



Modeling Water Age in Premise Plumbing Systems

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Levi Hauptert

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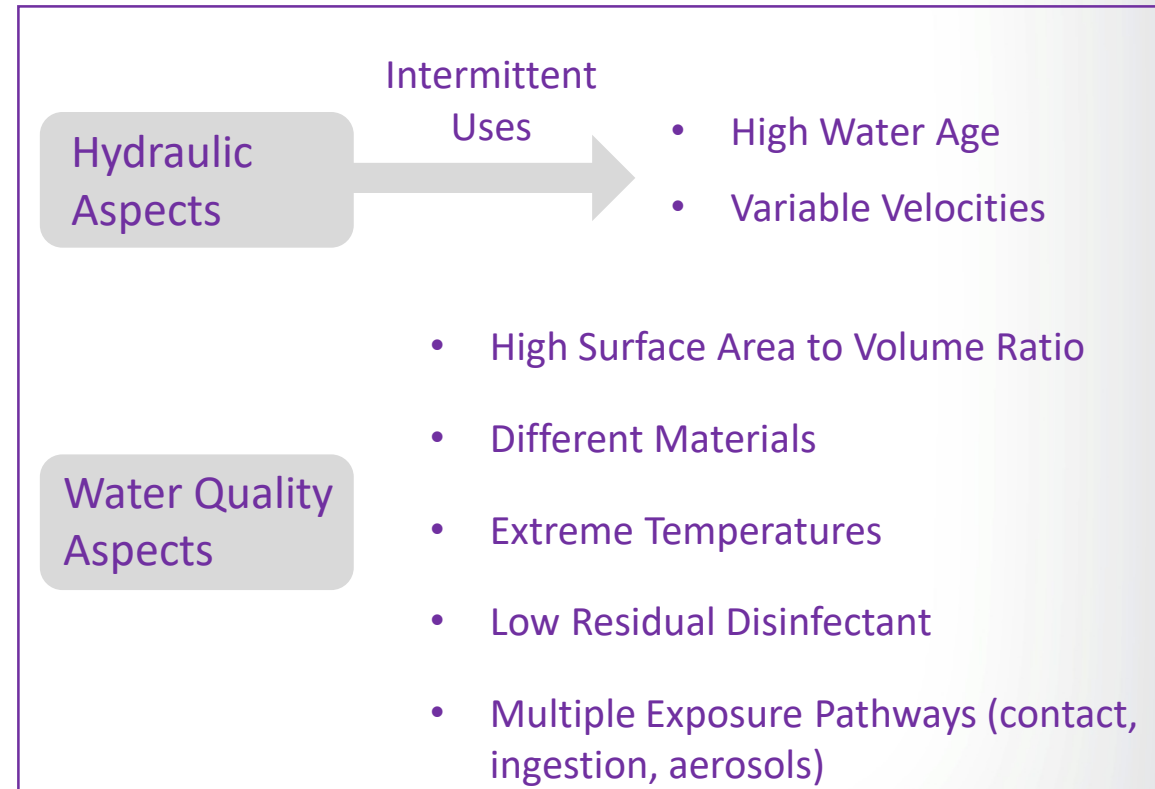
Outline

- Introduction
- Model Households
- Pattern Generation
- Scenarios
- Results
- Conclusions



- Framework for analyzing exposure to contaminants in premise plumbing systems
- Agent-based demand generation and analysis tool
- Using Monte Carlo methods to build pseudo-realistic usage patterns for multi-person homes
- Water age study demonstrates use of these tools

Premise Plumbing Challenges





Background

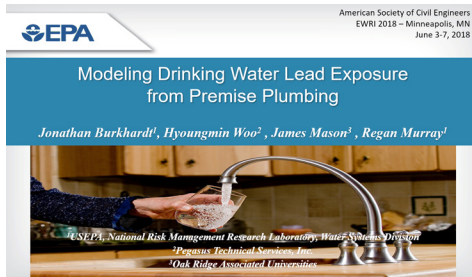
- Alternative Agent-Based Approaches
 - PRPSym – Buchberger & Li, World Env. And Water Resources Congress 2007
 - SIMDEUM – Blokker, et al., Drink. Water Eng. Sci, 2008
- Additional Work on Premise Plumbing Systems
 - Buchberger & Wu, J. Hydraulic Eng. 1995
 - WUDESIM – Abokifa, et al., Water Research 2016
 - Grayman, et al., WDSA 2008
 - Grayman & Buchberger, 8th WDSA Symposium Cincinnati 2006



