United States Environmental Protection Agency

EPA Tools and Resources Webinar: Non-Potable Water Reuse

October 17, 2018

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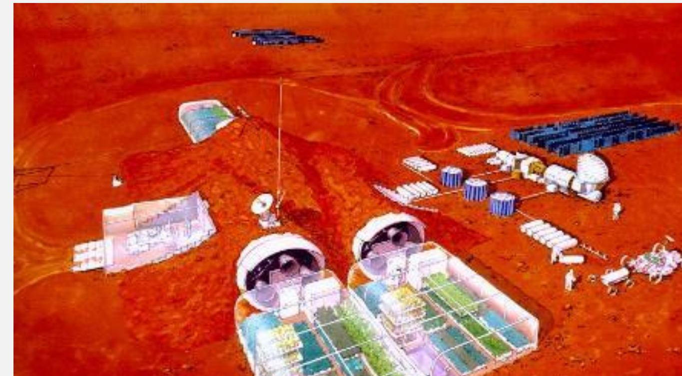
My Extraterrestrial Background





"If we knew how to live on Mars, we'd know how to reduce our footprint on Earth. Space colonization is the Rosetta stone for earthly sustainability because it's entirely about living in the absence of ecosystem services. The Moon, Mars and the asteroids are a great experimental laboratory that we're ignoring at our own peril."

Karl Schroeder

Buildings Produce Water

Precipitation collected from roofs and above-grade surfaces

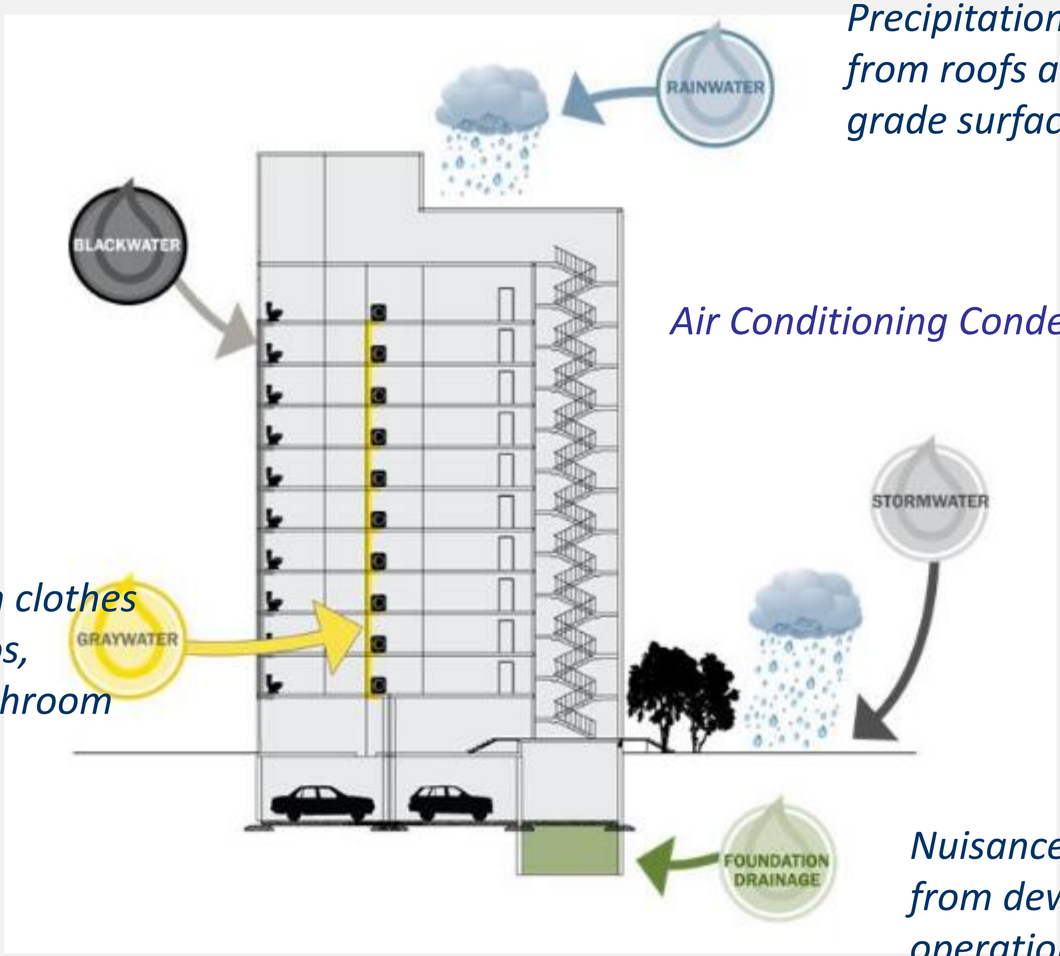
Wastewater from toilets, dishwashers, kitchen sinks, and utility sinks

Air Conditioning Condensate

Precipitation collected at or below grade

Wastewater from clothes washers, bathtubs, showers, and bathroom sinks

Nuisance groundwater from dewatering operations



The Solaire: Battery Park, NYC

Produces: 25,000 gallons per day (gpd) of wastewater

Utilizes: Membrane bioreactor (MBR) treatment

Application: Toilet flushing, cooling, irrigation

Operating: Since 2004

Primary Driver: Reduced wastewater flow

Salesforce Tower: San Francisco, CA

1.6 million ft^2 office building

Utilizes: MBR blackwater system for up to 30,000 gpd

Application: Toilet flushing, irrigation, and cooling

Estimated commissioning: Early 2019

Drivers:

- Sustainability goals
- LEED certification
- Utilize existing dual-plumbing

Lake Vermilion State Park, Minnesota

Details: Shower building at Minnesota's newest state park

Utilizes: Graywater from showers and sinks

Application: Toilet Flushing (135,000 gallons per season)

Drivers:

- Limited drinking water due to naturally occurring arsenic

Also innovative stormwater (and melted snow) system associated with transit hub at Target field (>1 million gallons used in a local energy recovery center

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Innovation in Urban Water Systems

San Francisco • May 2014

- State-based initiative, led by San Francisco Public Utilities Commission (SFPUC)

