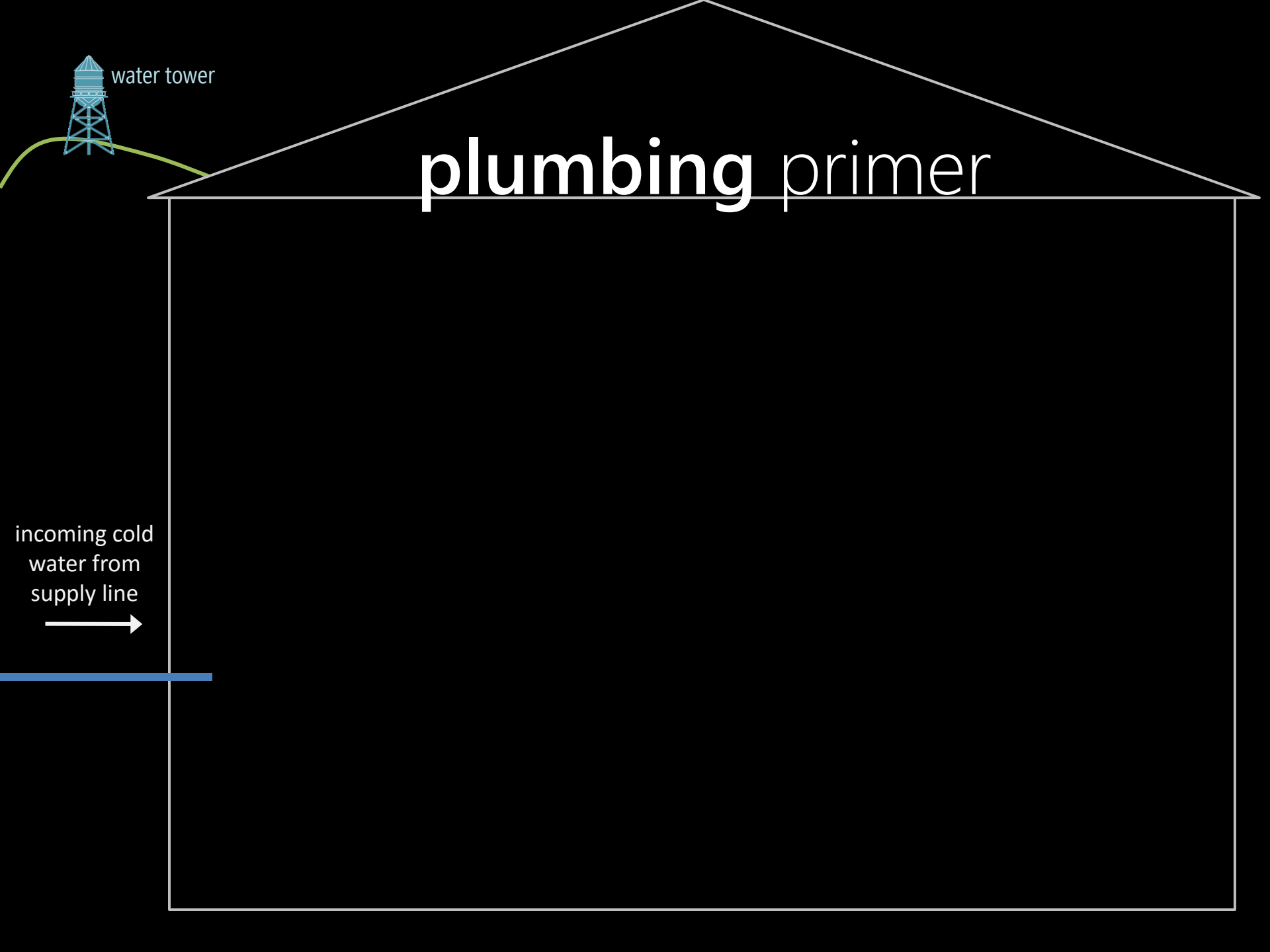


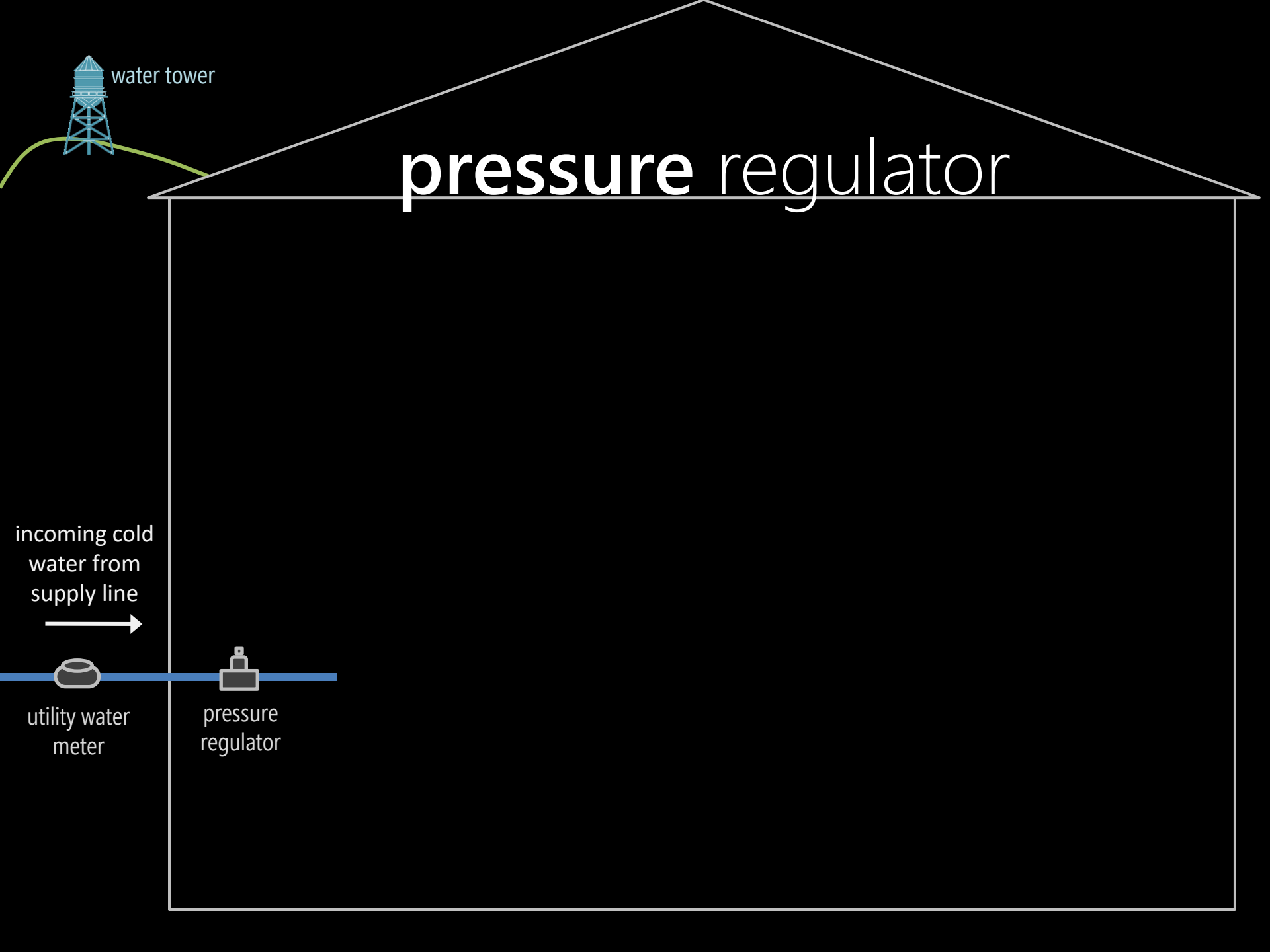
sensingfeedback

brief plumbing primer

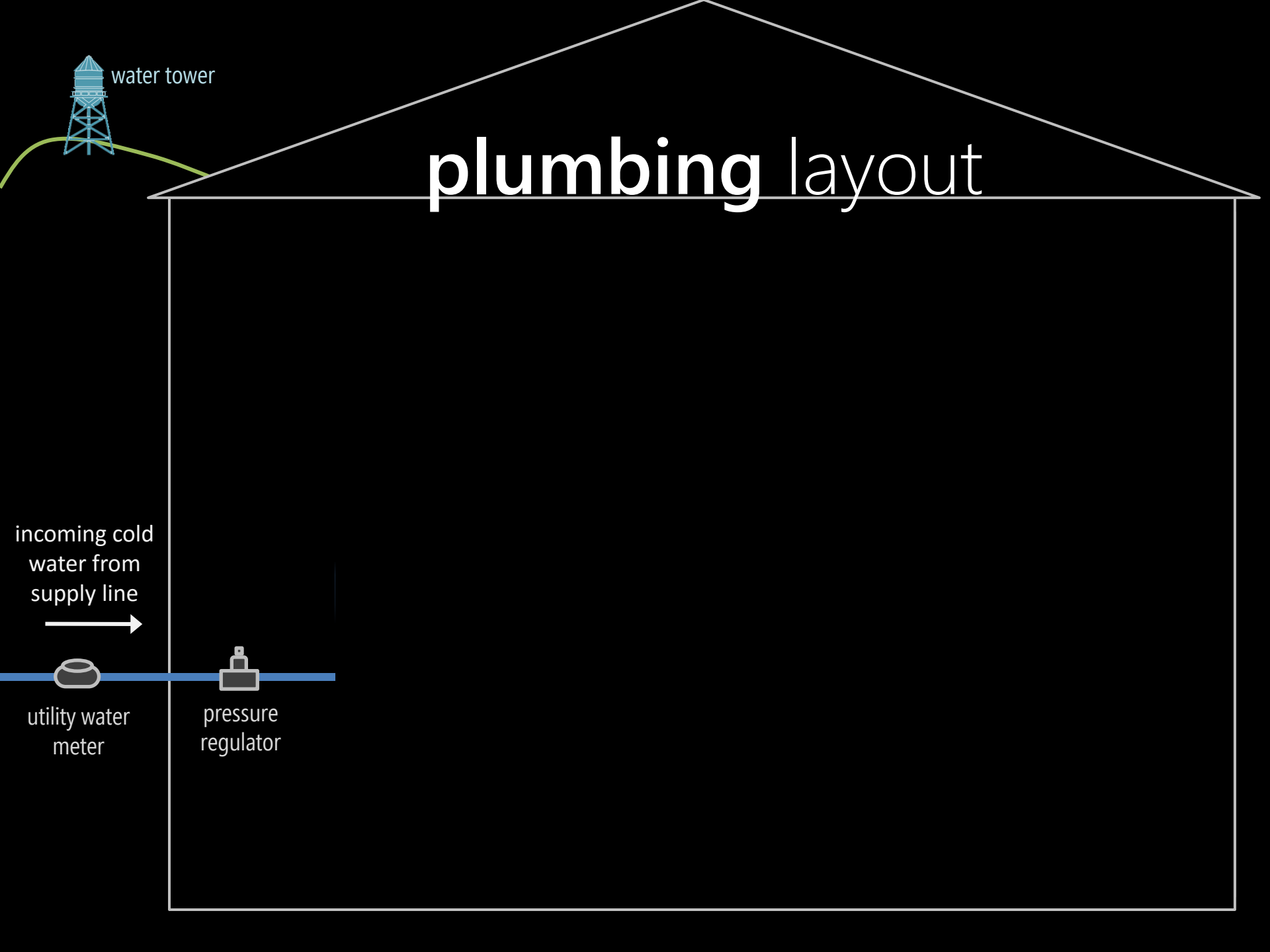


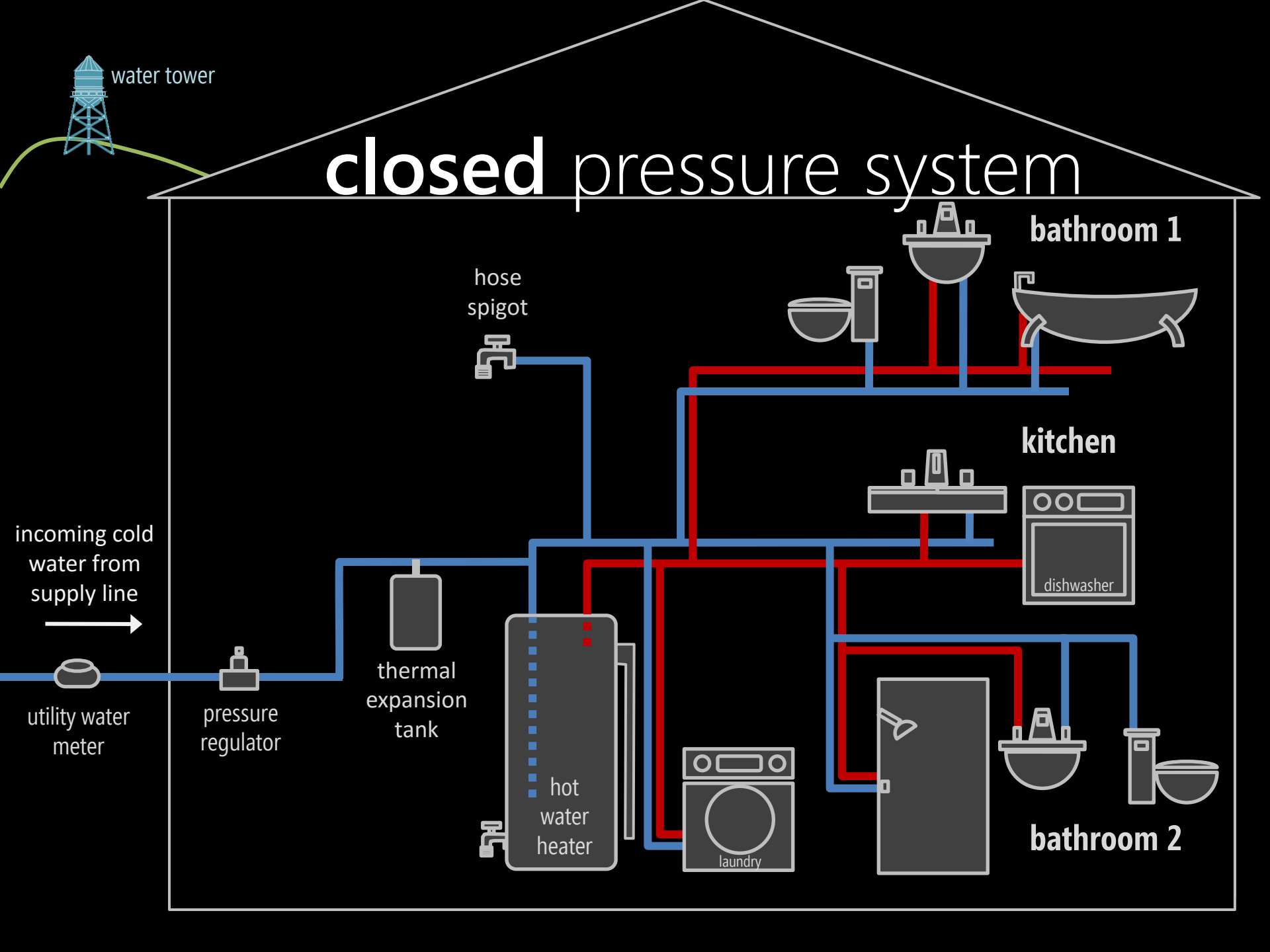
plumbing primer

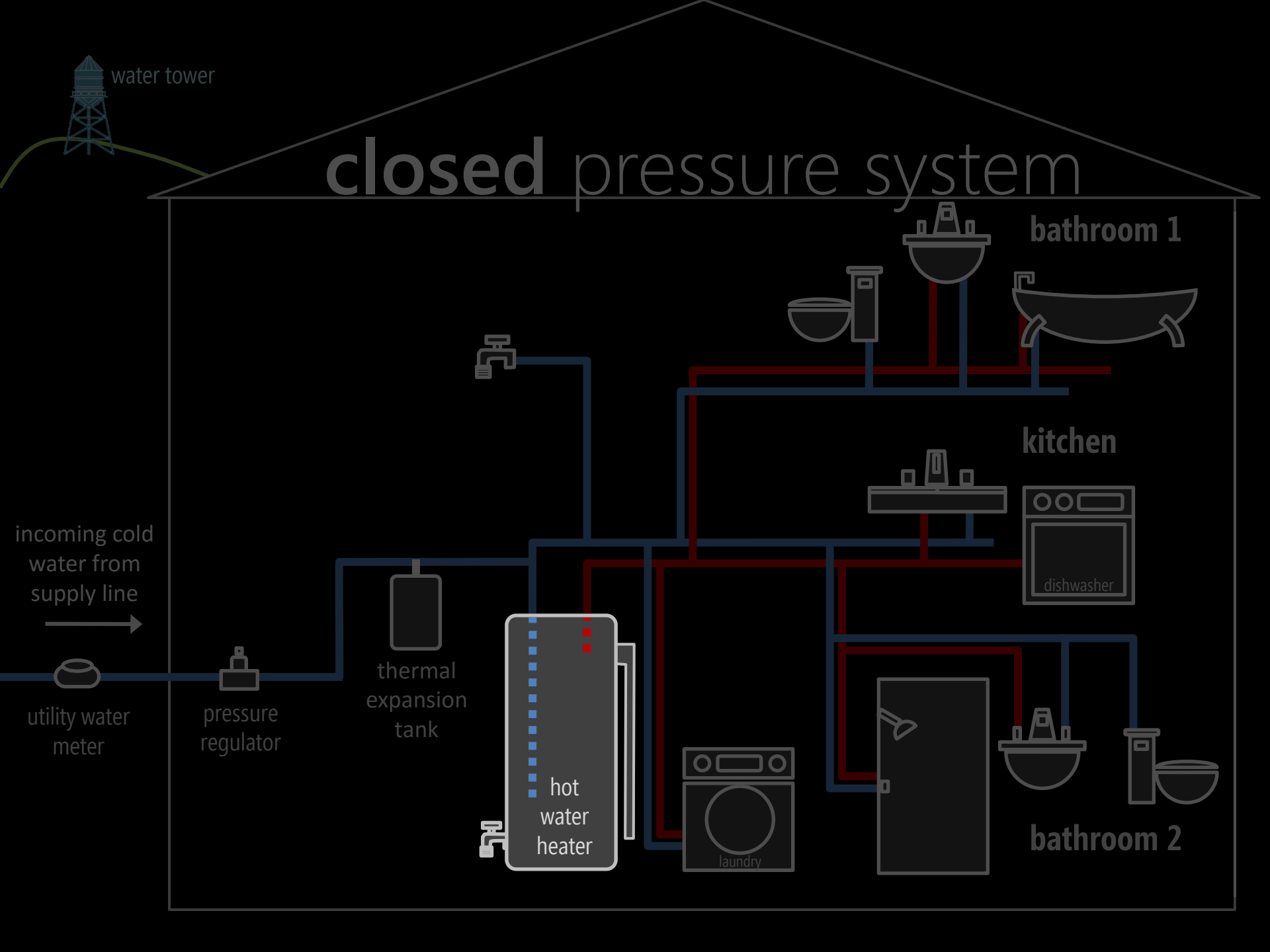

water tower
plumbing primer
incoming cold water from supply line

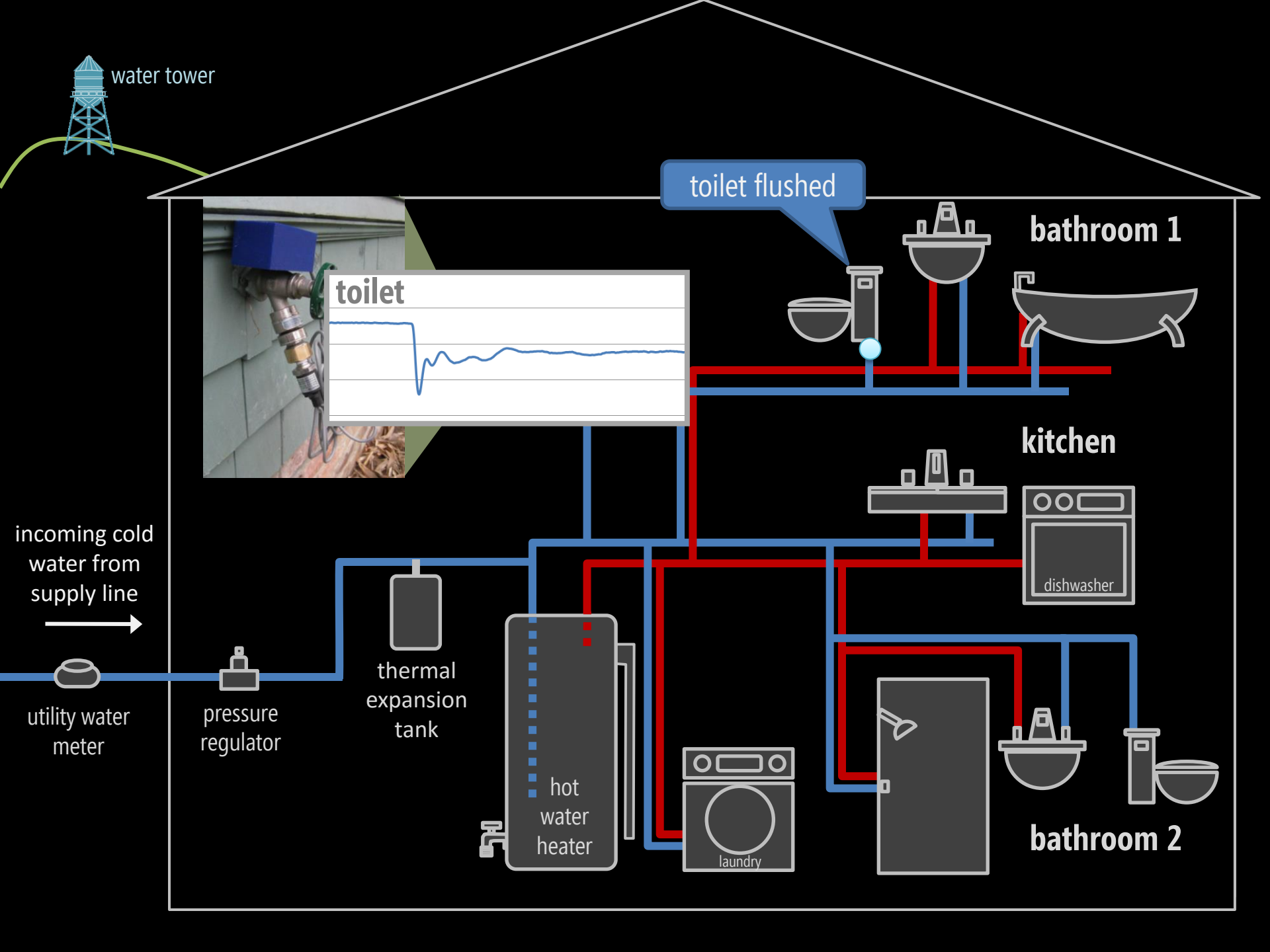

water tower
pressure regulator
incoming cold water from supply line
utility water meter
pressure regulator

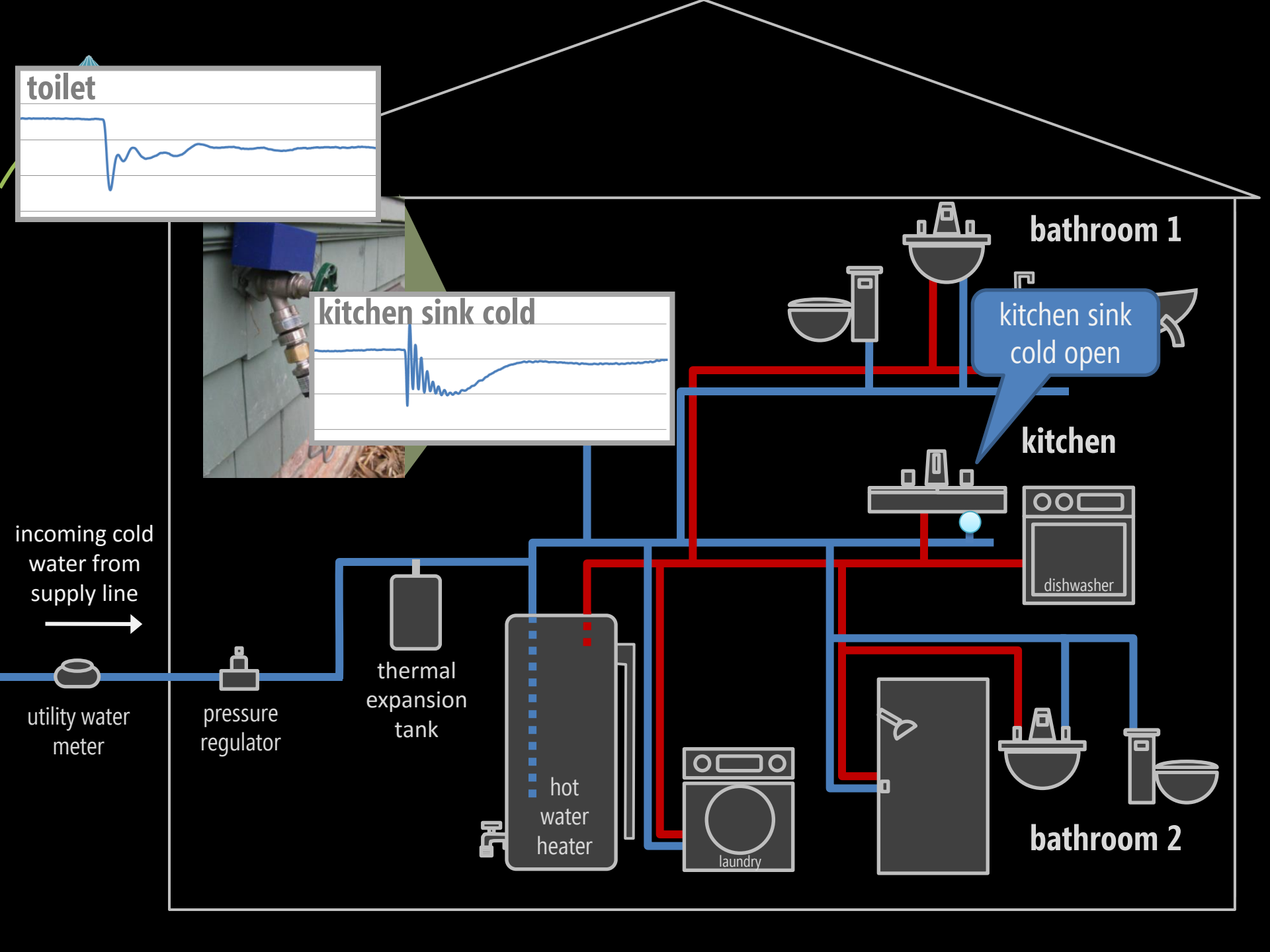
plumbing layout

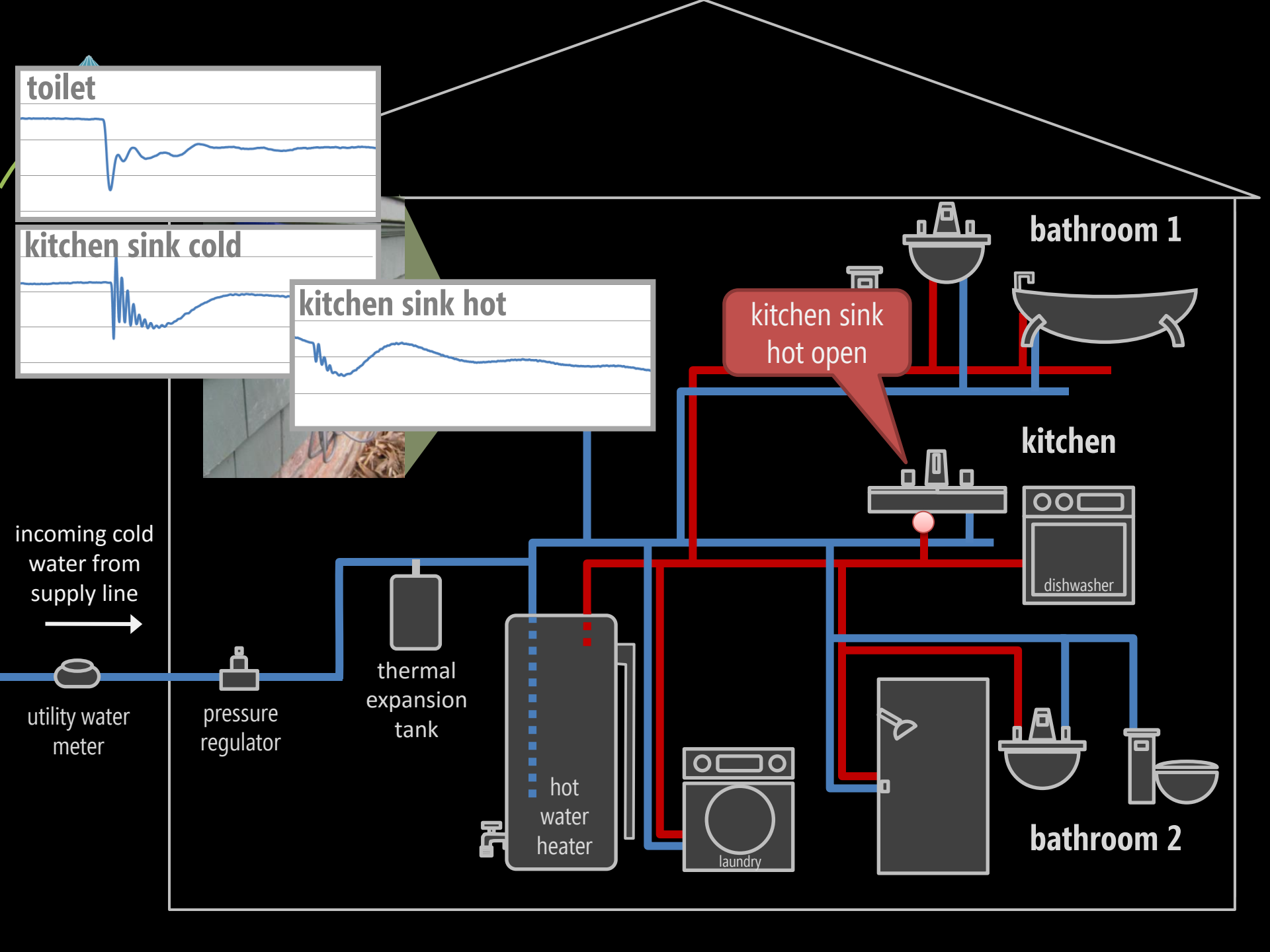


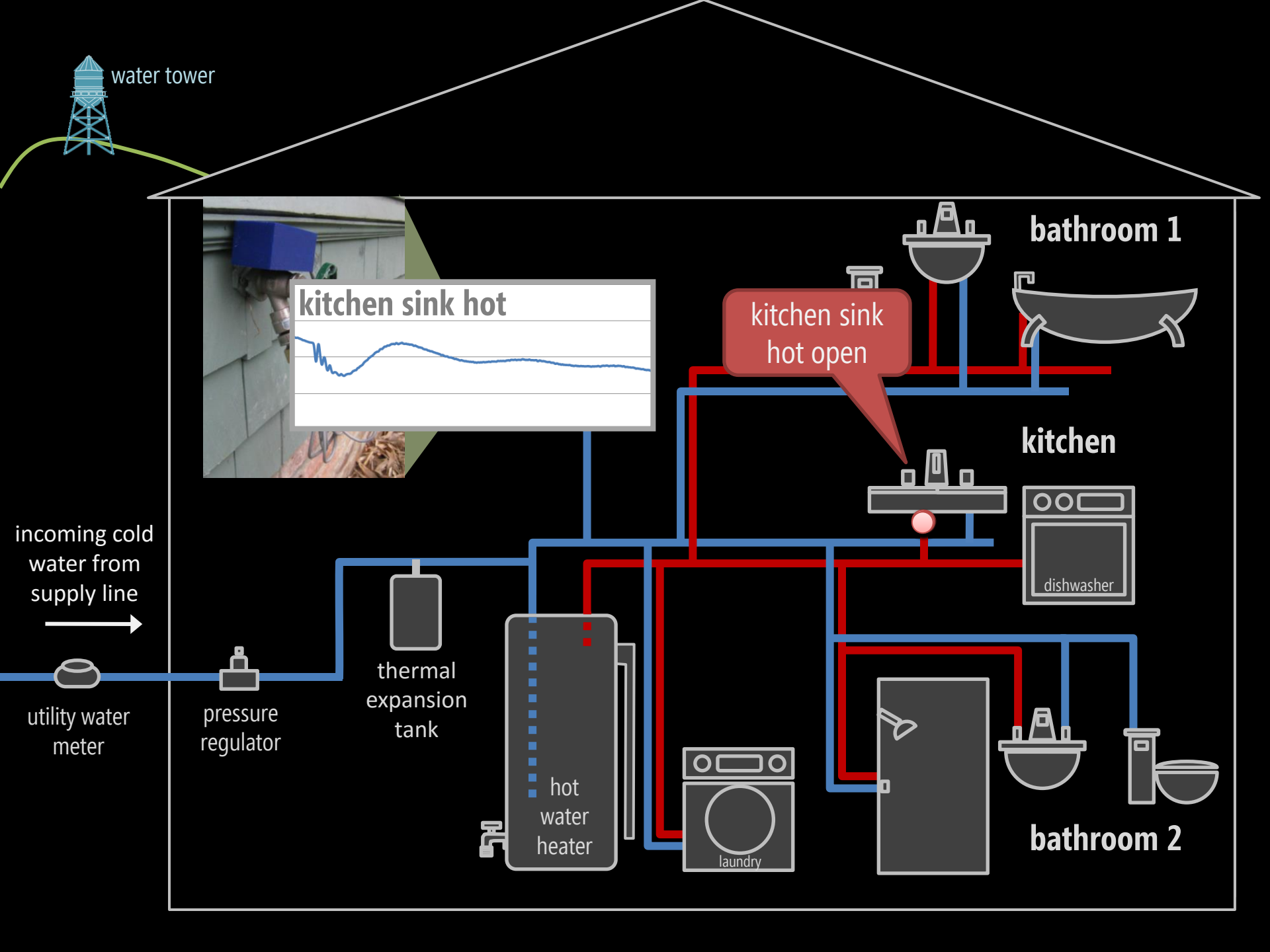

water tower
closed pressure system
bathroom 1
hose spigot
kitchen
dishwasher
incoming cold water from supply line
utility water meter
pressure regulator
thermal expansion tank
hot water heater
laundry
bathroom 2