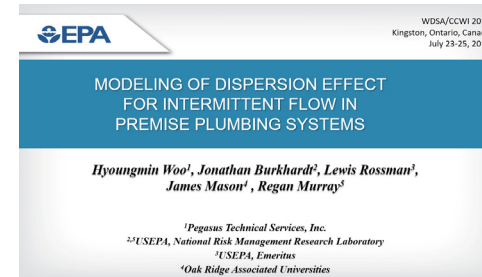


Background

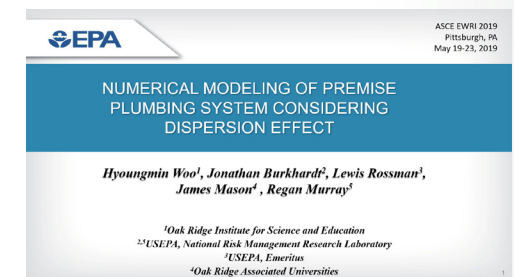
EWRI 2018



WDSA/CCWI 2018



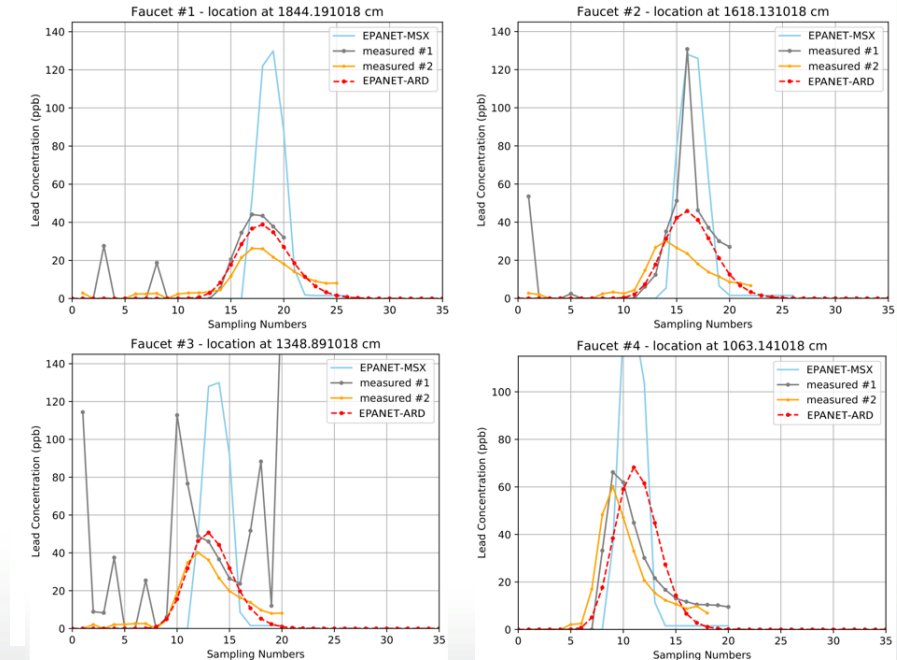
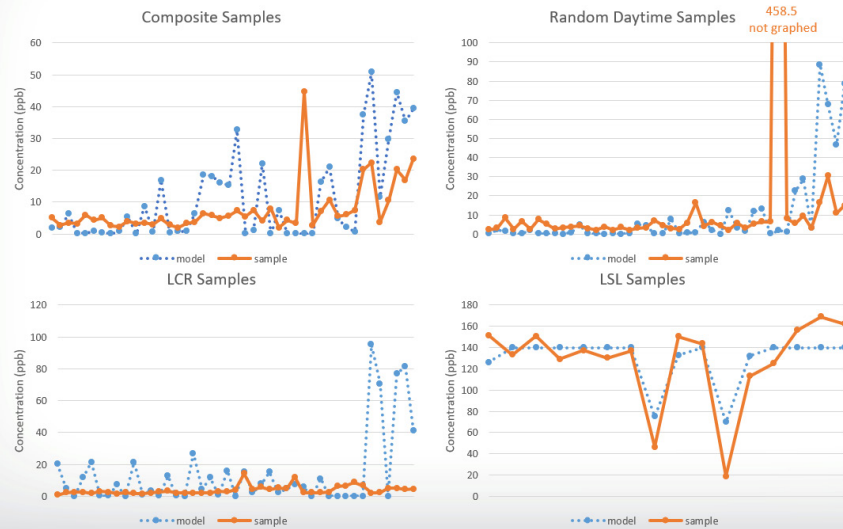
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Experimental Data & Introducing Dispersion



Sampling Comparison



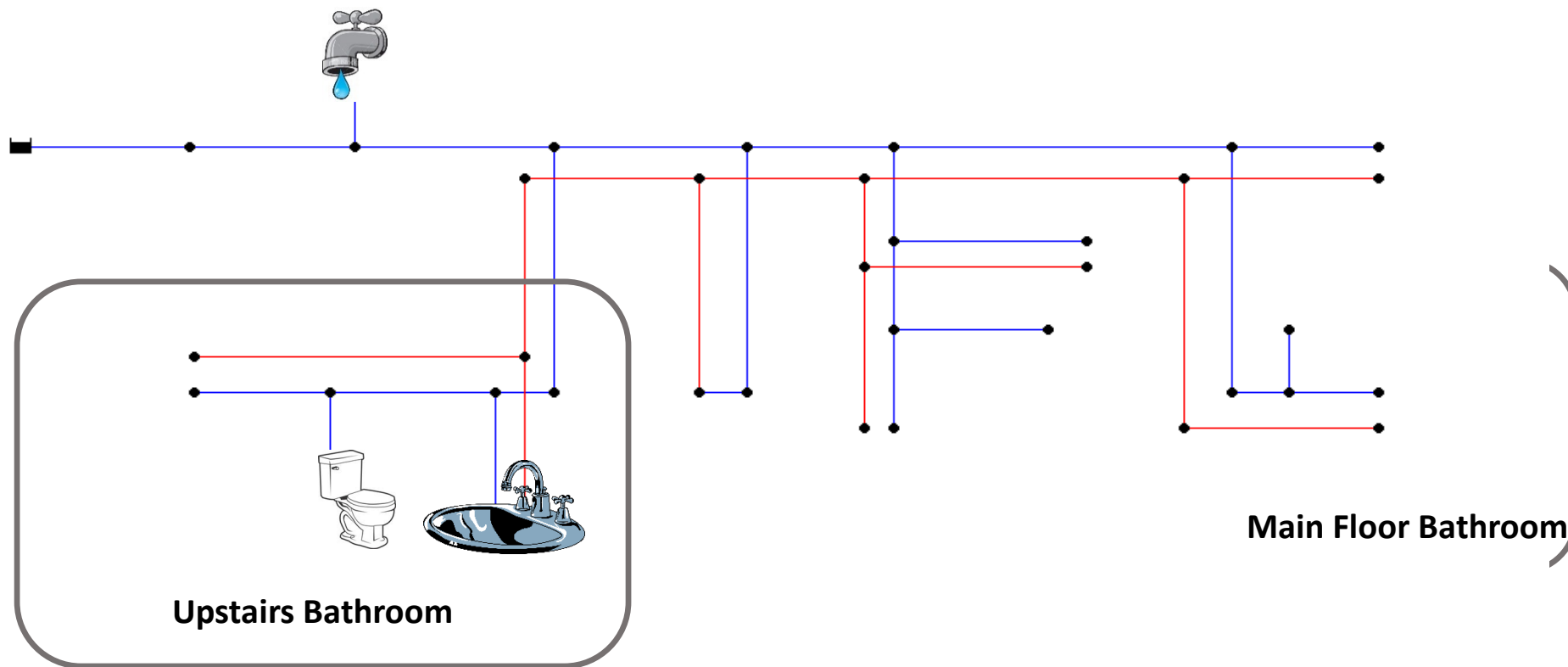


Development of Household Models

- Detailed measurements of pipe lengths, diameters & materials
- All fixtures represented with correct flow rates, volumes of use
 - Indoor and outdoor faucets
 - Toilets
 - Showers & baths
 - Dish washers
 - Washing machines
 - Refrigerators (ice makers, water)
- EPANET inp files created and available for use by research community



