Premise Plumbing Modeling Webinar Series
WDSA Task Committee
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Modeling Water Age in Premise Plumbing Systems

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Acknowledgements

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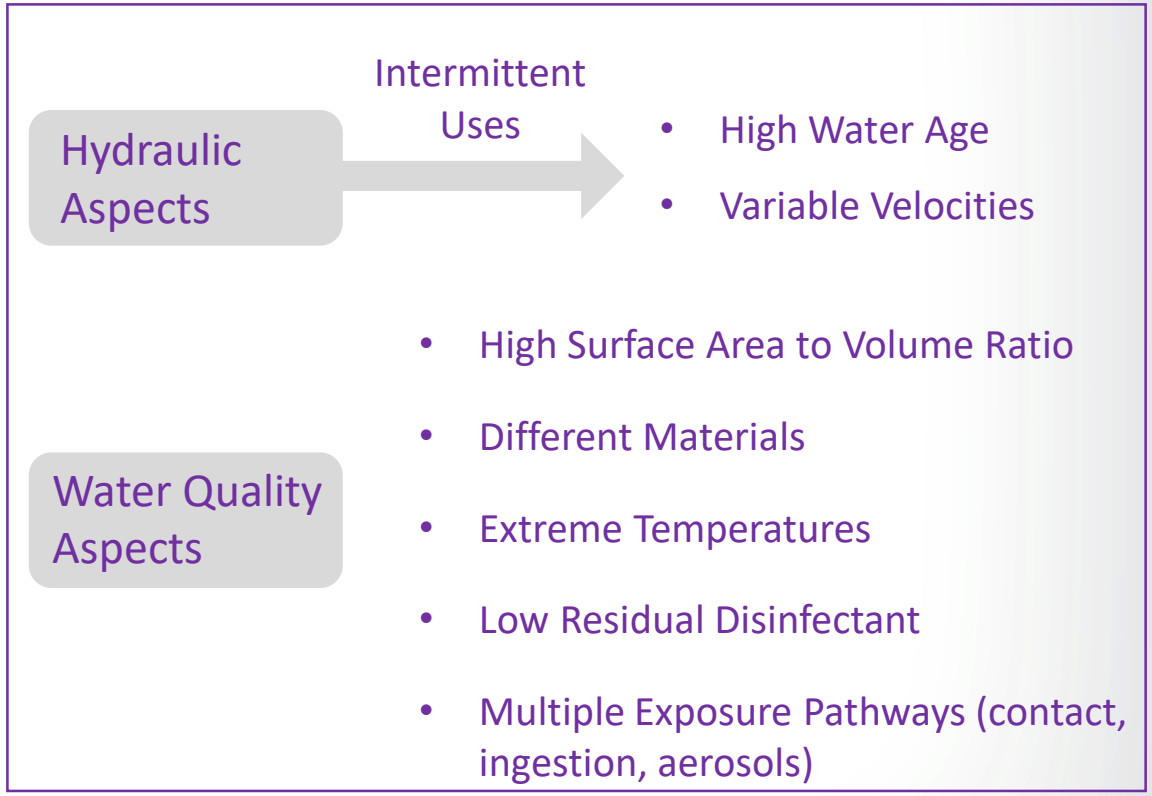
Outline

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

Introduction

- 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

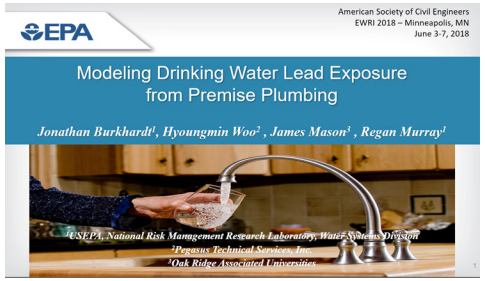


Background

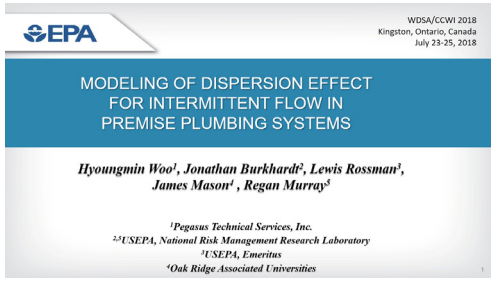
- Alternative Agent-Based Approaches
  - WatSup – Murray and Murray, J. Hydroinformatics 2005
  - PRPSym – Buchberger & Li, World Env. And Water Resources Congress 2007
  - SIMDEUM – Blokker, et al., Drink. Water Eng. Sci, 2008
- Additional Work on Premise Plumbing Systems
  - Buchberger & Wu, J. Hydraulic Eng. 1995
  - WUDESIM – Abokifa, et al., Water Research 2016
  - Grayman, et al., WDSA 2008
  - Grayman & Buchberger, 8th WDSA Symposium Cincinnati 2006