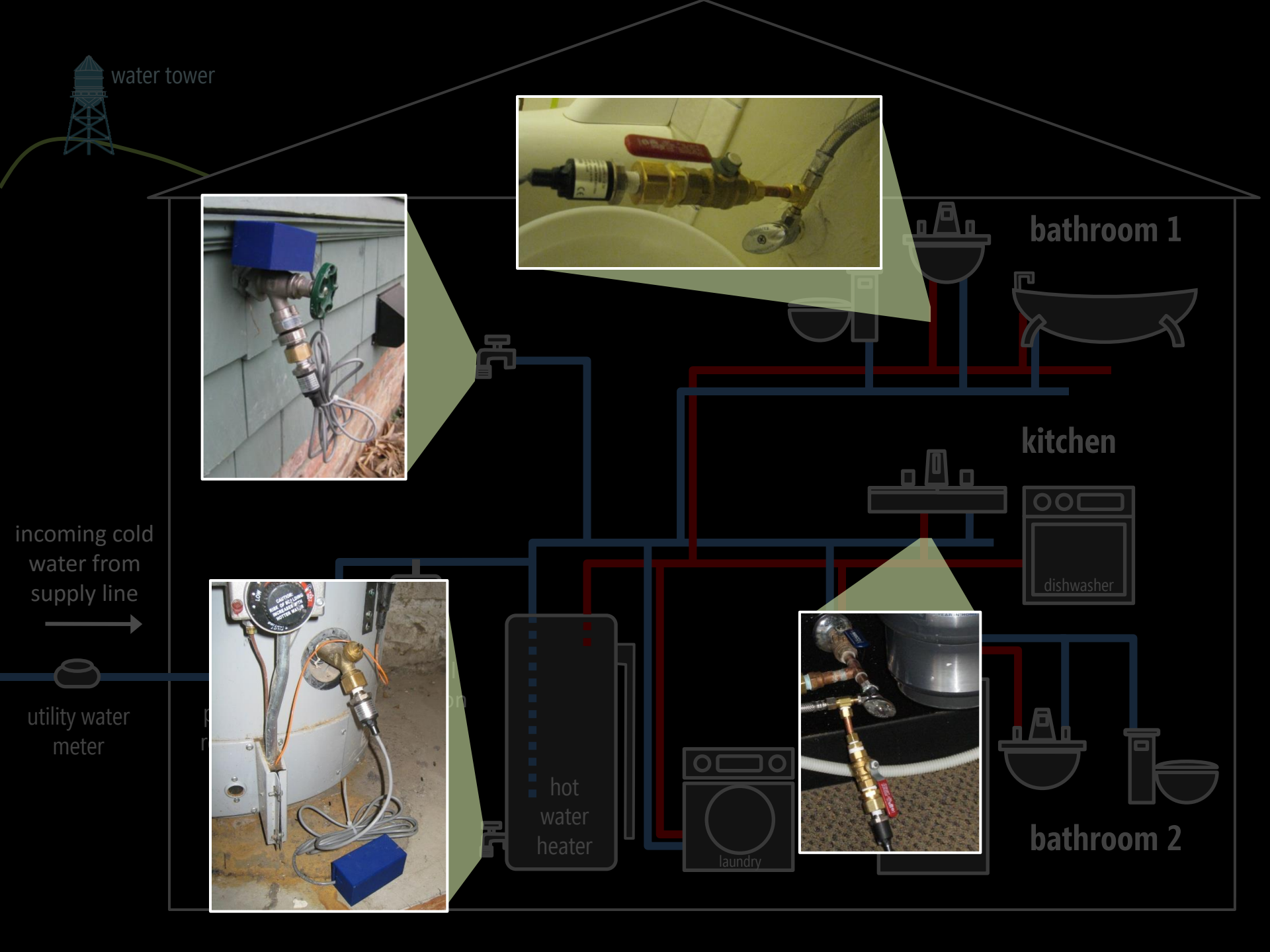

water tower
closed pressure system
bathroom 1
kitchen
dishwasher
incoming cold water from supply line
utility water meter
pressure regulator
thermal expansion tank
hot water heater
laundry
bathroom 2


water tower
toilet flushed
bathroom 1
toilet
kitchen
dishwasher
incoming cold water from supply line
utility water meter
pressure regulator
thermal expansion tank
hot water heater
laundry
bathroom 2

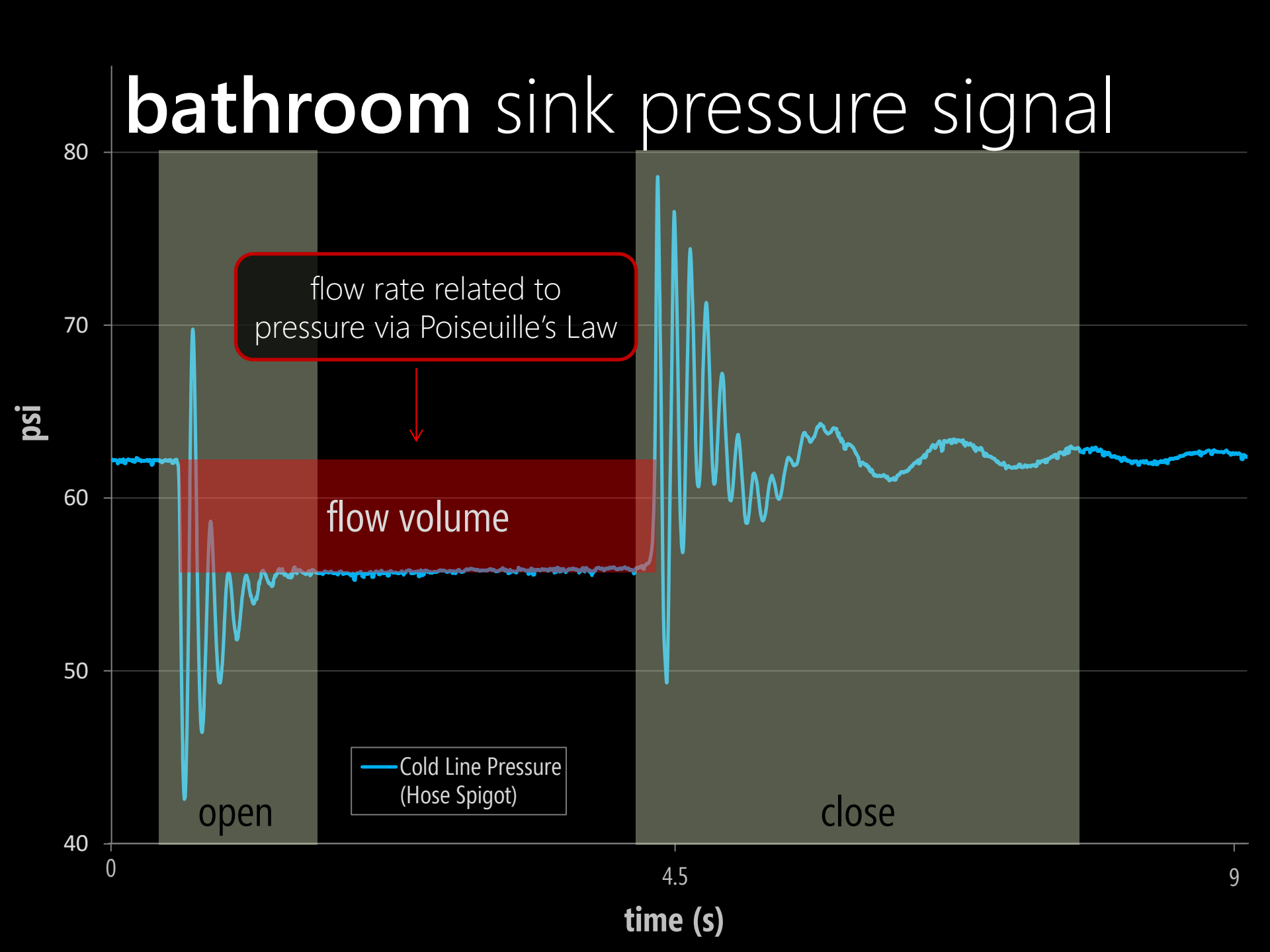

toilet
kitchen sink cold
bathroom 1
kitchen sink cold open
kitchen
dishwasher
incoming cold water from supply line
utility water meter
pressure regulator
thermal expansion tank
hot water heater
laundry
bathroom 2


toilet
kitchen sink cold
kitchen sink hot
bathroom 1
kitchen sink hot open
kitchen
dishwasher
incoming cold water from supply line
utility water meter
pressure regulator
thermal expansion tank
hot water heater
laundry
bathroom 2

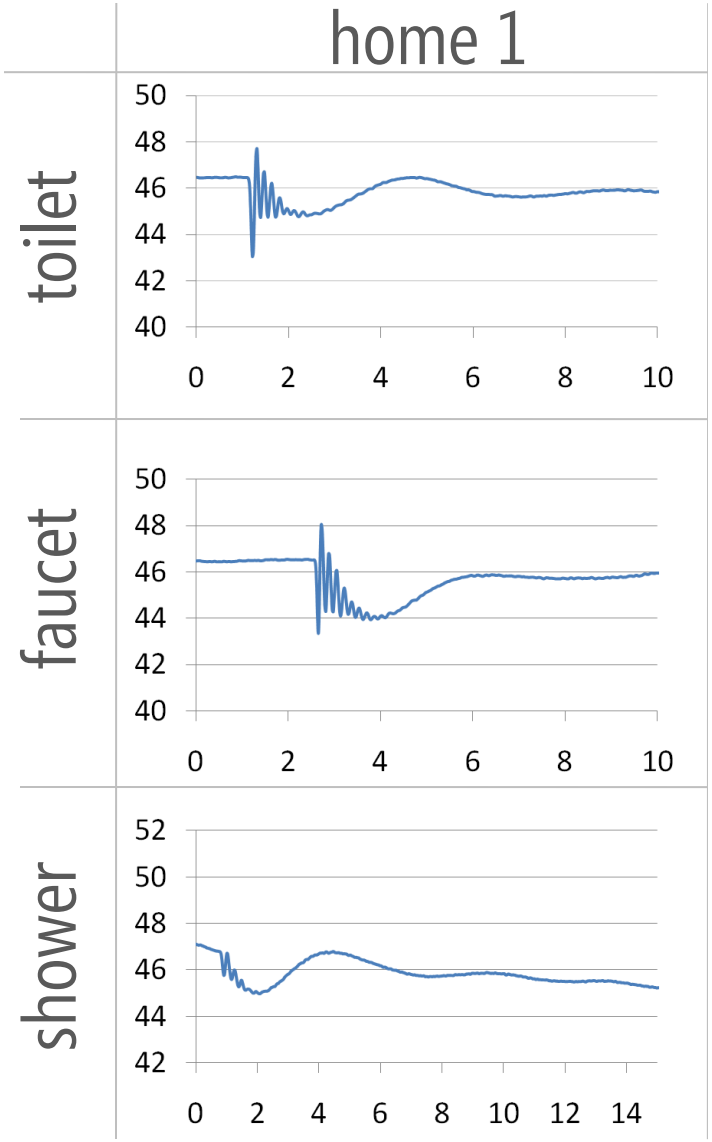

water tower
kitchen sink hot
kitchen sink hot open
bathroom 1
kitchen
dishwasher
incoming cold water from supply line
utility water meter
pressure regulator
thermal expansion tank
hot water heater
laundry
bathroom 2


water tower
bathroom 1
kitchen
dishwasher
incoming cold water from supply line
utility water meter
hot water heater
laundry
bathroom 2


bathroom sink pressure signal
80
70
60
50
40
psi
0
4.5
9
time (s)

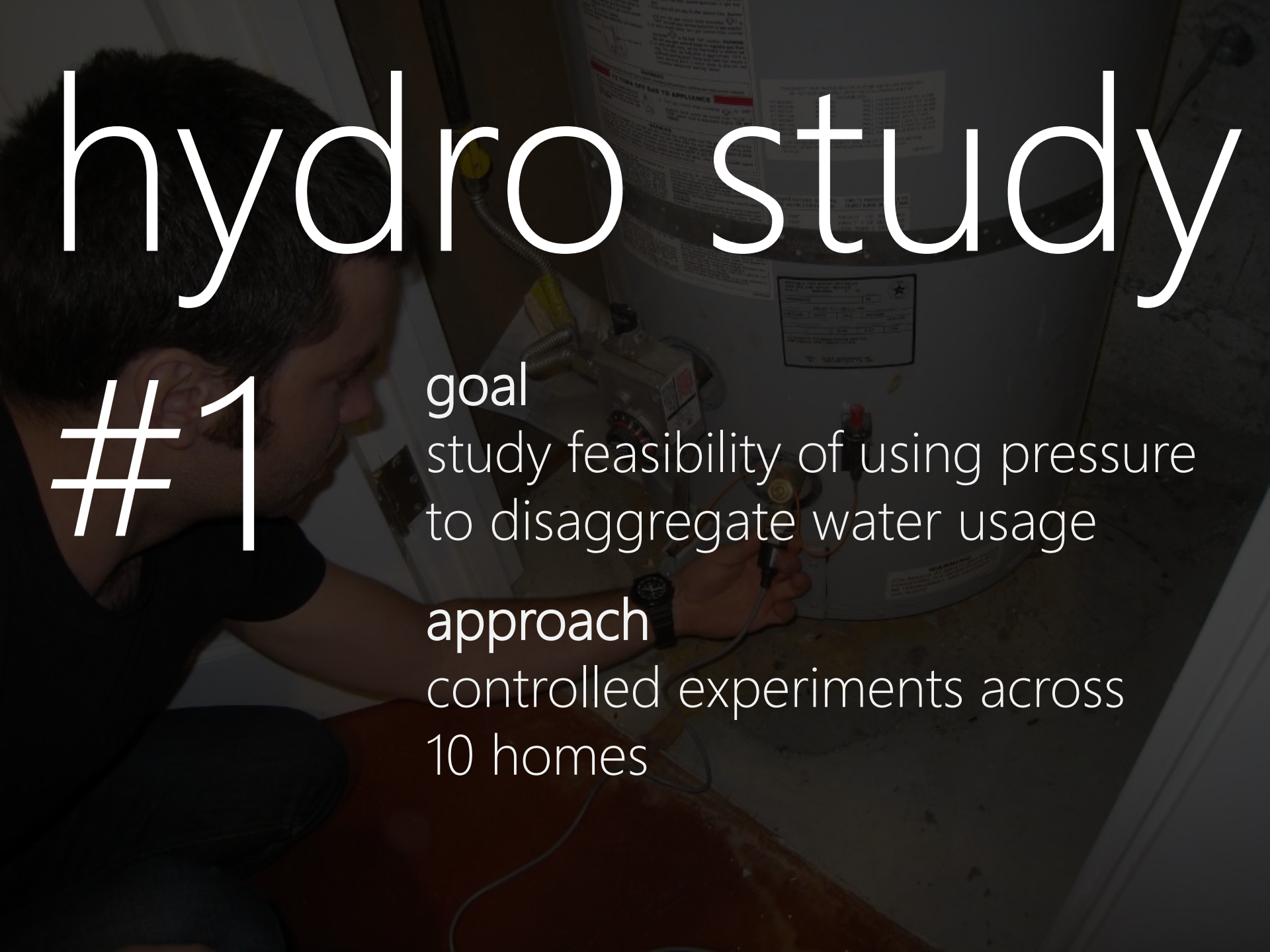

bathroom sink pressure signal
80
70
60
50
40
psi
flow rate related to
pressure via Poiseuille's Law
flow volume
Cold Line Pressure
(Hose Spigot)
open
close
0
4.5
9
time (s)

example open events



signature dependent on:

- fixture type
- valve type
- valve location in home

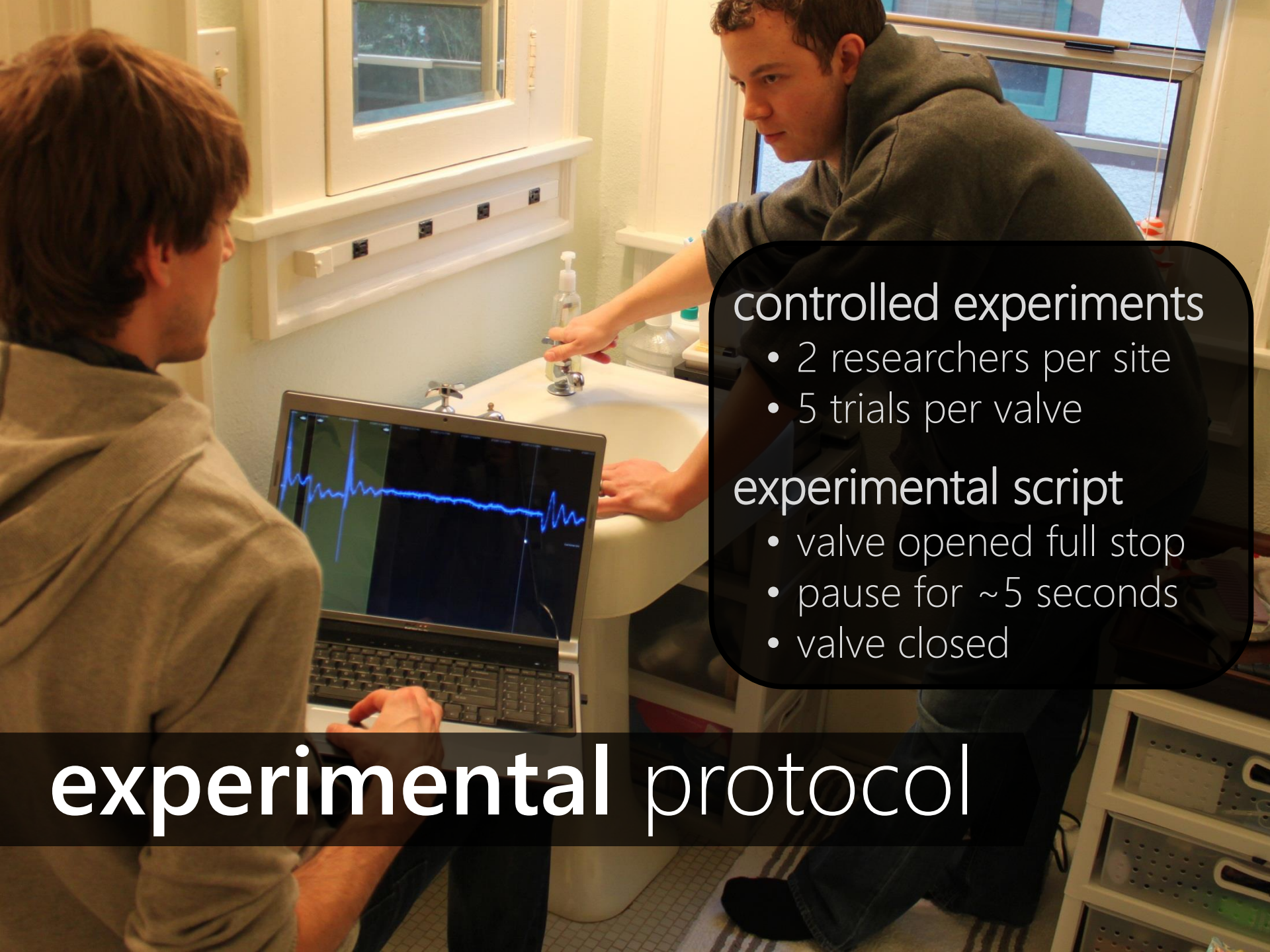


hydro study

#1

goal
study feasibility of using pressure to disaggregate water usage

approach
controlled experiments across 10 homes



controlled experiments

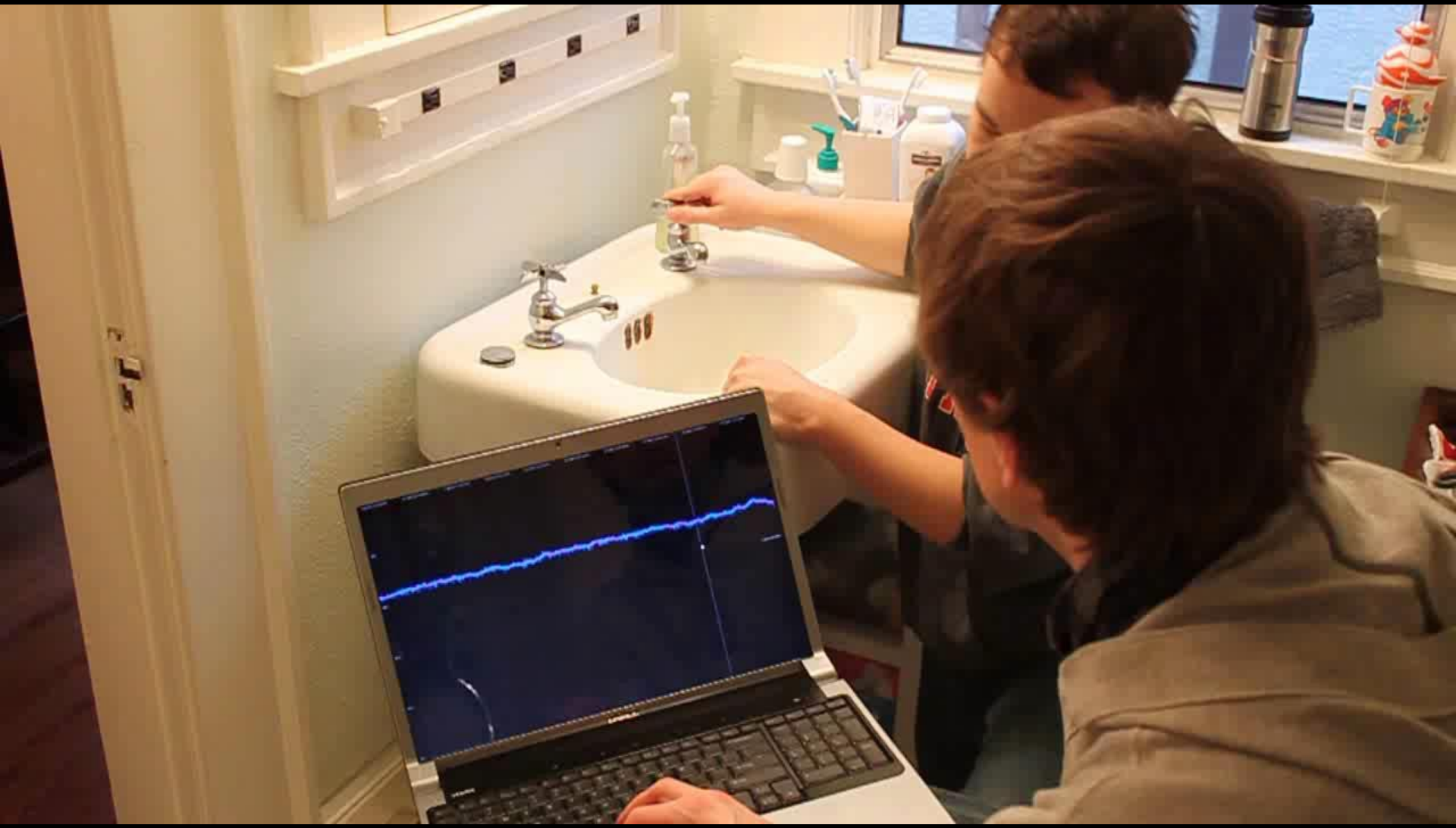
- 2 researchers per site
- 5 trials per valve