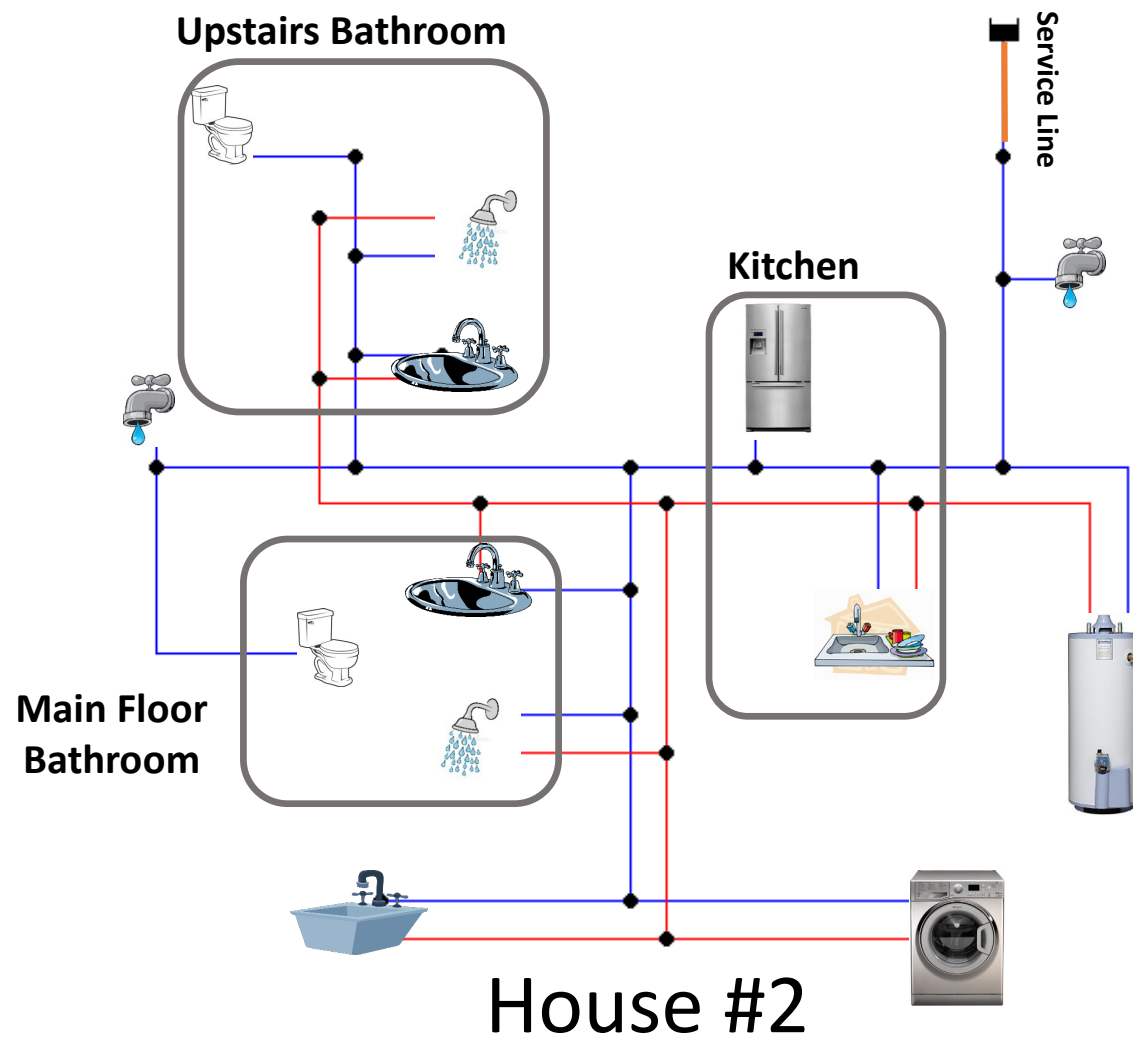
Household Model #1



House #1



Household Model #2





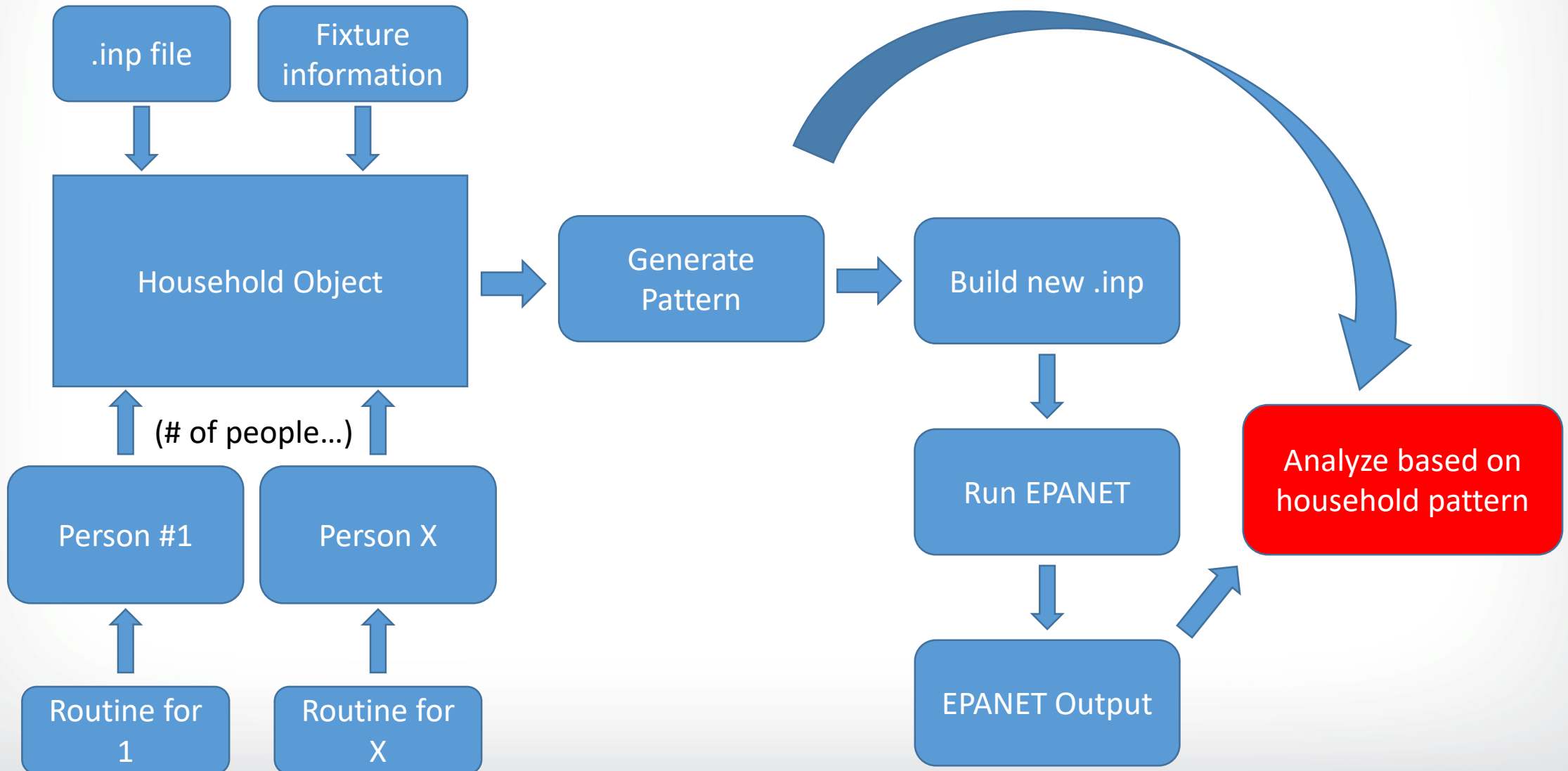
Pattern Generation Method

- Current Method

- Designed to ensure that a fixed number of uses are performed in a “routine”
- Also ensures volume of water used is consistent between trials
- Reason of use is stored for later analysis (‘drink of water’, ‘shower’, etc)
- Uses have possible times that they occur (all day, AM only, PM only, AM/PM)
- Each user can be assigned a unique routine
- Each start-time is assigned randomly based on the available timeframes for its use