Background

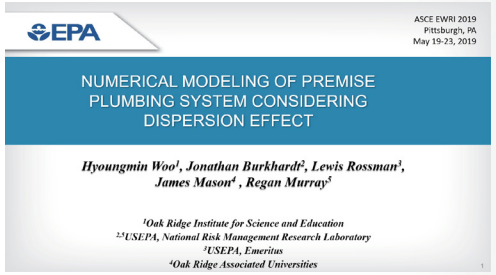
EWRI 2018



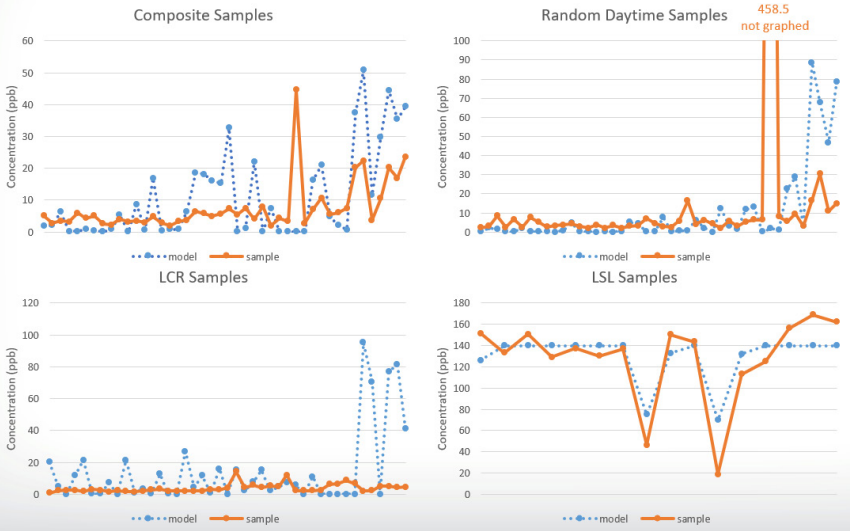
WDSA/CCWI 2018



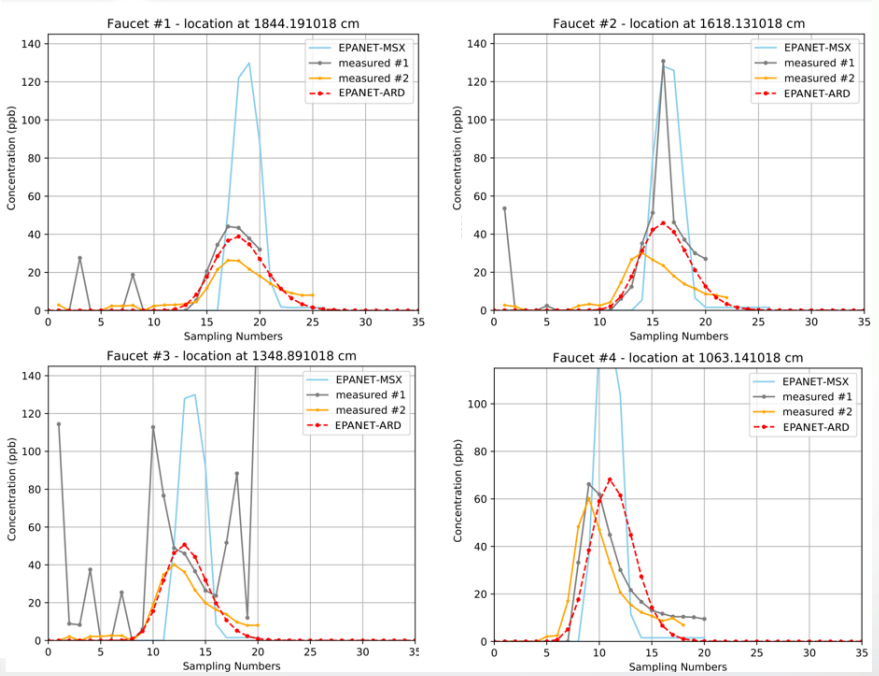
EWRI 2019



Sampling Comparison



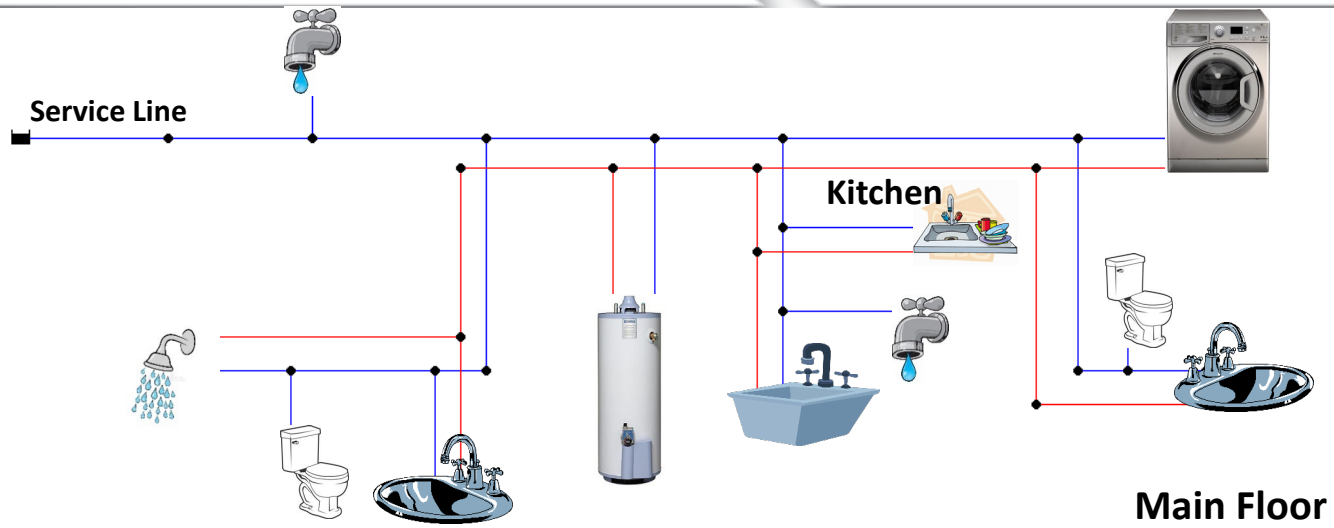
Experimental Data & Introducing Dispersion