experimental script

- valve opened full stop
- pause for ~5 seconds
- valve closed

experimental protocol

controlled data collection



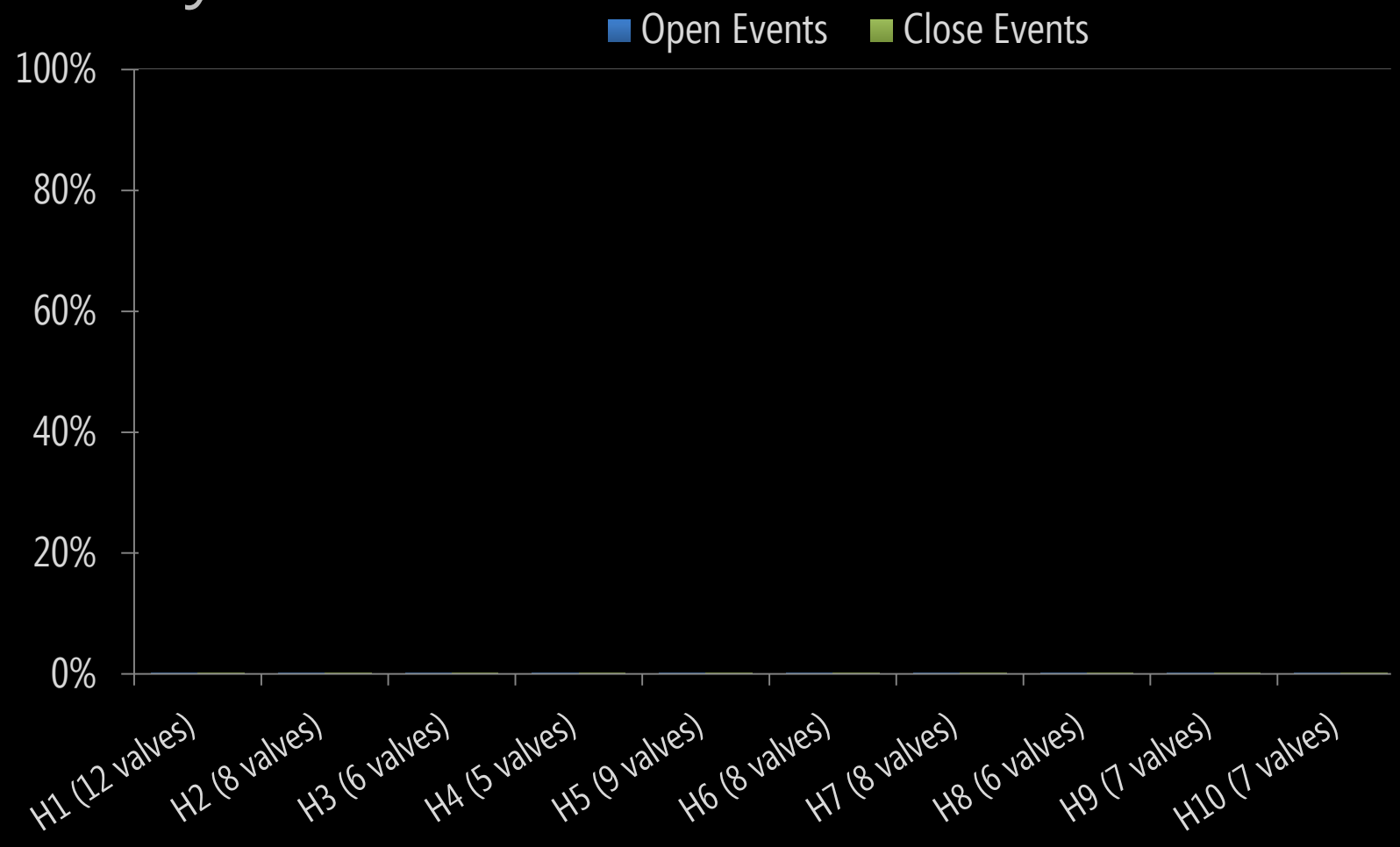
data collection stats

ten test sites

- 706 trials
- 155 flow trials
- 84 total fixtures tested

fixture classification results

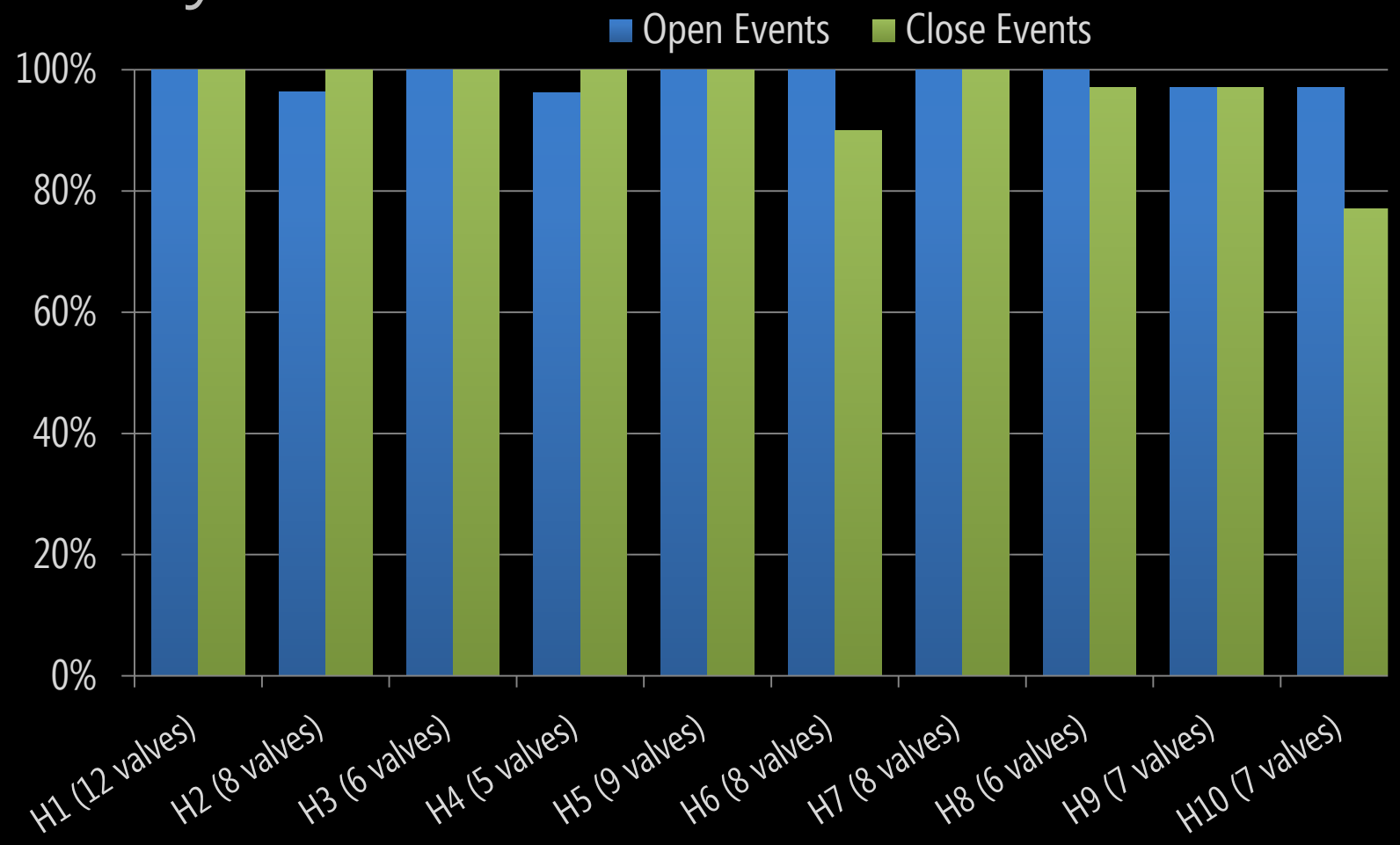
by home



10-fold cross validation

fixture classification results

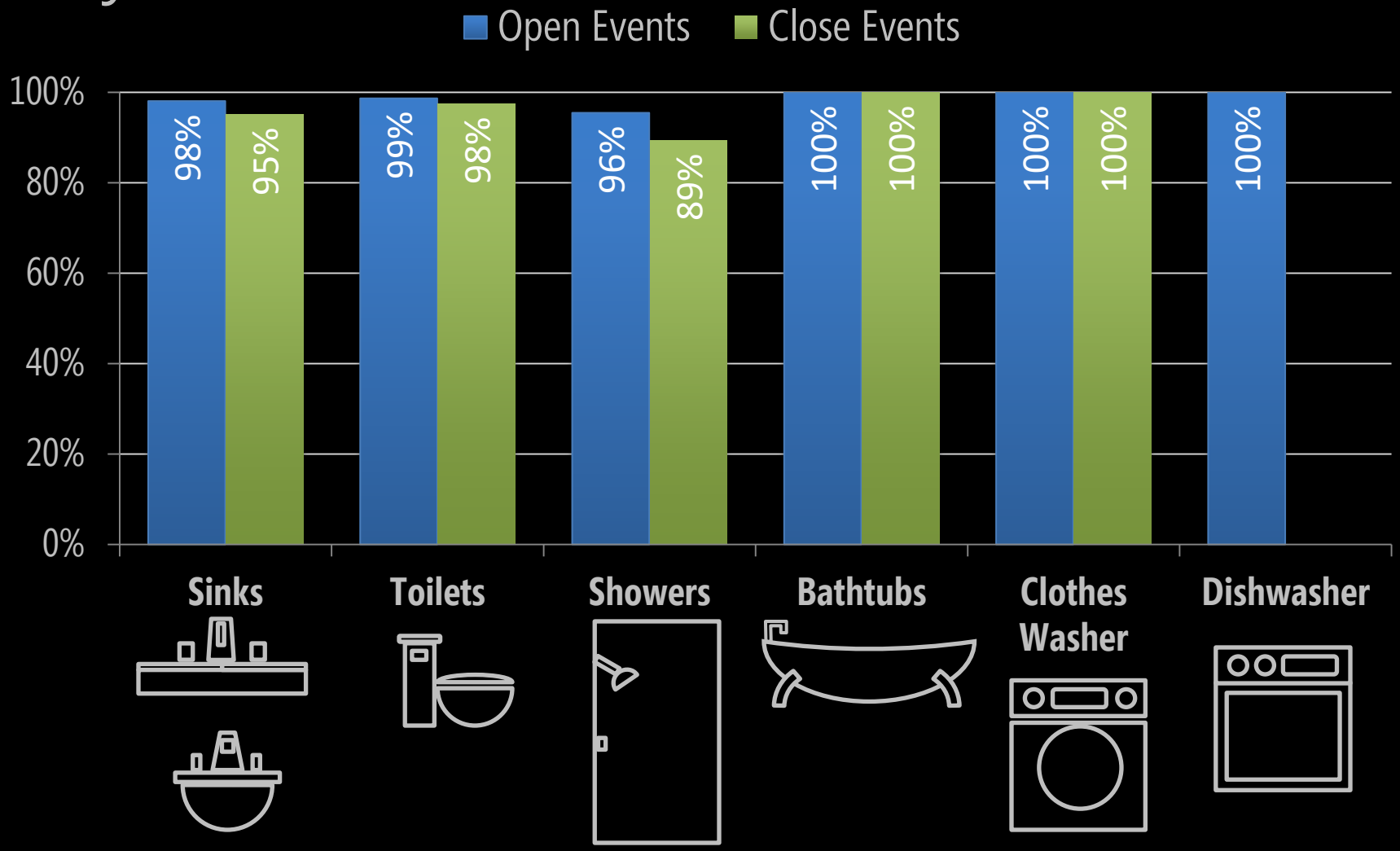
by home

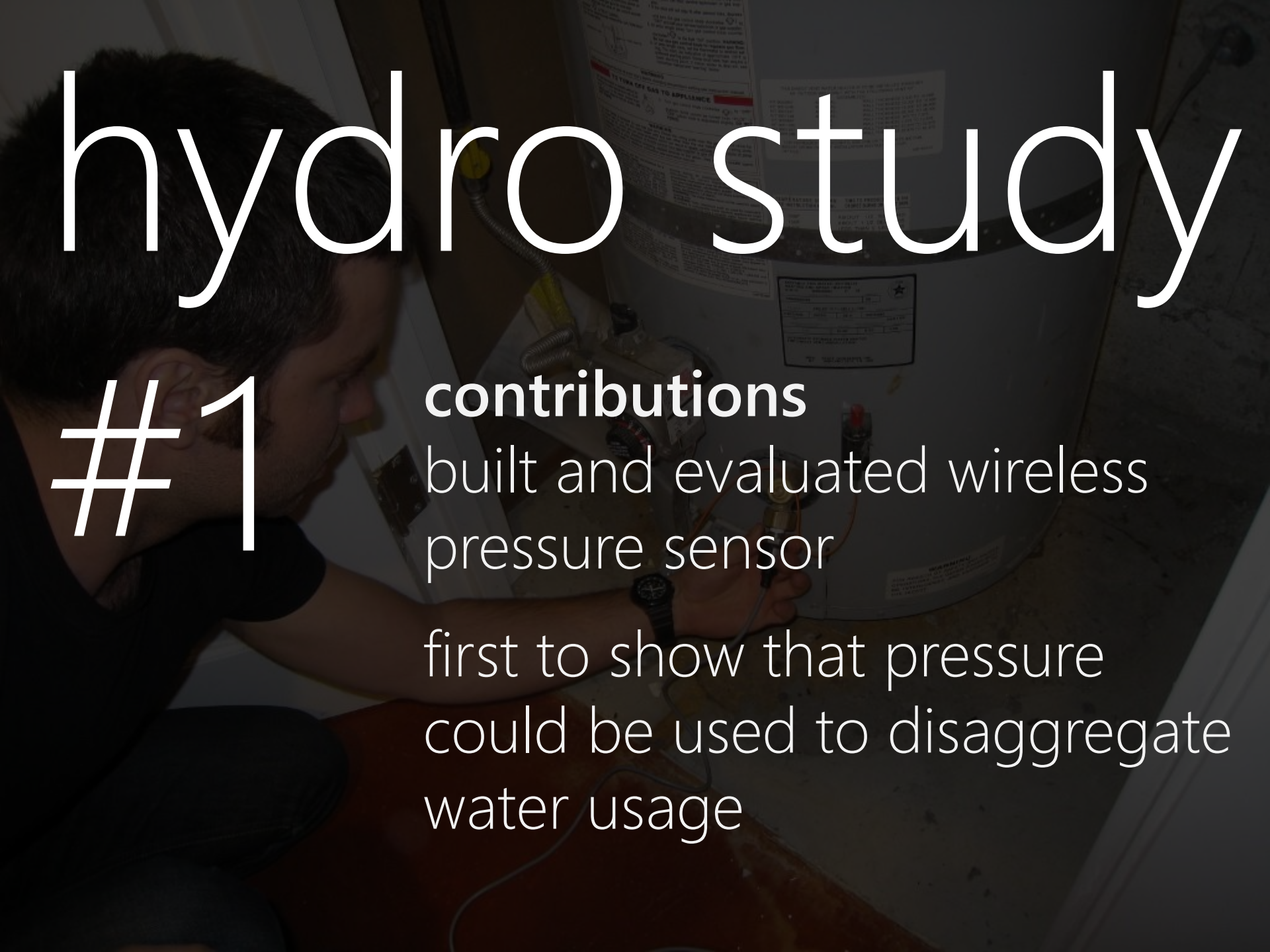


10-fold cross validation

fixture classification results

by fixture





hydro study

#1

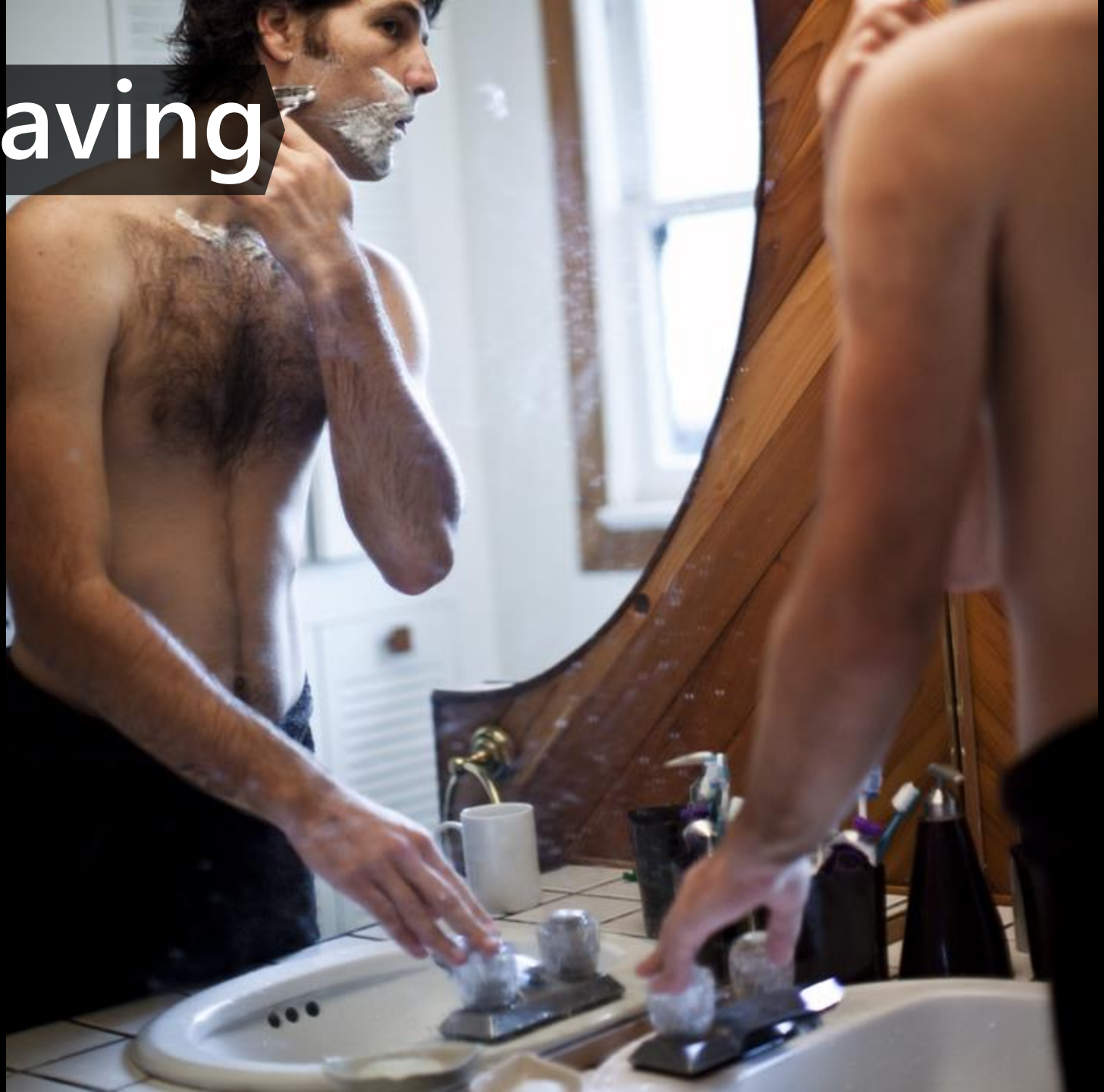
contributions

built and evaluated wireless pressure sensor

first to show that pressure could be used to disaggregate water usage

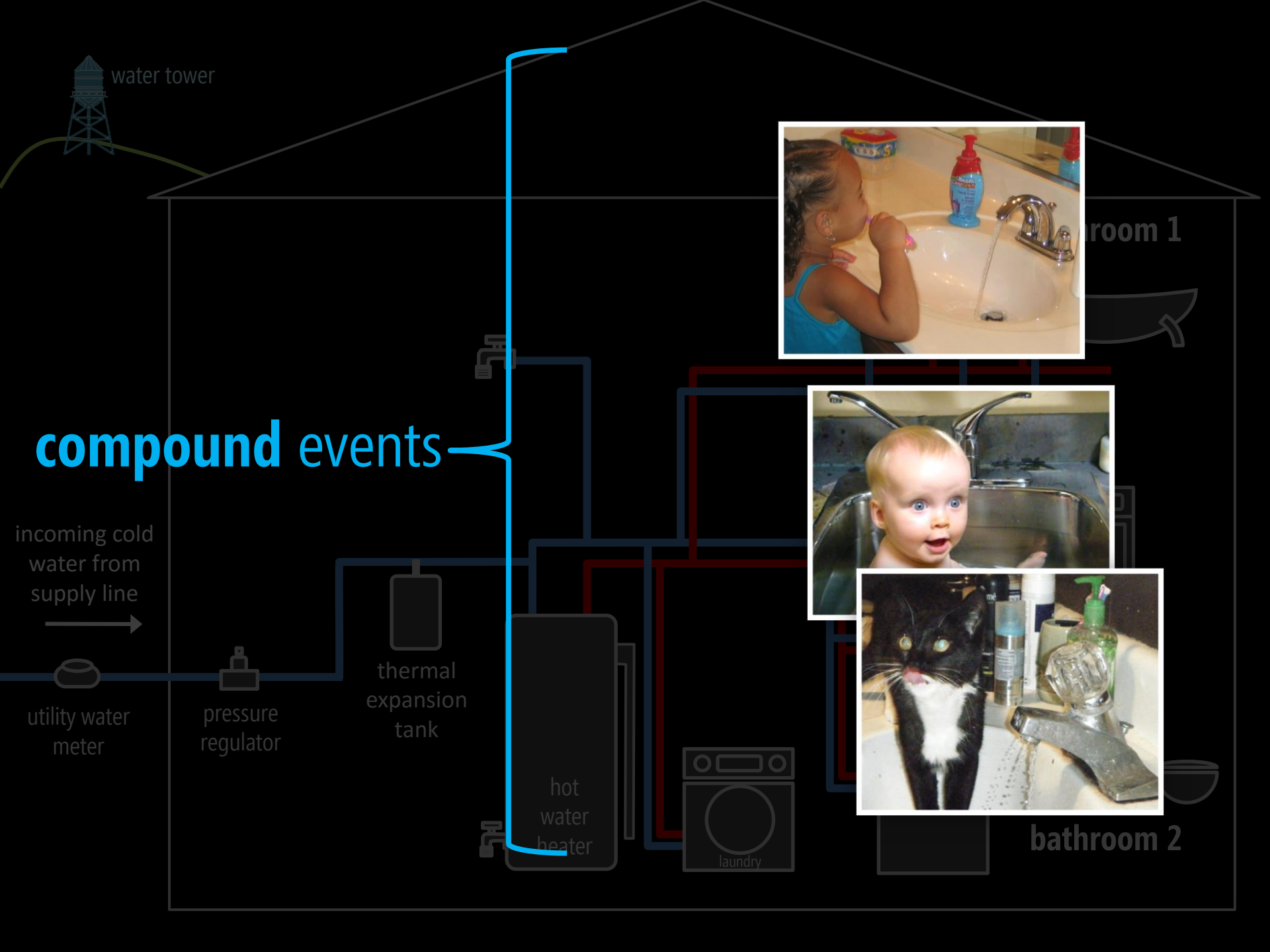

brushing teeth
Huggies
Clean & Fresh
hand soap
savon à mains

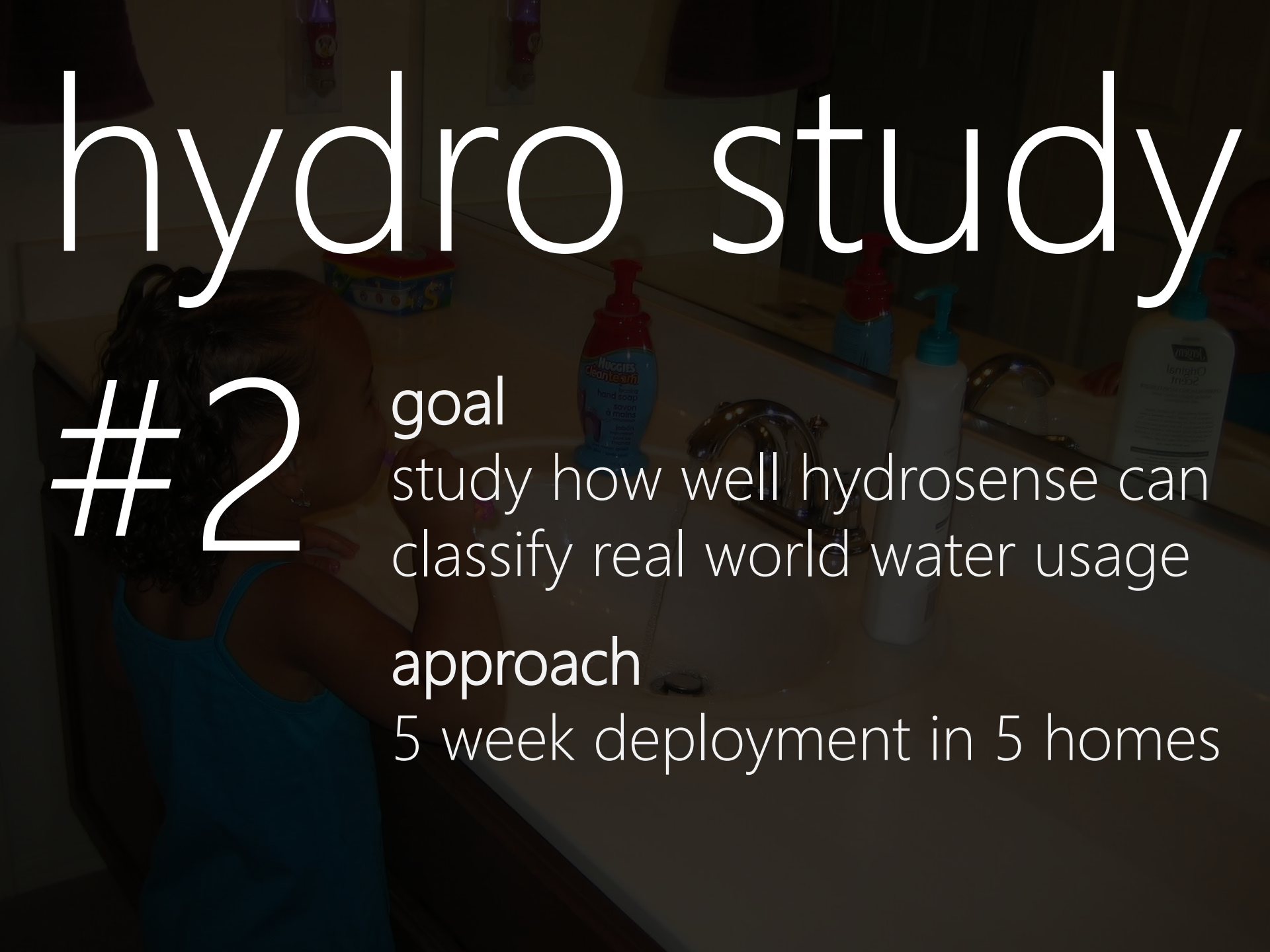
shaving




bathing

paw washing


water tower
compound events
incoming cold water from supply line
utility water meter
pressure regulator
thermal expansion tank
hot water heater
laundry
bathroom 2



hydro study

#2

goal

study how well hydrosense can classify real world water usage

approach

5 week deployment in 5 homes


in the first study, pressure waves were **manually** annotated with "ground truth labels" describing:
• the fixture used
• the water temperature


I’m about to flush the toilet!
Awesome! Marked it. Thanks Mr. Johnson

how

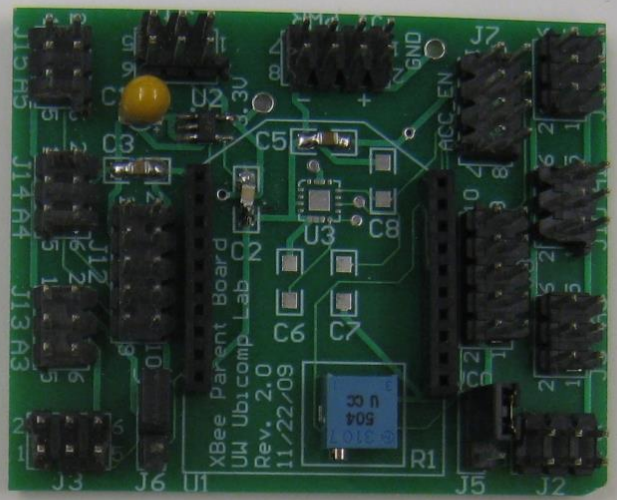
collect ground truth labels of

can we record **real-world** water usage?

after many failed solutions

custom ground truth data collection system

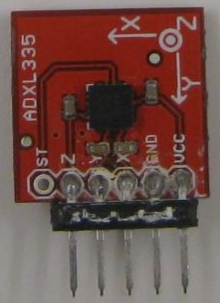
xbee wireless modem



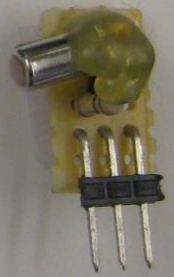
fixture usage sensor board

hall effect

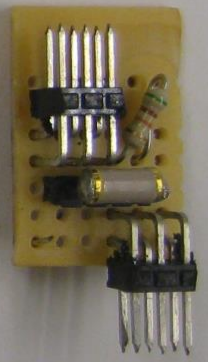
reed switch



3-axis accelerometer



unidirectional ball switch



omnidirectional ball switch

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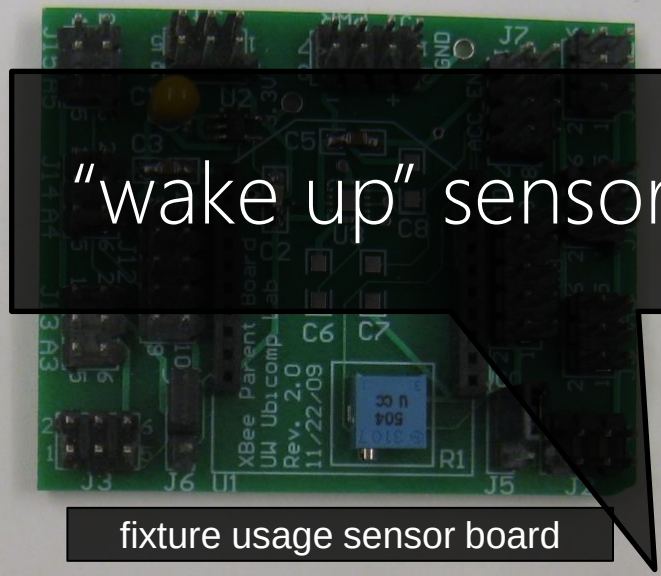

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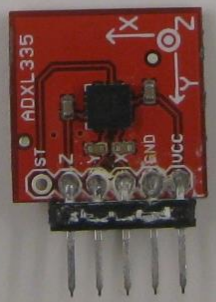

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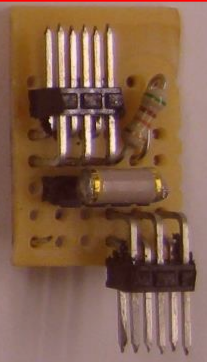
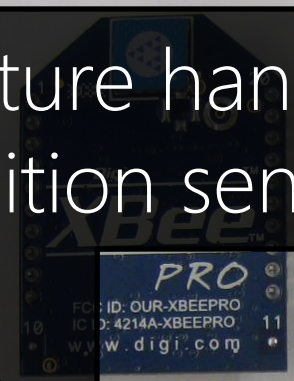


omnidirectional ball switch

custom ground truth data collection system

fixture handle position sensors



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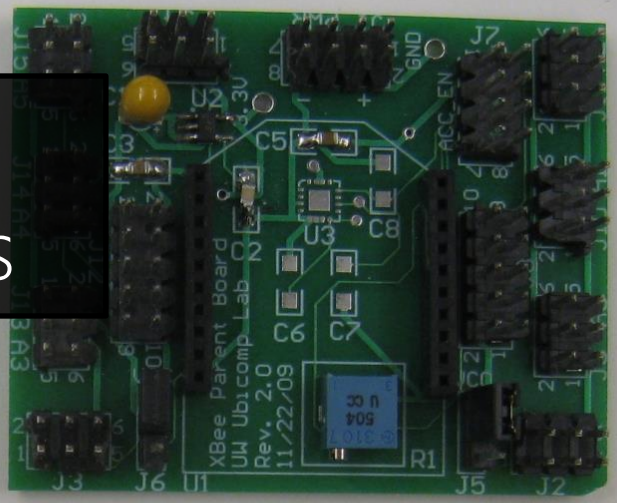

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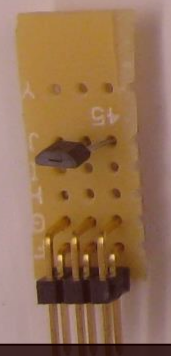

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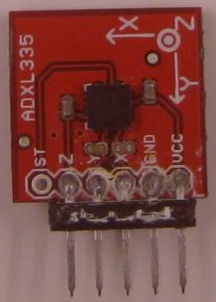

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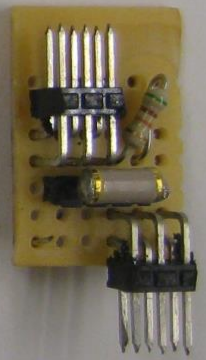
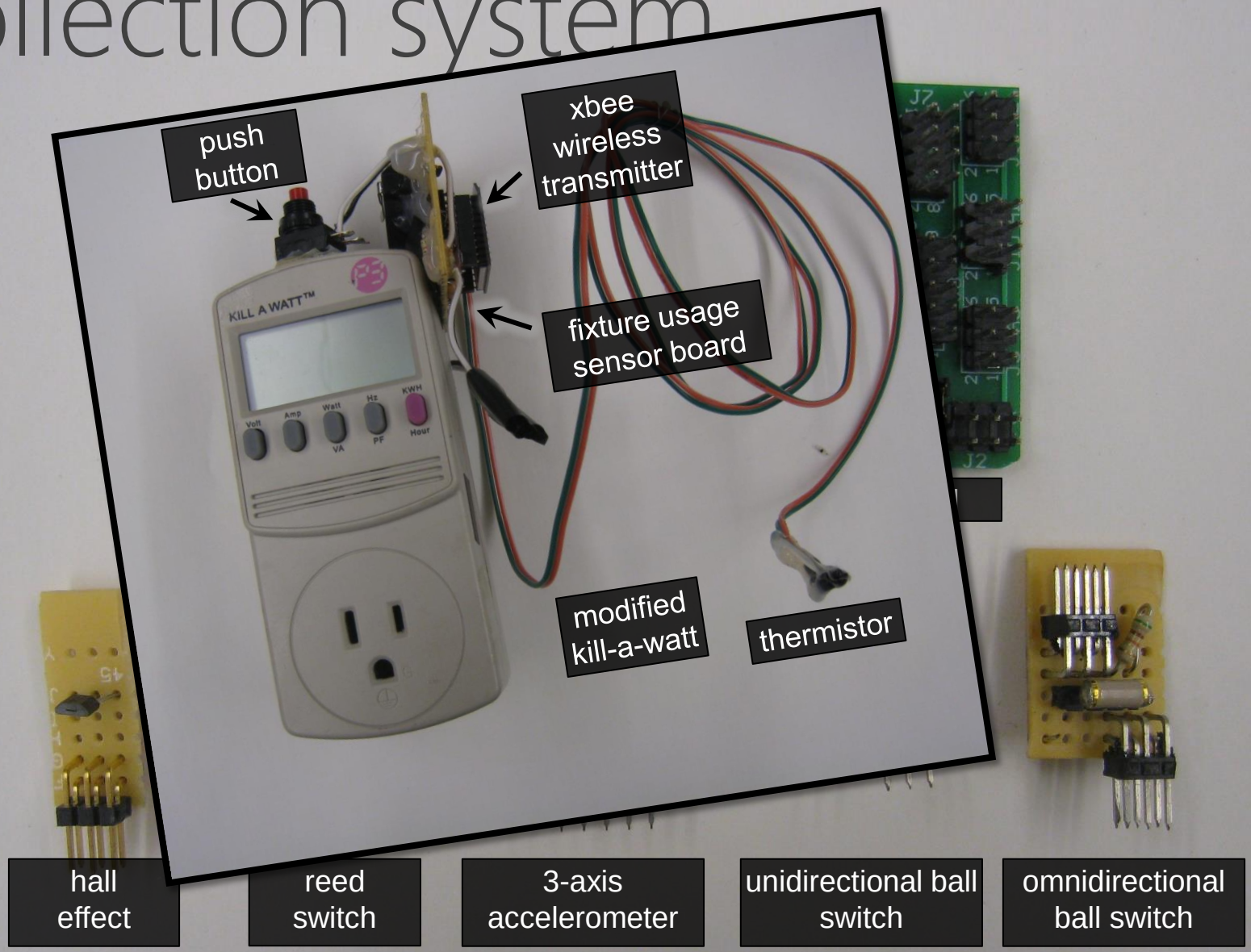
unidirectional ball switch



omnidirectional ball switch


accelerometer
Accelerometer
& Ball Switch
Taped on

custom ground truth data collection system

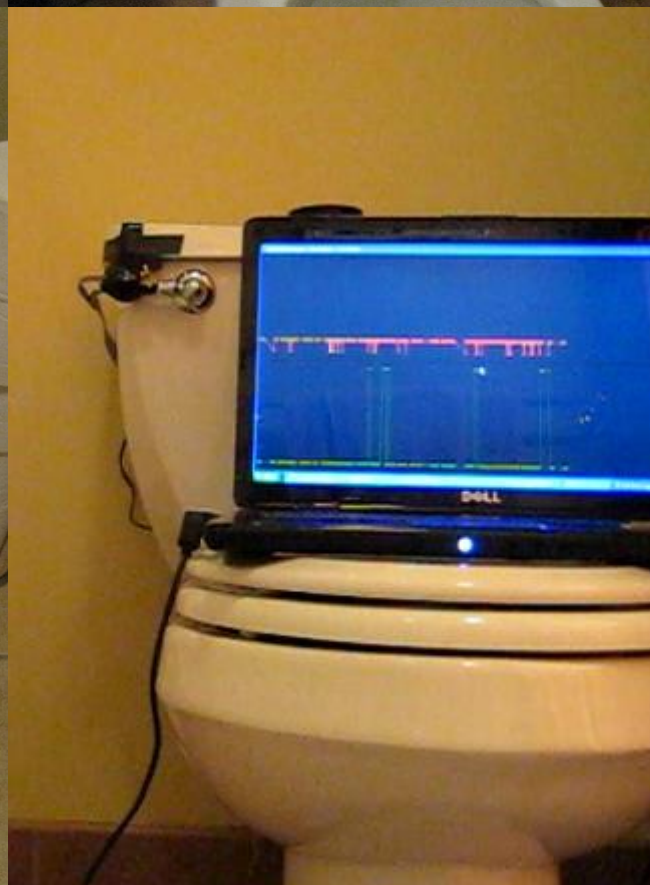


deployment sites

					
residents	2	2	4	2	2
size	3000 sqft	750 sqft	1200 sqft	700 sqft	750 sqft
floors	3	2	2	3rd flr	6th flr
fixtures	17	8	13	8	8
valves	28	13	21	13	13



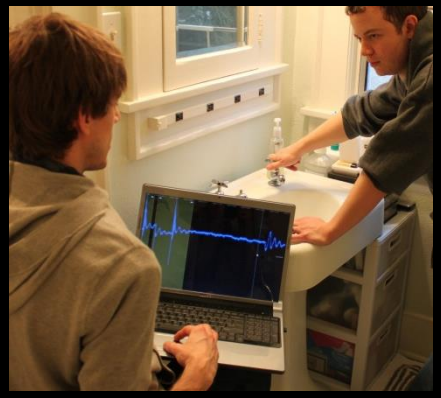




DELL


HOT
COLD

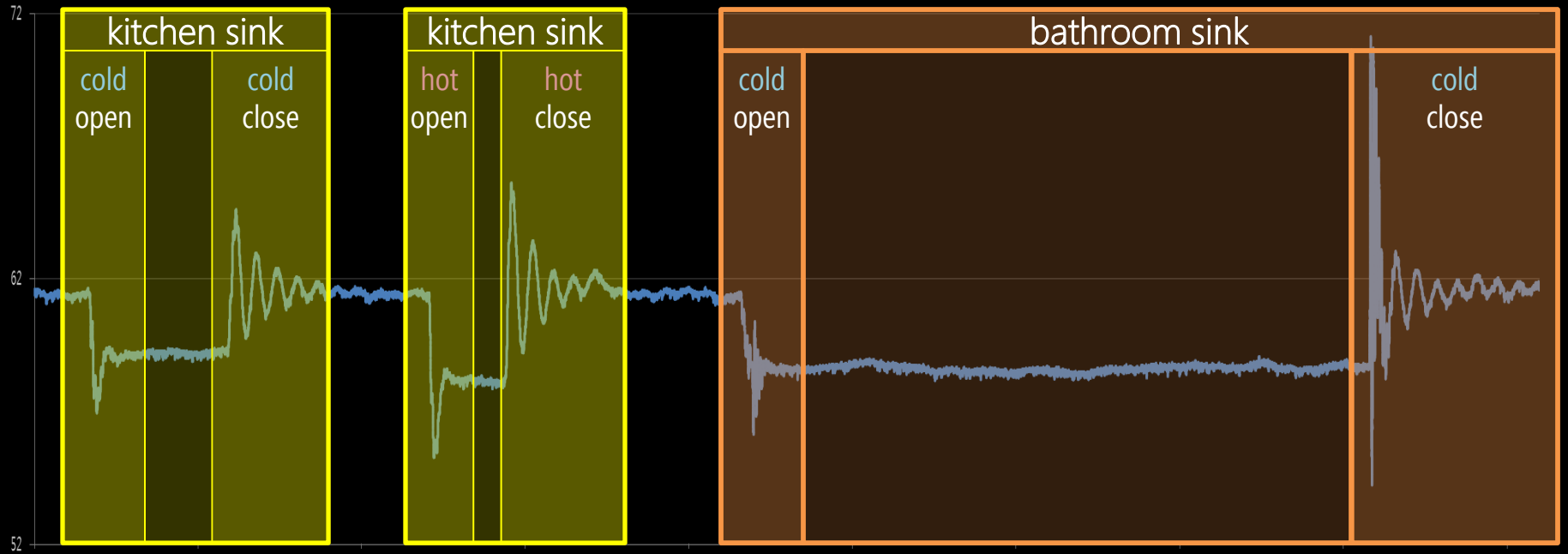

PB32
XBee
PULL KNOB TO START-PUSH TO STOP
XTRA RINSE
SET
COTTONS REGULAR
PERMANENT PRESS KNITS
PERMANENT PRESS
DELICATES
LIGHT SOIL
MEDIUM
HEAVY
POWER WASH
30 MIN AUTO SOAK
vy Duty Super Capacity
= RINSE
= EXTRA RINSE
= SPIN

ground truth labels

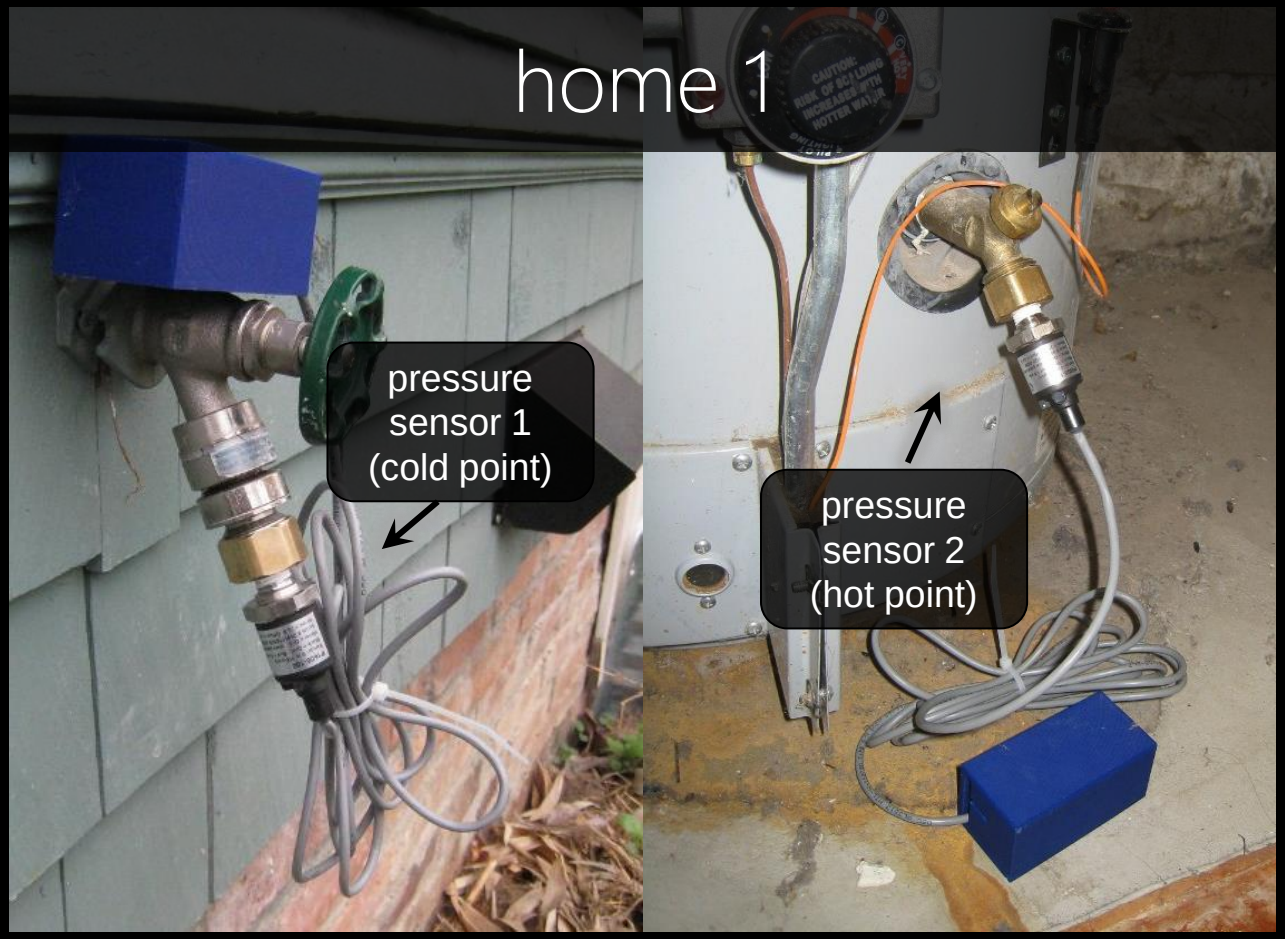


manual

automatic

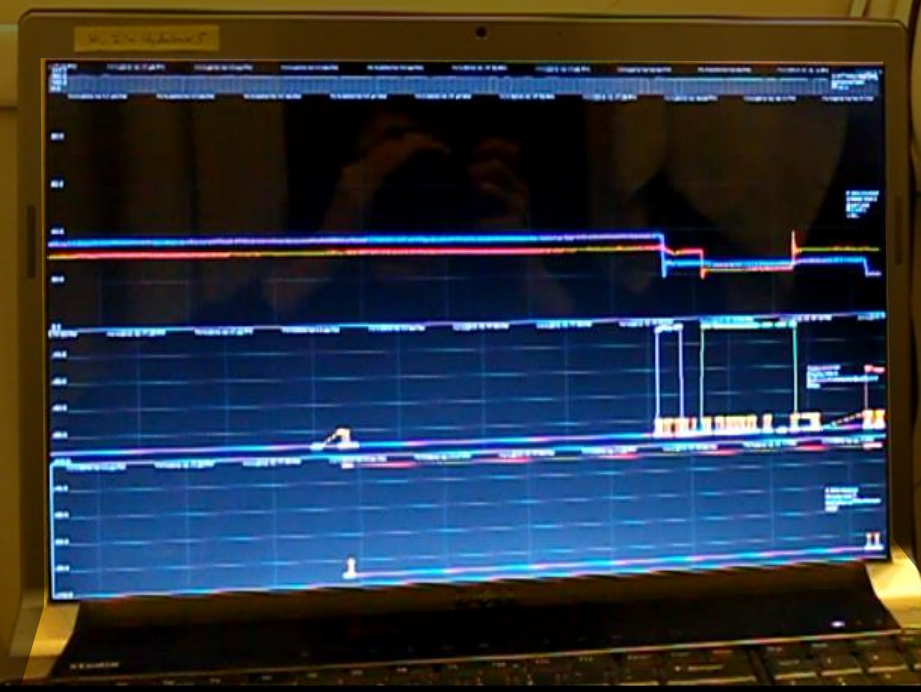


two pressure sensors per home



hydrosense data logger

records ground truth sensor data plus
two pressure streams for each home

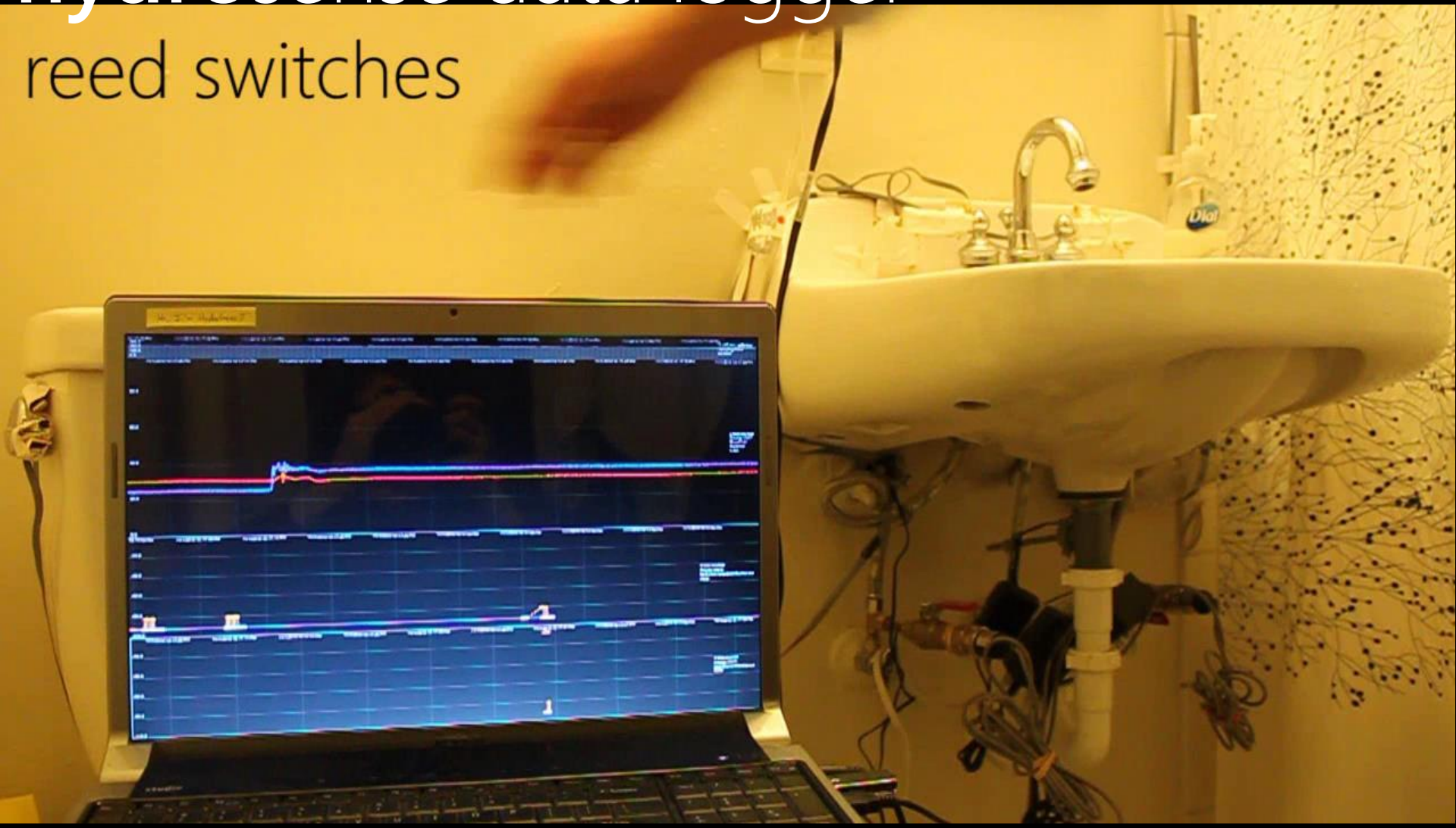


pressure stream
red = hot line
blue = cold line

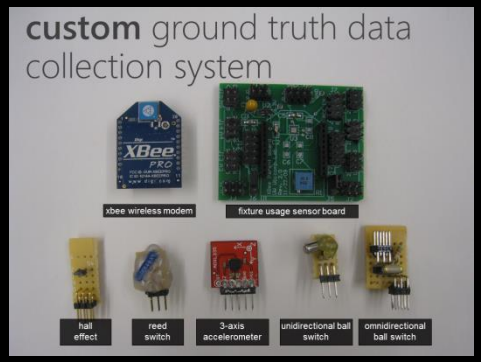
reed switches
high = active
low = inactive