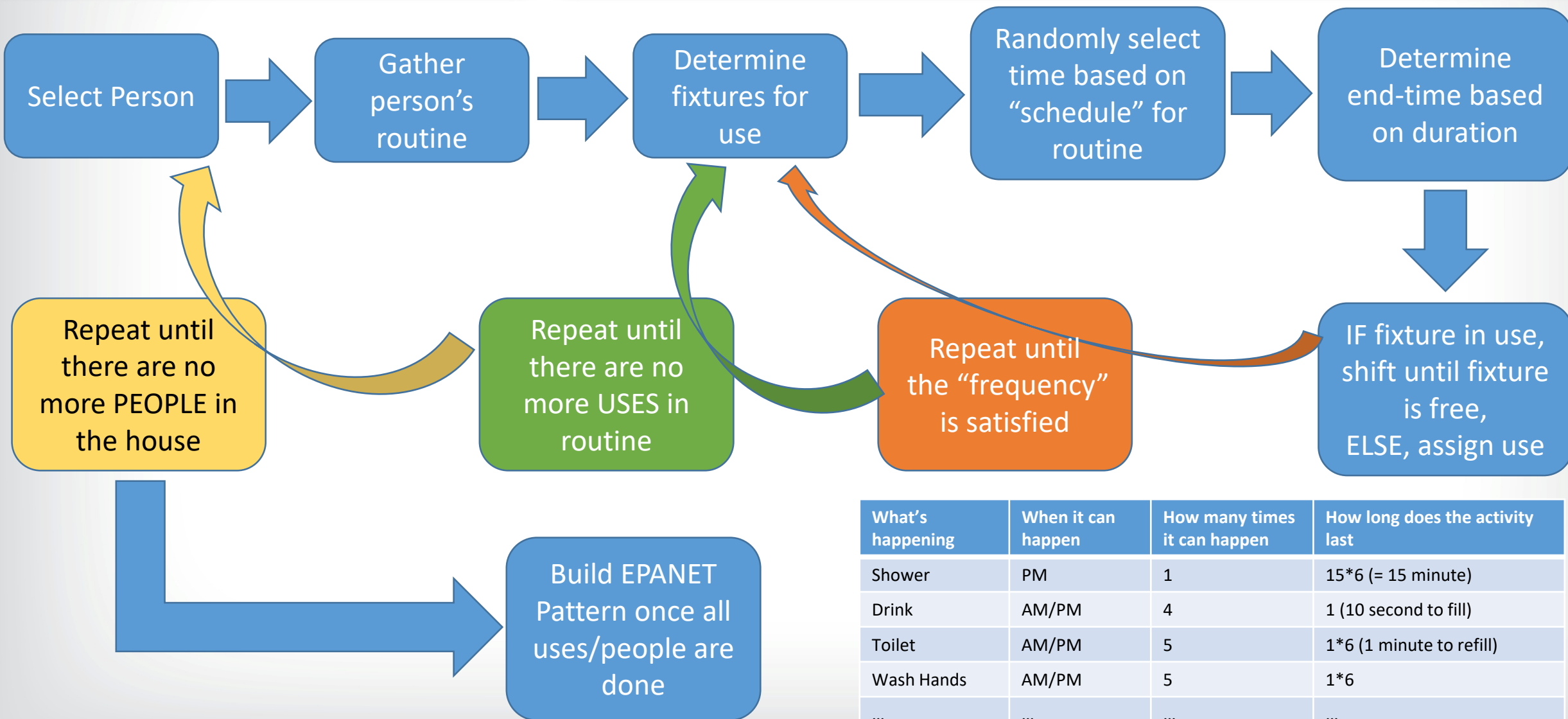
What's happening	When it can happen	How many times it can happen	How long does the activity last
Shower	PM	1	15*6 (= 15 minute)
Drink	AM/PM	4	1 (10 second to fill)
Toilet	AM/PM	5	1*6 (1 minute to refill)
Wash Hands	AM/PM	5	1*6
Brush Teeth	AM	1	1*2
Brush Teeth	PM	1	1*2