- Public utilities and health agencies participating

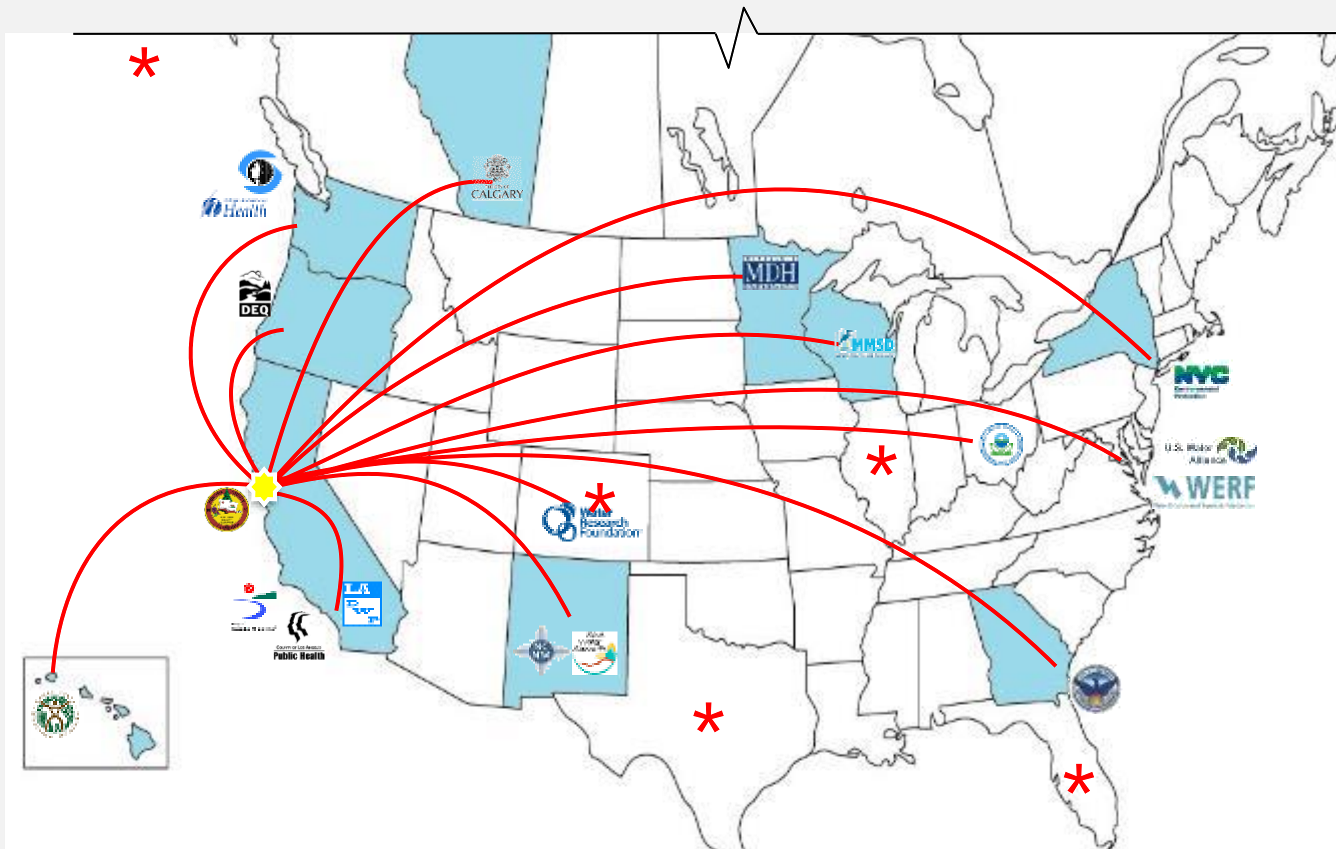
- Nationwide representation

National Blue Ribbon Commission for Onsite Non-potable Water Systems

San Francisco Water Power Sewer
Services of the San Francisco Public Utilities Commission

Key Needs Identified

- Local management programs are needed
- Water quality parameters and monitoring are needed to protect public health



US Water Alliance

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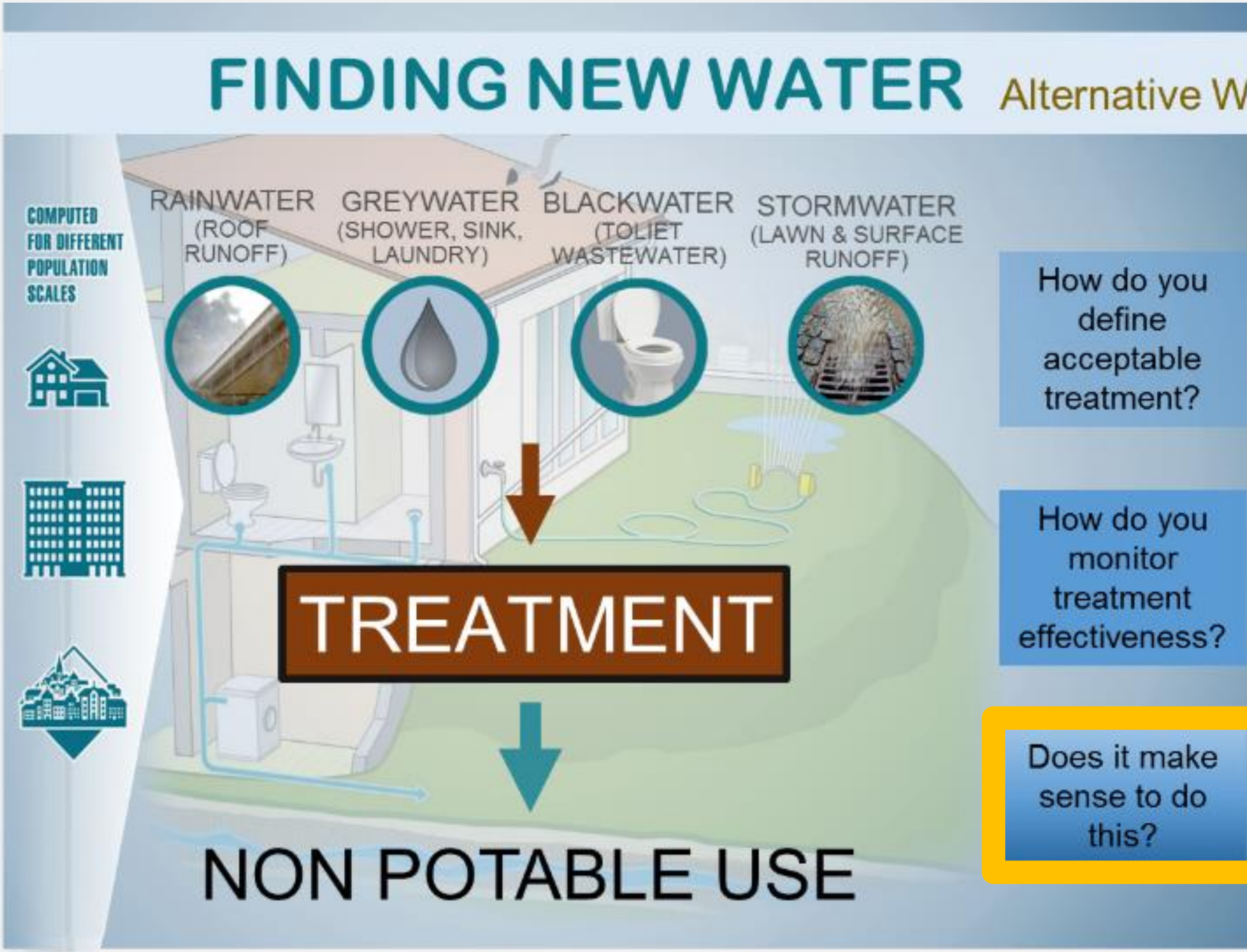
First Challenge