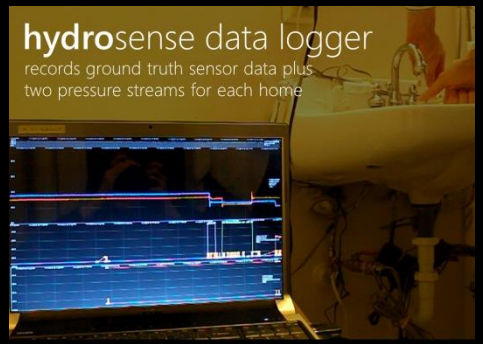
hydrosense data logger

reed switches

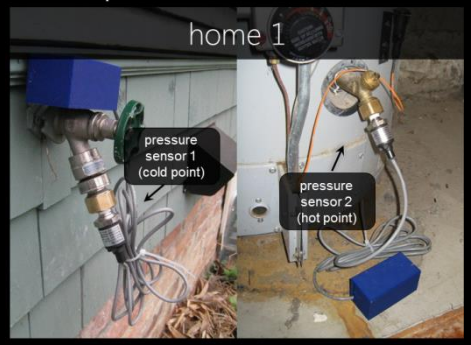


hydro deployment infrastructure

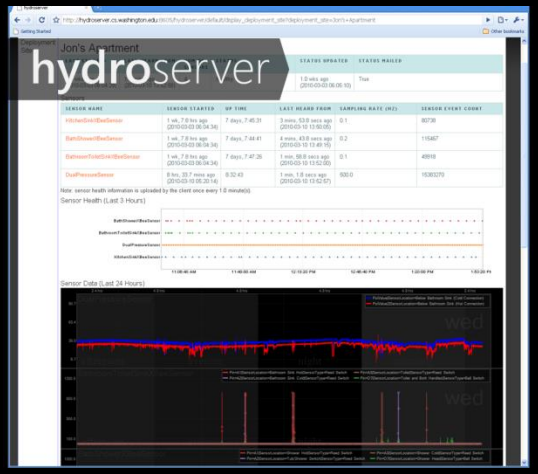




two pressure sensors

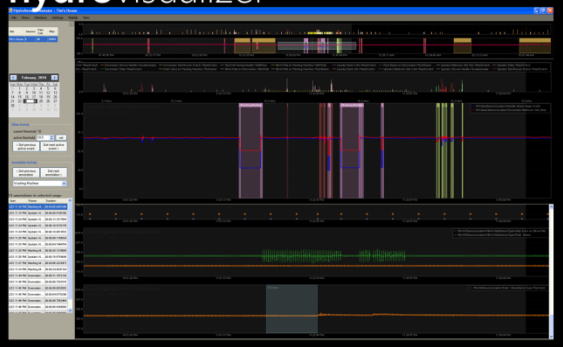


on-site sensing infrastructure

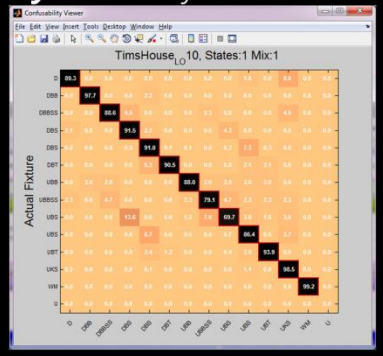


python web backend

hydrovisualizer



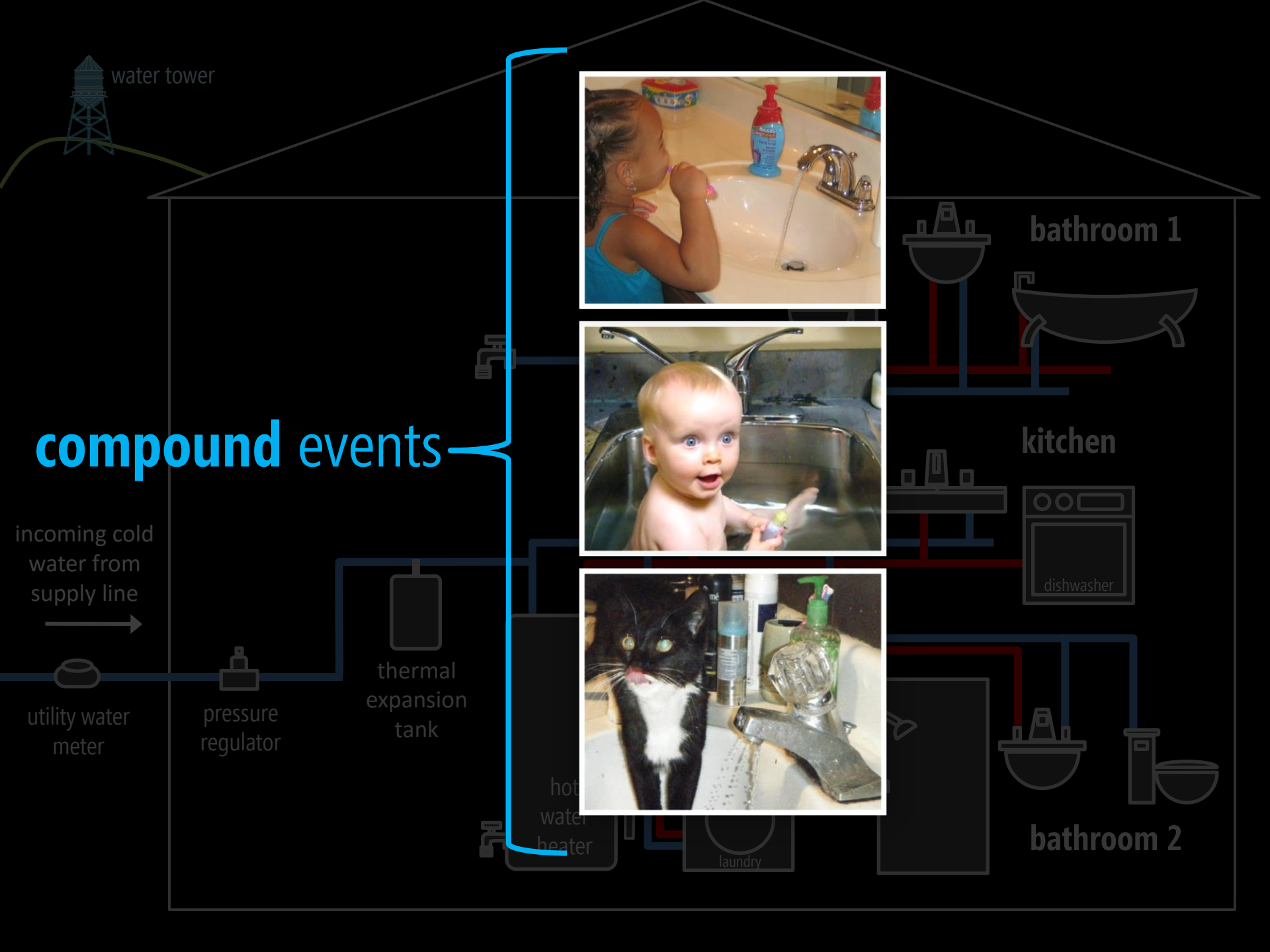
hydroanalyzer



c# and matlab analysis tools

5-week dataset

						totals
days	33	33	30	27	33	156
events	2374	3075	4754	2499	2578	14,960
events/day	71.9	93.2	158.5	92.6	78.1	95.9


water tower
compound events
incoming cold water from supply line
utility water meter
pressure regulator
thermal expansion tank
hot water heater
laundry
bathroom 1
kitchen
dishwasher
bathroom 2

22%

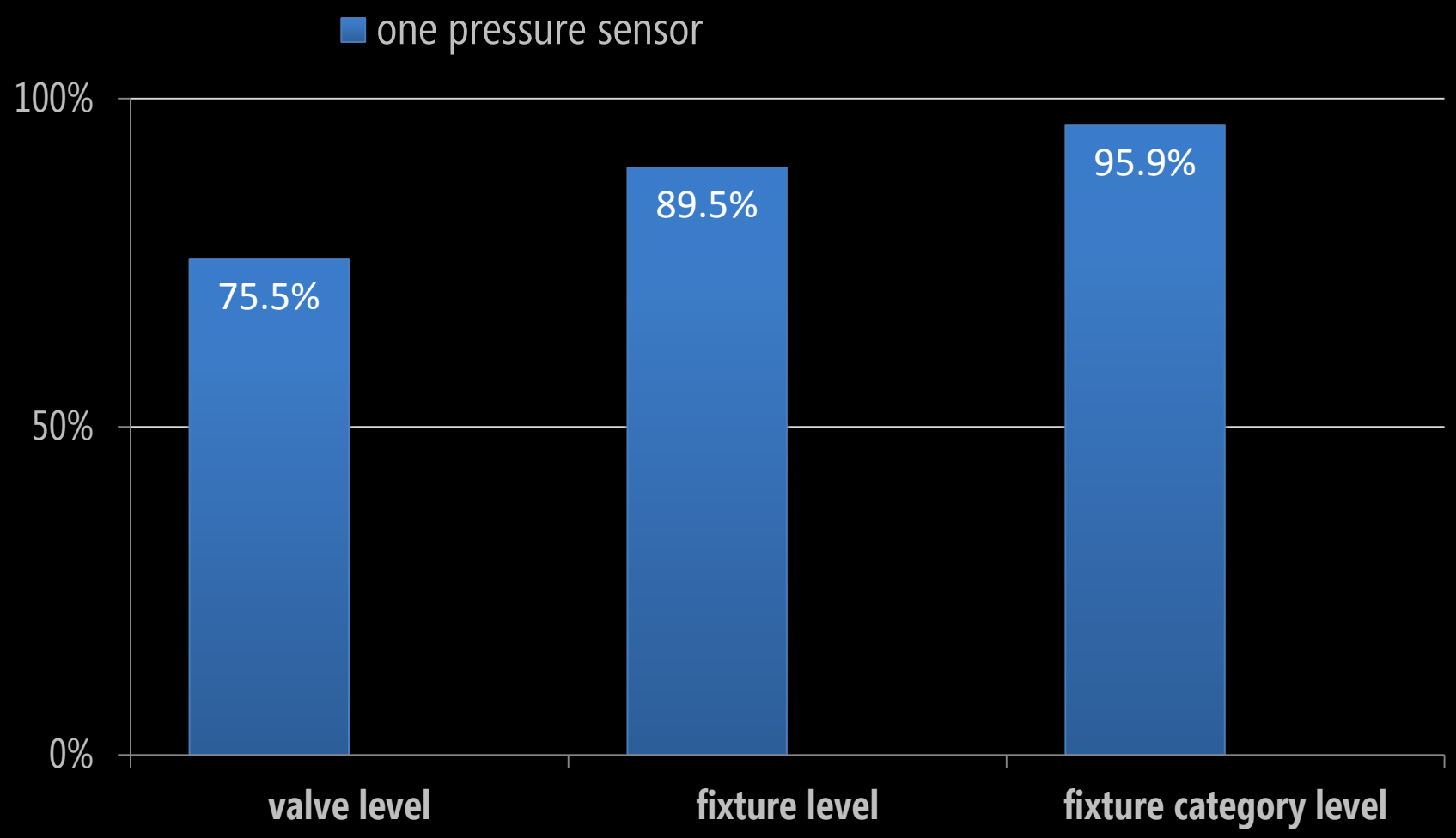
of all water events were compound

41.8%

of all bathroom sink events were compound

hydrosense classification results

real-world water usage data



hydrosense classification results

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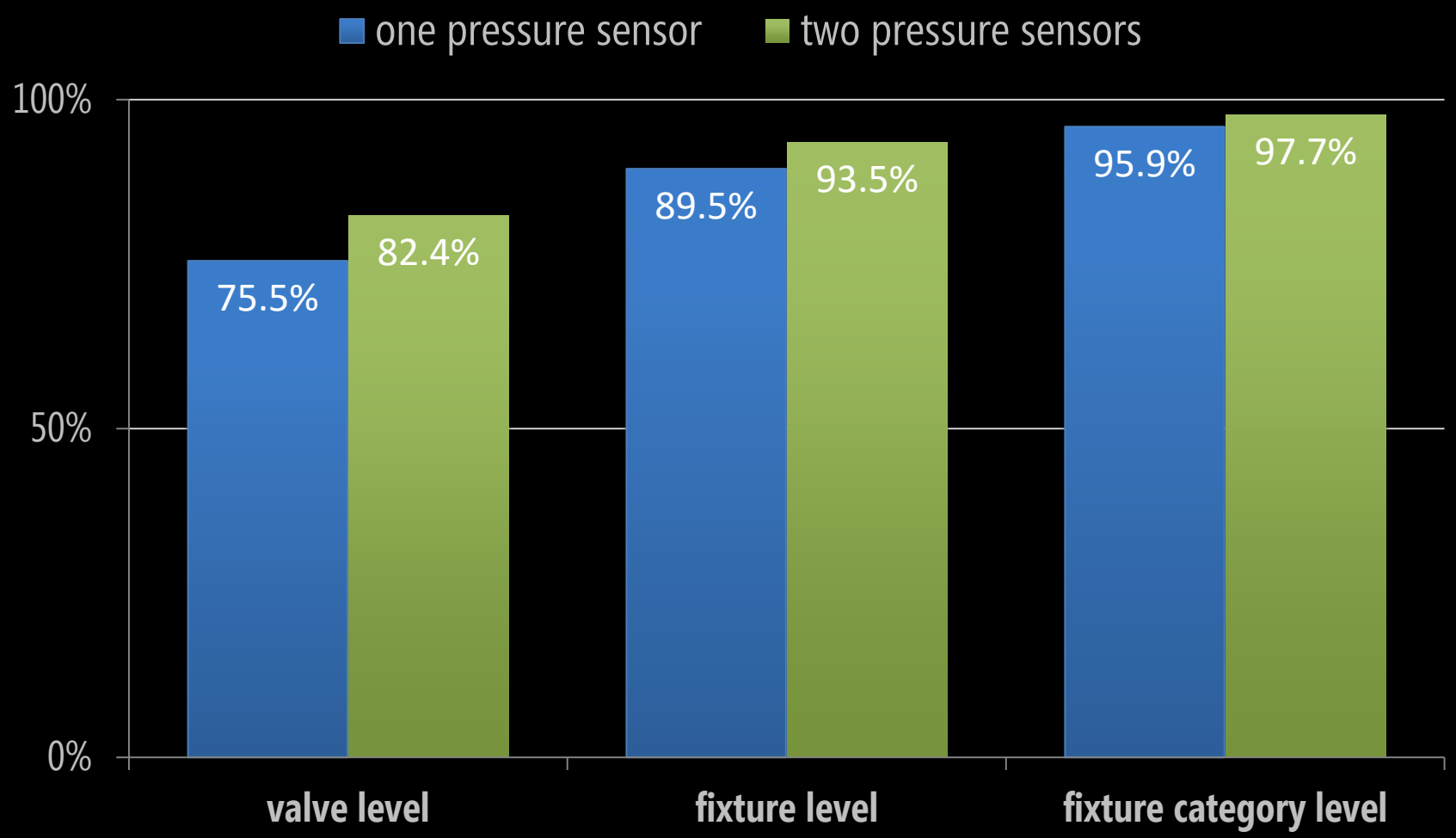
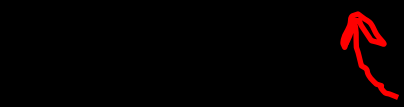


What do we do with **all this data**?



How should we approach this design process?

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?

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?

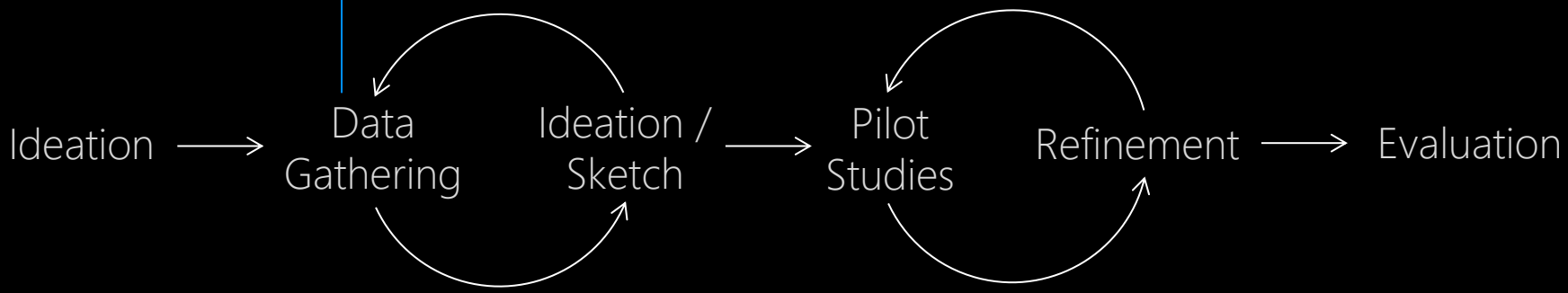
3. **How** might these visualizations impact behavior?

Two sets of designs:

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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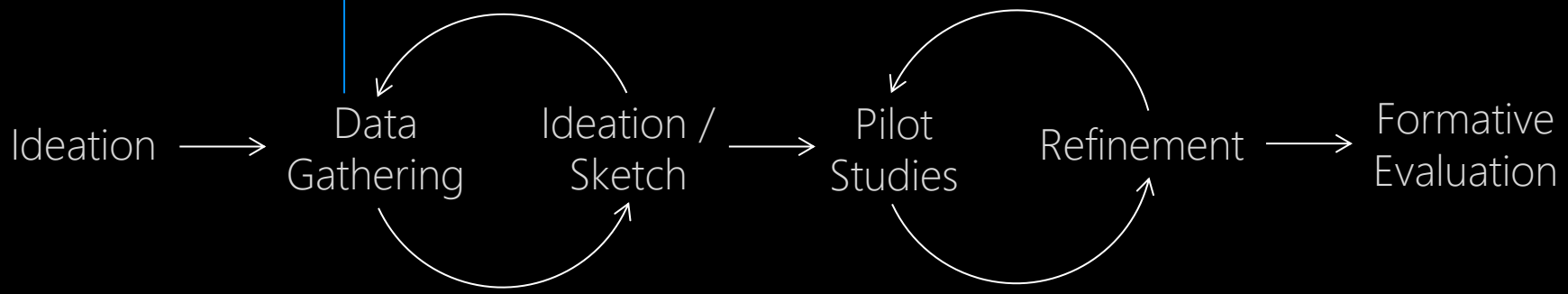

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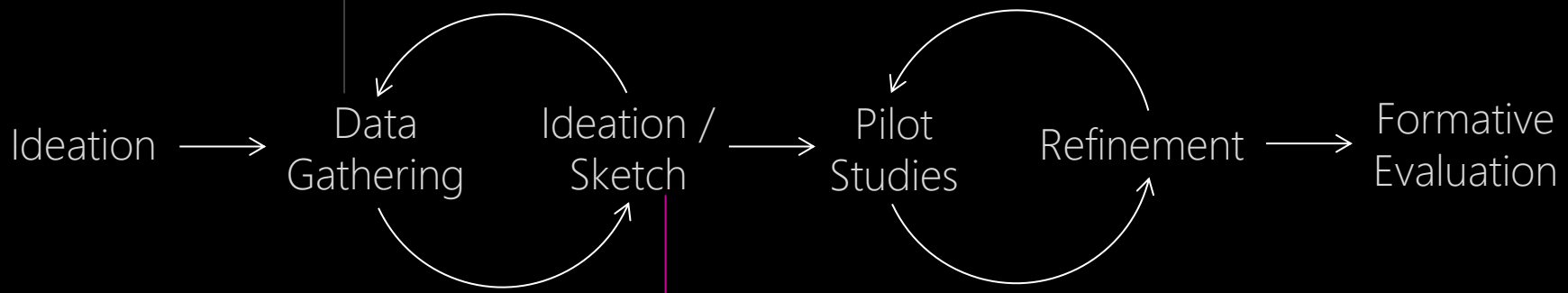


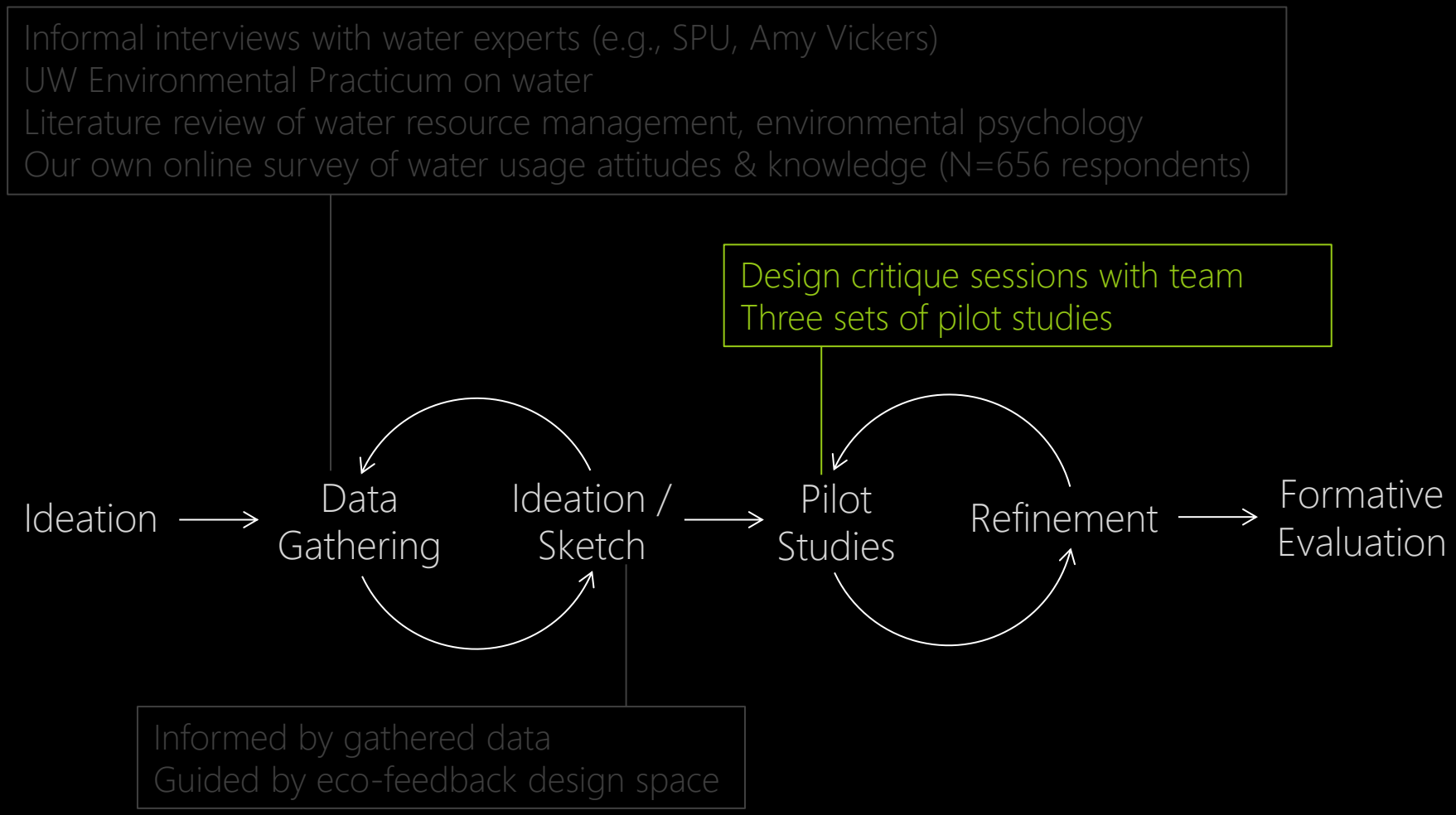
Informed by gathered data
Guided by eco-feedback design space

Iterative Design Process

Sketch

Lo-to-Mid Fidelity Mockup

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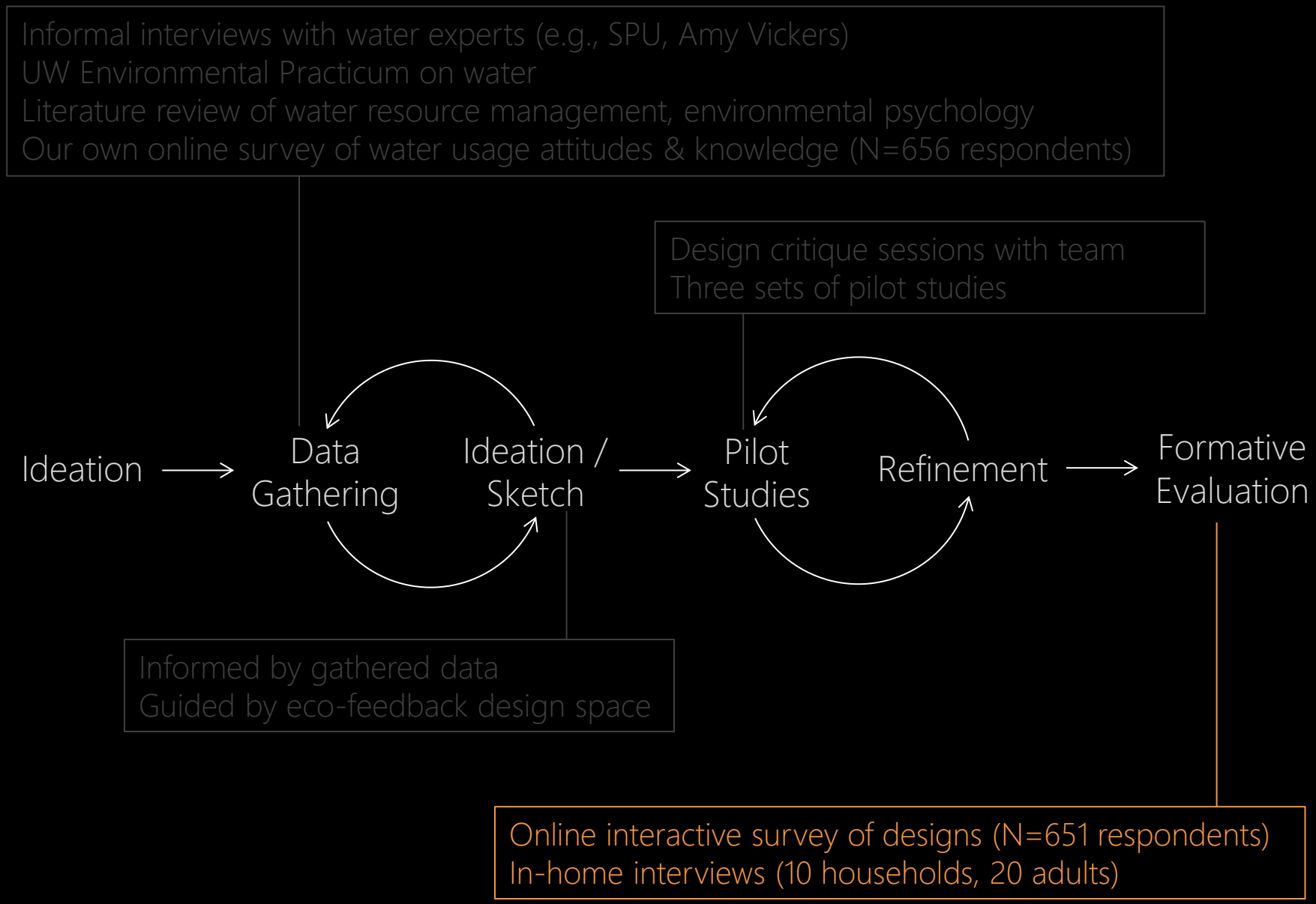
Design critique sessions with team
Three sets of pilot studies
Ideation
Data Gathering
Ideation / Sketch
Pilot Studies
Refinement
Formative Evaluation
Informed by gathered data
Guided by eco-feedback design space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Formative Evaluation
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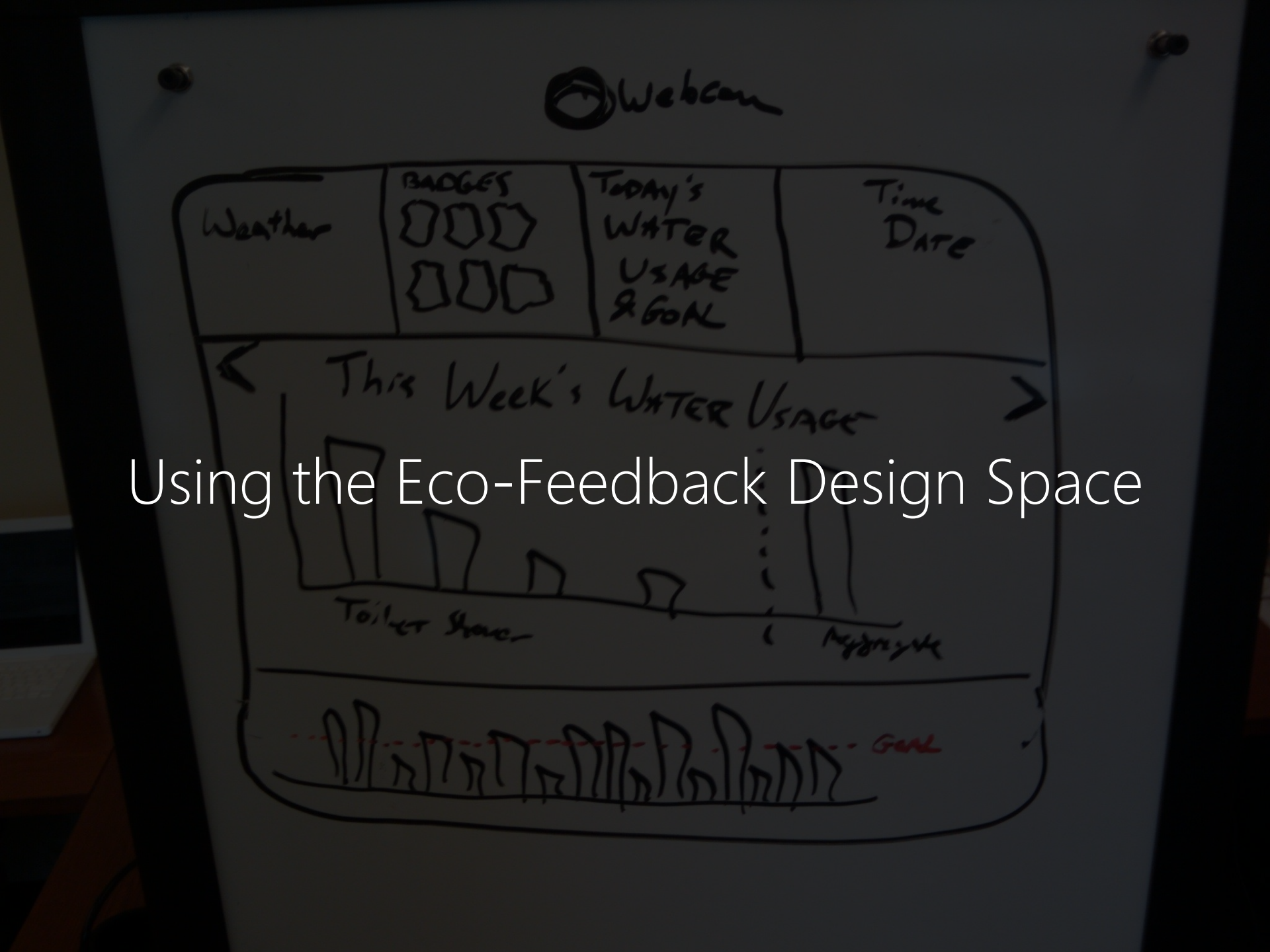
Guided by eco-feedback design space
Online interactive survey of designs (N=651 respondents)
In-home interviews (10 households, 20 adults)

Using the Eco-Feedback Design Space



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

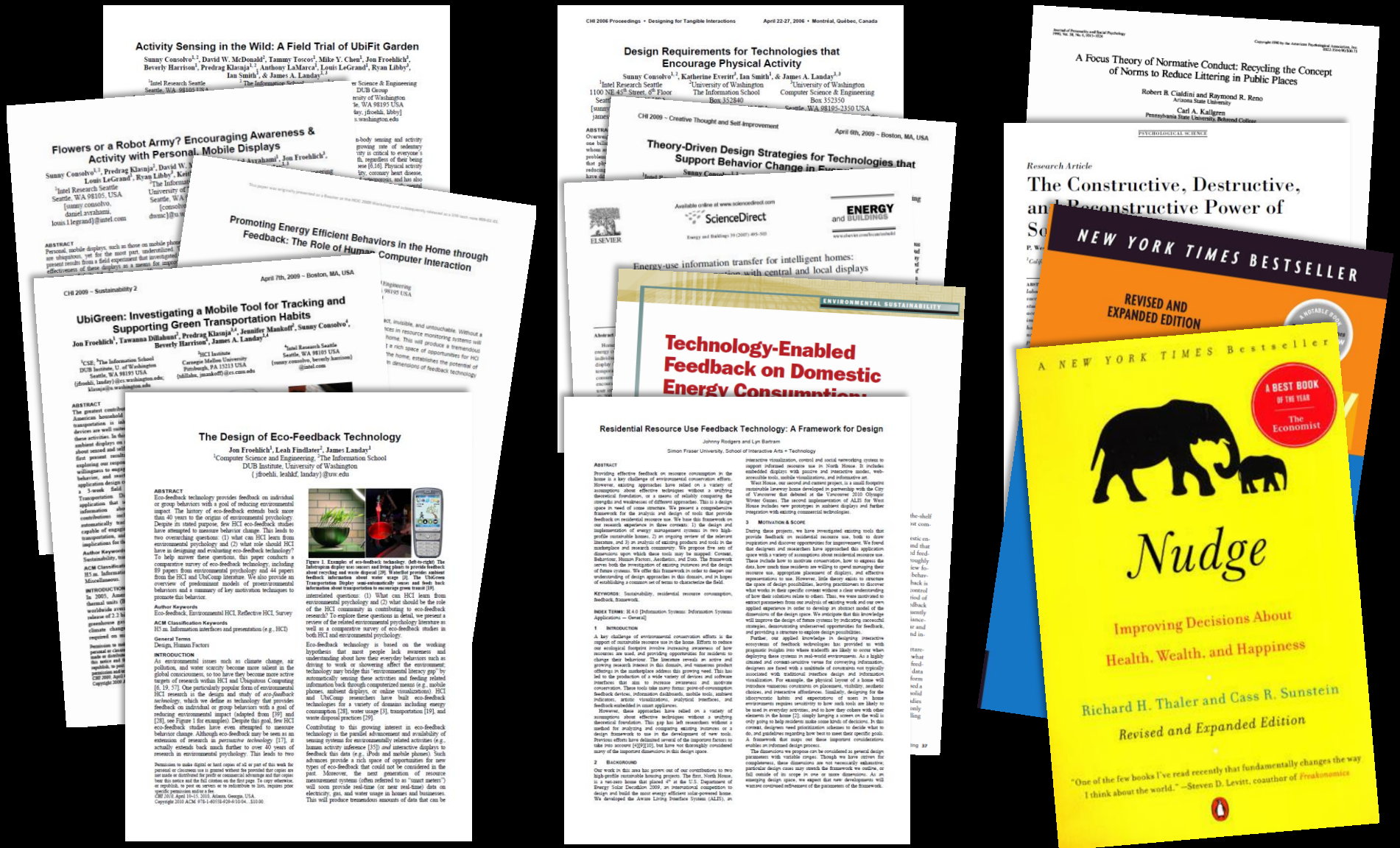
computation

- @ 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)
social aspects
support for user annotations
support for user corrections
data representation
inputs (modeled themes)
medium
user effort
push/pull
location
persuasive tactics