Conceptual System Model





Pattern Generation Process



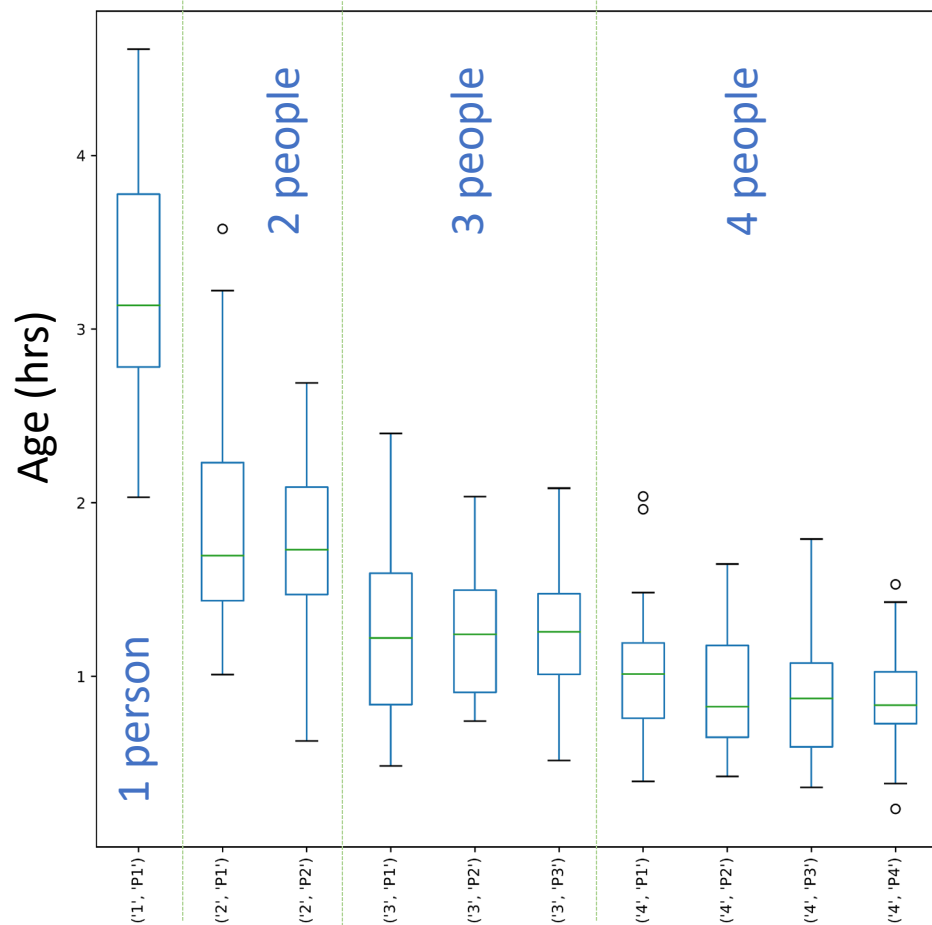


Study on Water Age Information

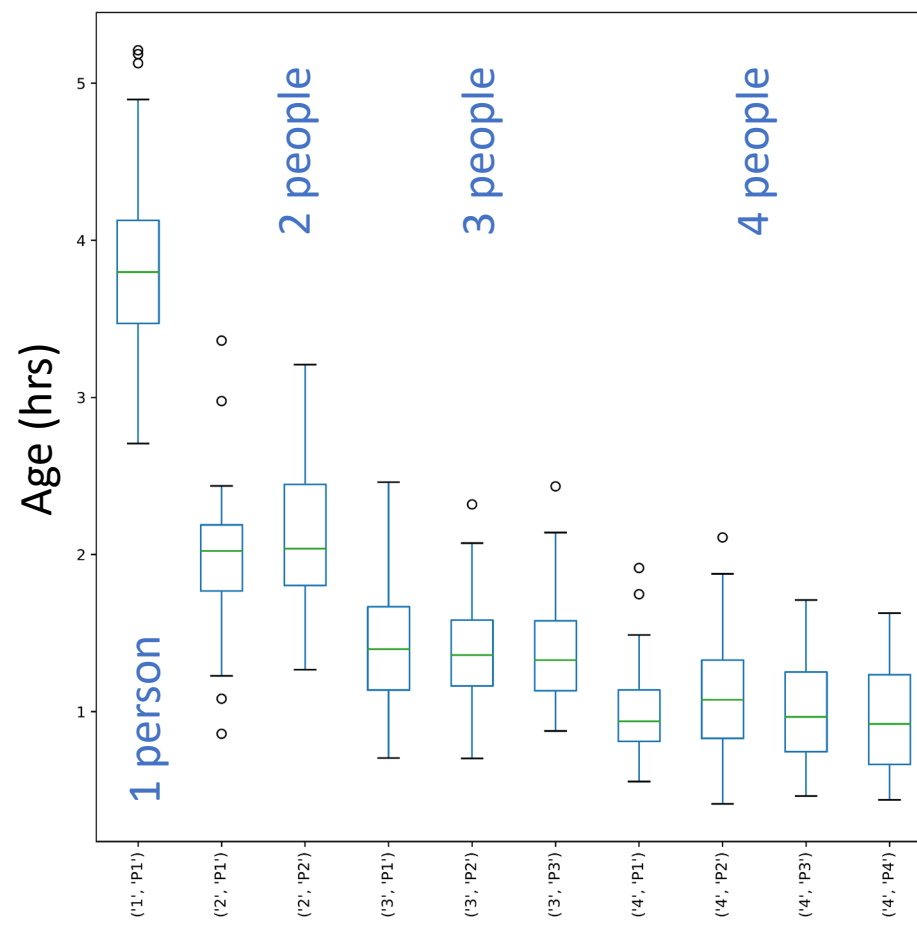
- EPANET 2.2 with AGE for water quality
 - Analyzed for relative water age—time since leaving water main or entering service line
- 600 variants of each type
- 1, 2, 3, 4 person cases
- ½" internal plumbing & ¾" internal plumbing
- High water use fixture & low water use (water conserving) fixture case (duration remains the same, just total volume would be lower)



Results (Drinking Activity – House #1 vs. #2)



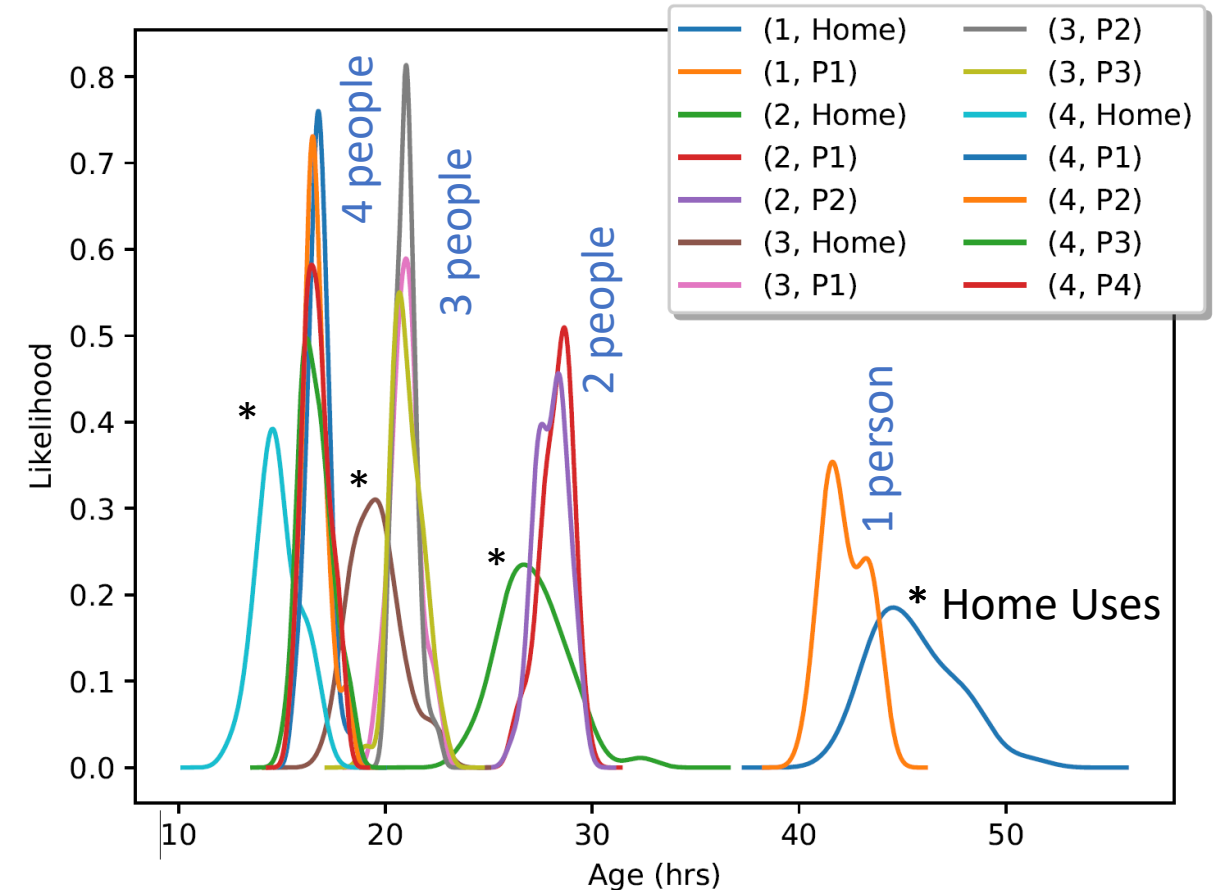
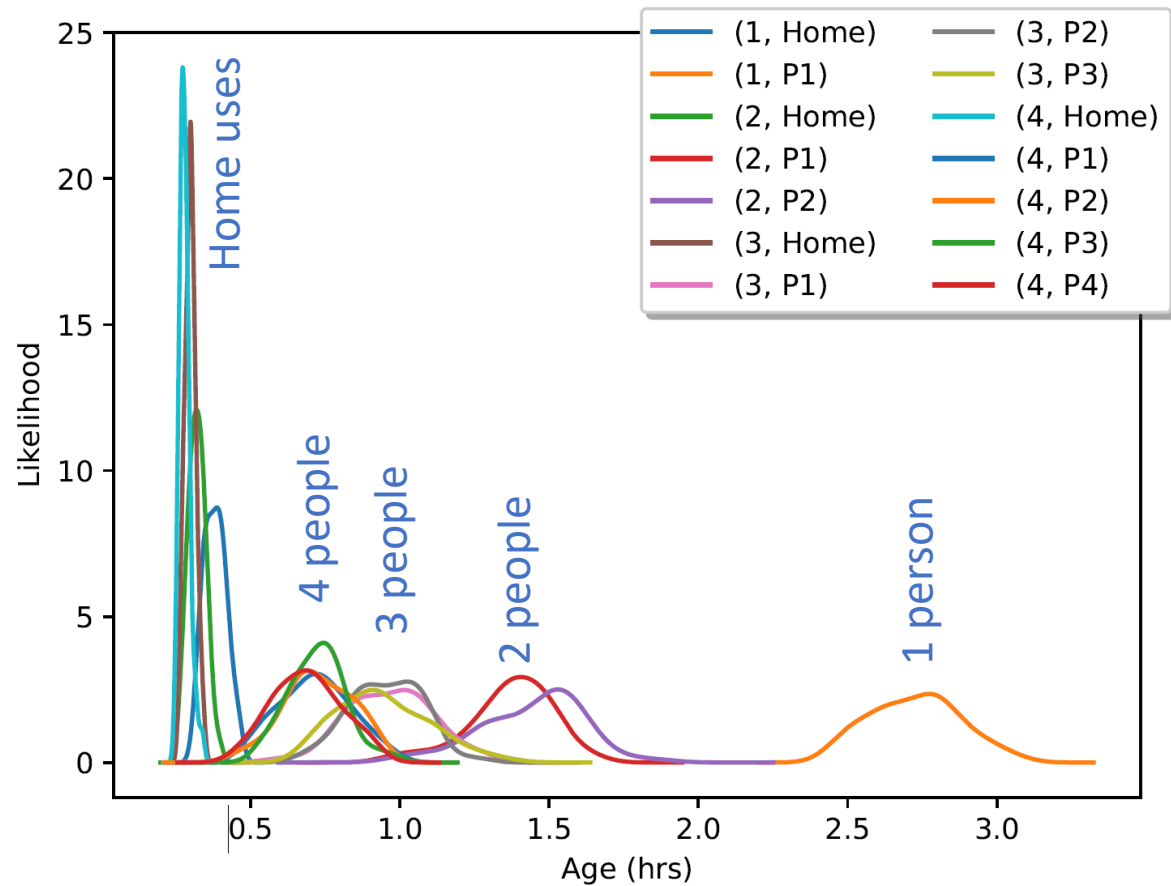
House #1