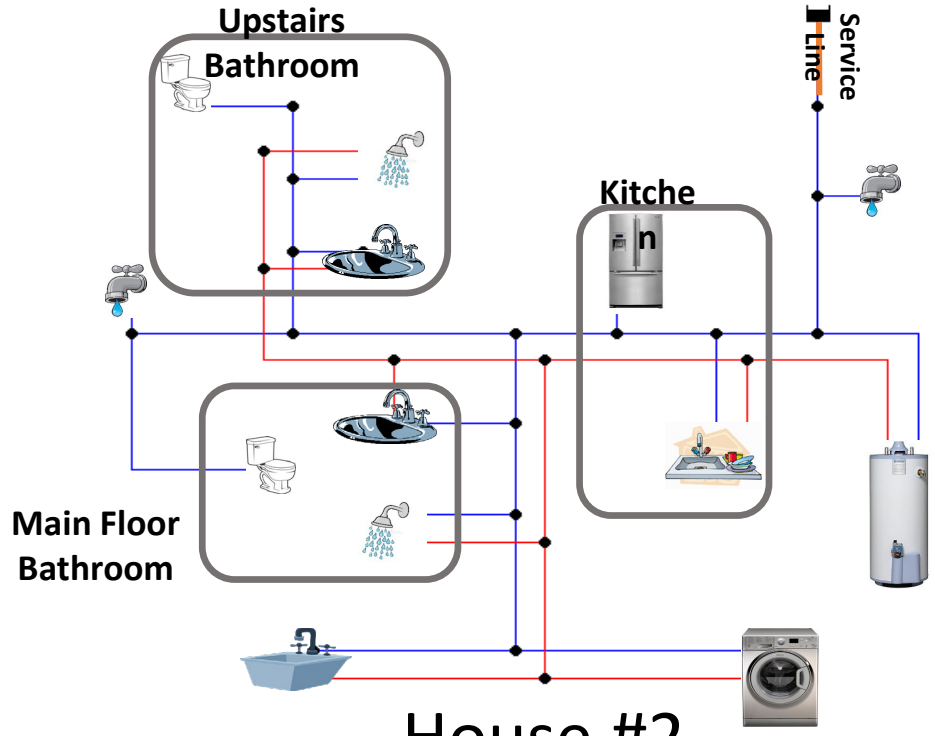
Development of Household Models

- 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 Models



House #1



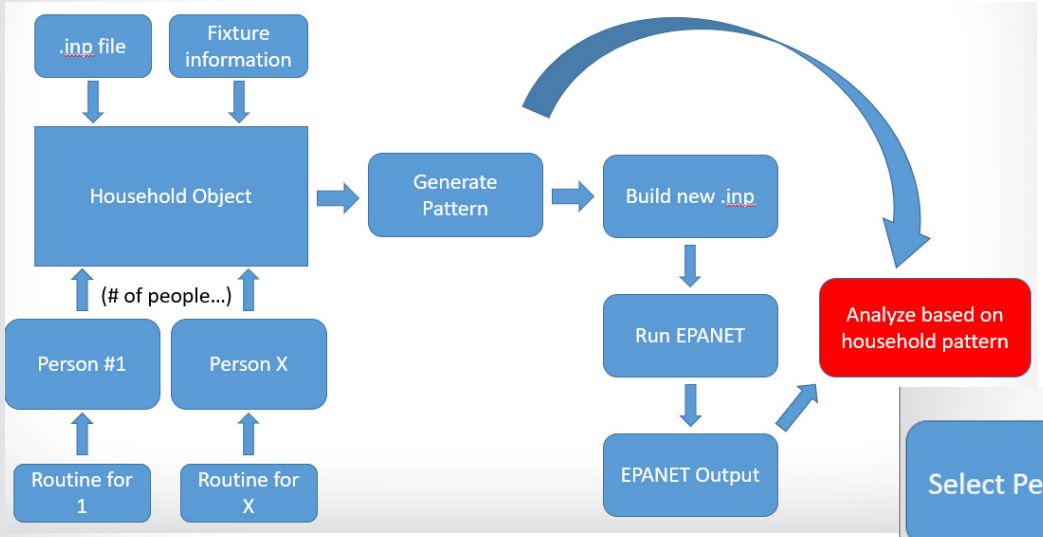
House #2

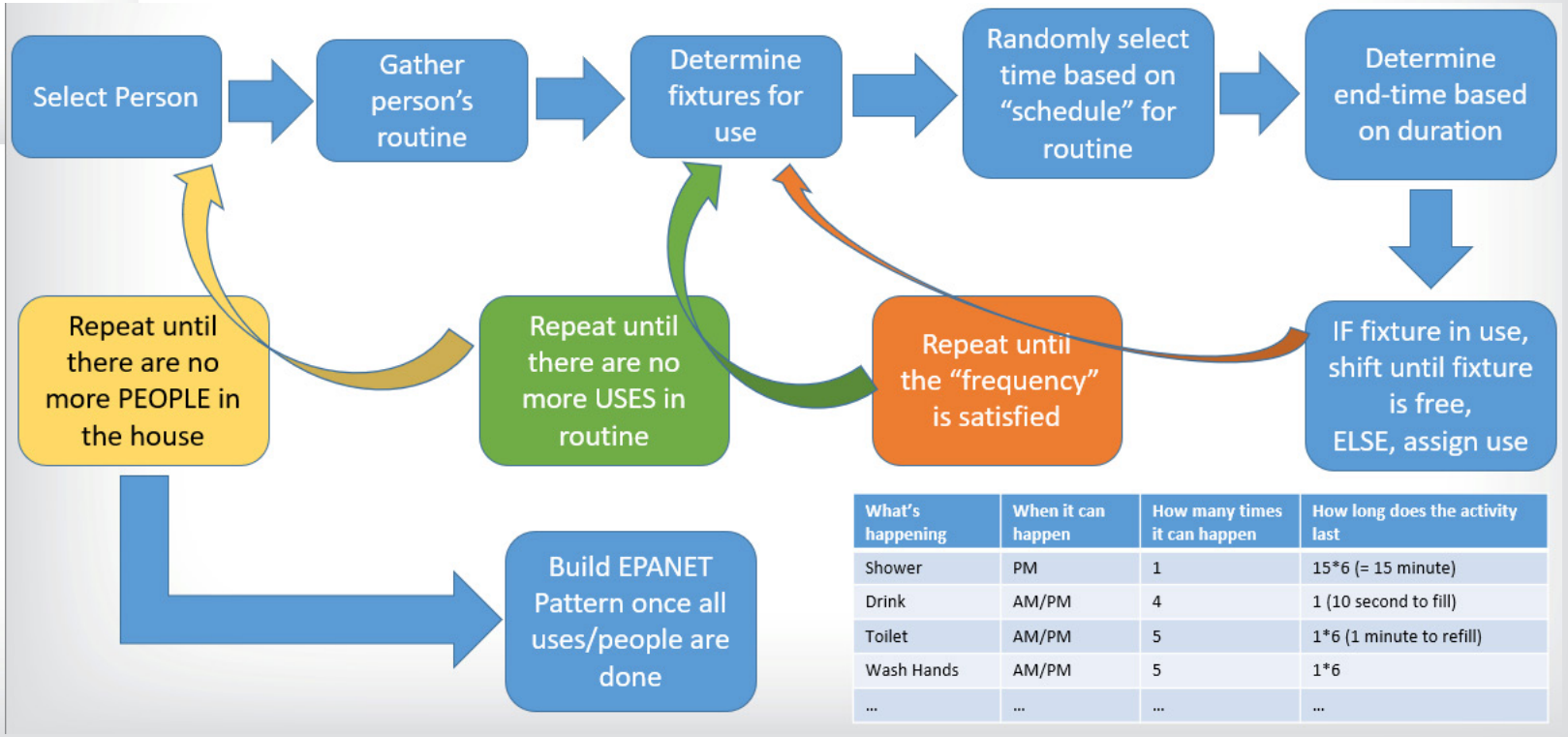
Pattern Generation Method

- 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

Overview of Pattern Generation