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- 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]


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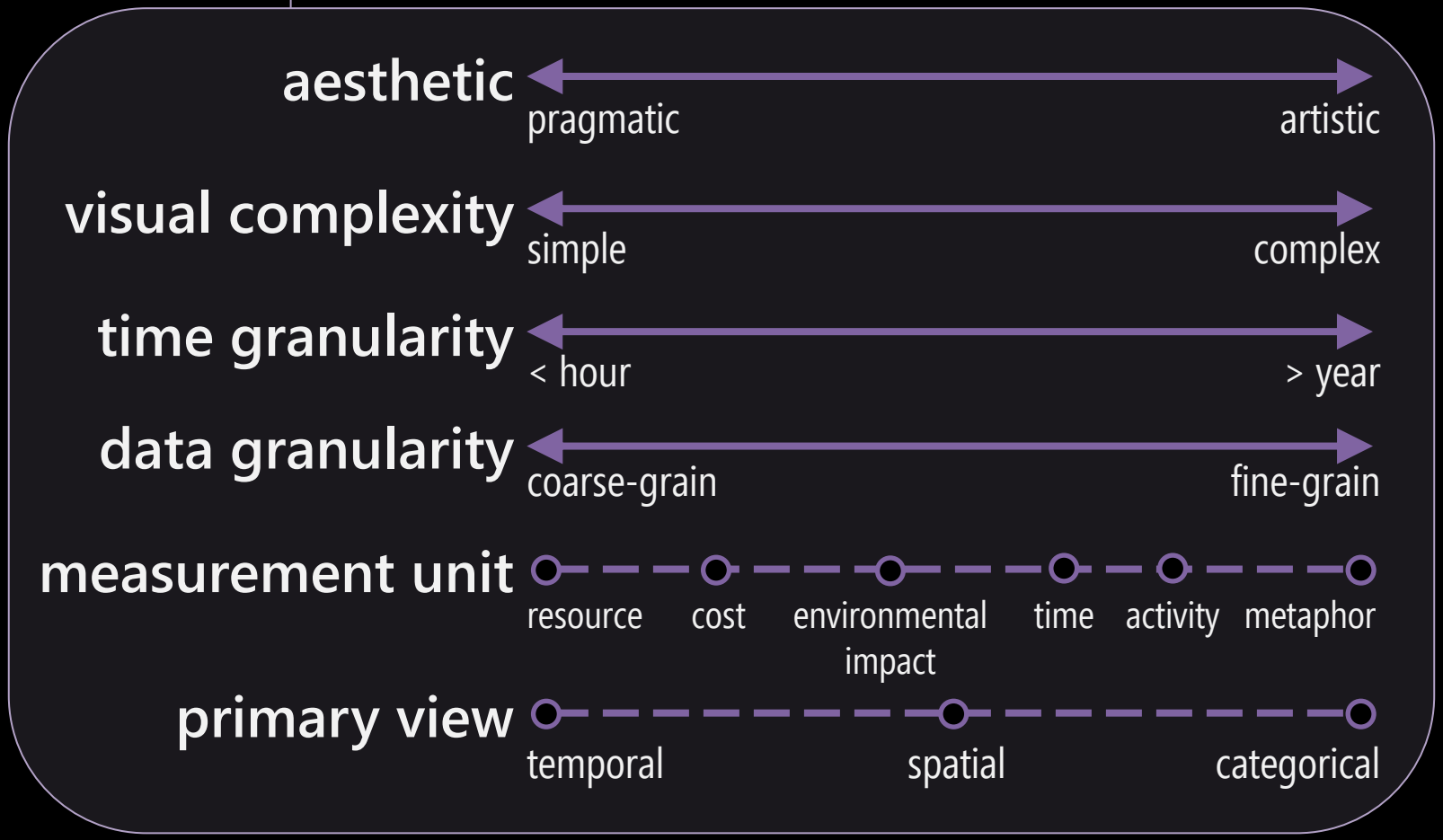
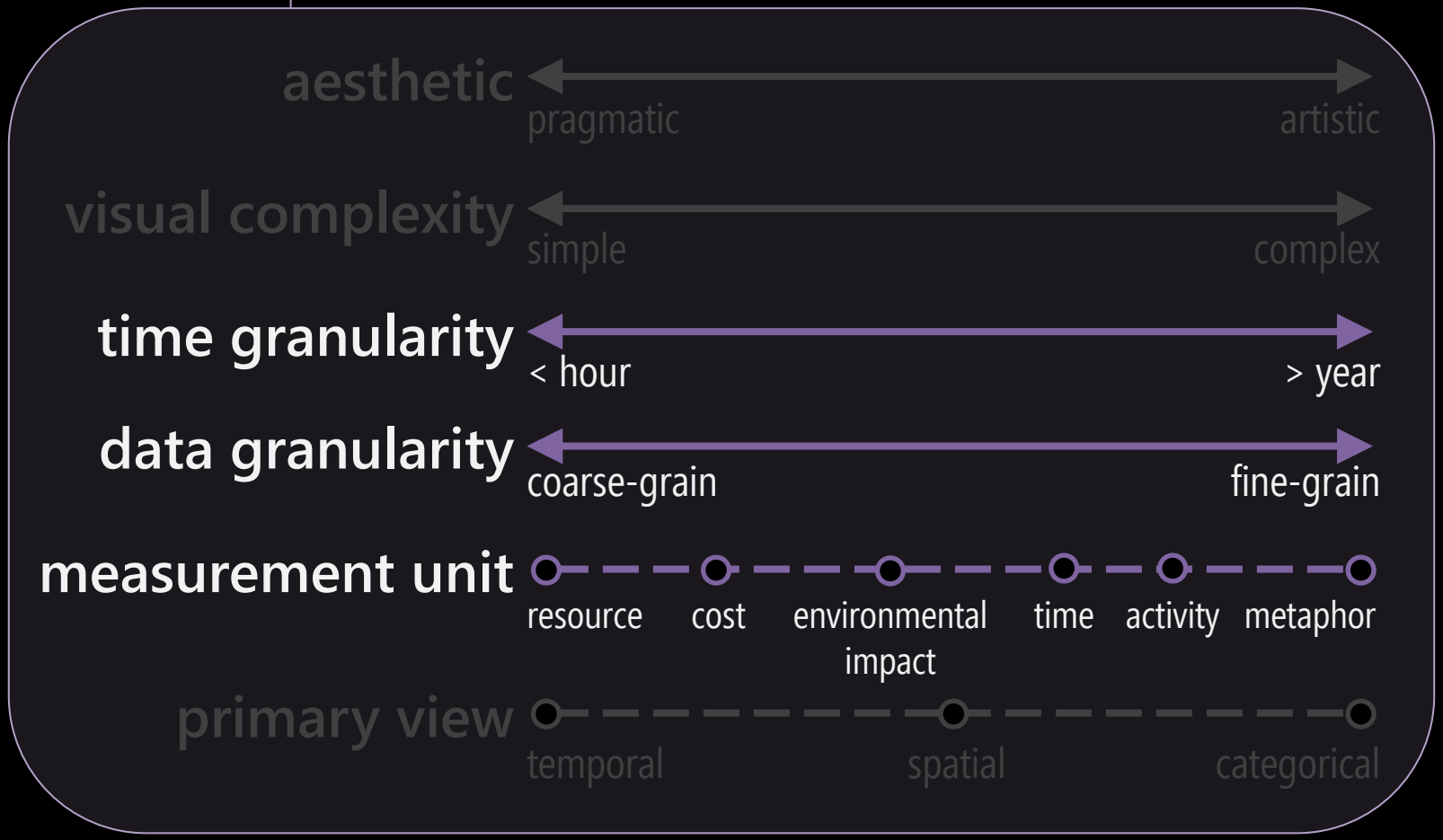
data representation

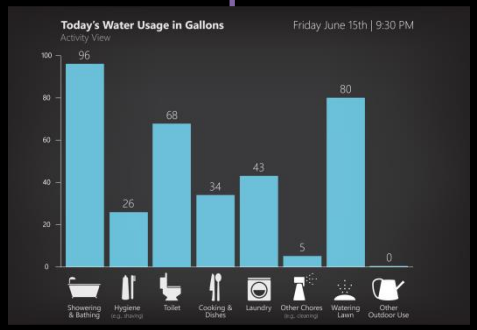


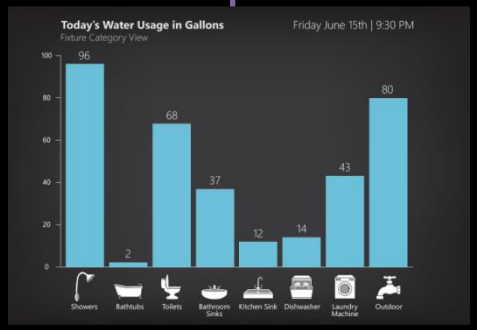
data representation

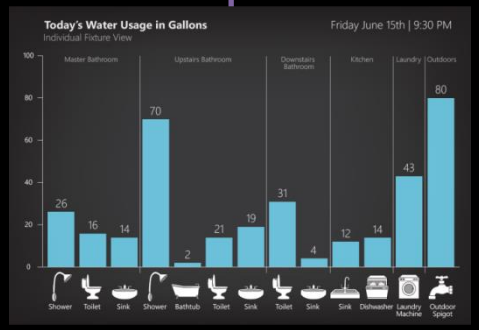


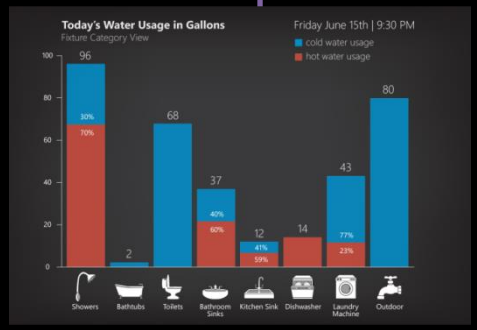
Data Granularity

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





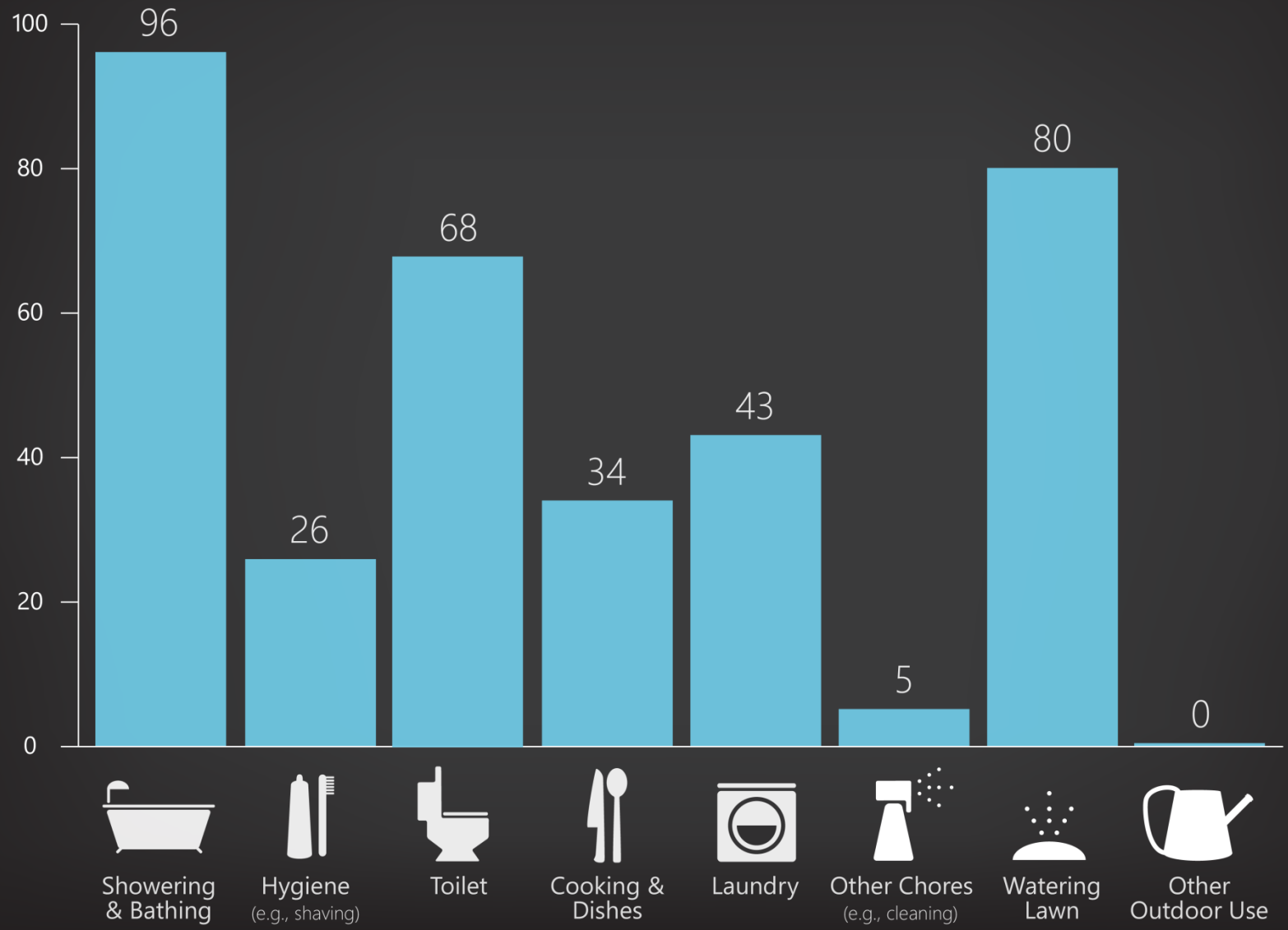




Today's Water Usage in Gallons

Activity View

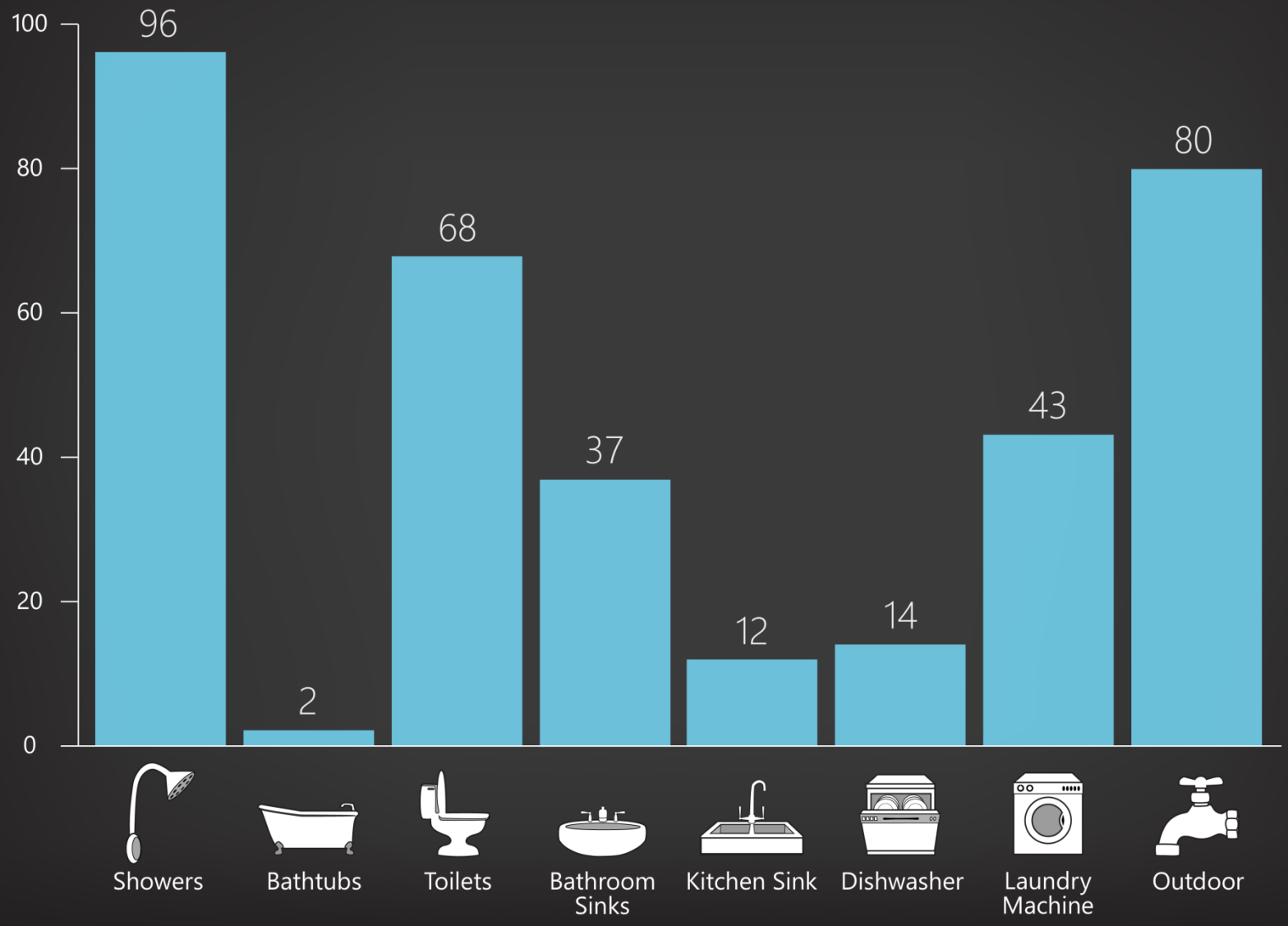
Friday June 15th | 9:30 PM



Today's Water Usage in Gallons

Fixture Category View

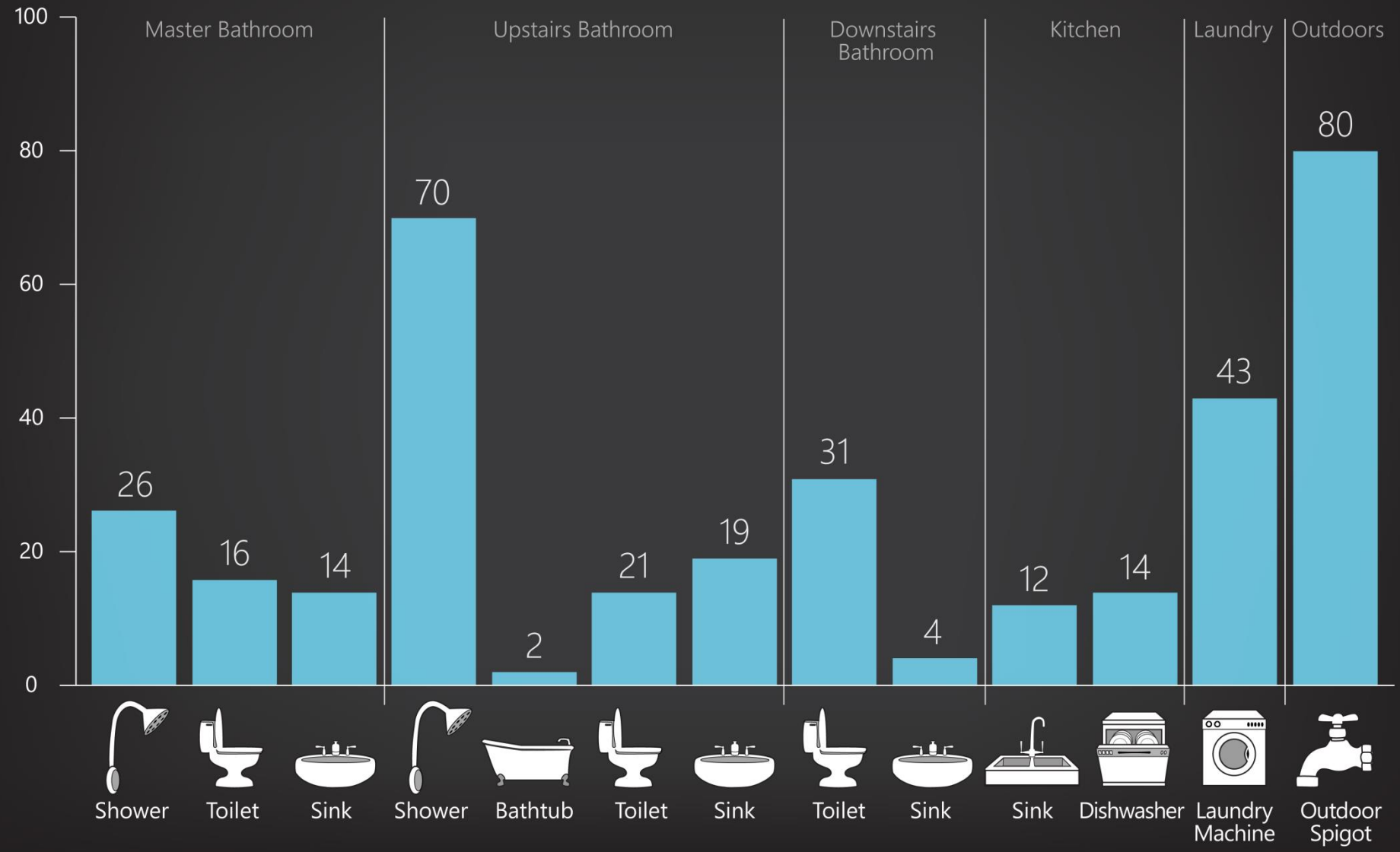
Friday June 15th | 9:30 PM



Today's Water Usage in Gallons

Individual Fixture View

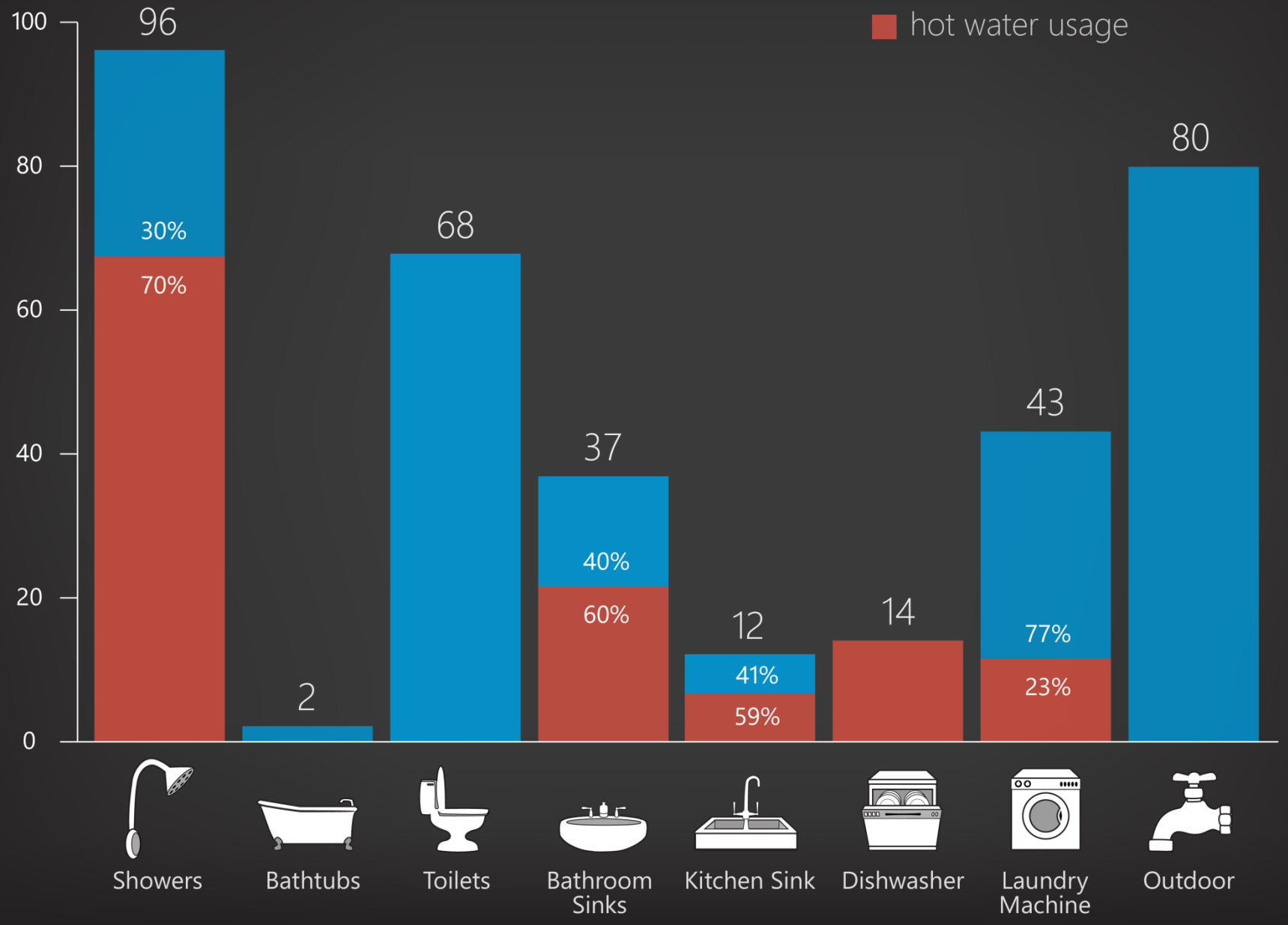
Friday June 15th | 9:30 PM



Today's Water Usage in Gallons

Fixture Category View: Hot vs Cold

Friday June 15th | 9:30 PM



Measurement Unit

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

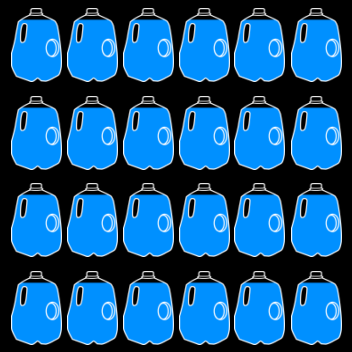
36 gallons of water

3 gpm

9 cents

12 minutes

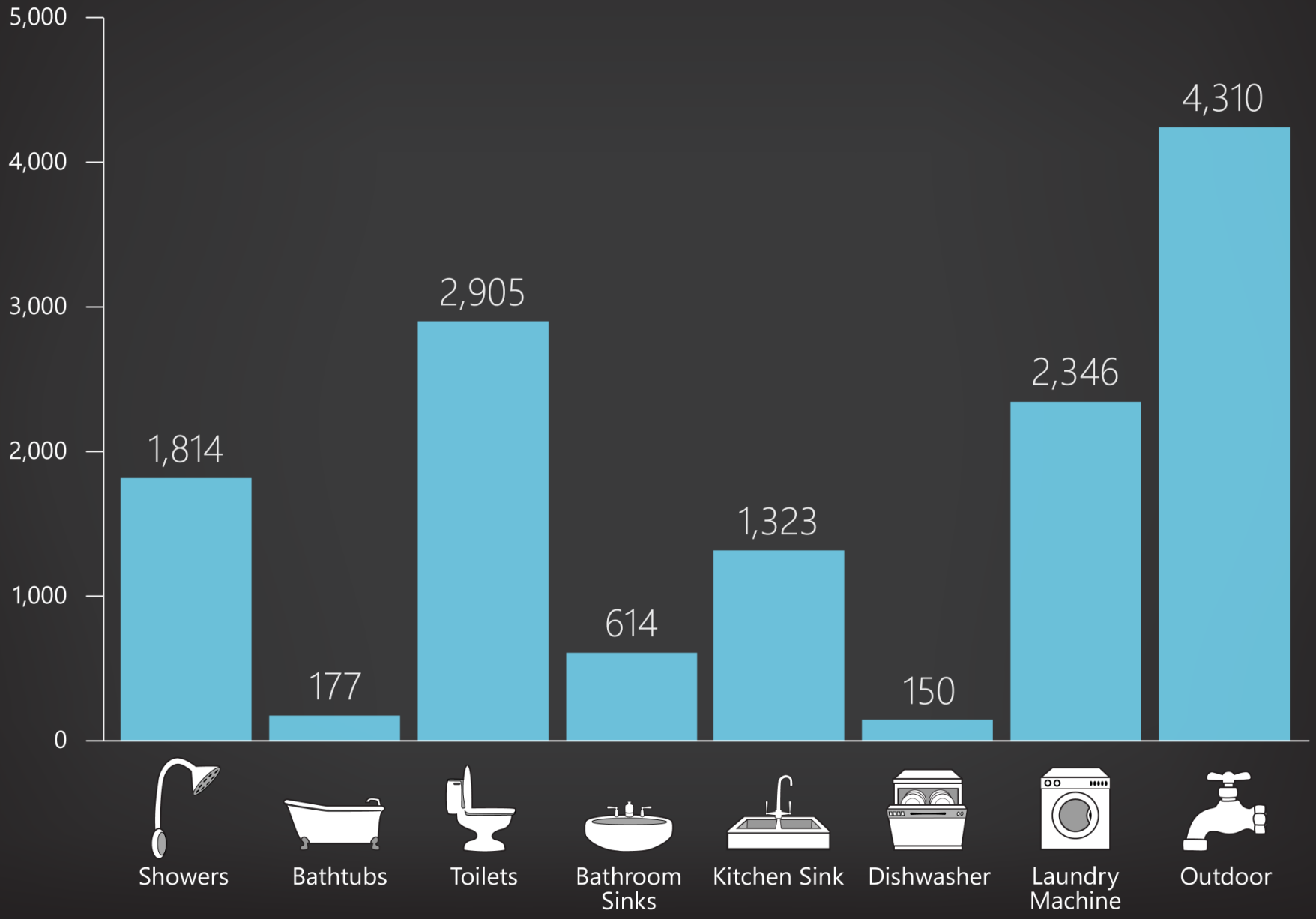
1 shower



This Month's Water Usage

Fixture Category View | In Gallons

Friday June 15th | 9:30 PM

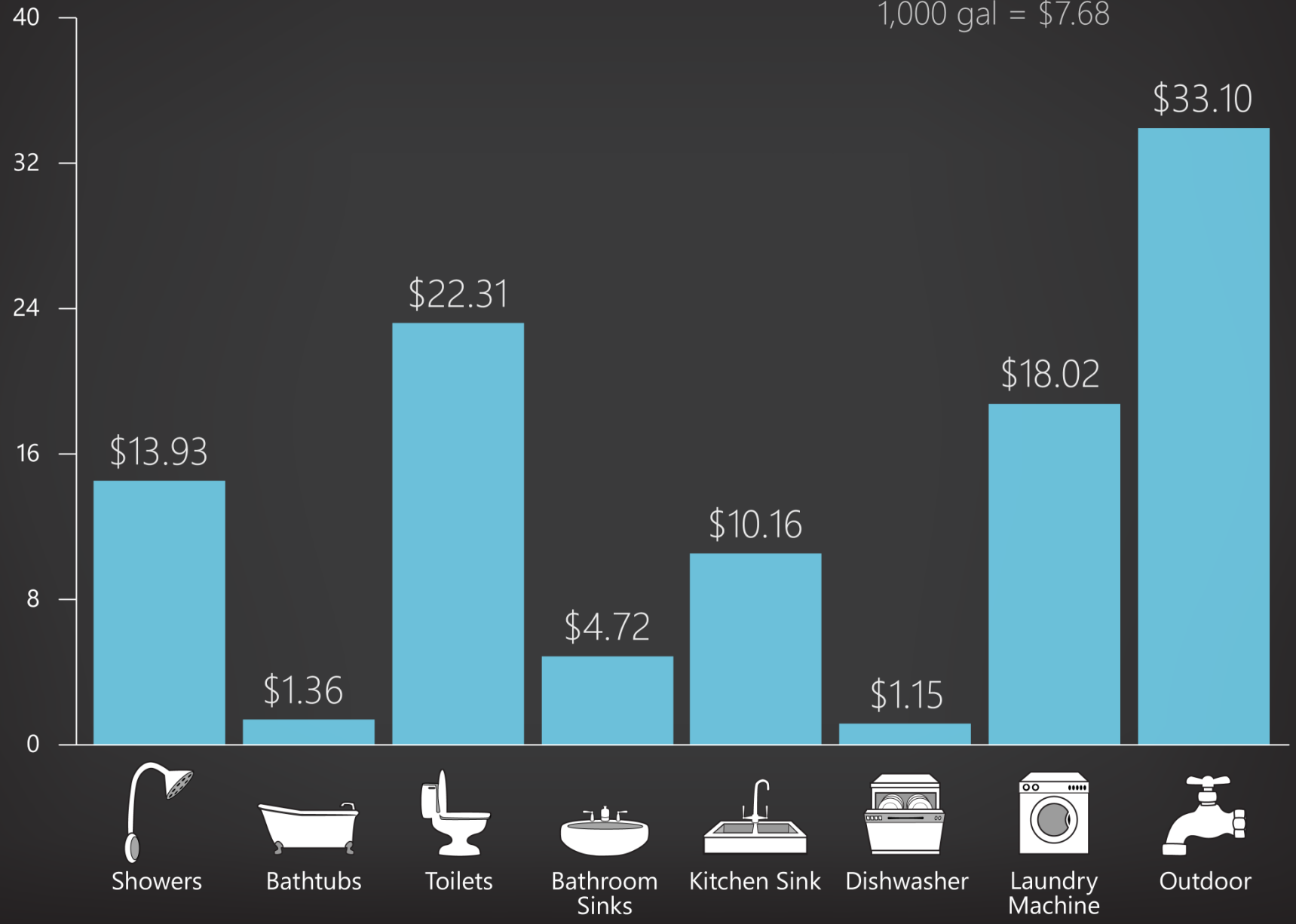


This Month's Water Usage

Fixture Category View | In Dollars

Friday June 15th | 9:30 PM

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

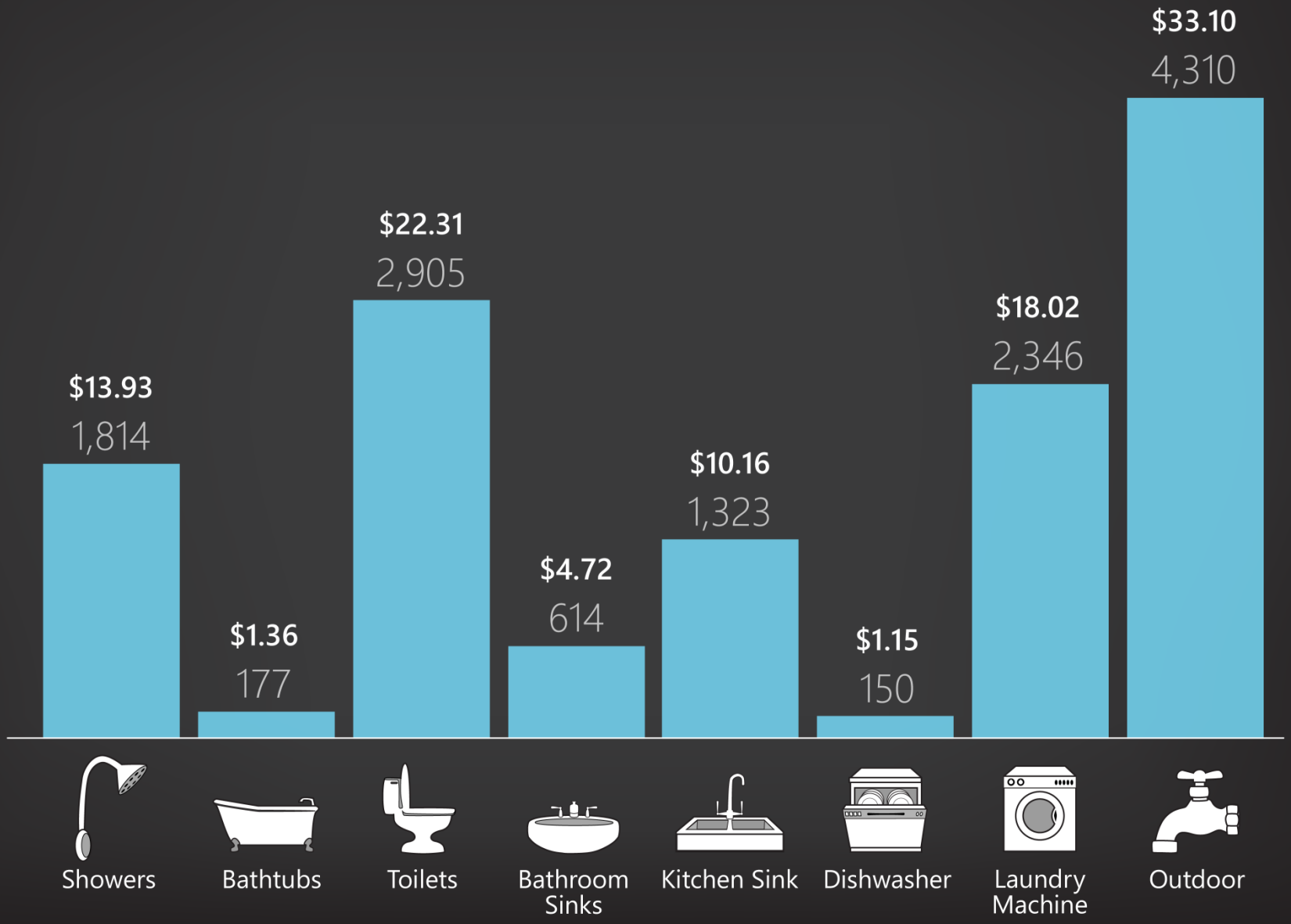


This Month's Water Usage

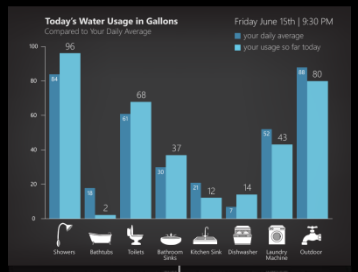
Fixture Category View | In Dollars & Gallons