House #2

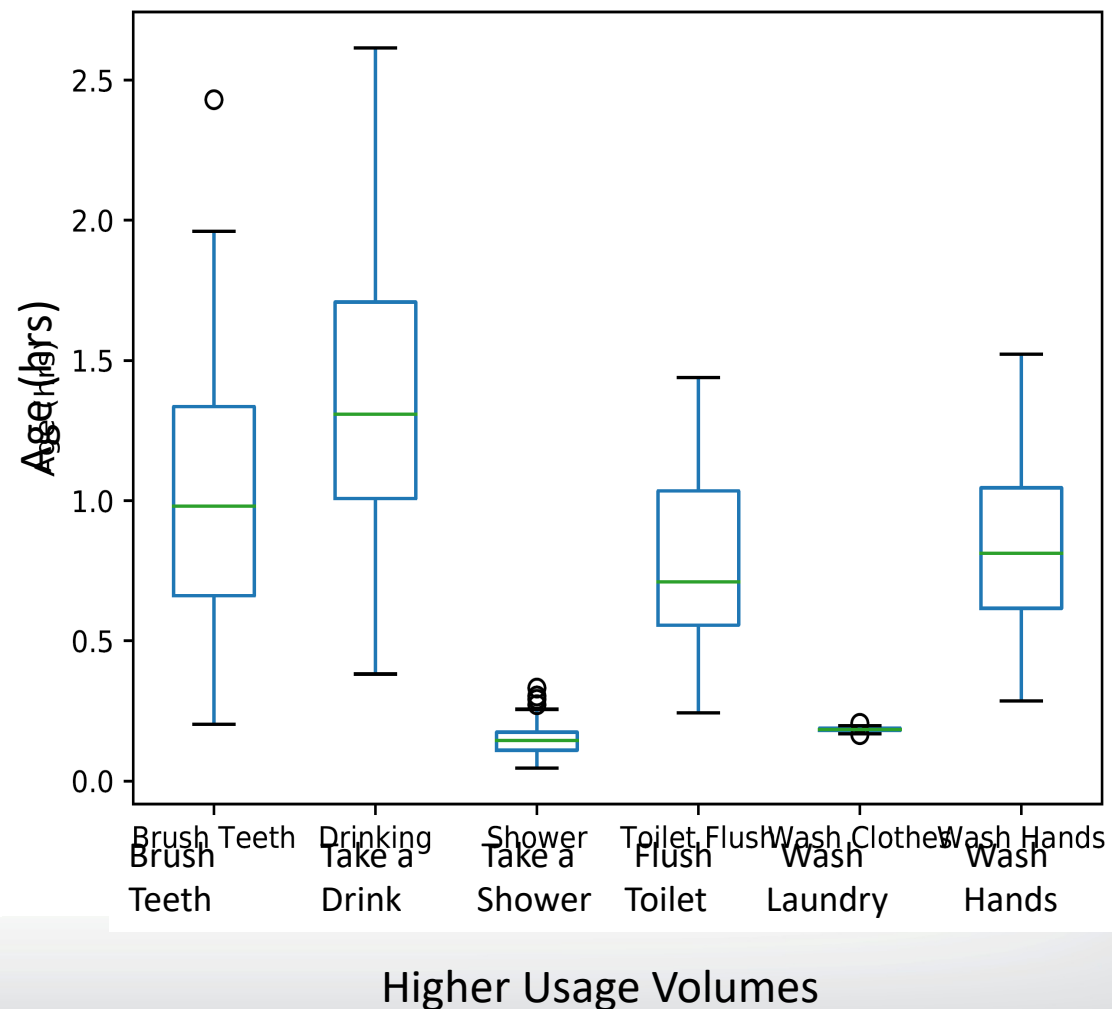
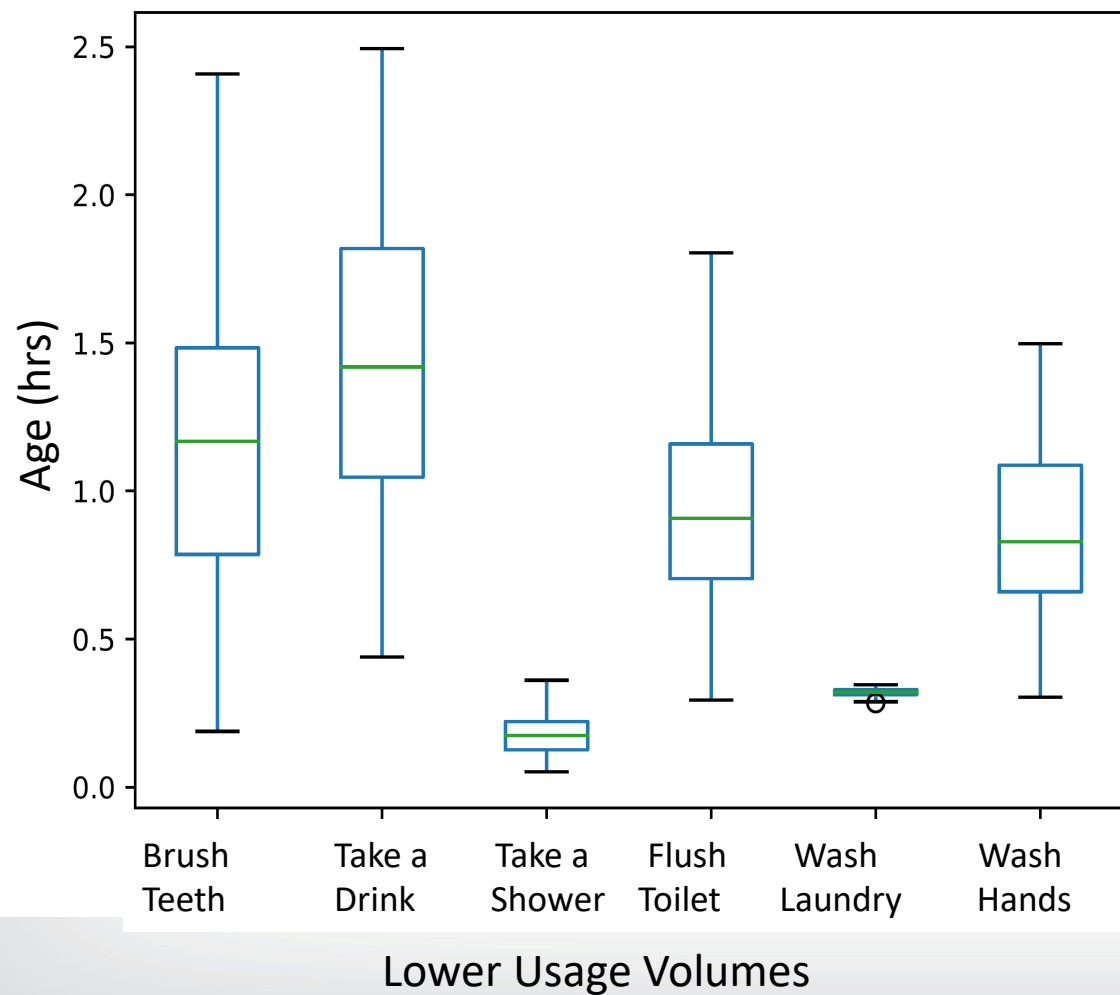