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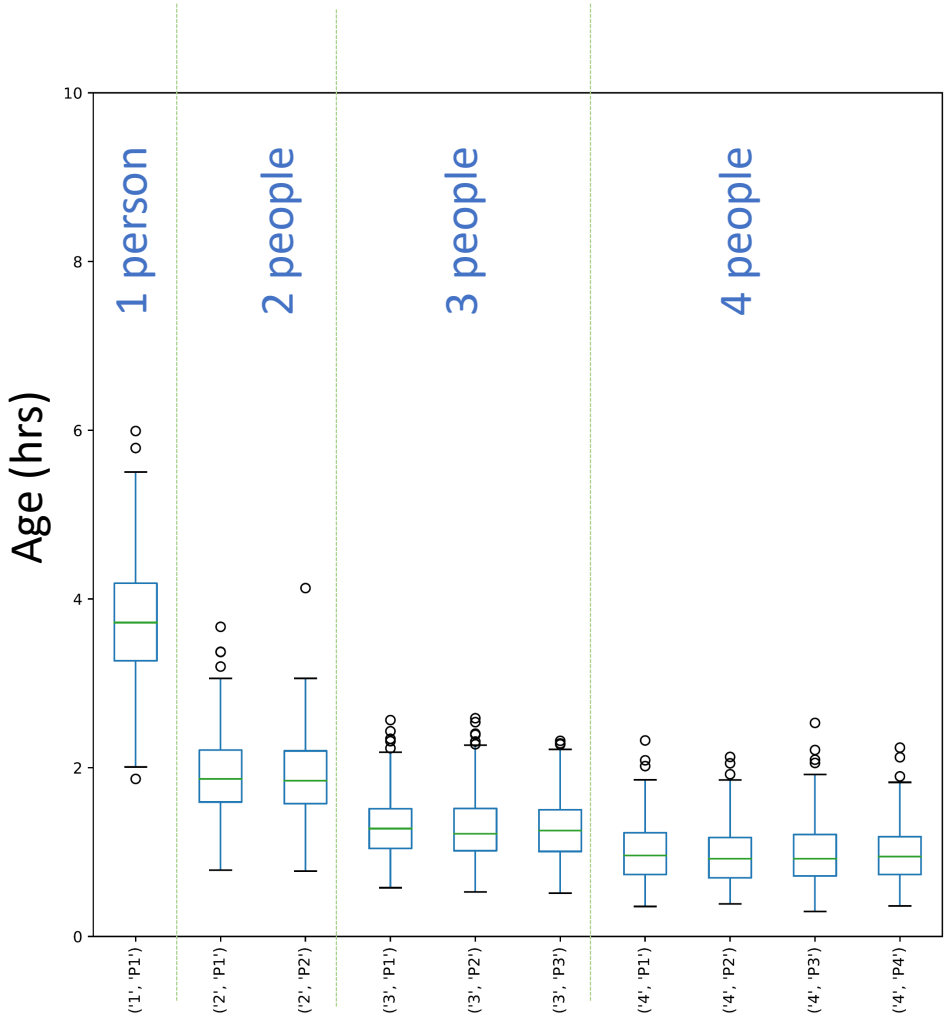
…	…	…	…

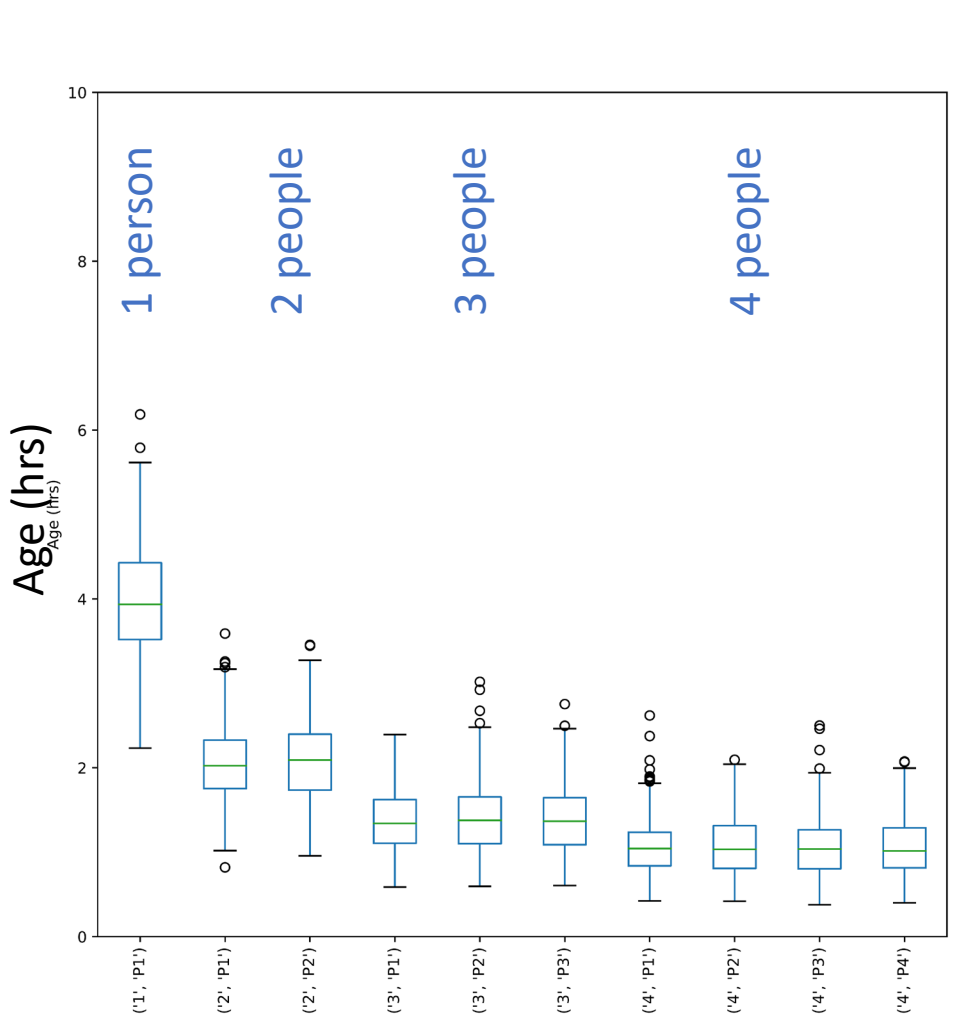
Study on Water Age Information

- EPANET 2.2 with AGE for water quality
  - Analyzed for relative water age—time since leaving water main or entering service line
- 360 random scenarios for each case
- 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)