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WATER ENVIRONMENT + REUSE FOUNDATION WE&RF

US Water Alliance

Report

It's complicated, lots of drivers . . .

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Potential Benefits of Reuse

- **Water scarcity** (finding more water)
- **Efficiency**
  - Treating water only as needed for its end use application (fit-for purpose)
  - Reusing water close to the source, avoiding construction of recycled water pipeline
  - Defers capital costs of large-scale infrastructure
- **Reduces pollution and loading** to sewers and water bodies
- **Increases resiliency and adaptability** of our water and wastewater infrastructure
- Generates **green space** in urban corridors
- Meets and exceeds **green building goals**

Addressing the Question: What are the Life Cycle Costs/Impacts?

Analyzing Scenarios to determine “Is it worth it?”

Example Scenario:

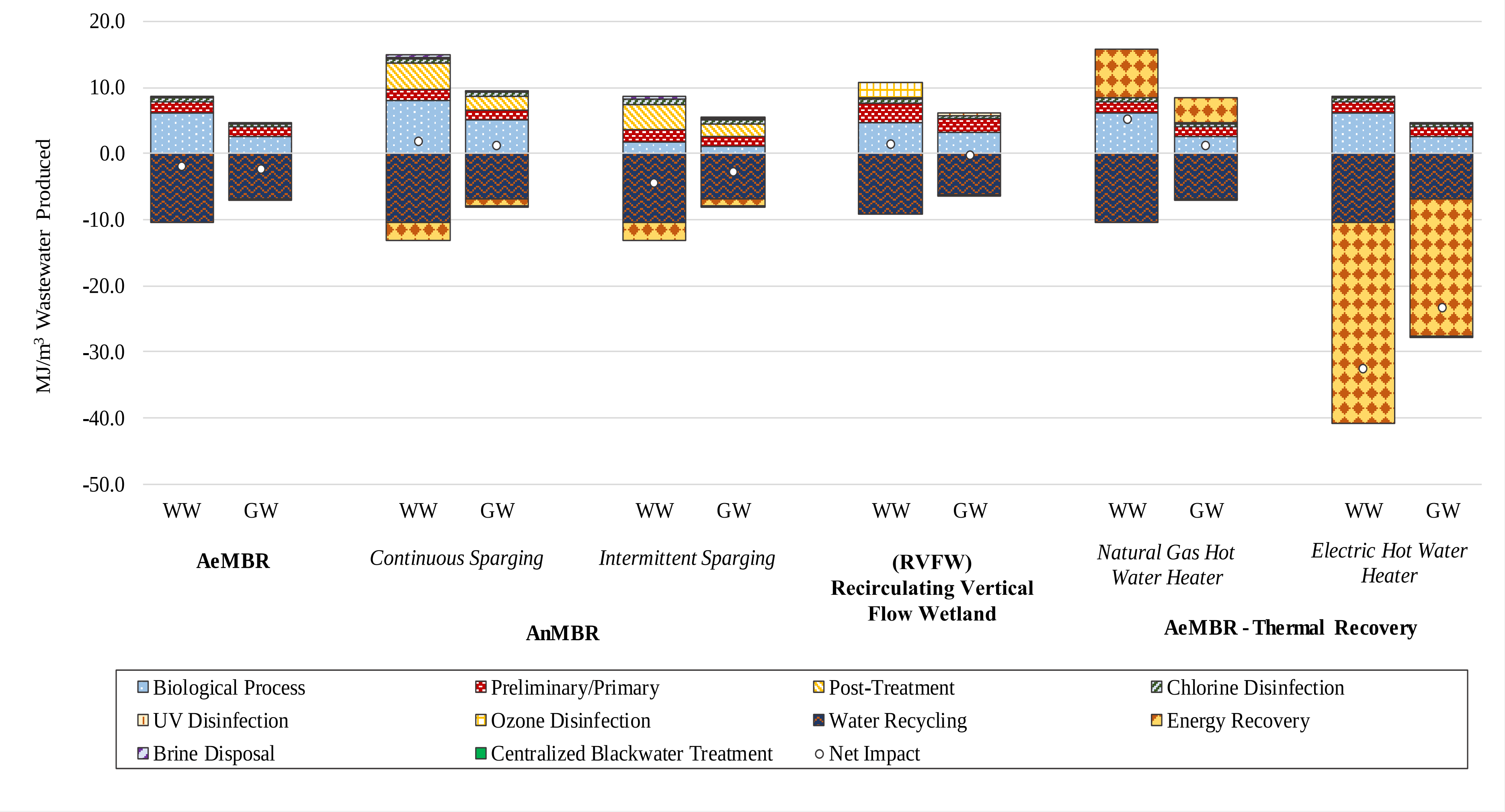
- Details: 19 story, 20,000 ft^2, mixed use, 1000 occupant building, ~25,000 gpd wastewater