Results (House #2 – Cold vs. Hot Age)





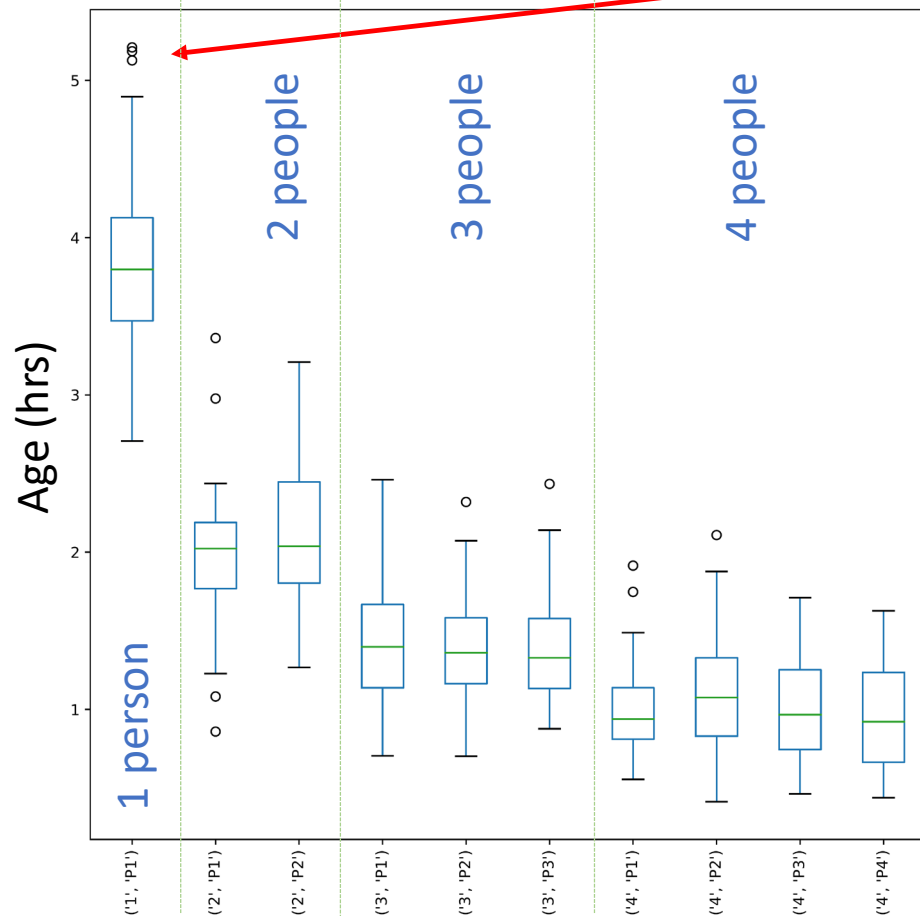
Results (House #2 – High vs. Low Use)