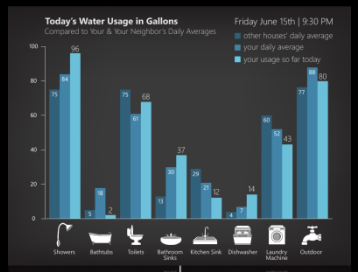
Friday June 15th | 9:30 PM

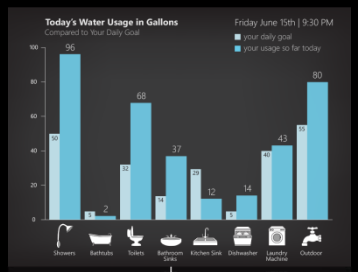
Your Current Water Rate:
1,000 gal = $7.68



comparison







comparison target

self — social — goal

comparison by time

past — projected

social comparison target

geographically proximal — demographically similar — selected social network

goal-setting strategy

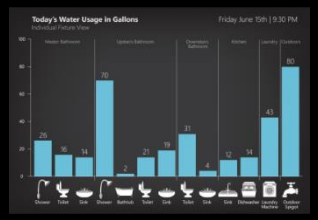
self-set — system-set — externally set

difficulty to reach comparison target

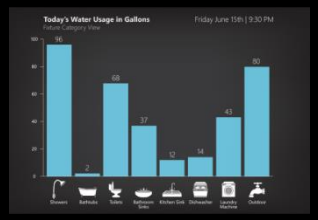
easy — hard

Design Dimensions Explored

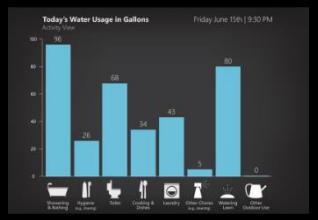
Data Granularity



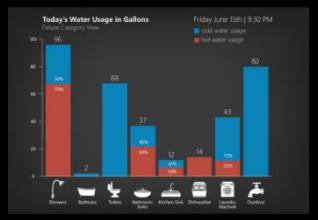
Individual Fixture



Fixture Category

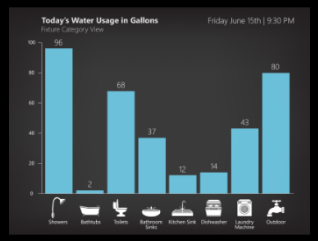


Activity

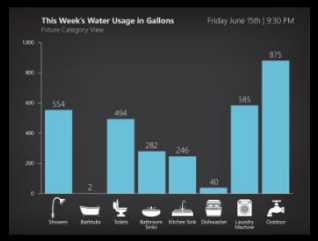


Hot and Cold

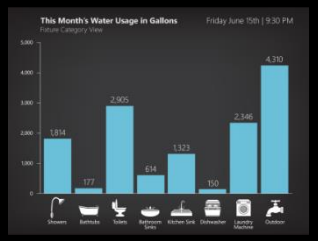
Time Granularity



So Far Today

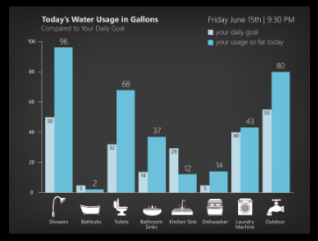


So Far This Week

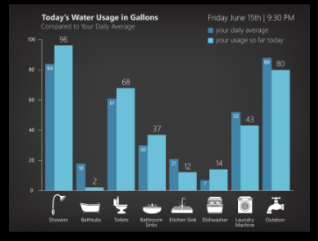


So Far This Month

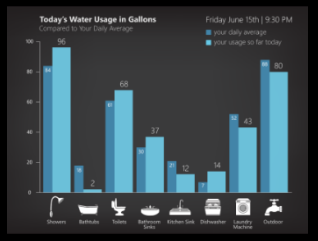
Comparison



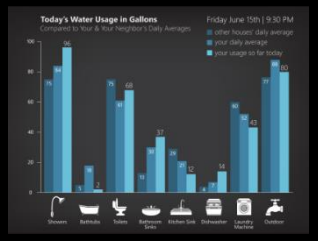
Self Comparison



To Others

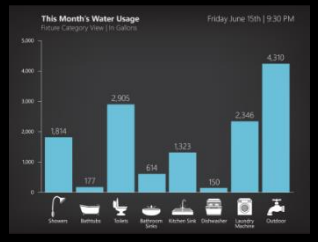


To A Goal



Social/Self

Measurement Unit



In Gallons

In Dollars

Dollars / Gallons

Including Sewage

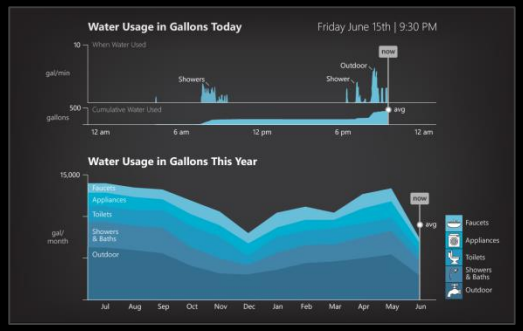
Two sets of designs:

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.

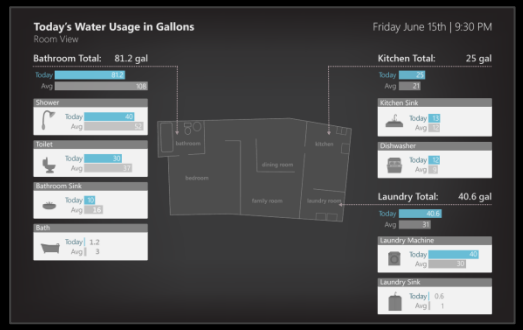
DESIGN SET 2: DESIGN PROBES

Design Probes Explored

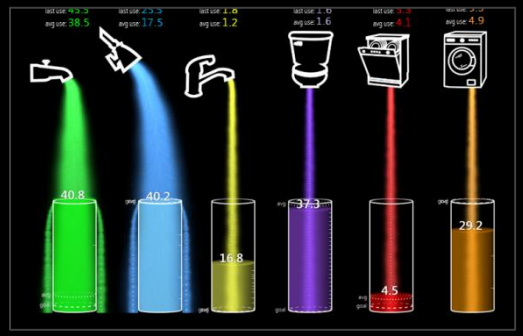


Time-Series

Aquatic Eco-system

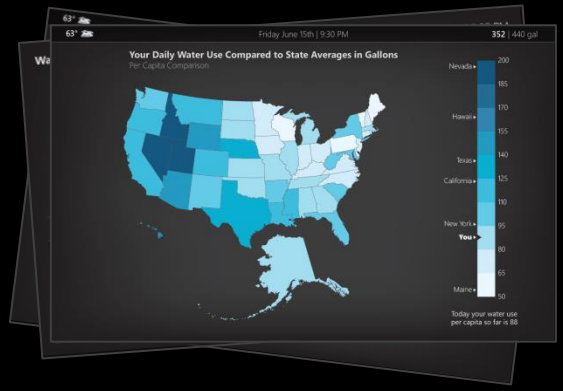


Spatial



Rainflow

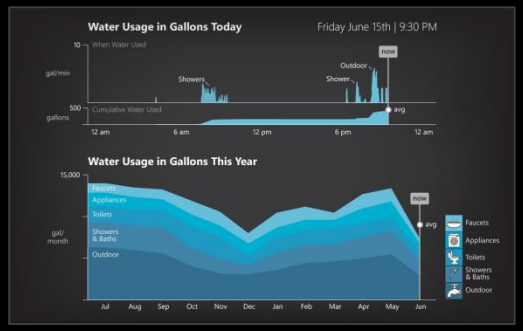
Per-Occupant



Other

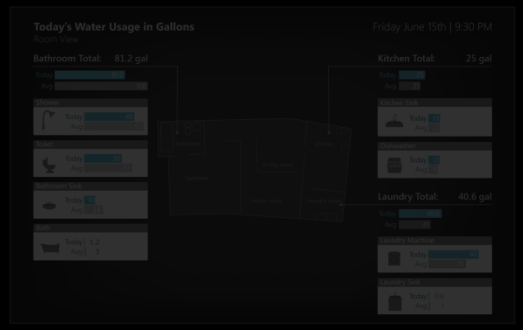
DESIGN SET 2: DESIGN PROBES

Design Probes Explored



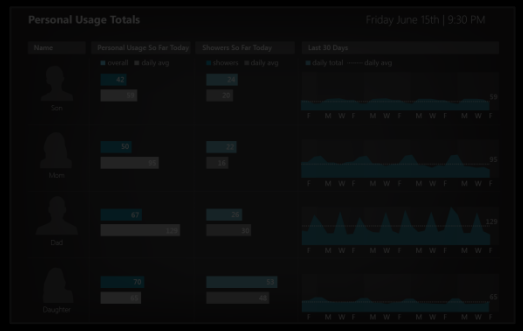
Time-Series

Aquatic Eco-system

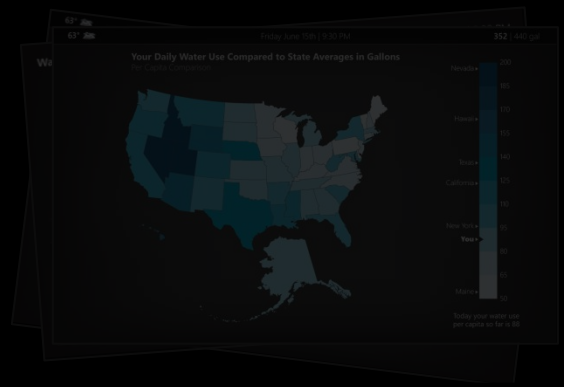


Spatial

Rainflow

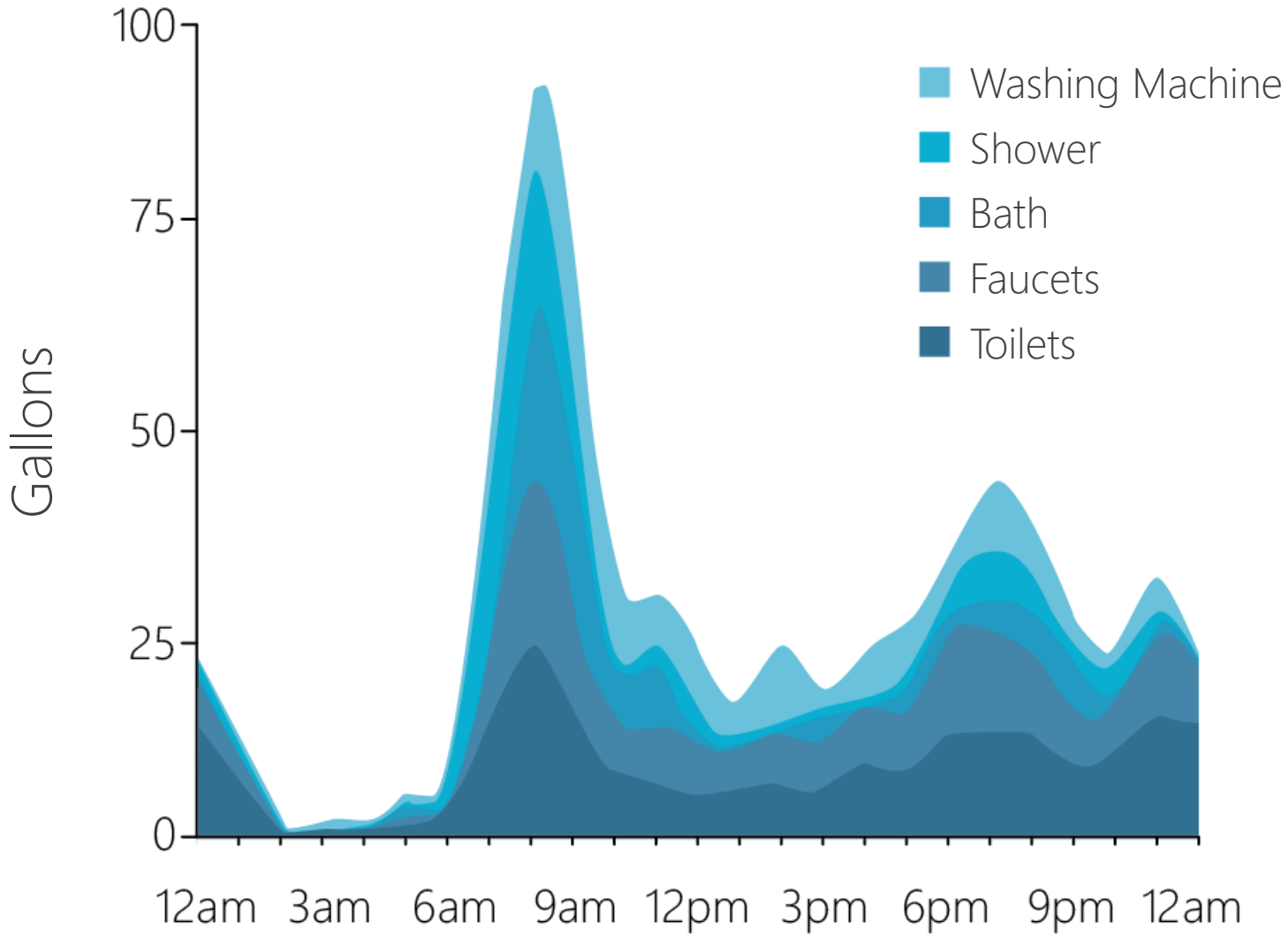


Per-Occupant



Other

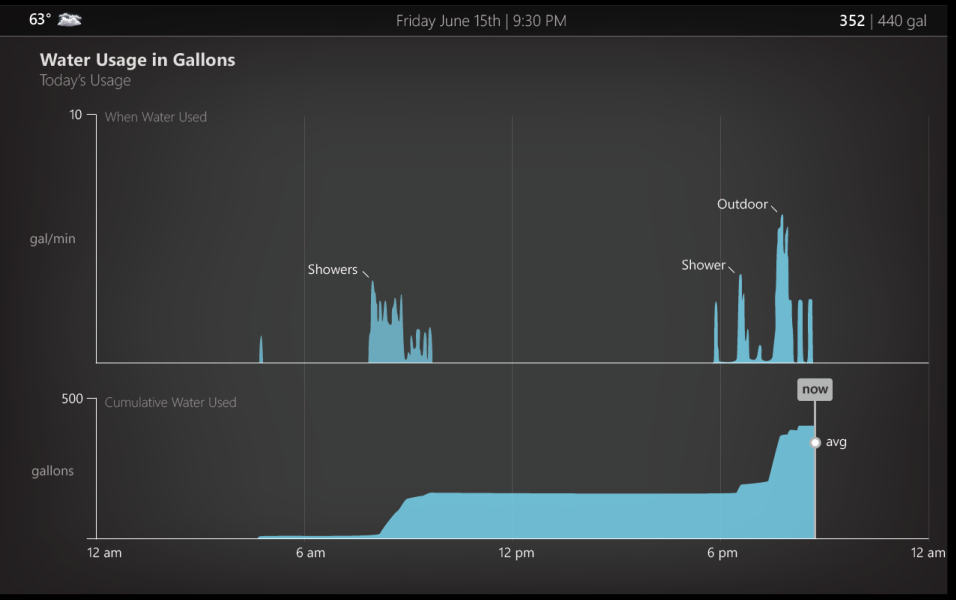
Daily Patterns of Water Usage

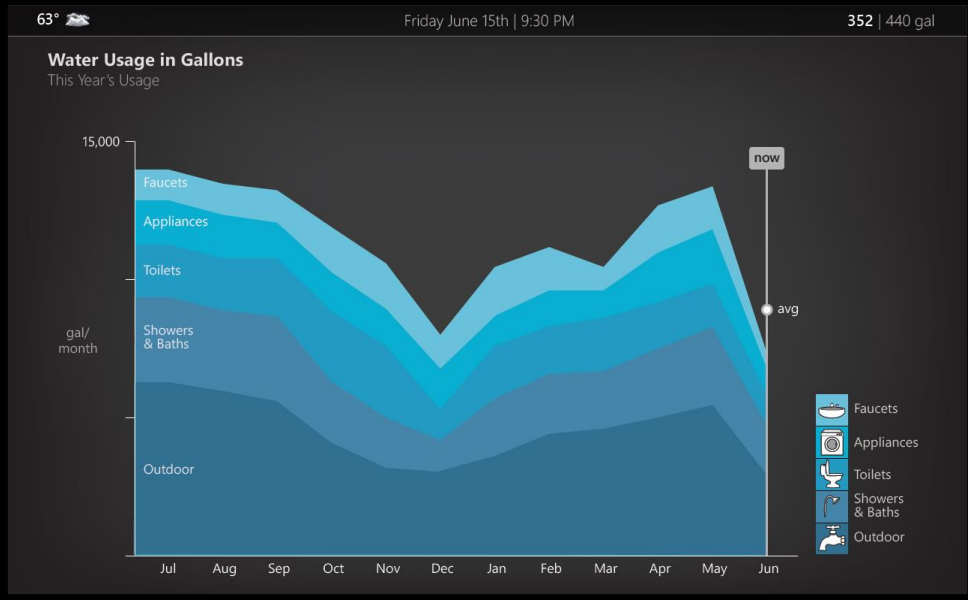


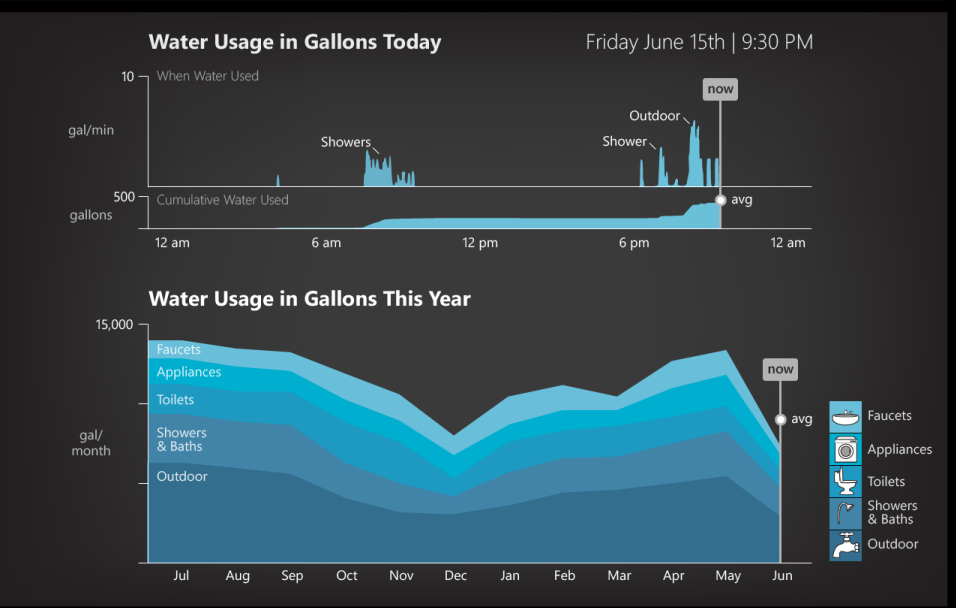
[Adapted from Butler, Building and Environment, 1993]