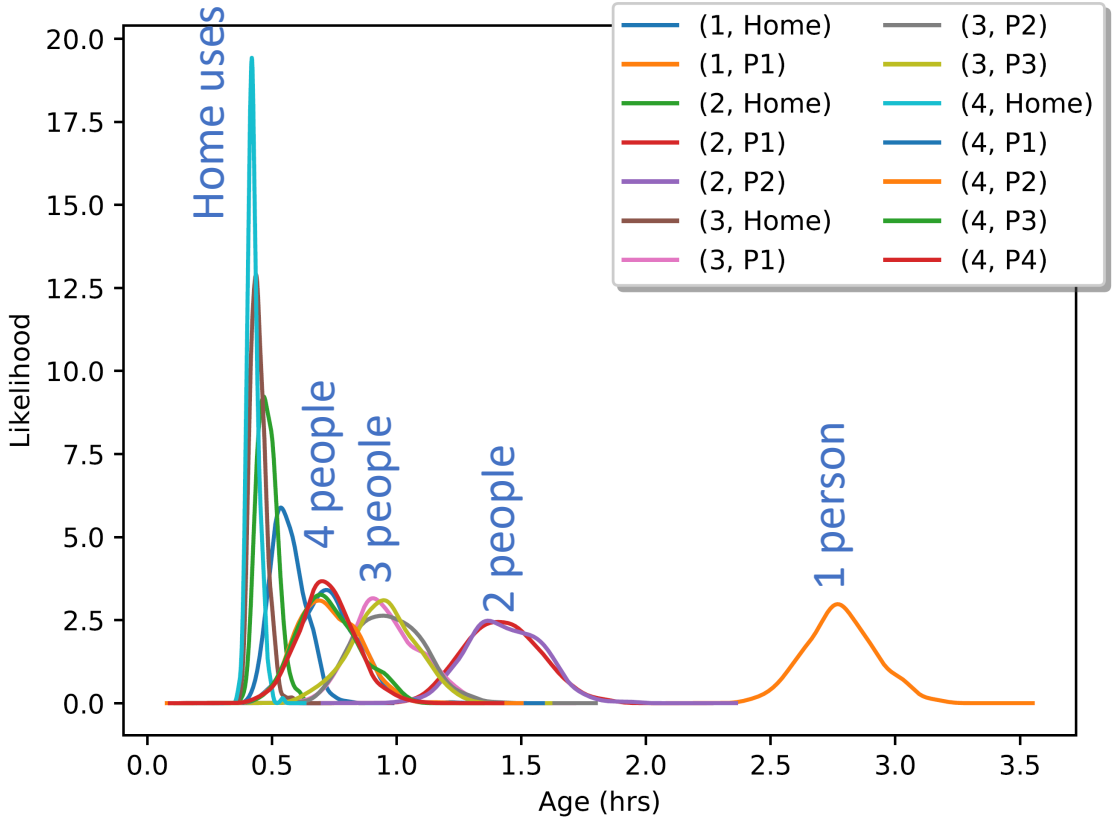


House #1

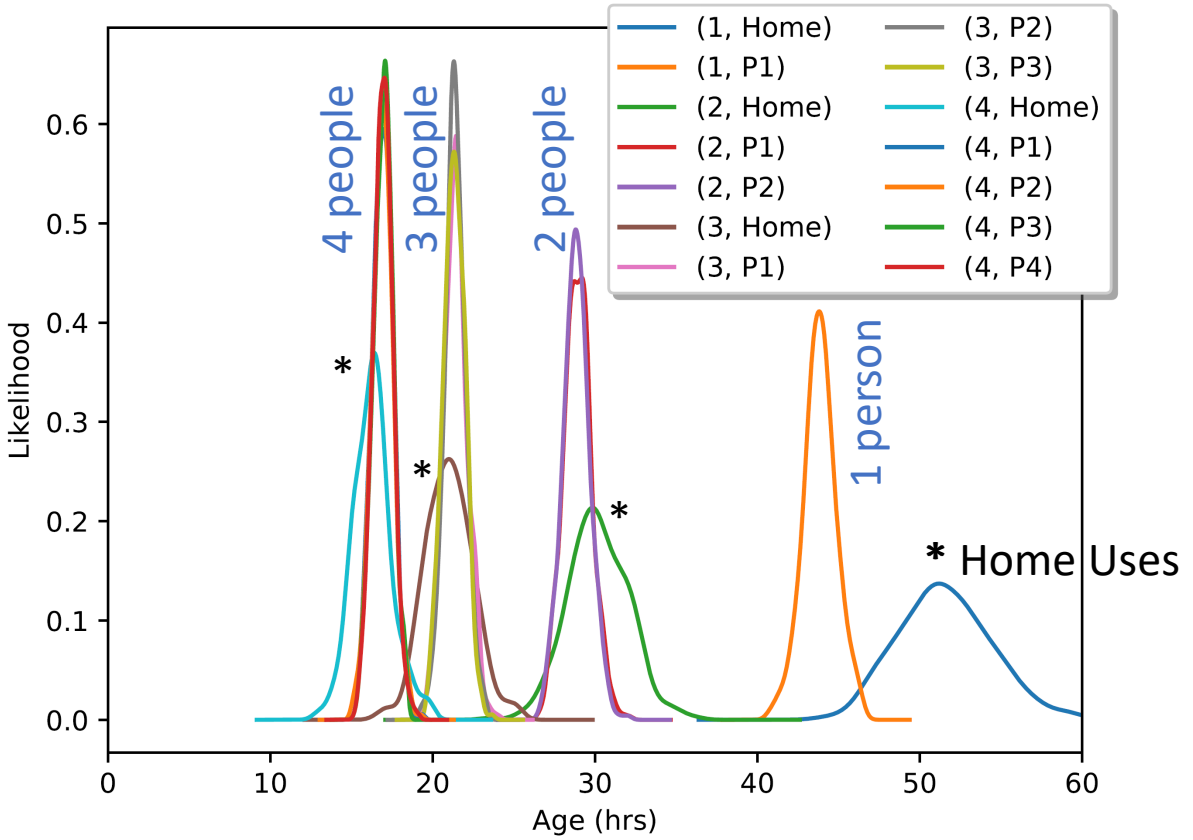


House #2

Results (House #2 – Cold vs. Hot Age)