- Options: Compare combined wastewater (WW) vs. source-separated greywater (GW)

Alternative treatment approaches:

- Aerobic (AeMBR) vs. Anaerobic MBR (AnMBR)
- Vertical Flow Wetland
- Heat recovery

Results: Cumulative Energy Use Tradeoffs at the Building Scale



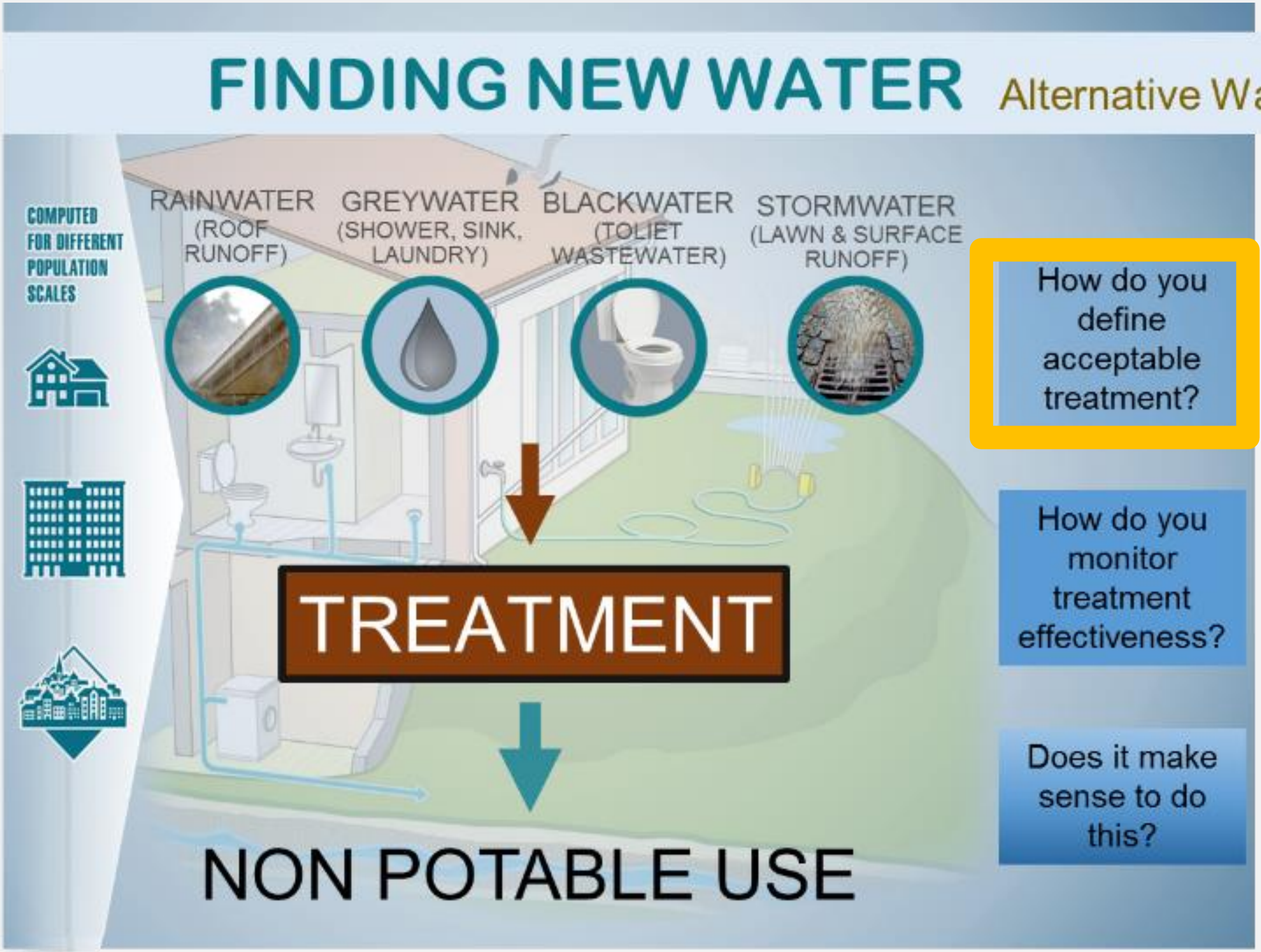
Net benefits in energy use for most options

Results: Systems-Level Analysis Summary

- Net benefits if account for avoided drinking water impacts
- Recovery of thermal energy can provide significant improvements
- System level benefits of recovering chemical energy (via anaerobic membrane bioreactors) diminished by costs of removing reduced nitrogen from produced water

Next Steps: System level impacts of using other water sources (roof collected rainwater, local stormwater, air conditioning condensate) as a function of different climates

Second Challenge



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Report

Graywater Use to Flush Toilets

Varying Standards

	BOD_5 (mg L^{-1})	TSS (mg L^{-1})	Turbidity (NTU)	Total Coliform (cfu/ 100ml)	*E. Coli* (cfu/ 100ml)	Disinfection
California	10	10	2	2.2	2.2	0.5 – 2.5 mg/L residual chlorine
New Mexico	30	30	-	-	200	-
Oregon	10	10	-	-	2.2	-
Georgia	-	-	10	500	100	-
Texas	-	-	-	-	20	-
Massachusetts	10	5	2	-	14	-
Wisconsin	200	5	-	-	-	0.1 – 4 mg L^{-1} residual chlorine
Colorado	10	10	2	-	2.2	0.5 – 2.5 mg/L residual chlorine
Typical Graywater	80 - 380	54 -280	28-1340	$10^{7.2}$ – $10^{8.8}$	$10^{5.4}$ – $10^{7.2}$	N/A

These are indicator of fecal pollution, not predictors of risk.

Meeting standards means reducing the presence of pathogens by orders of magnitude – this informs "log reduction" targets

National Sanitation Foundation 350 Water Quality for Graywater Use for Toilet Flushing

Parameter	Class R[a] Test Average	Class R[a] Single Sample Maximum	Class C[b] Test Average	Class C[b] Single Sample Maximum
$CBOD_5$ (mg/l)	10	25	10	25
TSS (mg/l)	10	30	10	30
Turbidity (NTU)	5	10	2	5
E. coli (MPN/100 ml)	14	240	2.2	200
pH (SU)	6.0-9.0		6.0-9.0	
Storage vessel residual chlorine (mg/l)	≥ 0.5 - ≥ 2.5		≥ 0.5 - ≥ 2.5	

[a] Class R: Flows through graywater system are less than 400 gpd
[b] Class C: Flows through graywater system are less than 1500 gpd

Standardization is an improvement, but not risk based.