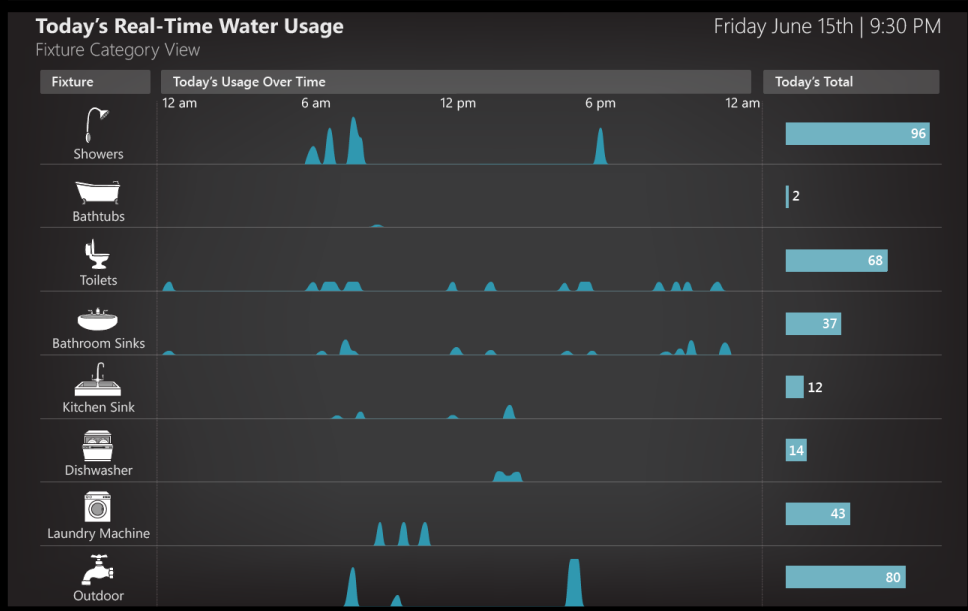
DESIGN SET 2: DESIGN PROBES

Time-Series Views



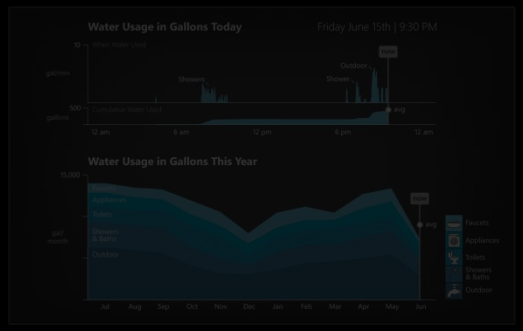






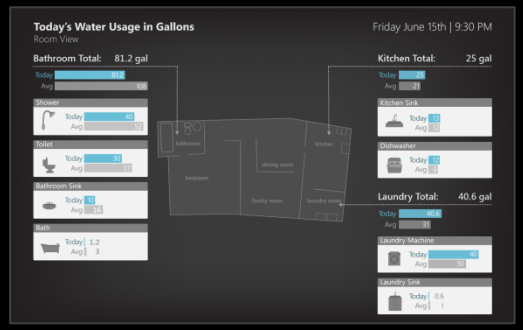
DESIGN SET 2: DESIGN PROBES

Design Probes Explored

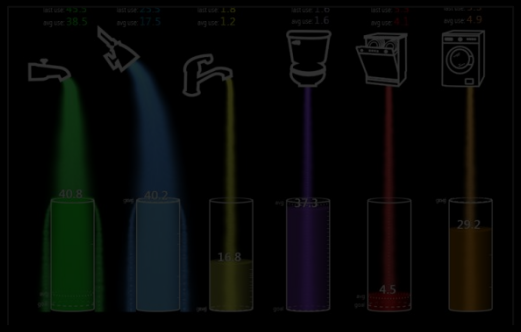


Time-Series

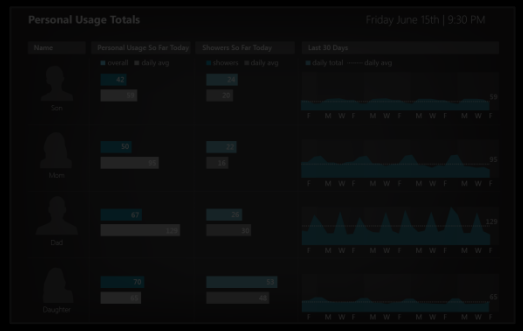
Aquatic Eco-system



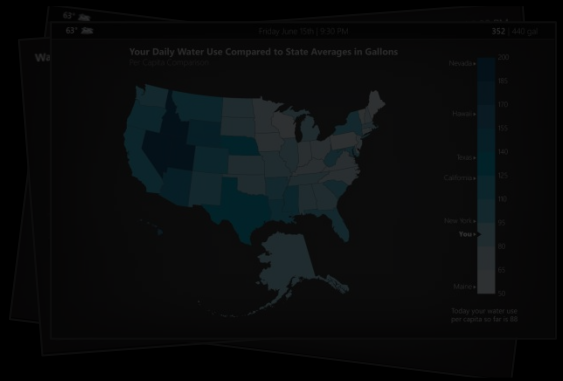
Spatial



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

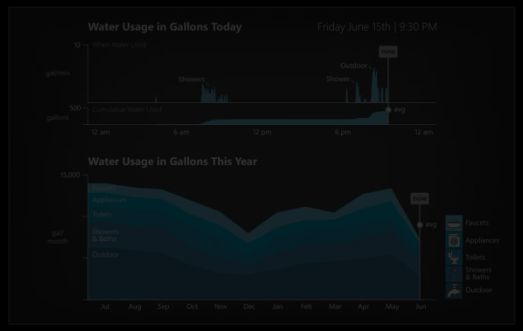
Today 40.6
Avg 31

Laundry Machine
Today 40
Avg 30

Laundry Sink
Today 0.6
Avg 1

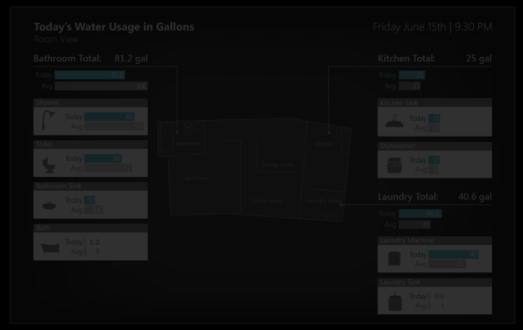
DESIGN SET 2: DESIGN PROBES

Design Probes Explored

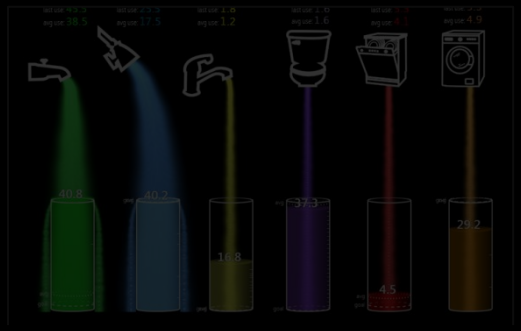


Time-Series

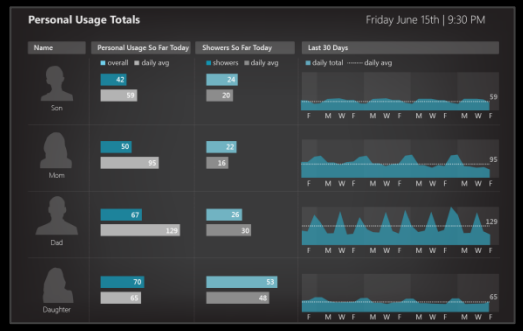
Aquatic Eco-system



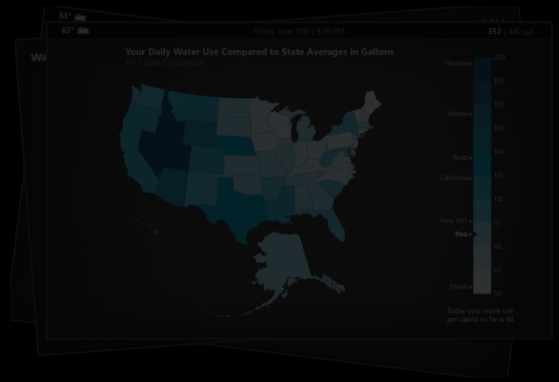
Spatial



Rainflow



Per-Occupant



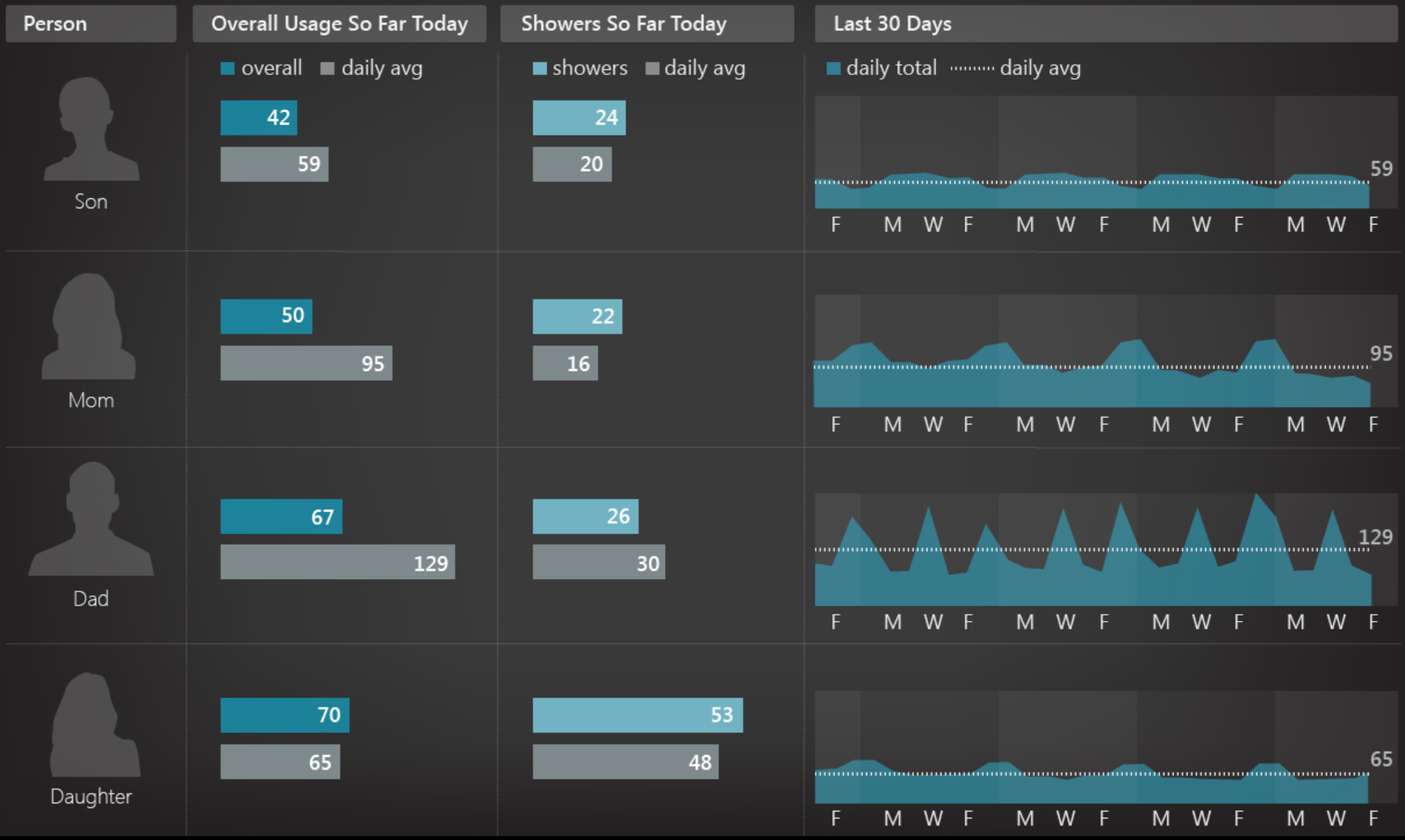
Other

DESIGN SET 2: DESIGN PROBES

Per-Occupant View

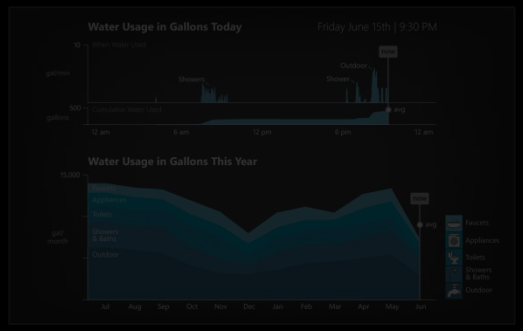
Personal Usage Totals

Friday June 15th | 9:30 PM



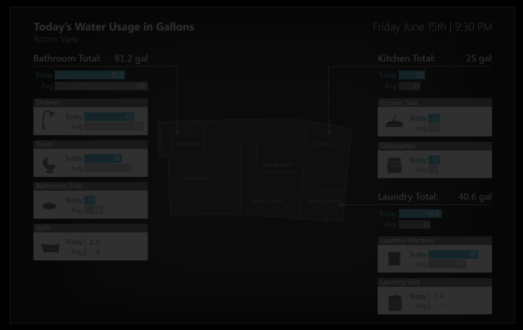
DESIGN SET 2: DESIGN PROBES

Design Probes Explored

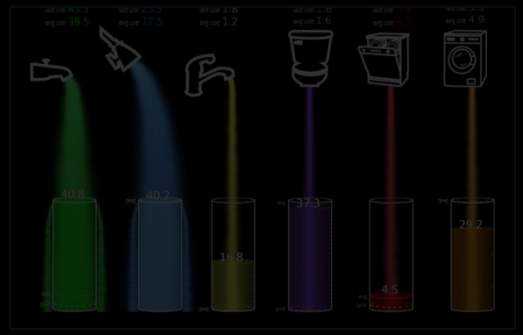


Time-Series

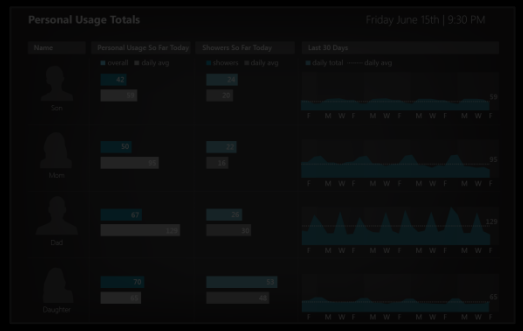
Aquatic Eco-system



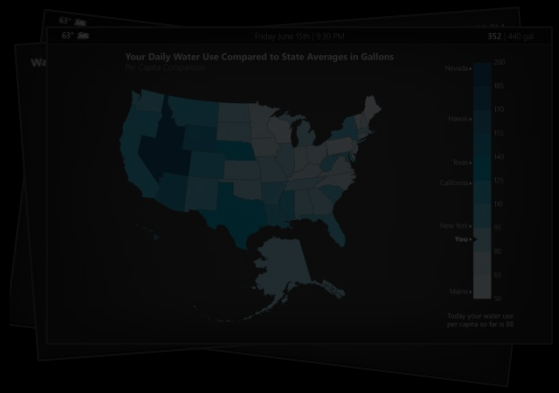
Spatial



Rainflow



Per-Occupant



Other

Aquatic Ecosystem Design Influences

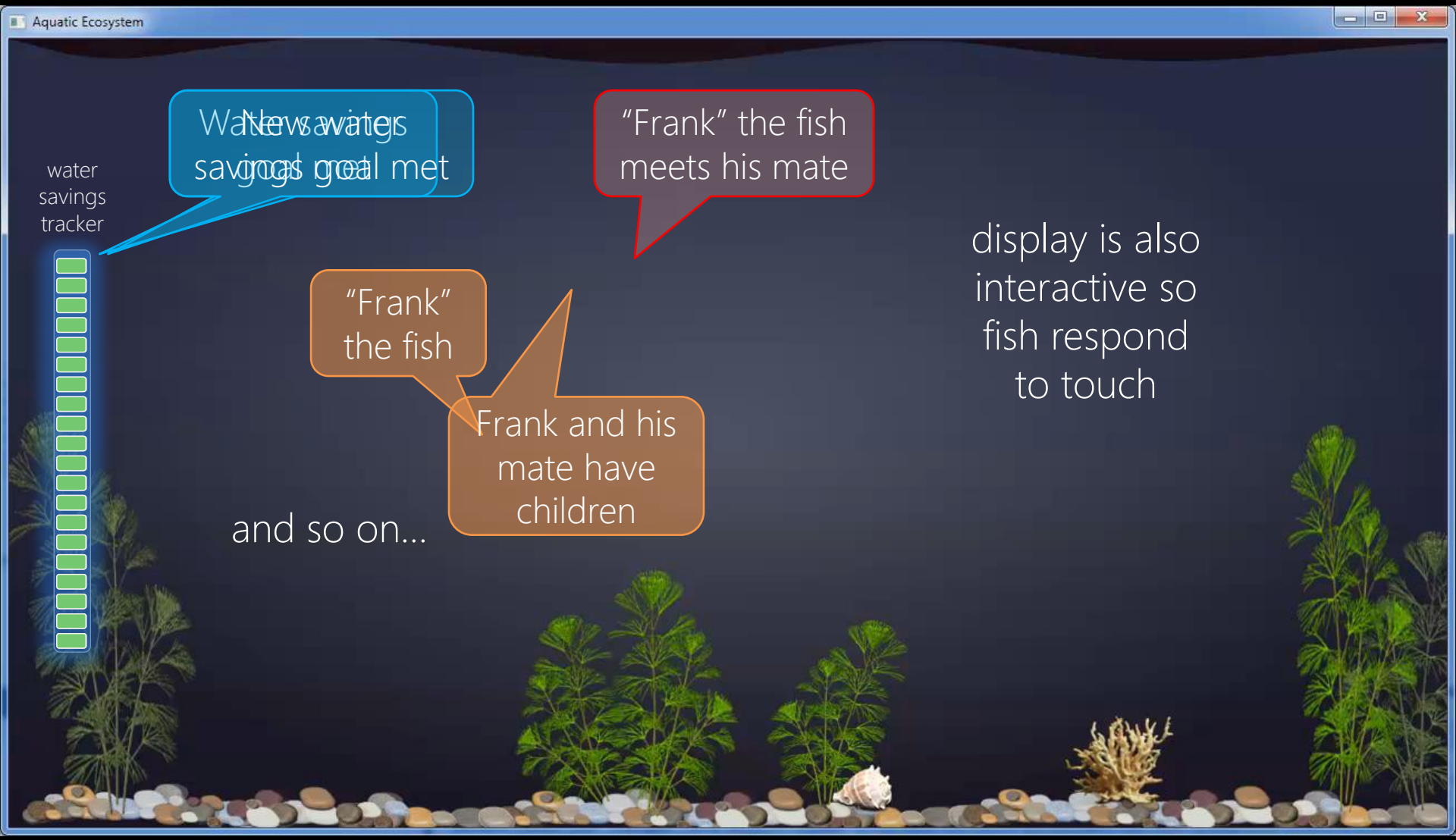
ubifit

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

ubigreen

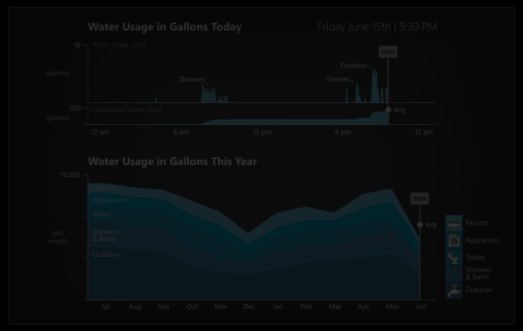
Froehlich *et al.*, CHI 2009

Aquatic Ecosystem View Movie



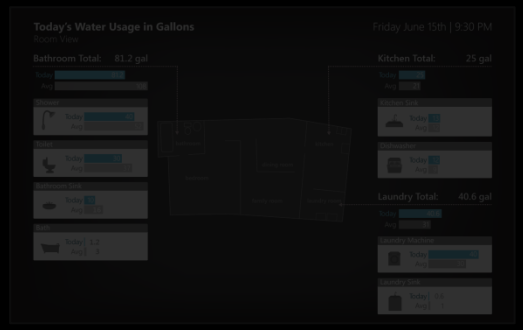
DESIGN SET 2: DESIGN PROBES

Design Probes Explored

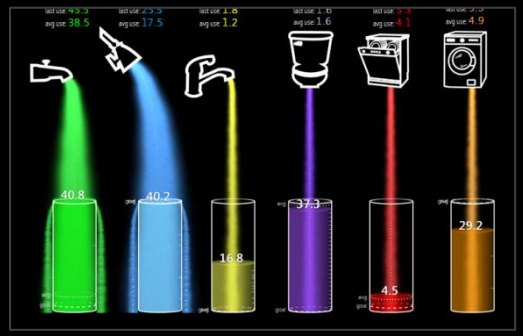


Time-Series

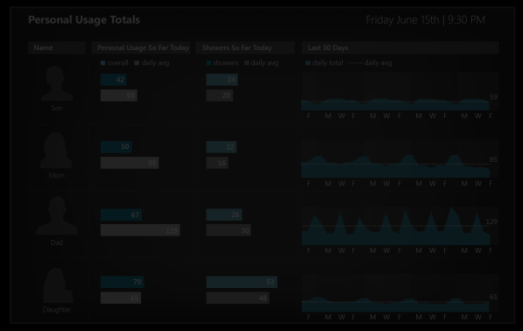
Aquatic Eco-system



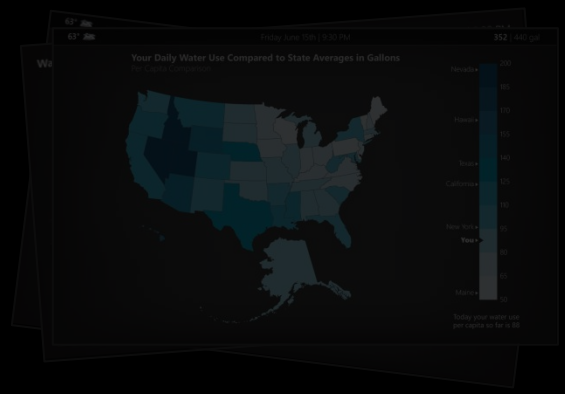
Spatial



Rainflow

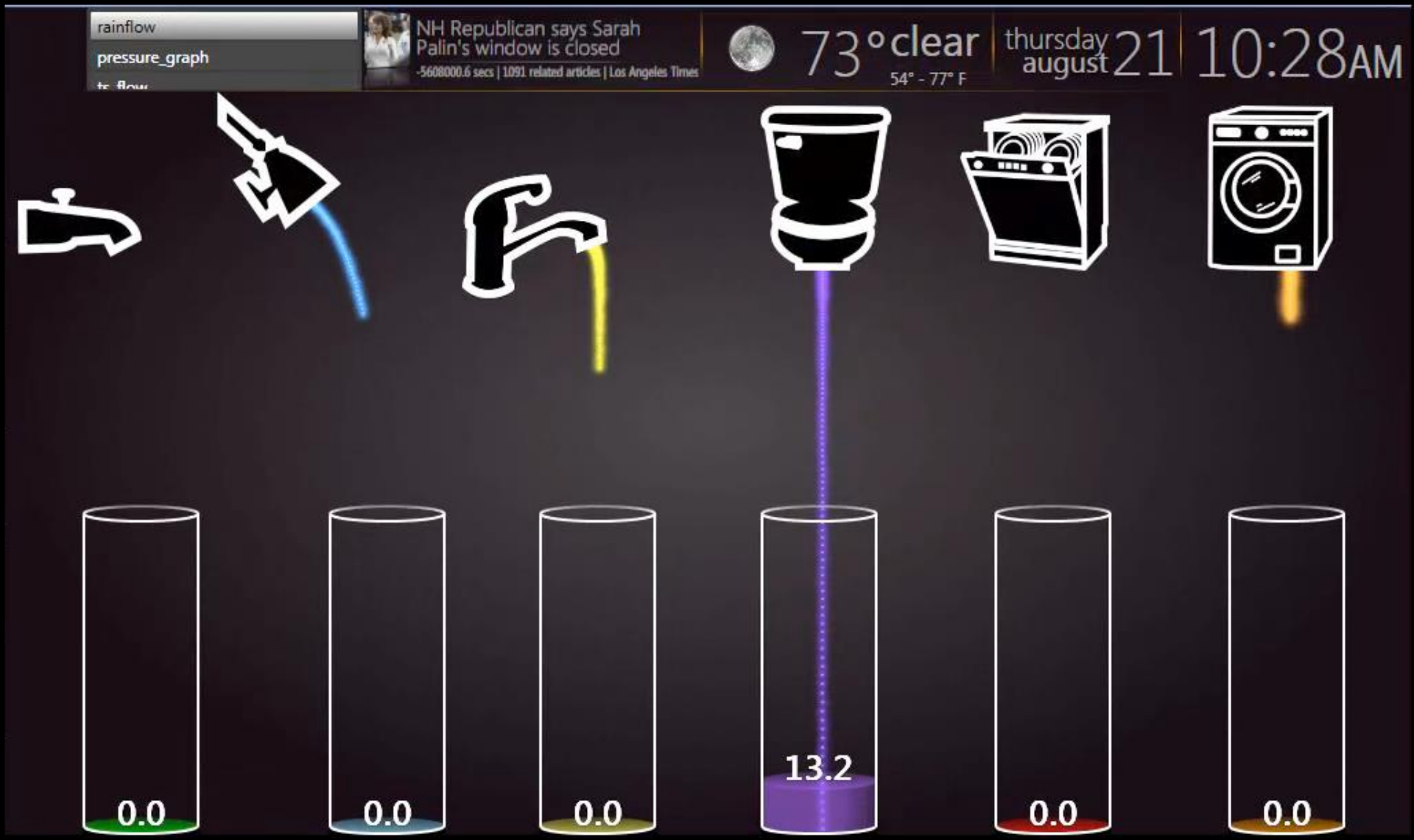


Per-Occupant



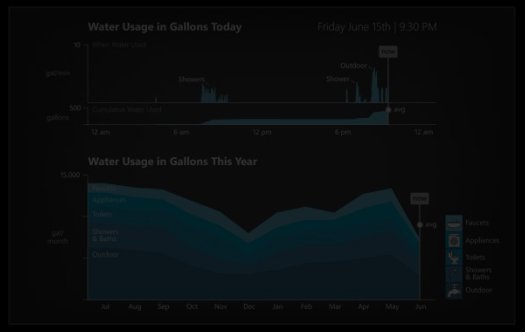
Other

Rainflow View Movie



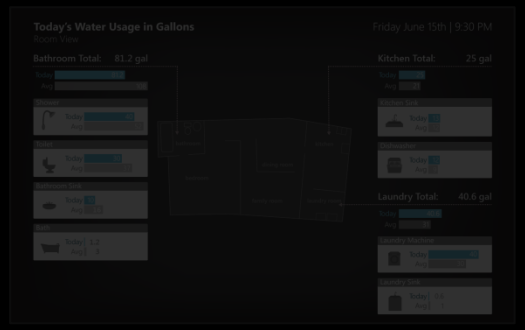
DESIGN SET 2: DESIGN PROBES

Design Probes Explored

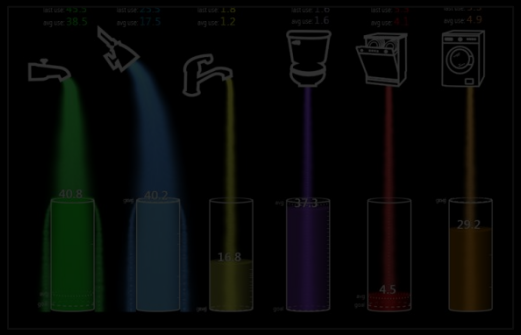


Time-Series

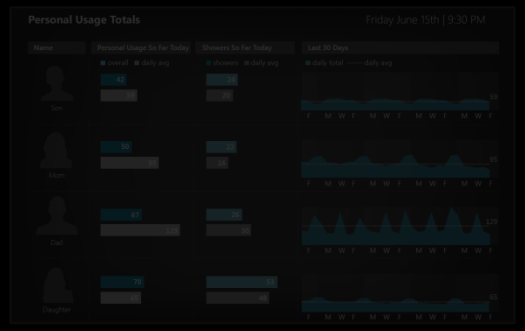
Aquatic Eco-system



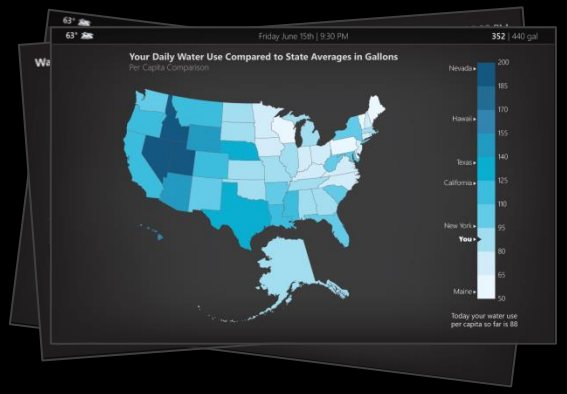
Spatial



Rainflow



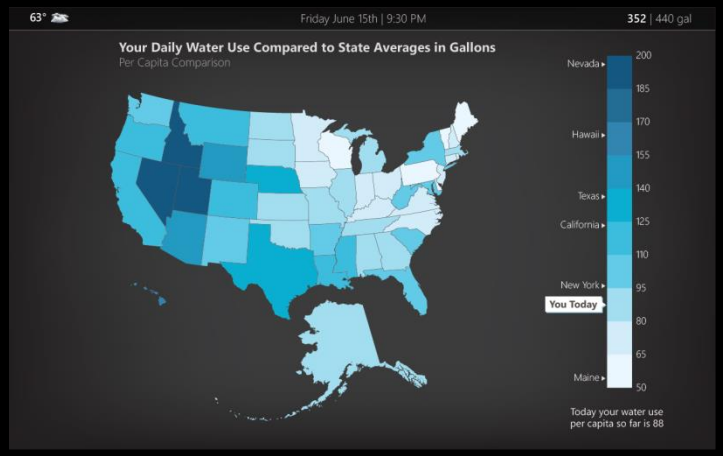
Per-Occupant



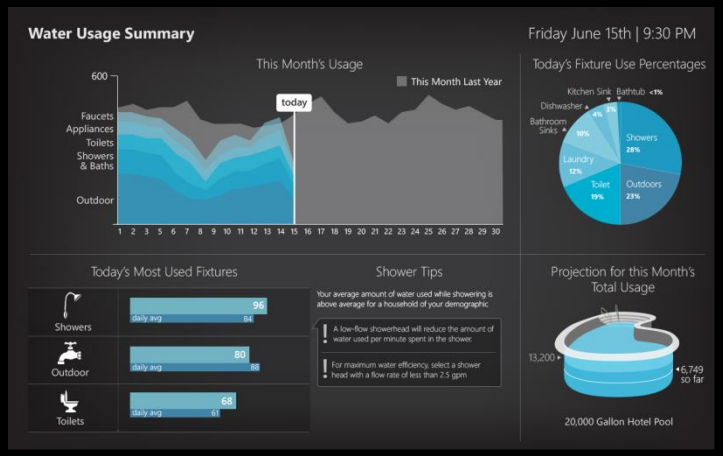
Other

DESIGN SET 2: DESIGN PROBES

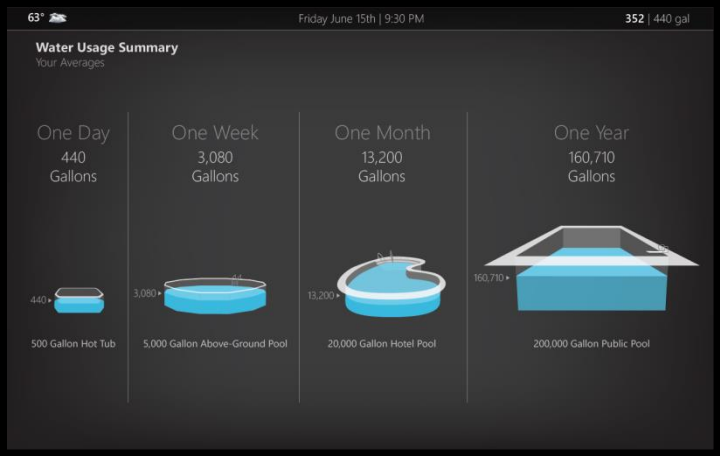
Other Design Probes



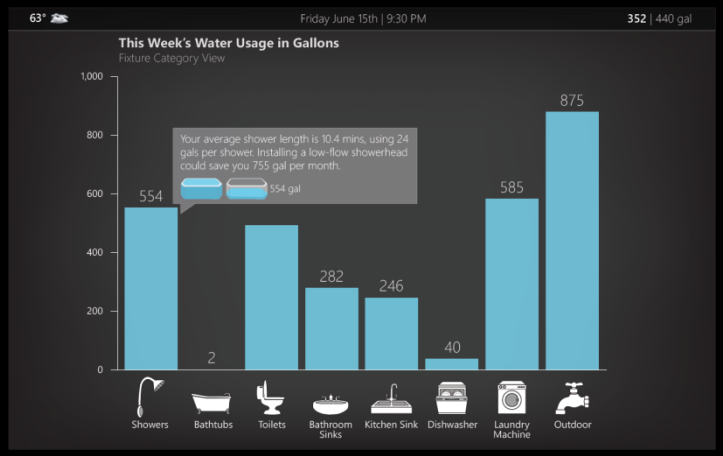
Geographic Comparisons



Dashboards

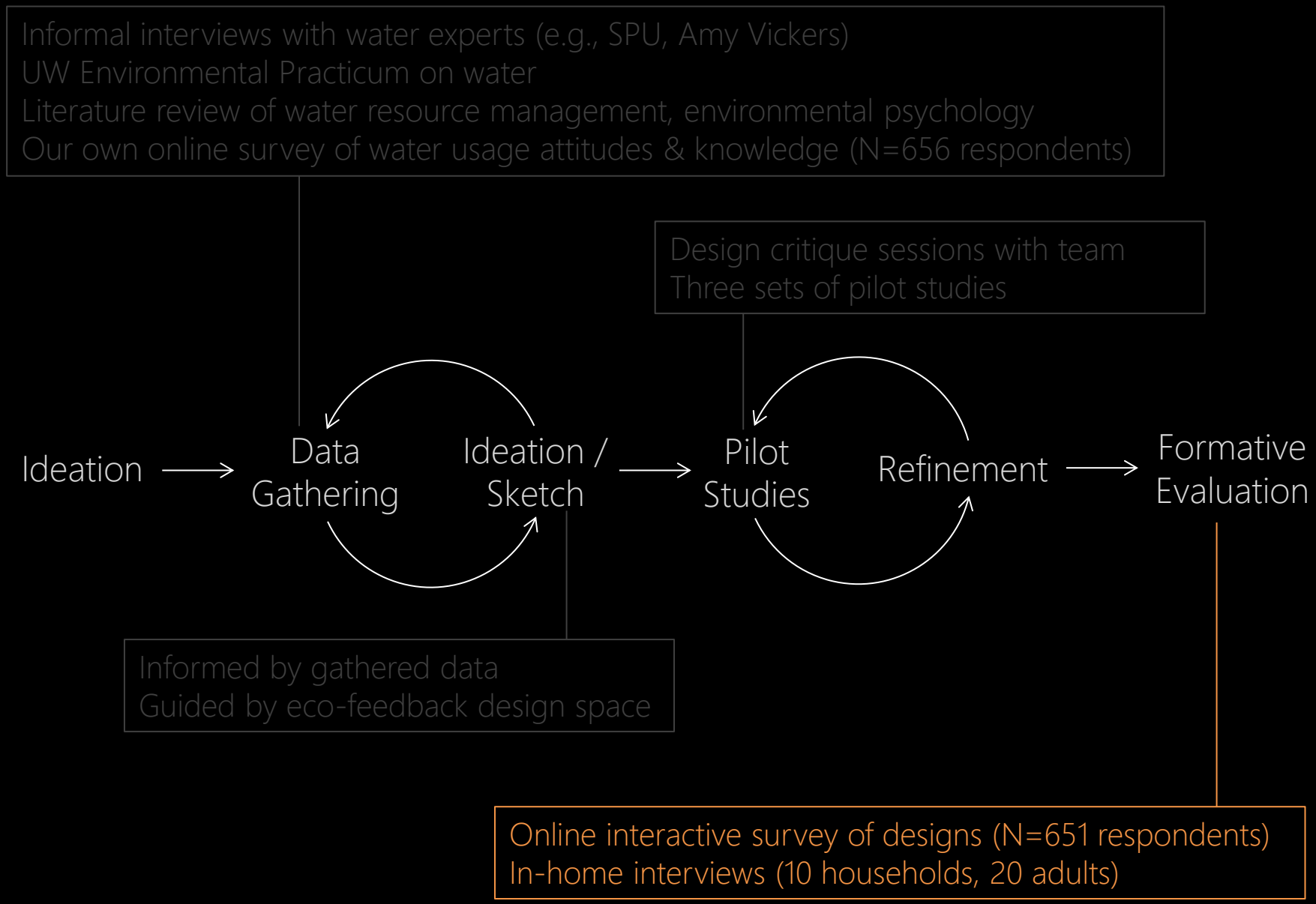


Metaphorical Unit Designs



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%

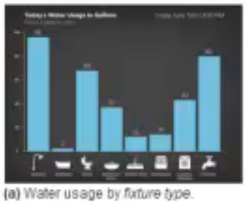
Water Feedback Evaluation Survey

Hot and Cold Breakdown

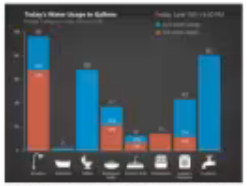
44%

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*.

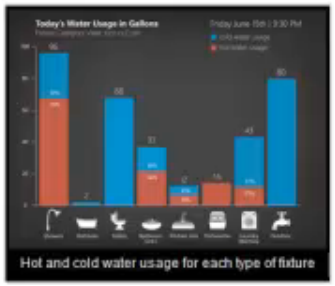


(b) Water usage by fixture type with *hot and cold breakdown*.

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



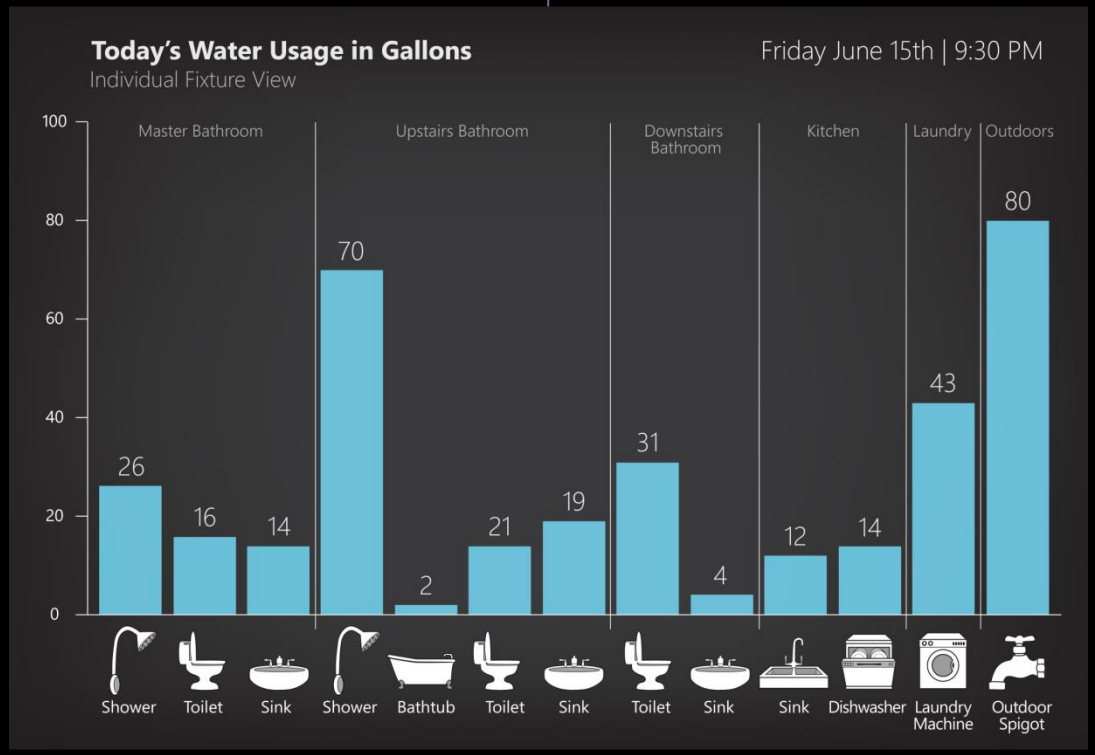


Daily average consumption by fixture for the month of May
69.3 gallons
of water consumed per day on average
Weekly consumption pattern for the month of May
average consumption for this day of the week
average daily consumption
M T W T F S S

Findings

Data Granularity

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



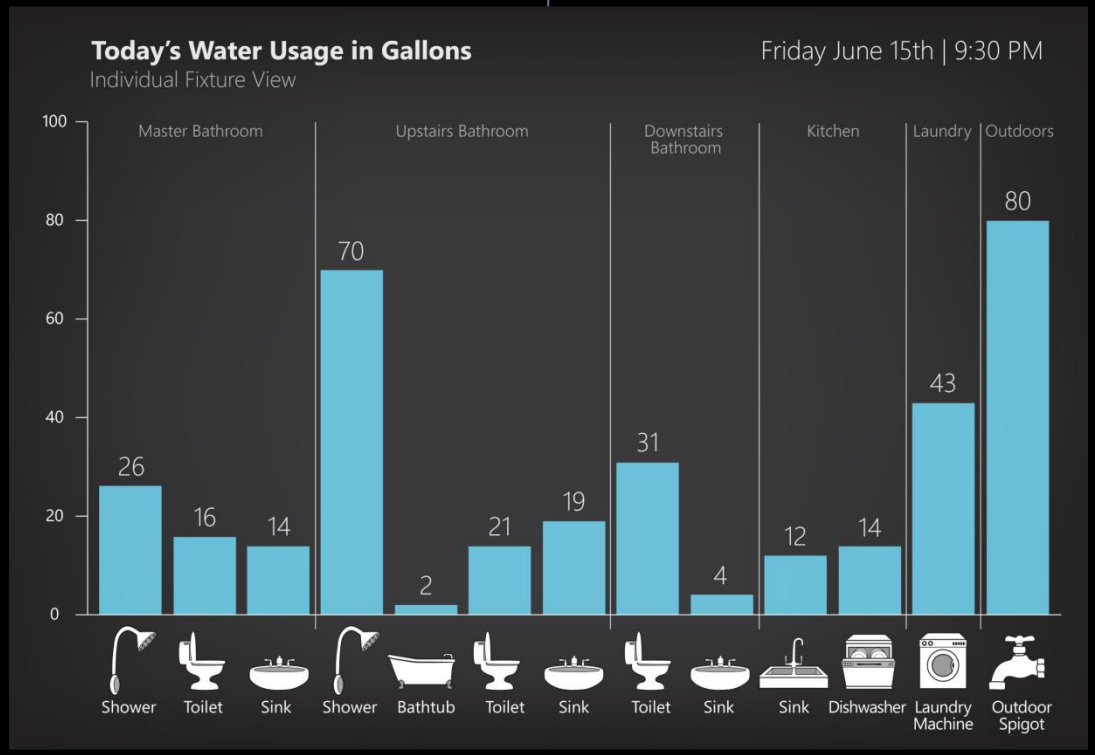
"This display lets you more easily identify the specific areas that need attention"

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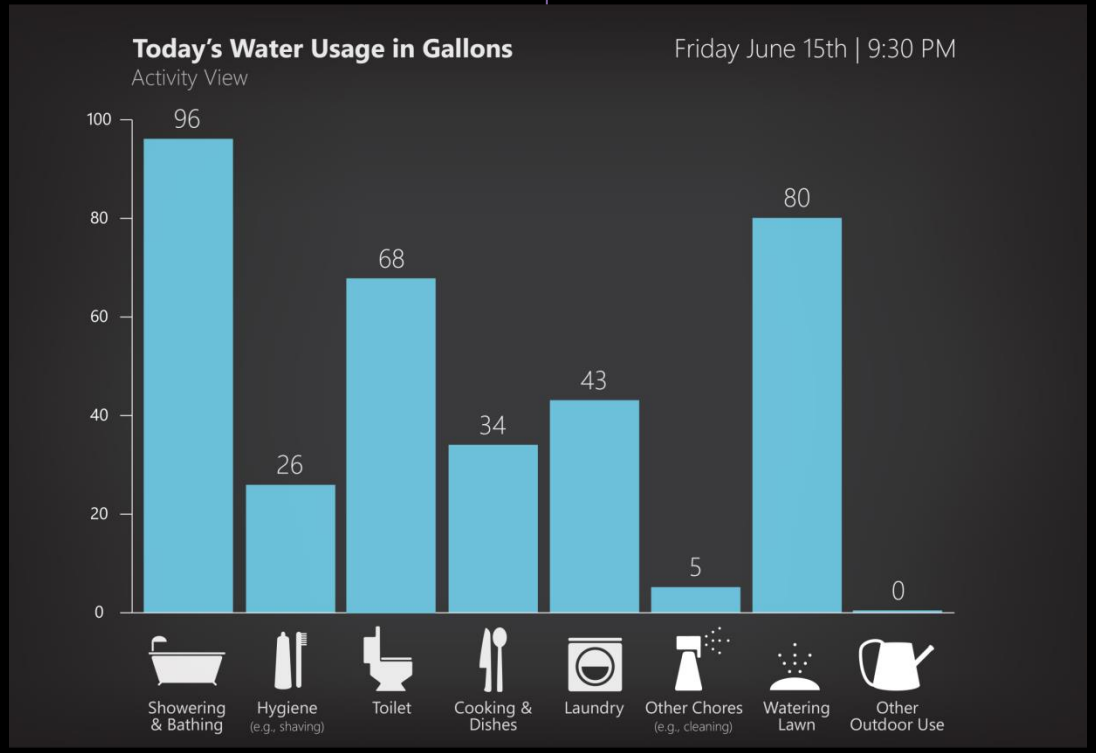
coarse-grain ≥neighbor-hood | home | room | activity | fixture category | fixture | ≤ valve **fine-grain**



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

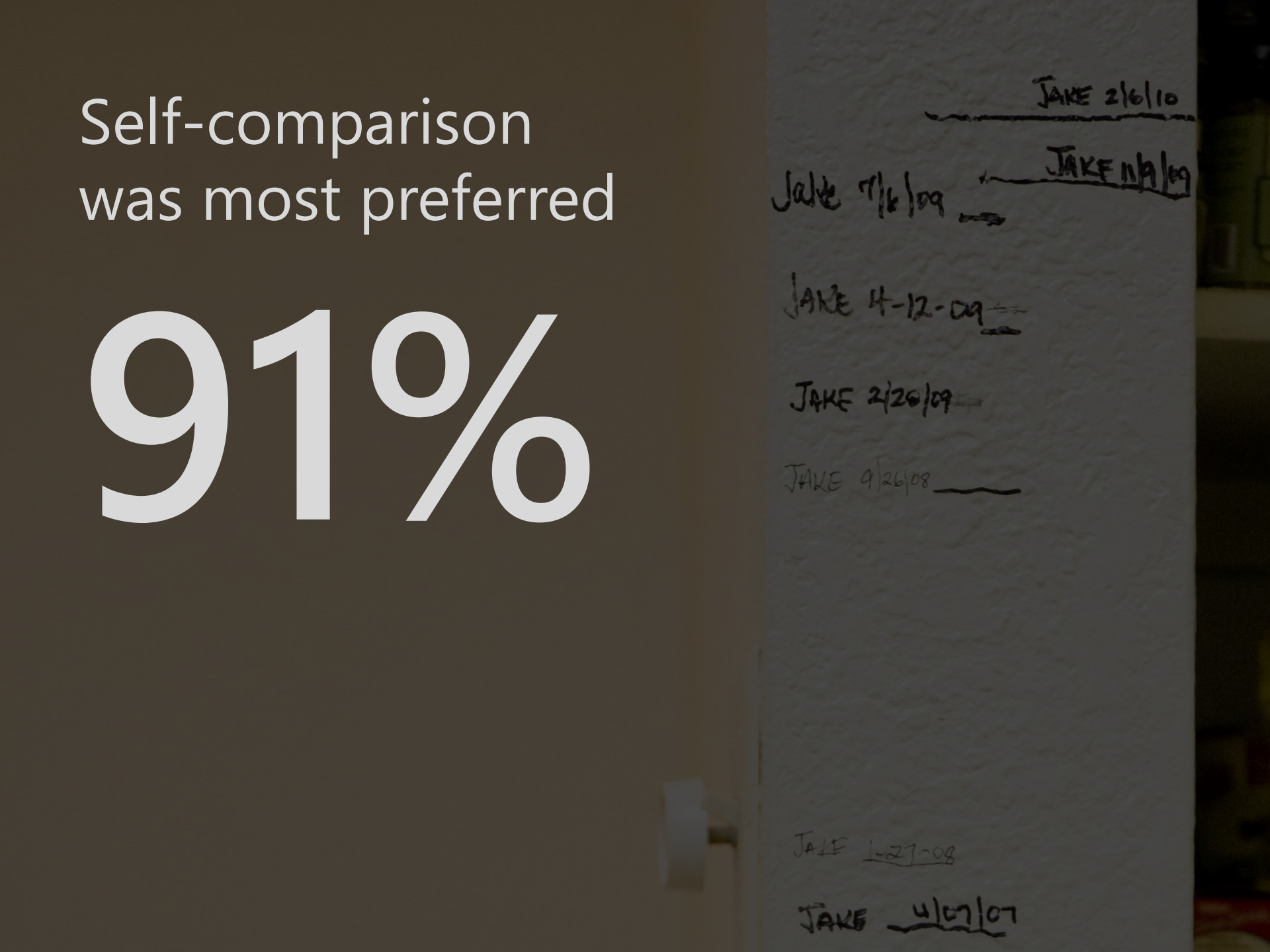
> I don't think very well in 'thousands of gallons', but $20 I can understand. That's a case of beer down the drain, if you will

R48


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

Self-comparison
was most preferred

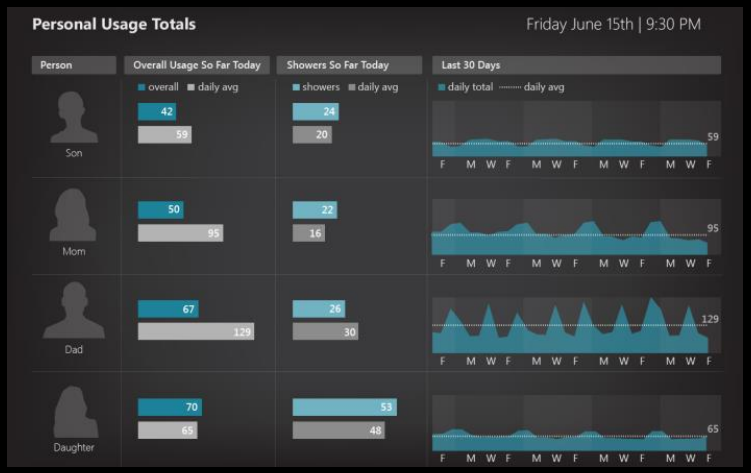
91%



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

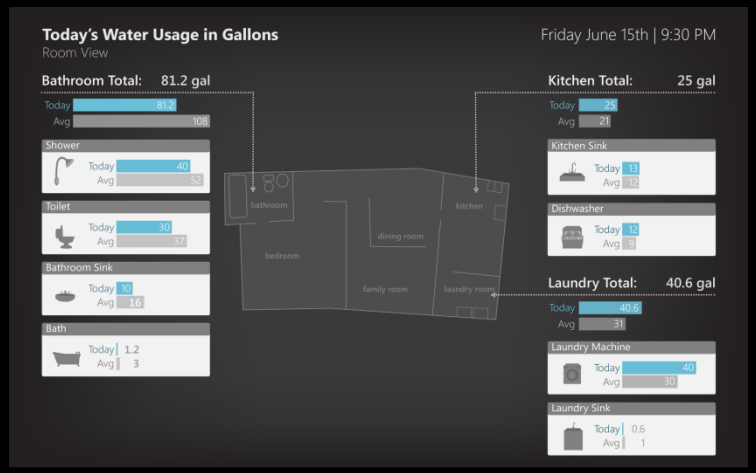
> It pits the family members against each other rather than encouraging collaboration

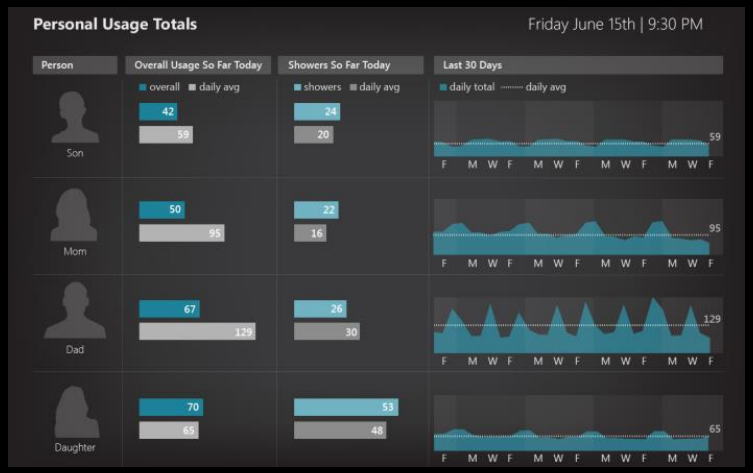
R485

> [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

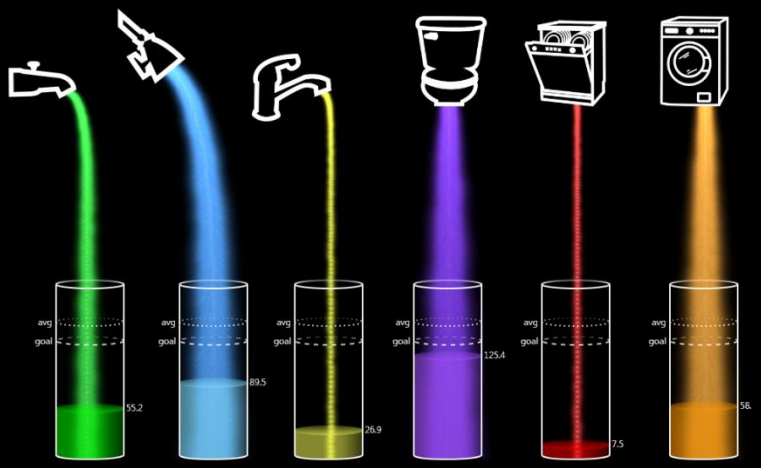
"There's no reason to add an element of 'blame' to conservation efforts within a family"

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"

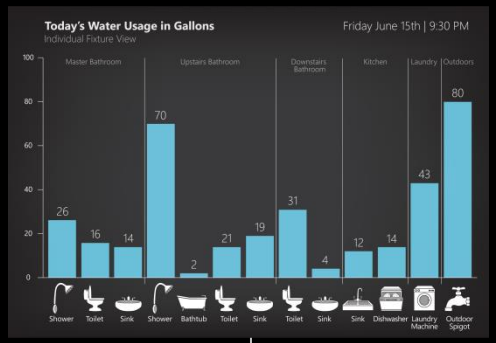
I4.1

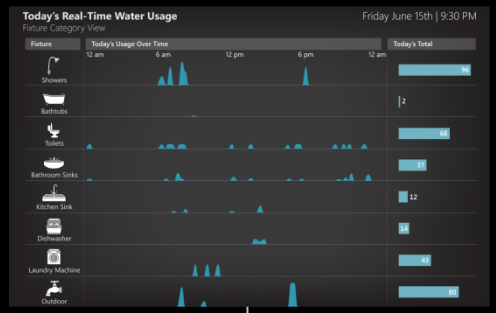
"It doesn't appeal to me as much. I don't do Foursquare. This distracts me a little bit and it doesn't make me think about my usage"

I4.2

Useful as an educational tool?