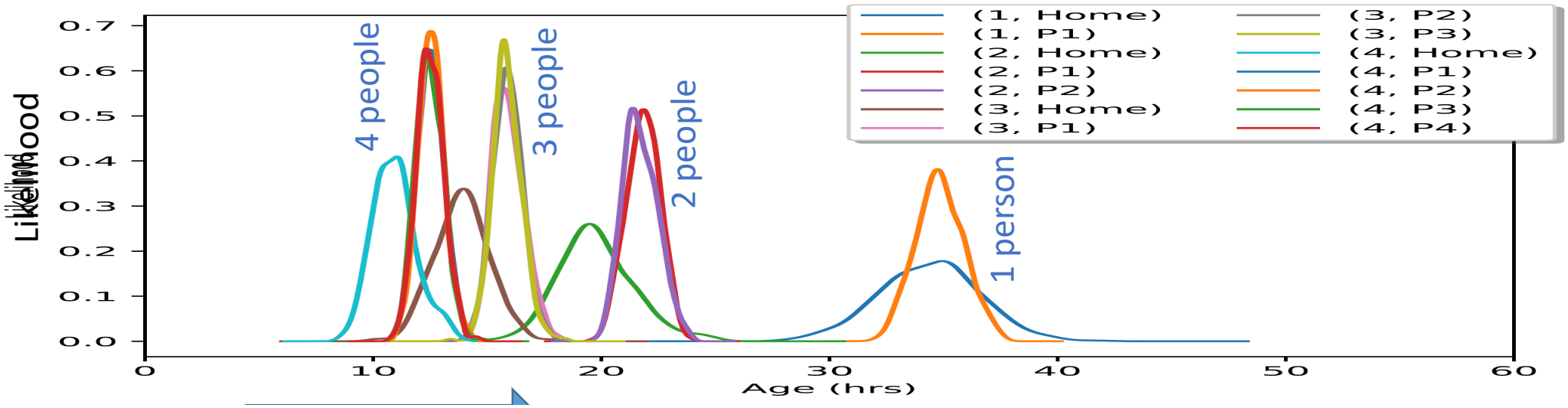
Cold Water Uses



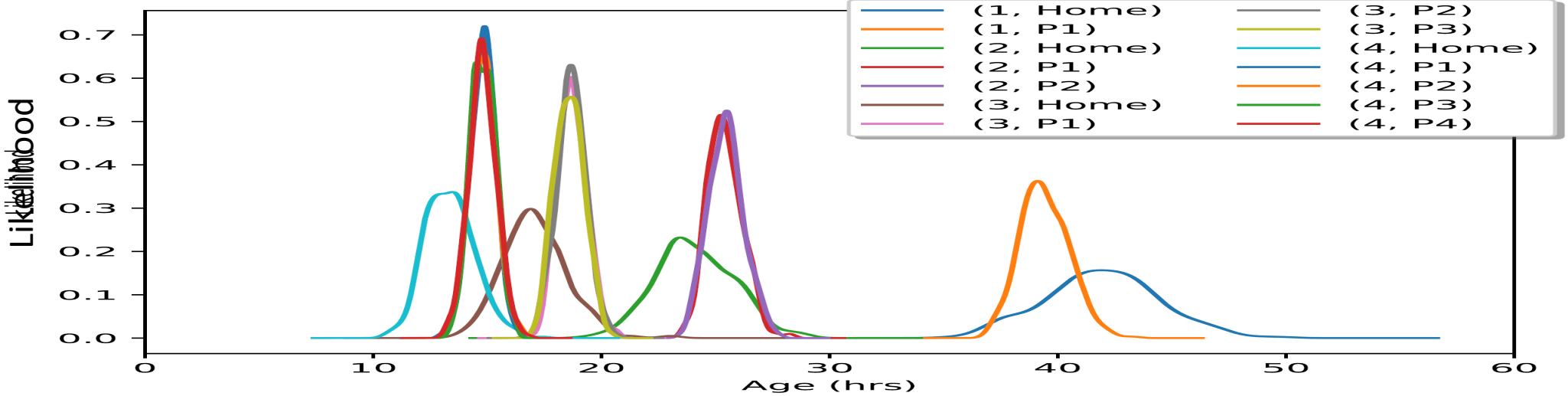
Hot Water Uses

Results (House #2 –Hot Age, 40 gal. vs 50 gal. HWH)

40 gallon



50 gallon

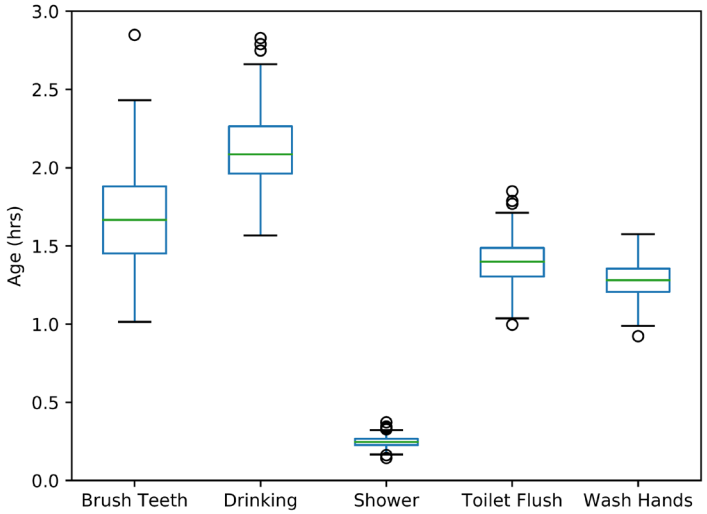


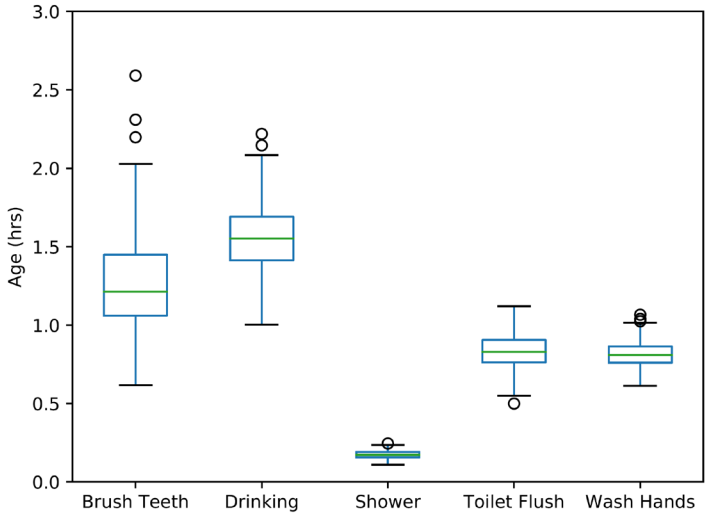
Results (House #2 – High vs. Low Use)