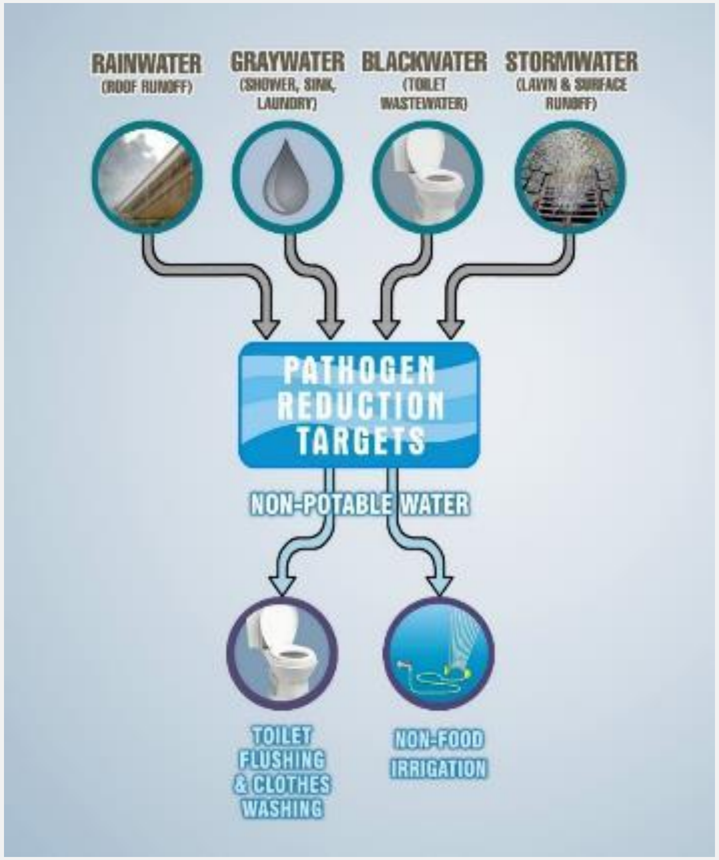
What do those levels of *E. coli* mean in terms of risk?

Approach: Developing Risk-based Pathogen Reduction Targets

- "Risk-based" targets attempt to achieve a specific level of protection (aka tolerable risk or level of infection)
  - 10^{-4} infections per person per year (ppy)
  - 10^{-2} infections ppy

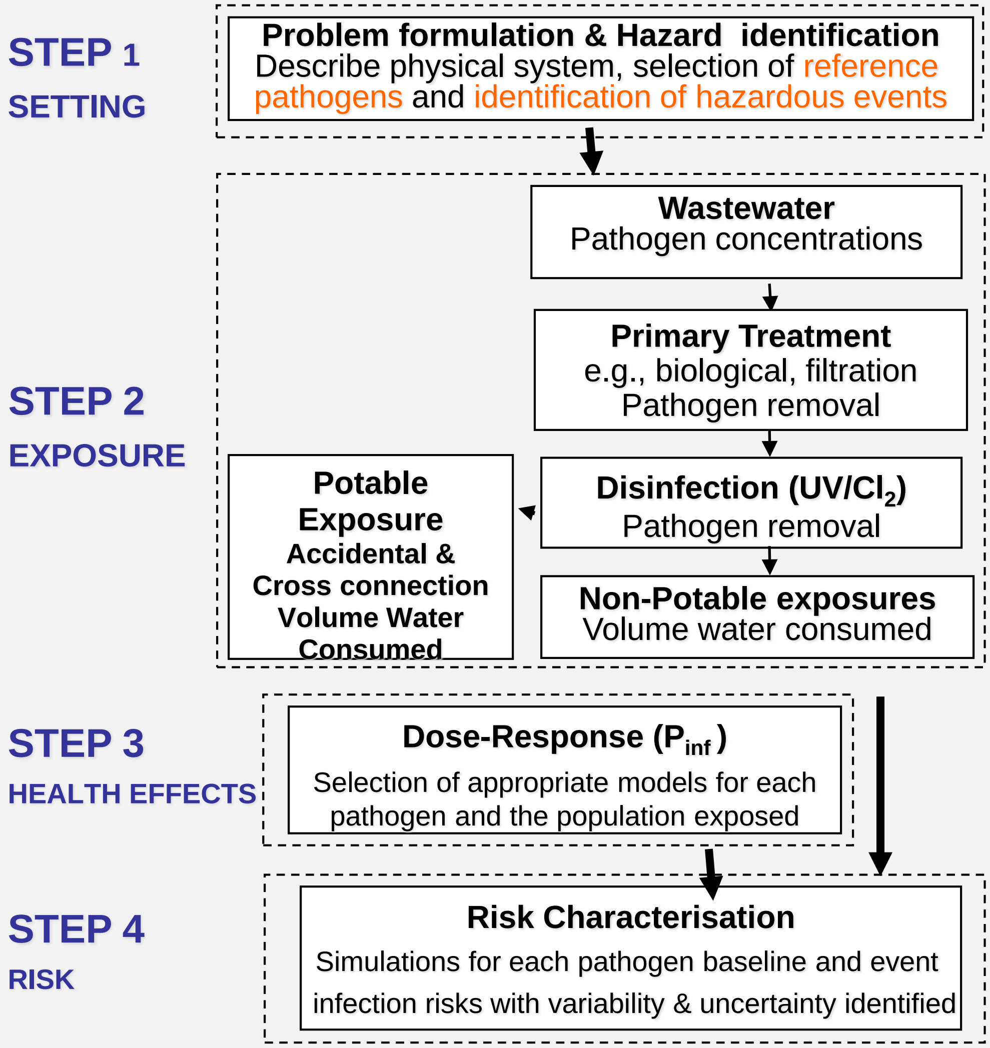
- Example: World Health Organization (2006) risk-based targets for wastewater reuse for agriculture