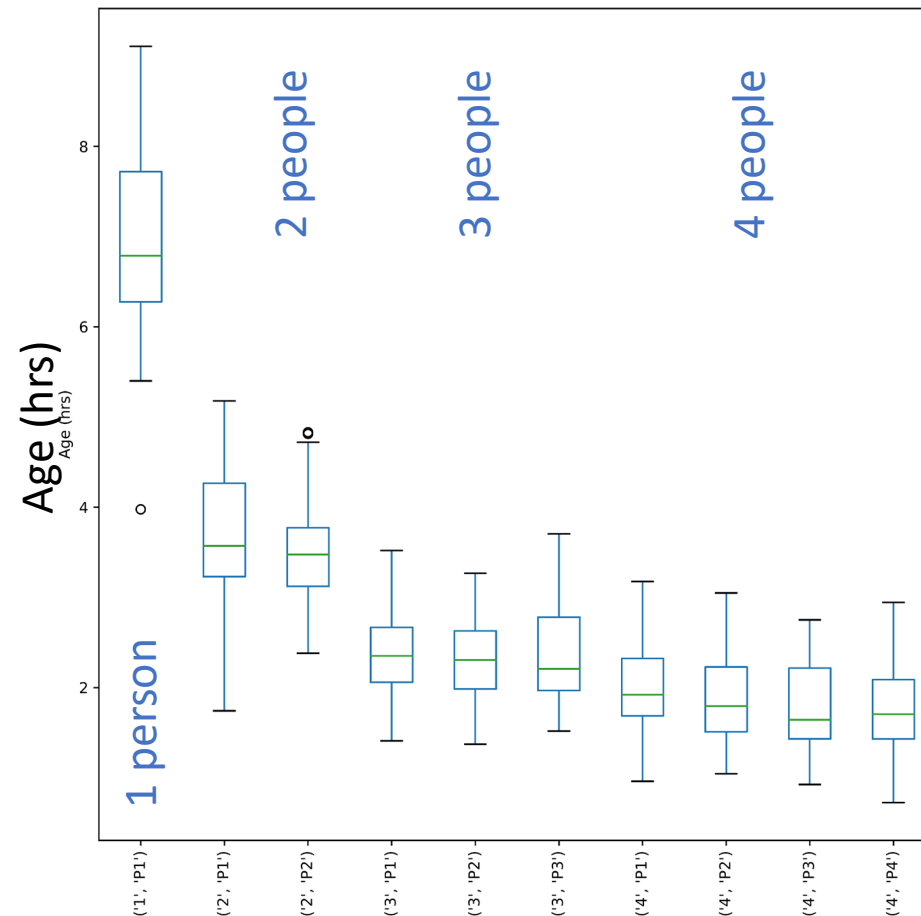


Results (House #2 – ½" vs ¾" internal pipes) Drinking Water Activity

Note the scale



½" Actual Pipe Diameter

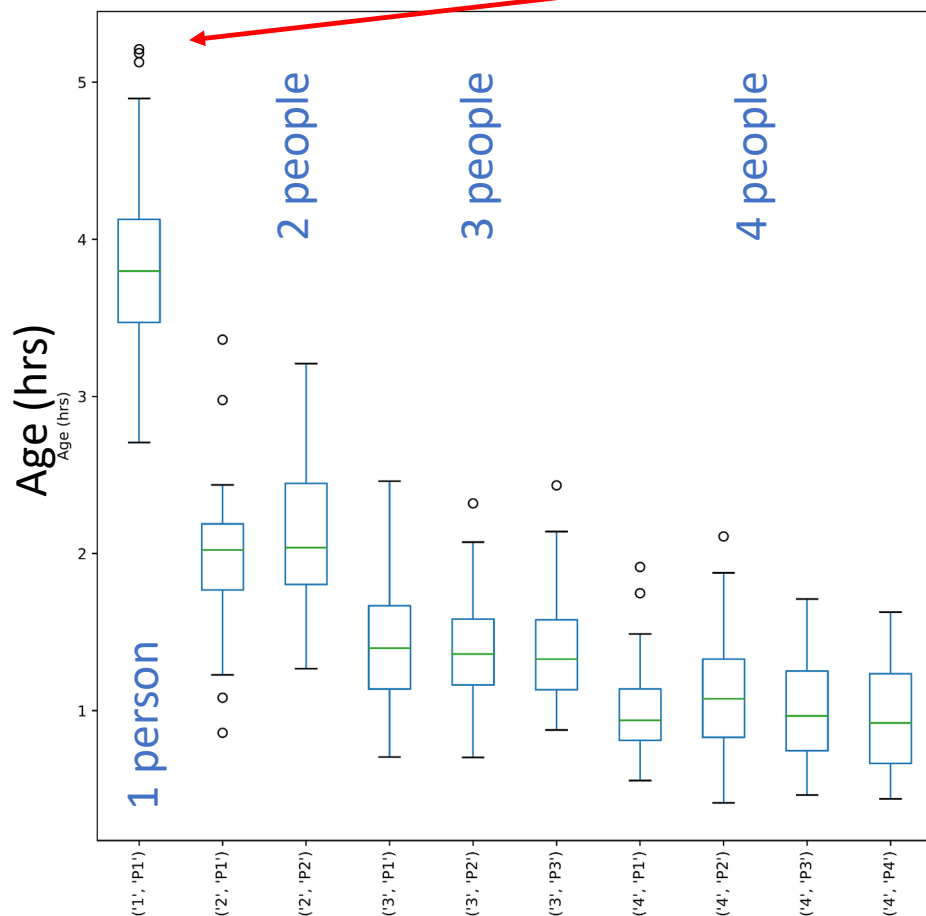


¾" Hypothetical Pipe Diameter

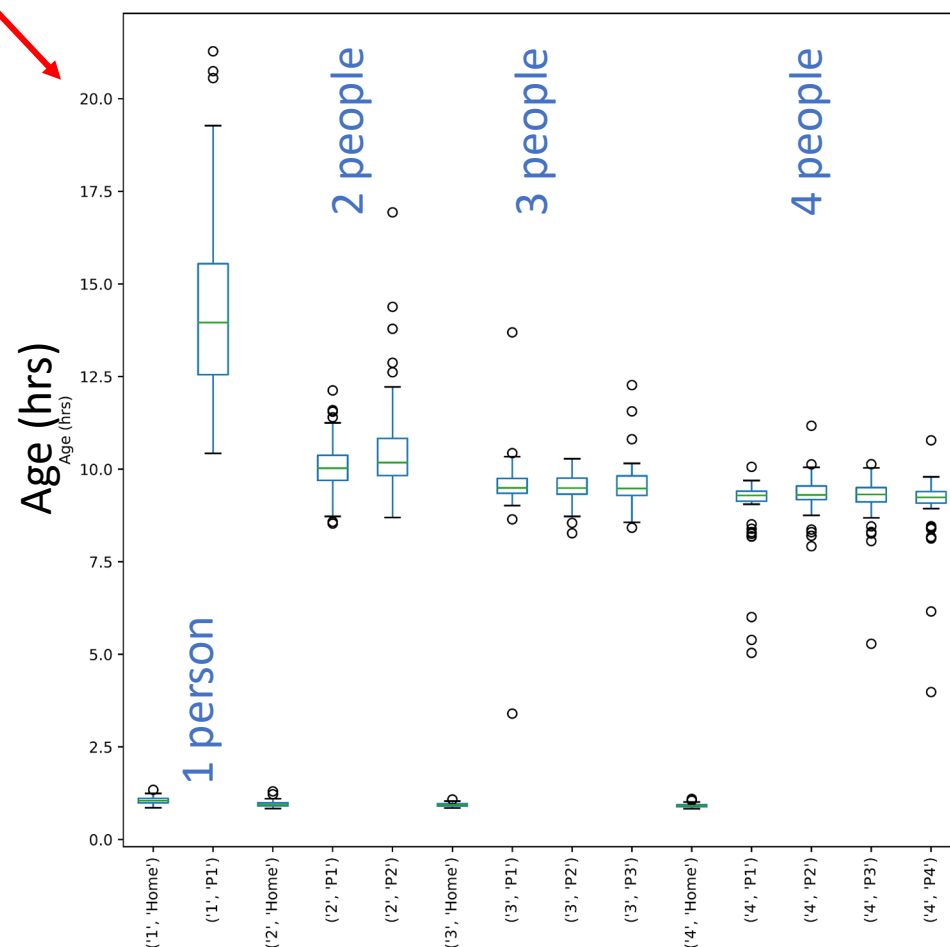


Results (House #2 – Mean vs. Max Relative Age)

Scale



Mean Relative Water Age



Max Relative Water Age

Work/School
Overnight
Stagnations



Conclusions / Future Work

• Conclusions

- Framework developed to allow for testing a variety of premise plumbing scenarios
- Relative water age is impacted by number of people, pipe diameters, usage patterns & type of fixtures
- Single use max relative age for a person is closer to stagnation period in home, even with more people
- Hot water relative age is impacted by residence time in hot water heater

• Future Work

- Develop additional household models for different types of homes
- Continue adding features to better simulate home uses
- Add linked usages
- Add probabilistic tools for demand generation
- Conduct probabilistic exposure assessment study for specific contaminants prevalent in homes
- Conduct study evaluating home/building flushing routines following contamination incidents



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Questions?