Lower Usage Volumes

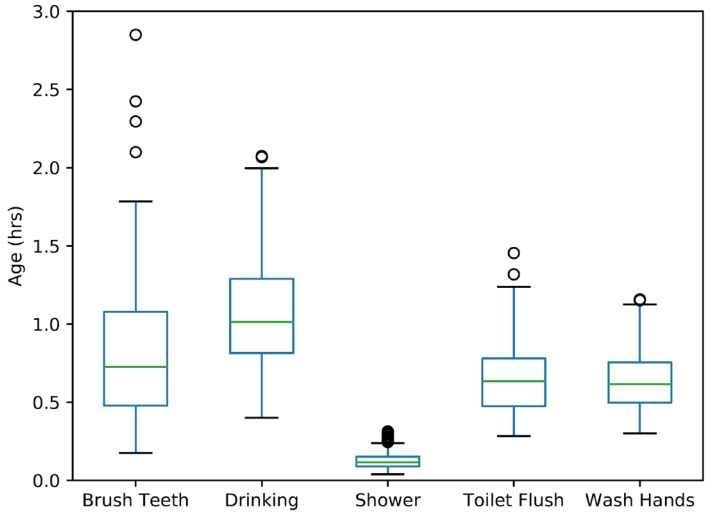
Higher Usage Volumes

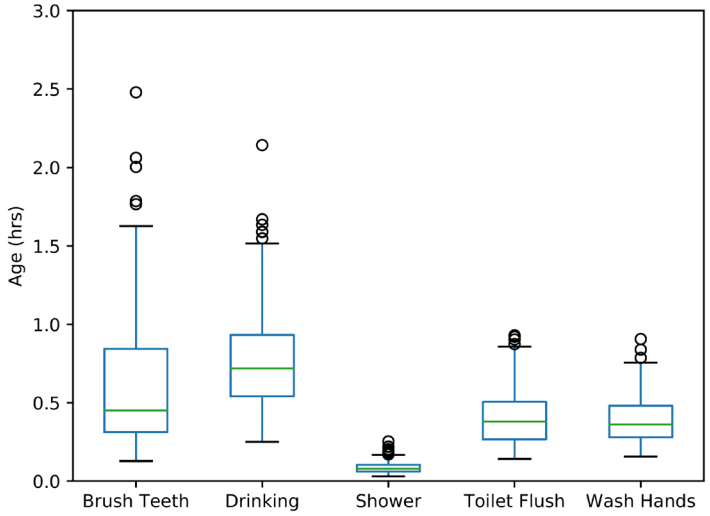
1 Person





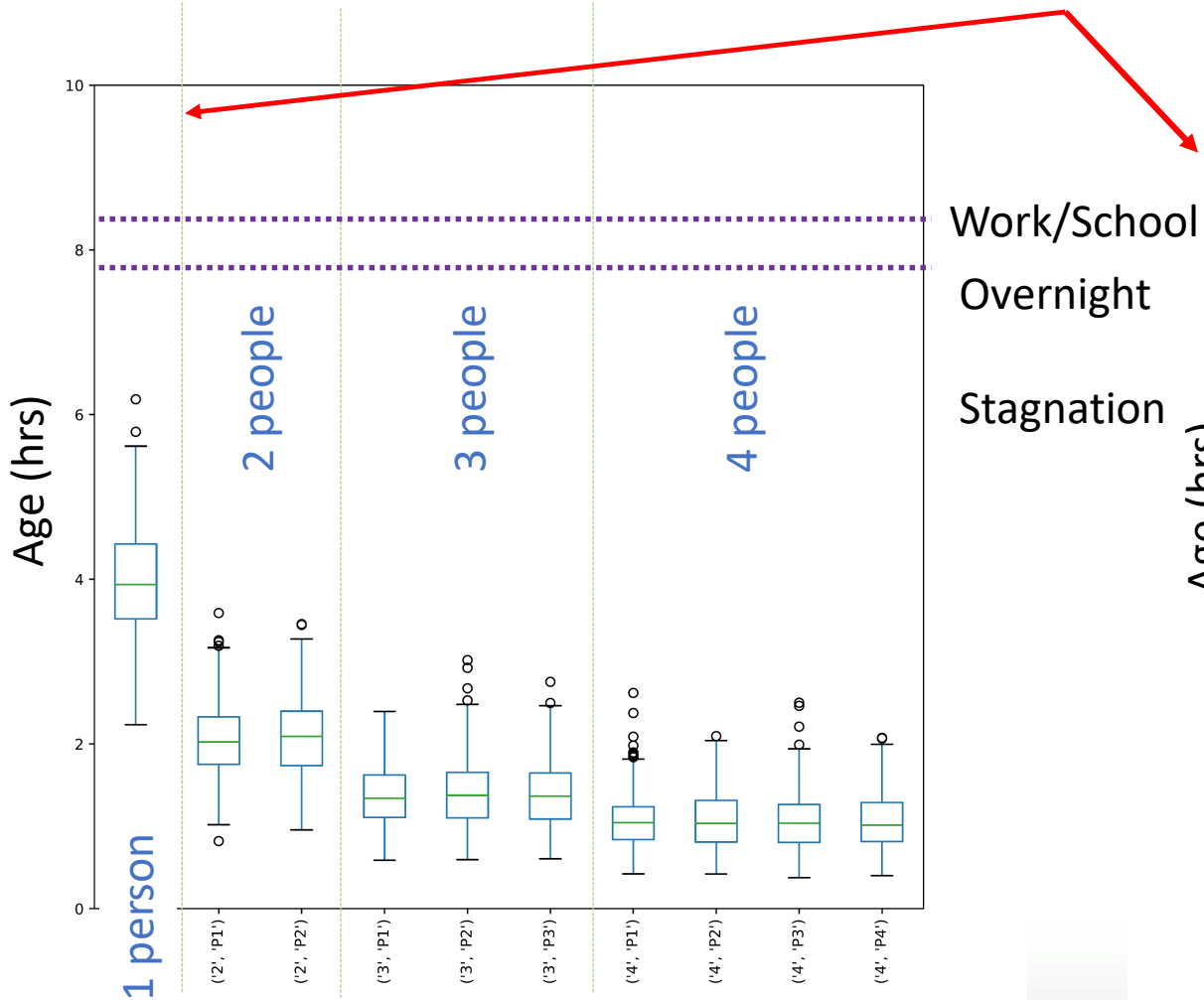
4 People



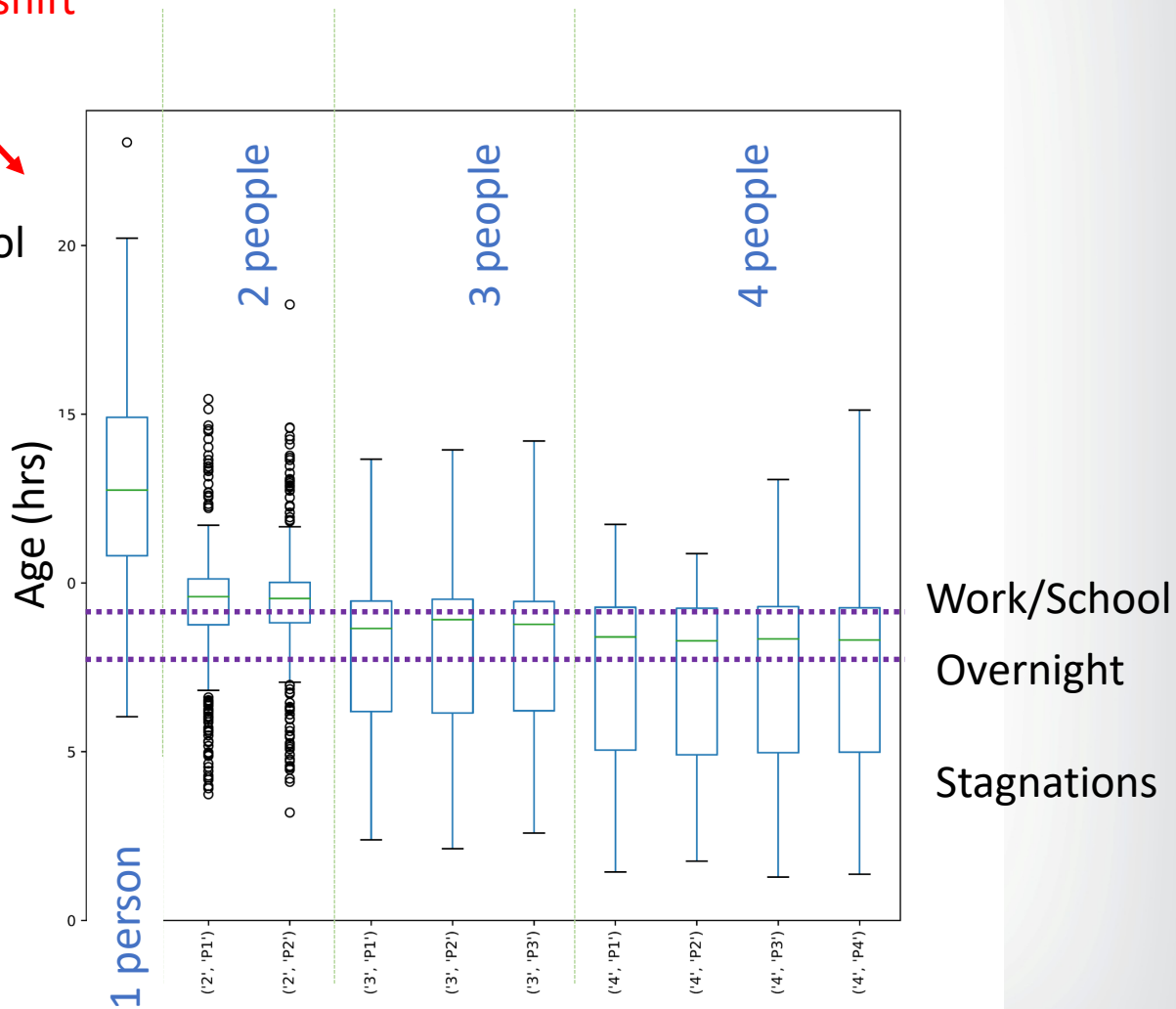


Results (House #2 – Mean vs. Max Relative Age)