Quantitative Microbial Risk Assessment (QMRA)



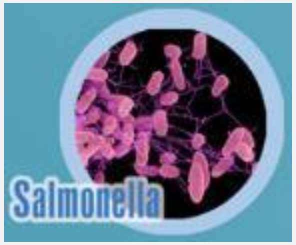
QMRA process **to inform log reduction targets**

Quantitative Microbial Risk Assessment (QMRA)



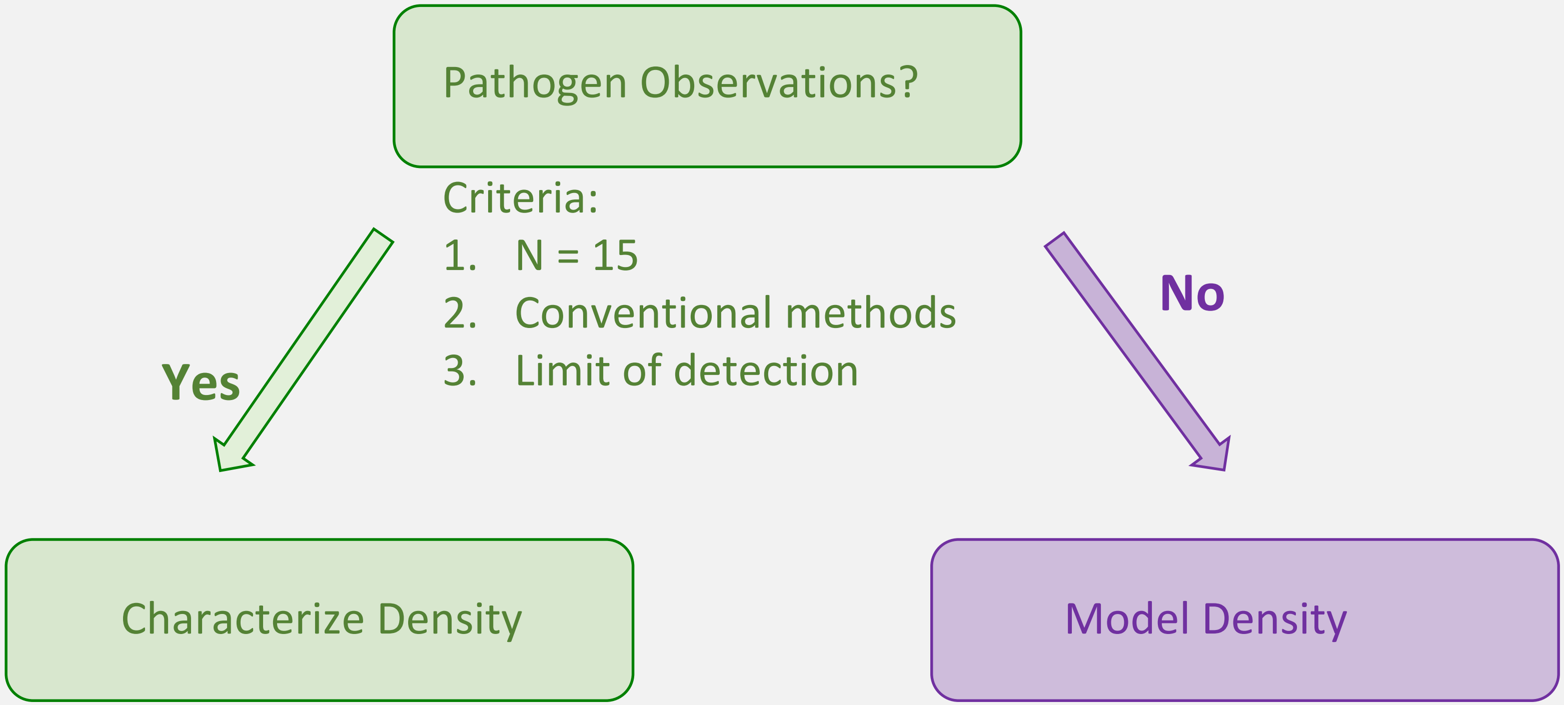
Reference Pathogens Needed

Each class will have different standards for necessary reductions in reused water



Viruses | Bacteria | Parasites/Protozoa

Critical First Step in Modeling: Estimating Initial Pathogen Density



Limited availability of data on pathogen levels for all of the water types

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Results

ORD's QMRA models and risk predictions were published so they can be used to develop log reduction targets (LRTs)

Water Use Scenario	$\log_{10}$ Reduction Targets for 10^{-4} (10^{-2}) Per Person Per Year Benchmarks[b,i]		
	Enteric Viruses[c]	Parasitic Protozoa[d]	Enteric Bacteria[e]
Domestic Wastewater or Blackwater			
Unrestricted irrigation	8.0 (6.0)	7.0 (5.0)	6.0 (4.0)
Indoor use[f]	8.5 (6.5)	7.0 (5.0)	6.0 (4.0)
Graywater			
Unrestricted irrigation	5.5 (3.5)	4.5 (2.5)	3.5 (1.5)
Indoor use[g]	6.0 (4.0)	4.5 (2.5)	3.5 (1.5)
Stormwater (10^{-1} Dilution)			
Unrestricted irrigation	5.0 (3.0)	4.5 (2.5)	4.0 (2.0)
Indoor use	5.5 (3.5)	5.5 (3.5)	5.0 (3.0)
Stormwater (10^{-3} Dilution)			
Unrestricted irrigation	3.0 (1.0)	2.5 (0.5)	2.0 (0.0)
Indoor use	3.5 (1.5)	3.5 (1.5)	3.0 (1.0)
Roof Runoff Water[h]			
Unrestricted irrigation	Not applicable	No data	3.5 (1.5)
Indoor use	Not applicable	No data	3.5 (1.5)

Sharvelle et al. (2017). Risk-Based Framework for the Development of Public Health Guidance for Decentralized Non-Potable Water Systems.