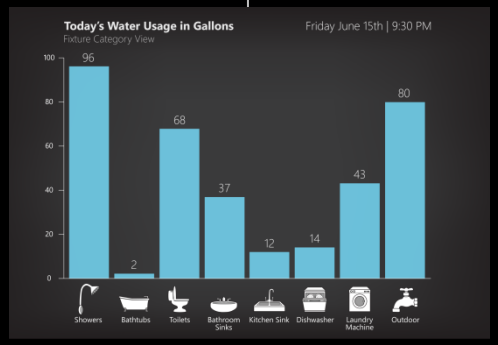
Privacy Spectrum

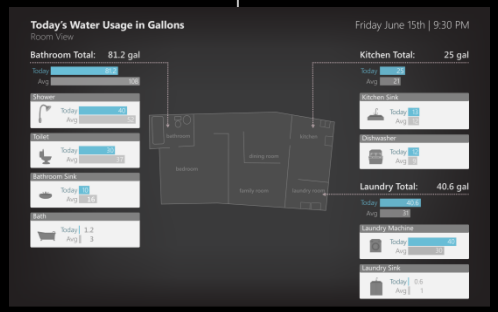


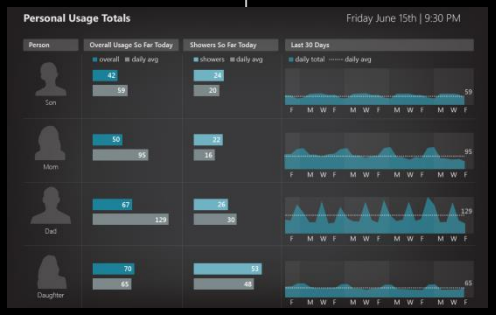


Least Invasive

Most Invasive







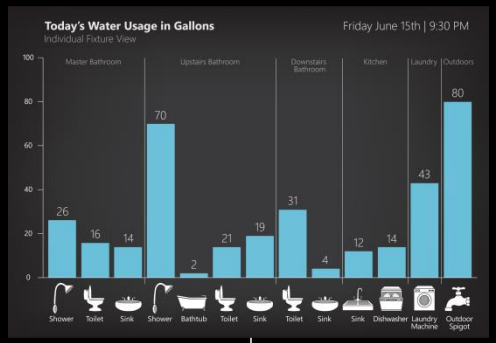
“It’s incredibly invasive. And other people’s water consumption is not my business.”

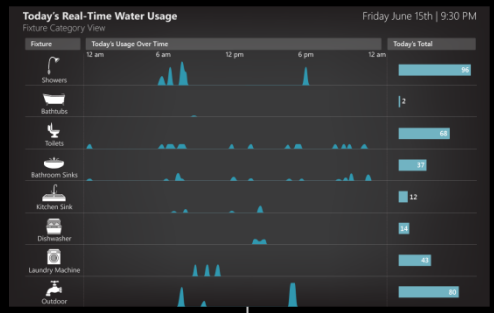
R25

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

R25

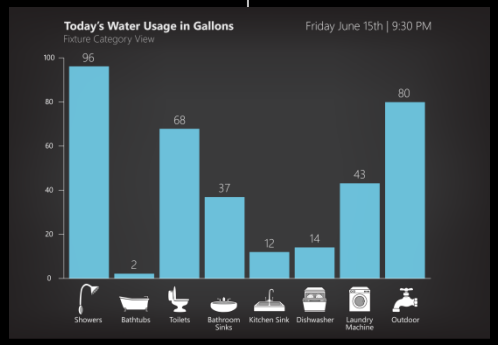
Privacy Spectrum

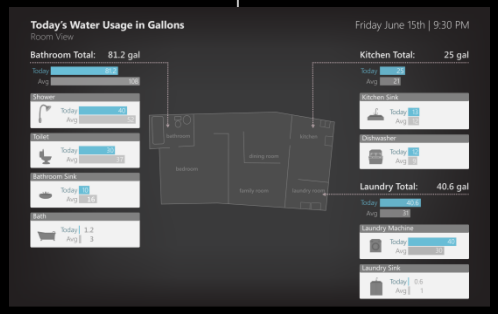




Least Invasive

Most Invasive





Display Location Preferences

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

I2.1

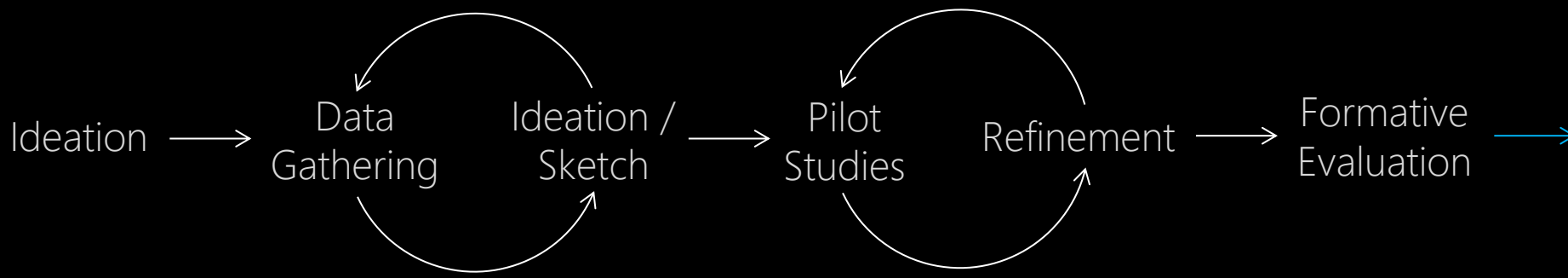
Display Location Preferences

kitchen

near thermostat

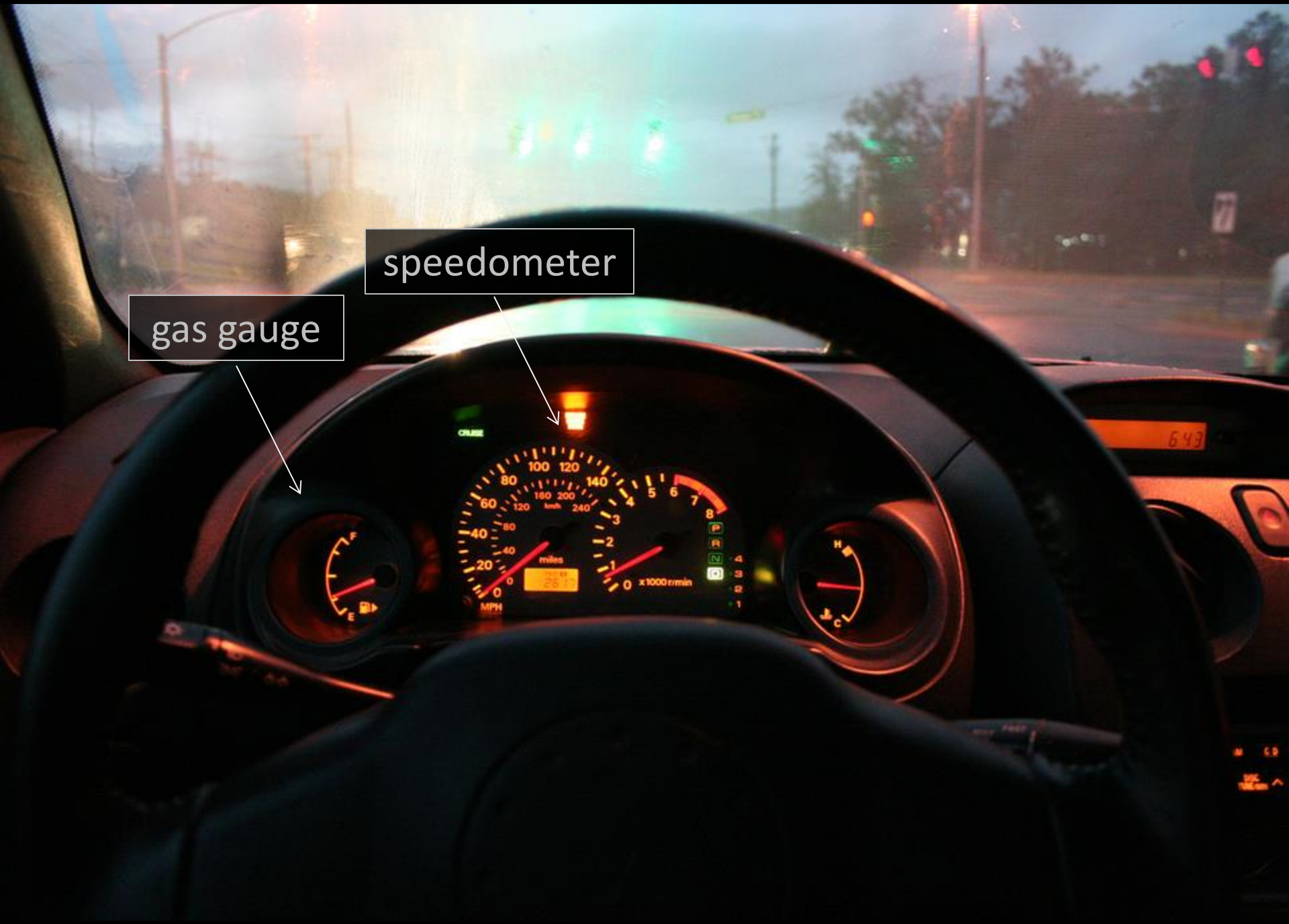
high traffic areas

accessible when needed


Ideation
Data Gathering
Ideation / Sketch
Pilot Studies
Refinement
Formative Evaluation

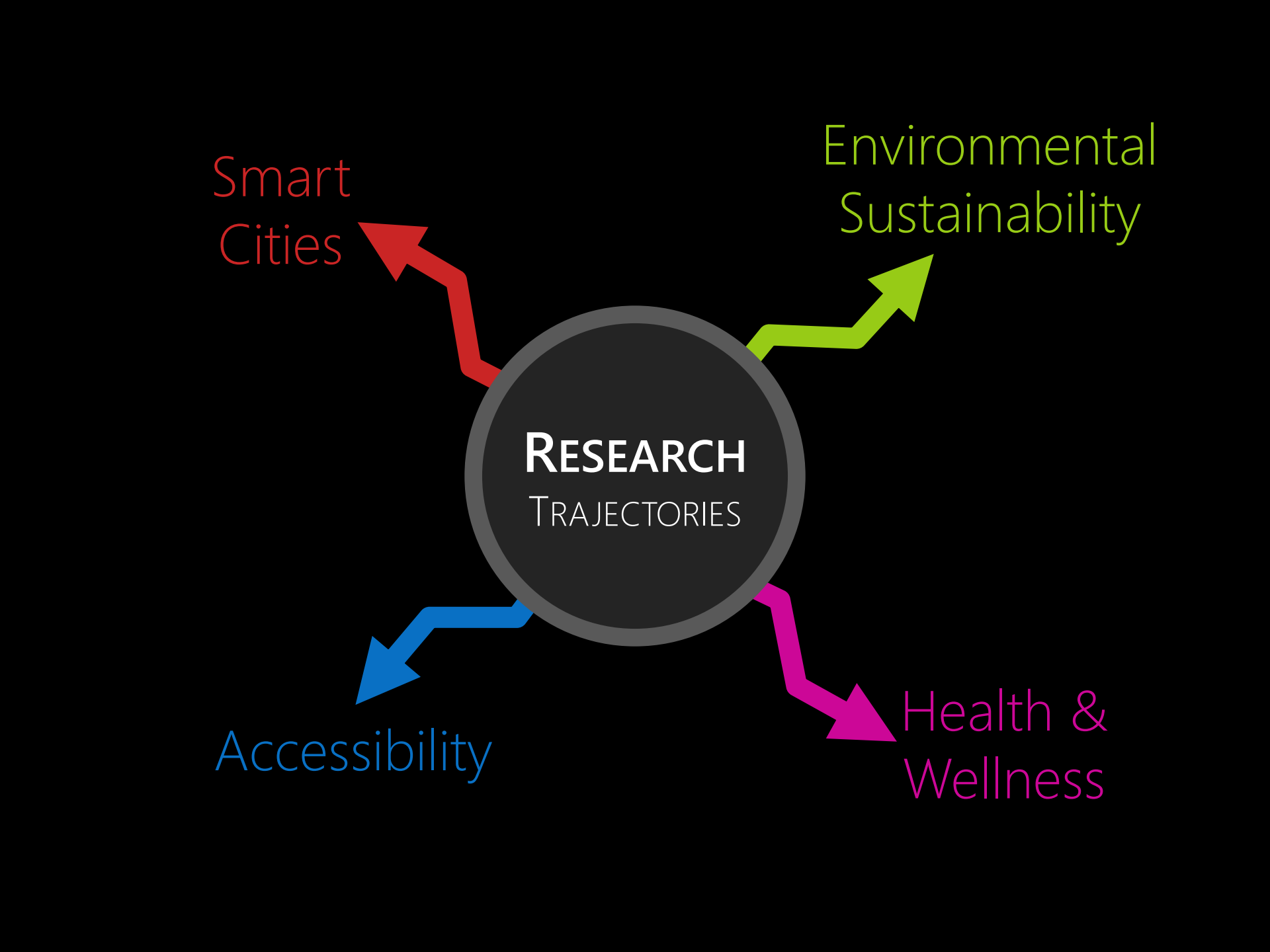
In Closing


Generation 1
commodore
commodore
1541


speedometer
gas gauge


CRUISE
643
0 1 2 3 4 5 6 7 8
x1000 r/min
P R N D
4 3 2 1
H
C

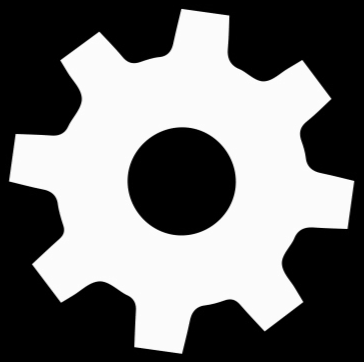

become a better
you
sensing
feedback


Smart Cities
Environmental Sustainability
RESEARCH
TRAJECTORIES
Accessibility
Health & Wellness

Come work with us!

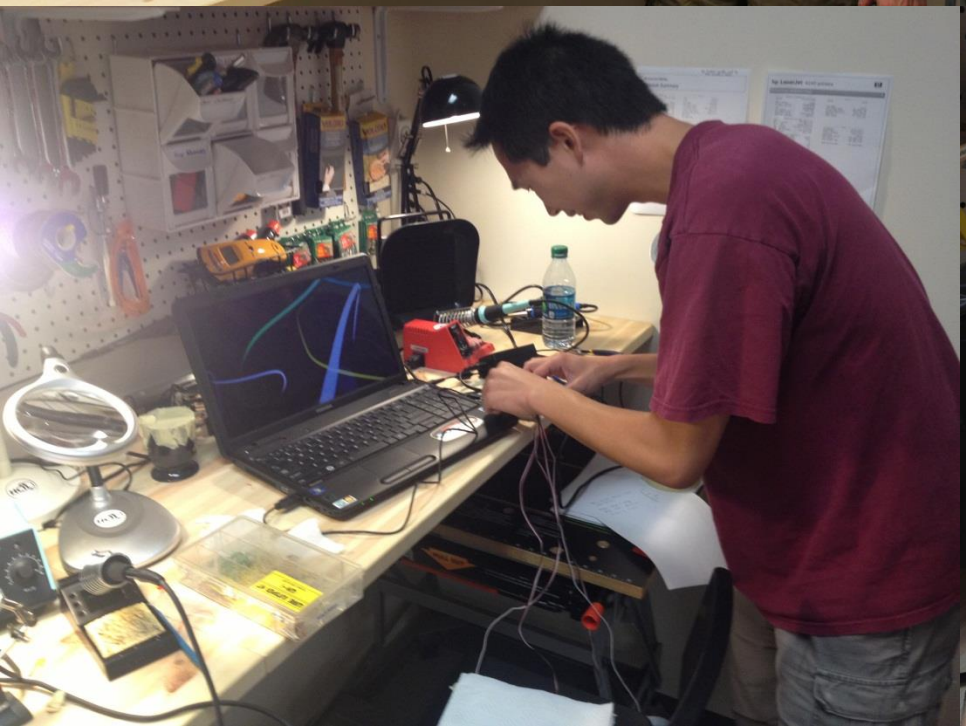
CS grad applications are **due Dec 15th**
iSchool grad applications are **due Dec 1st**

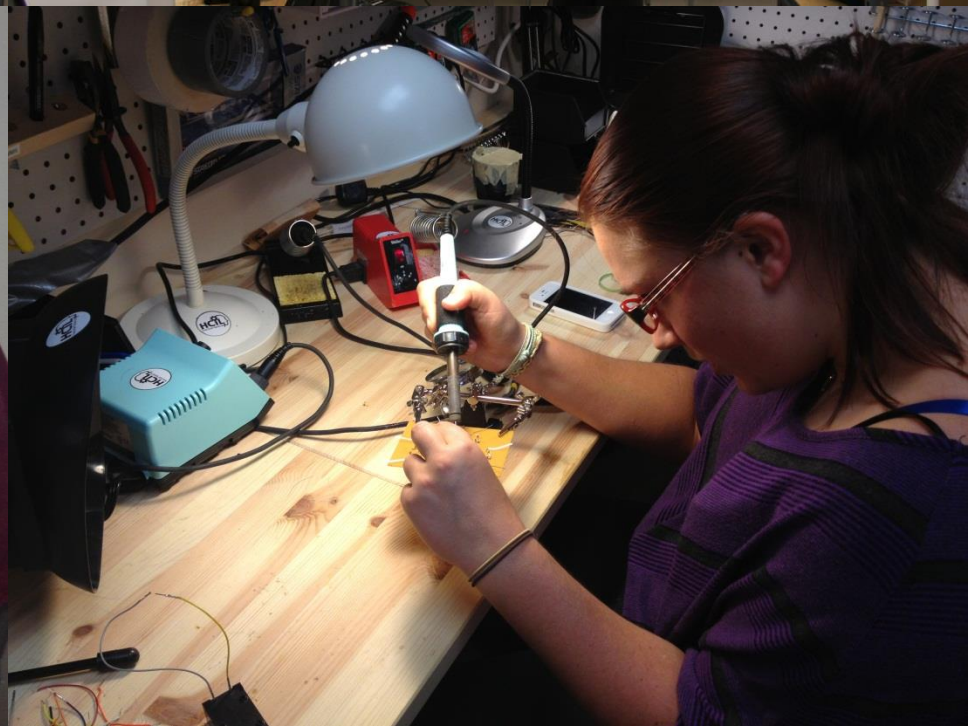
Now in our 30th year!



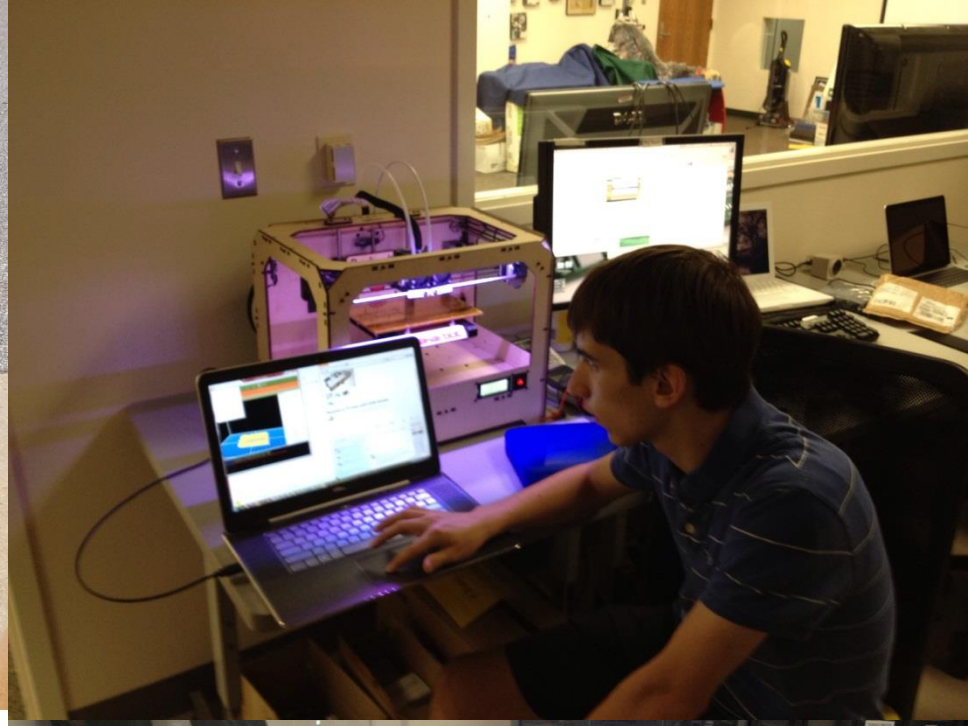
HCIL Expansion
Just Opened!

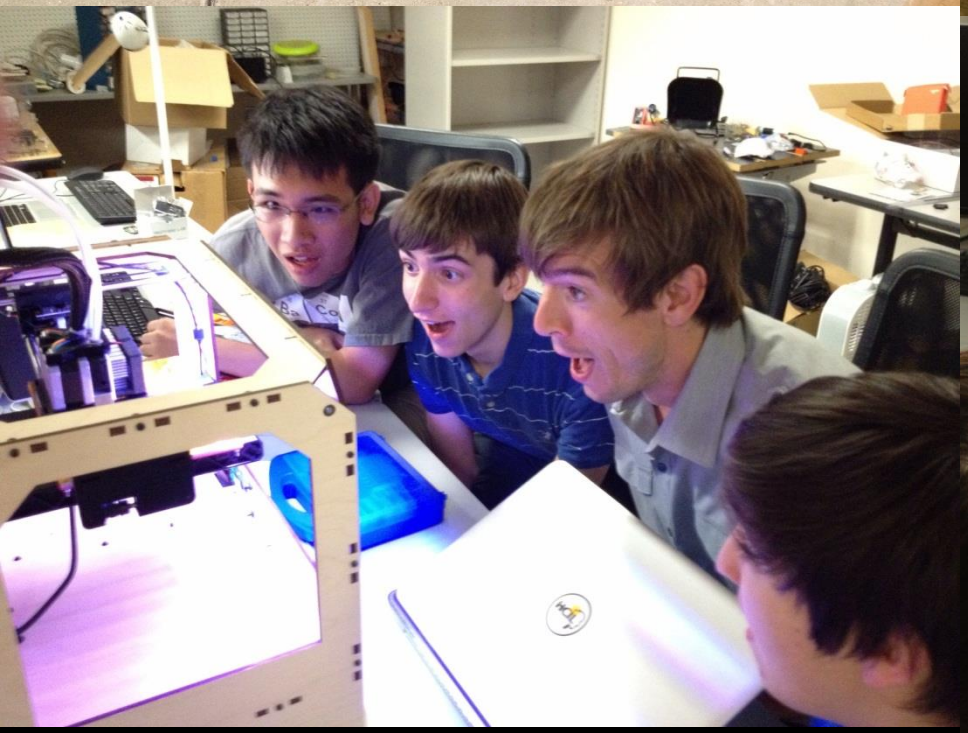

HCIL Expansion
Just Opened!
HCIL
hackerspace

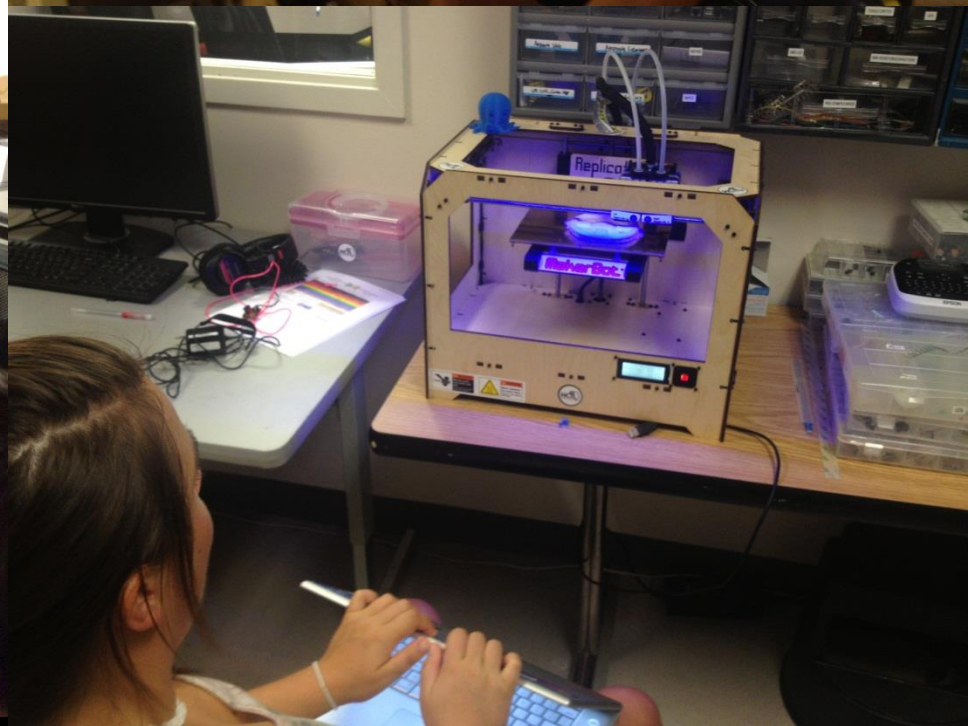





MakerBot







The Water **Eco-Feedback** Team!


SolaiRamanathan


JoshPeterson


InnessWragg

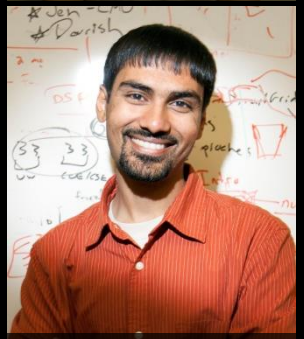

FabiaFu


MazhengminBai


MarilynOstergren


EricLarson


LeahFindlater

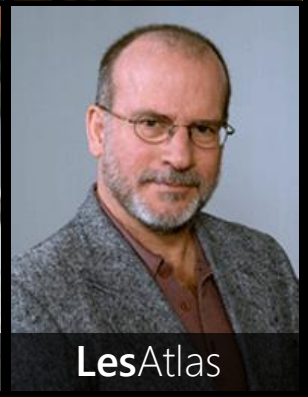

ShwetakPatel

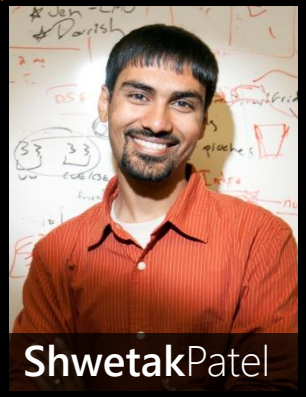

JamesLanday

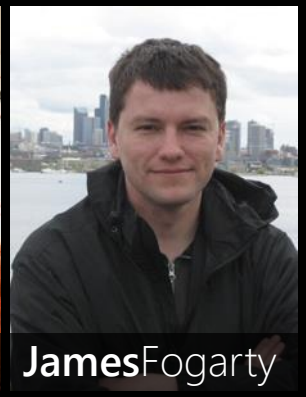
Acknowledgements:

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
David Hsu, Assistant Professor City and Regional Planning, UPenn
Sara Sheridan for her early design work

The HydroSense Team!







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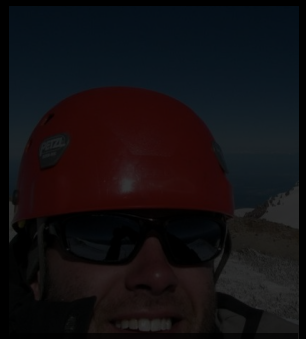
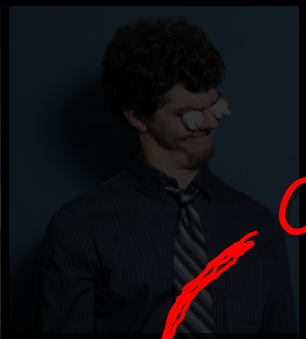


ConorHaggerty



Elliot Saba

TimCampbell

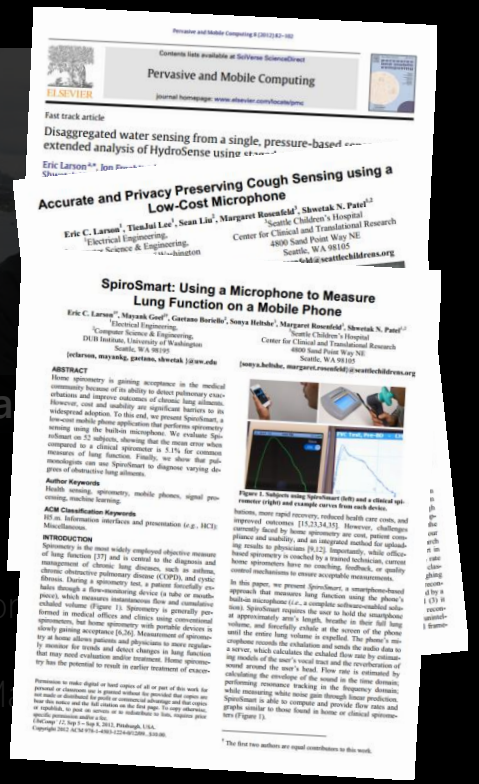
On the job market this year!

EricLarson

CV Highlights

Health and sustainability sensing expert. Signal processing guru.

16 conference papers
4 journal papers
4 best paper nominations
Multiple research awards



Pervasive and Mobile Computing

Disaggregated water sensing from a single, pressure-based ... extended analysis of HydroSense using ...

Accurate and Privacy Preserving Cough Sensing using a Low-Cost Microphone

SpiroSmart: Using a Microphone to Measure Lung Function on a Mobile Phone

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Sara Sheridan for her early design work

Reflections of Ourselves

Sensing and Feedback to Inform Everyday Human Behavior

Human Computer Interaction Laboratory

@jonfroehlich

Assistant Professor Computer Science

UNIVERSITY OF MARYLAND

Persuasiveness Scale

information rendered
neutrally

information rendered
persuasively


CRUISE
100 120
80
140
60
160 200
120 km/h 240
40
80
20
40
0
0
MPH
miles
2611
3
2
1
0
x1000 r/min
4
5
6
7
8
P
R
N
D
4
3
2
1
F
E
H
C
643
Does your car render
MPH persuasively?


YOUR SPEED
22
Is this more persuasive?

Are Vehicle-Activated Signs **Effective**?

Average speed reduction of ~7 mph

Statistically significant 1/3rd reduction in accidents

Why are the signs effective?
Do drivers habituate to them?
At what point past the sign, do drivers speed up?
Would speed reductions last if the sign were removed?
How could you make a more effective sign?

Winnett & Wheeler., **Vehicle-Activated Signs – A Large-scale Evaluation**, *TRL Report TRL548*, 2002


Enabling direct comparison
SPEED LIMIT
25
23
YOUR SPEED


46
DAYS IN HOSPITAL BED
SPEED LIMIT
25
SLOWER IS BETTER
ELM GROVE POLICE


YOUR SPEED
mph
reward
YOUR SPEED
mph
punishment
Welcome to Kingston
Spaces Available
Fairfield Area
Bentall Centre
John Lewis
Seven Kings
Eden Walk
St James
Bittoms
OPEN
640
OPEN
OPEN


A rationale!
SLOW
CAUTION
CHILDREN
YOUR
SPEED
6
SPEED
LIMIT
25
SPEED
LIMIT
25

Could it be **Boulder, CO?**

Persuasiveness Scale

speedometer

plain vas

rationale vas

comparison vas

fear vas

reinforcement vas

information rendered
neutrally

information rendered
persuasively

What other types of spectrums exist?

How could they be represented to help the process of design?