Note the scale shift



Mean Relative Water Age



Max Relative Water Age

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
  - Median 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 lead and legionella in homes and buildings
  - Conduct study evaluating home/building flushing routines following contamination incidents

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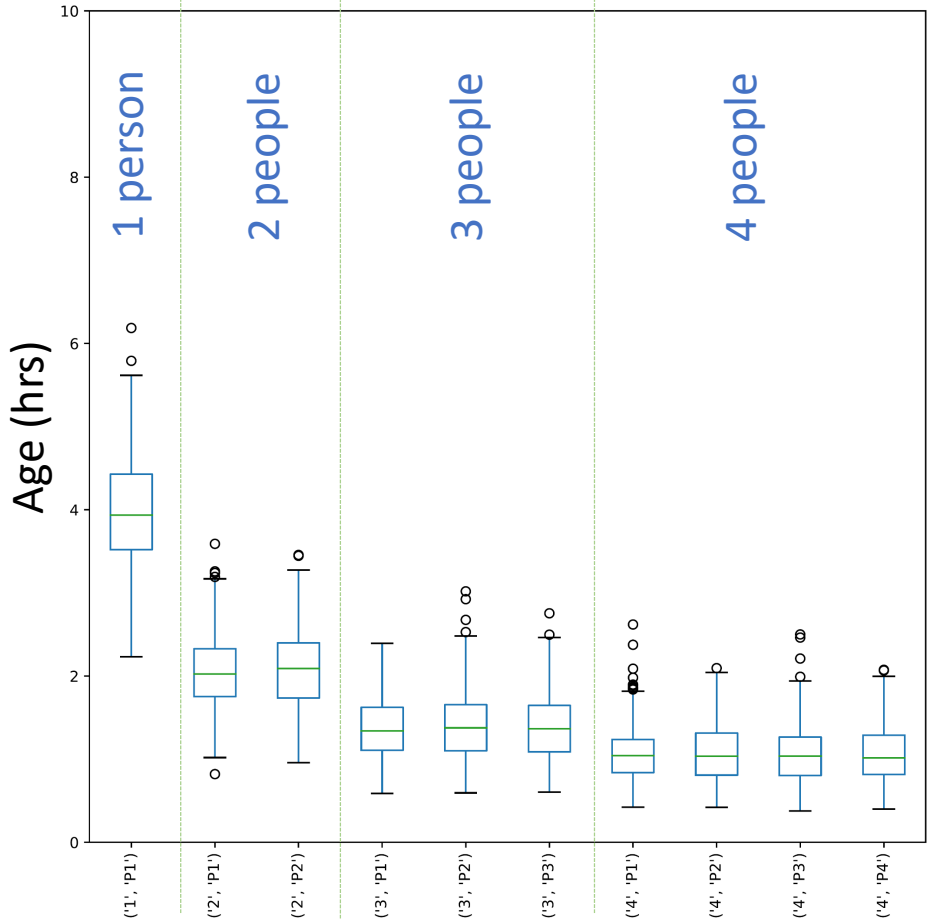
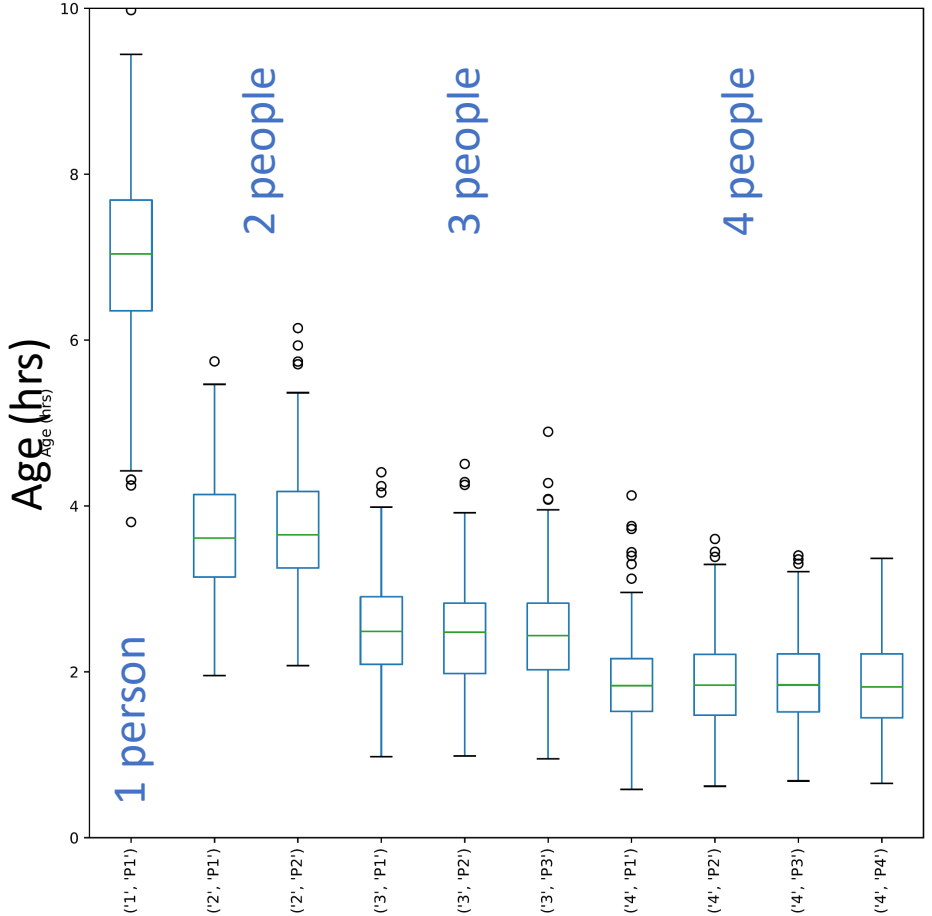
Questions?

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



½” Actual Pipe Diameter



¾” Hypothetical Pipe Diameter