Epidemiology-Based Approach

Fecal contamination of water

- Fecal indicator concentration in water
- Indicator content of raw feces

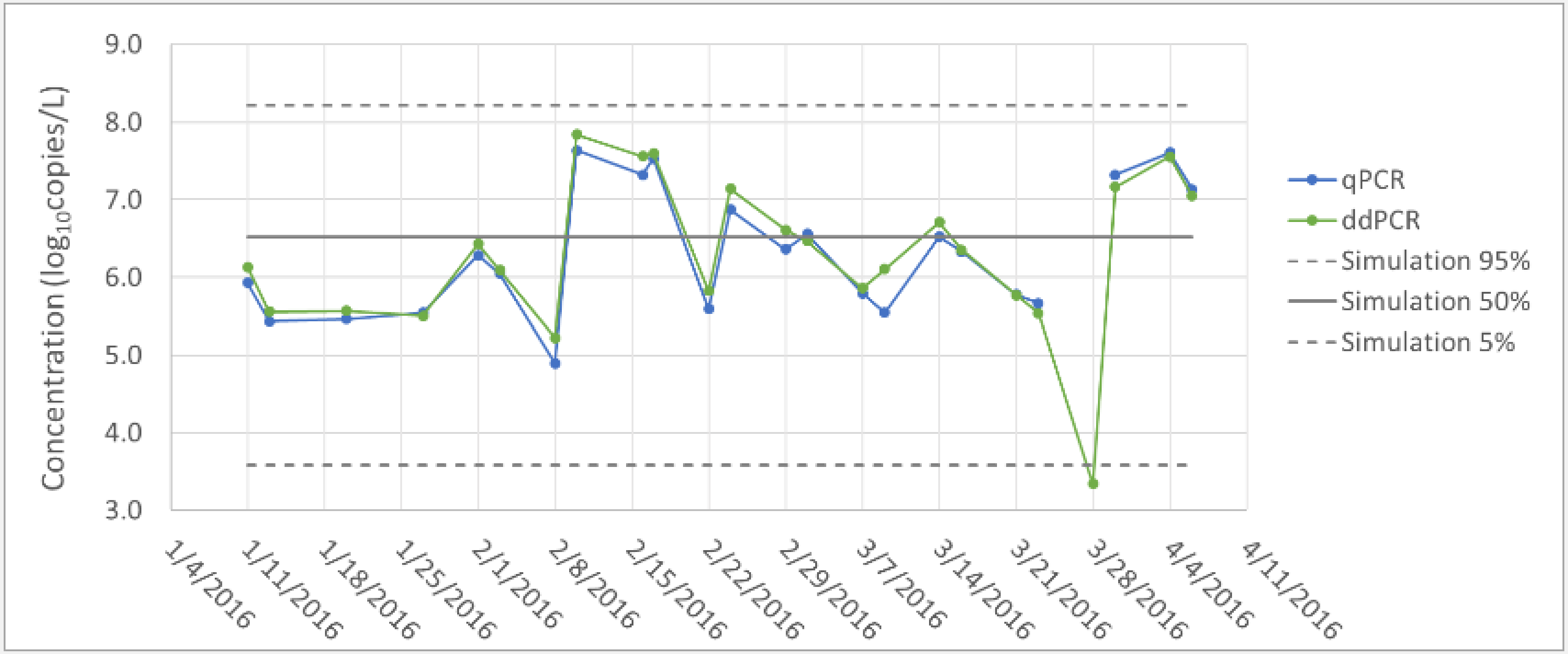
Number of users shedding pathogens

- Population size
- Infection rates
- Pathogen shedding durations

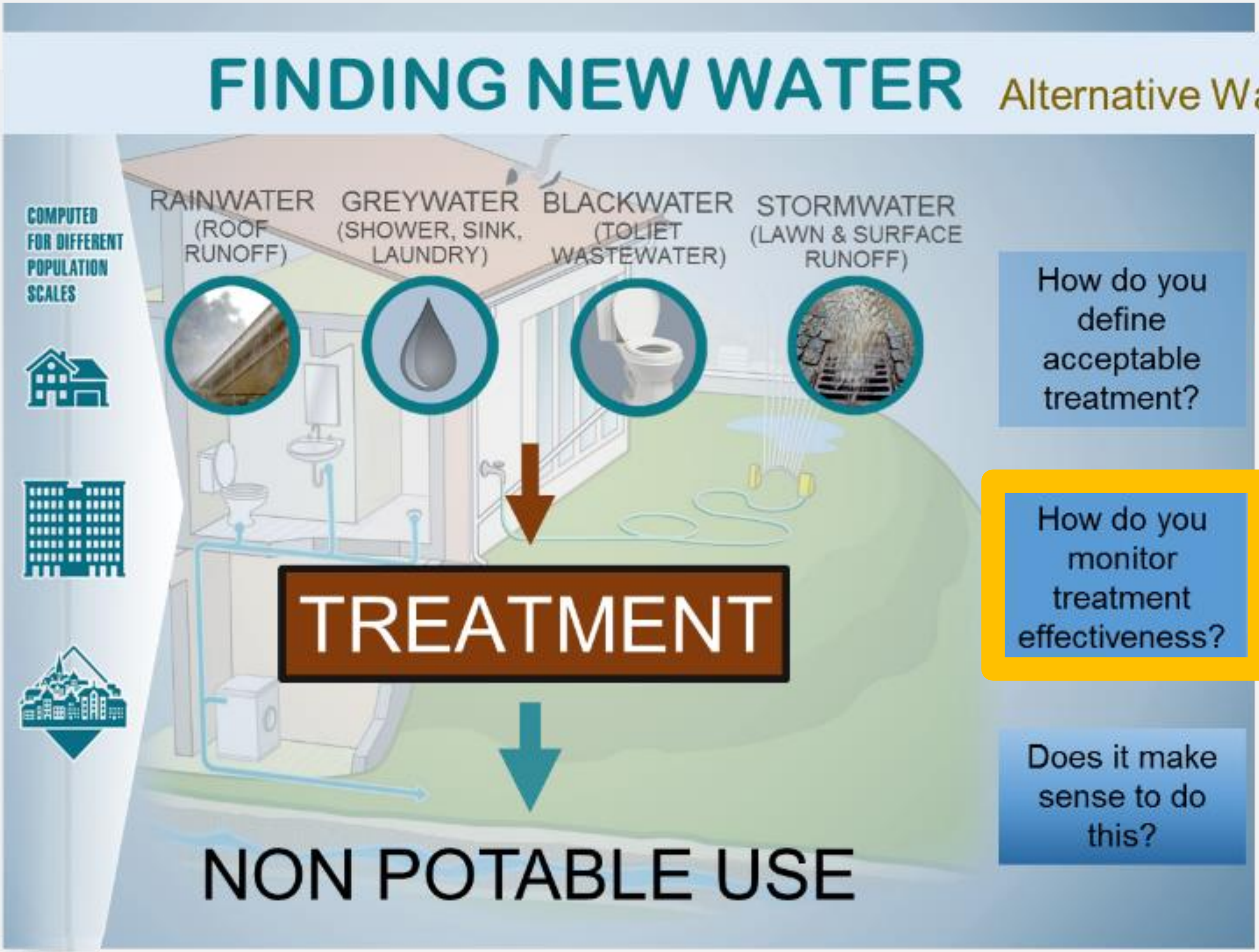
Pathogen concentrations in water

- Pathogen densities in feces during an infection
- Dilution by non-infected individuals

Result: Model Adequately Brackets Online Wastewater Measures from SFPUC Building



Third Challenge



Partners

Report

Monitoring

- You design a system to meet the risk based performance targets
  - A treatment train with multiple barriers with sufficient log reduction credits
- How do you verify performance?
- Routine monitoring of indicator organisms does not provide real time, risk-based information required for operation of non-potable reuse systems
- Proposed monitoring approach:
  - Operational Monitoring
    - Ongoing verification of system performance
    - Continuous observations
    - Surrogate parameters correlated with LRTs
  - Start-up and Commissioning
    - Validation monitoring
  - Controls for out of specification
    - “Revalidation”

But What Biological Target?

- Measure pathogens
  - Hundreds of potential pathogens
  - Sporadic occurrence
  - Can be expensive
  - Negative results
- Measure biological surrogates that represent pathogens
  - Typical surrogates (fecal indicator organisms) too dilute
  - Spike with surrogate, calculate reduction
    - Challenge to spike large systems
  - *Endogenous microbes as alternative biological surrogates*

Research Strategy to Identify Endogenous Biological Surrogates

Age of the Microbiome

Quantify endogenous biological surrogates

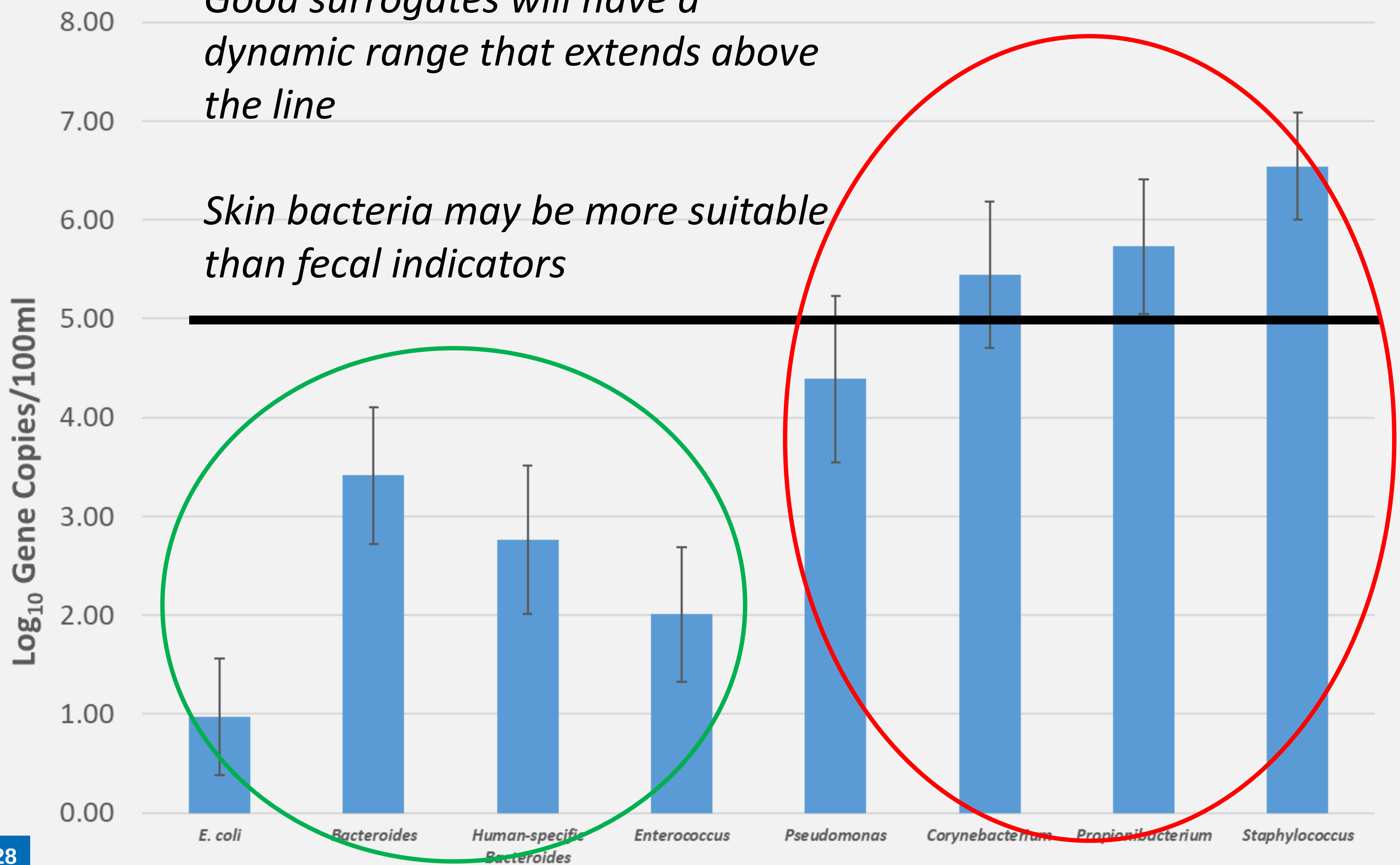
- How abundant are the candidate surrogates? Must be at or above LRT
- Are candidate surrogates consistently present in influent?

Compare log reduction profiles of candidate surrogates and pathogens through treatment processes

Quantification of Candidate Bacterial Surrogates in Laundry Graywater

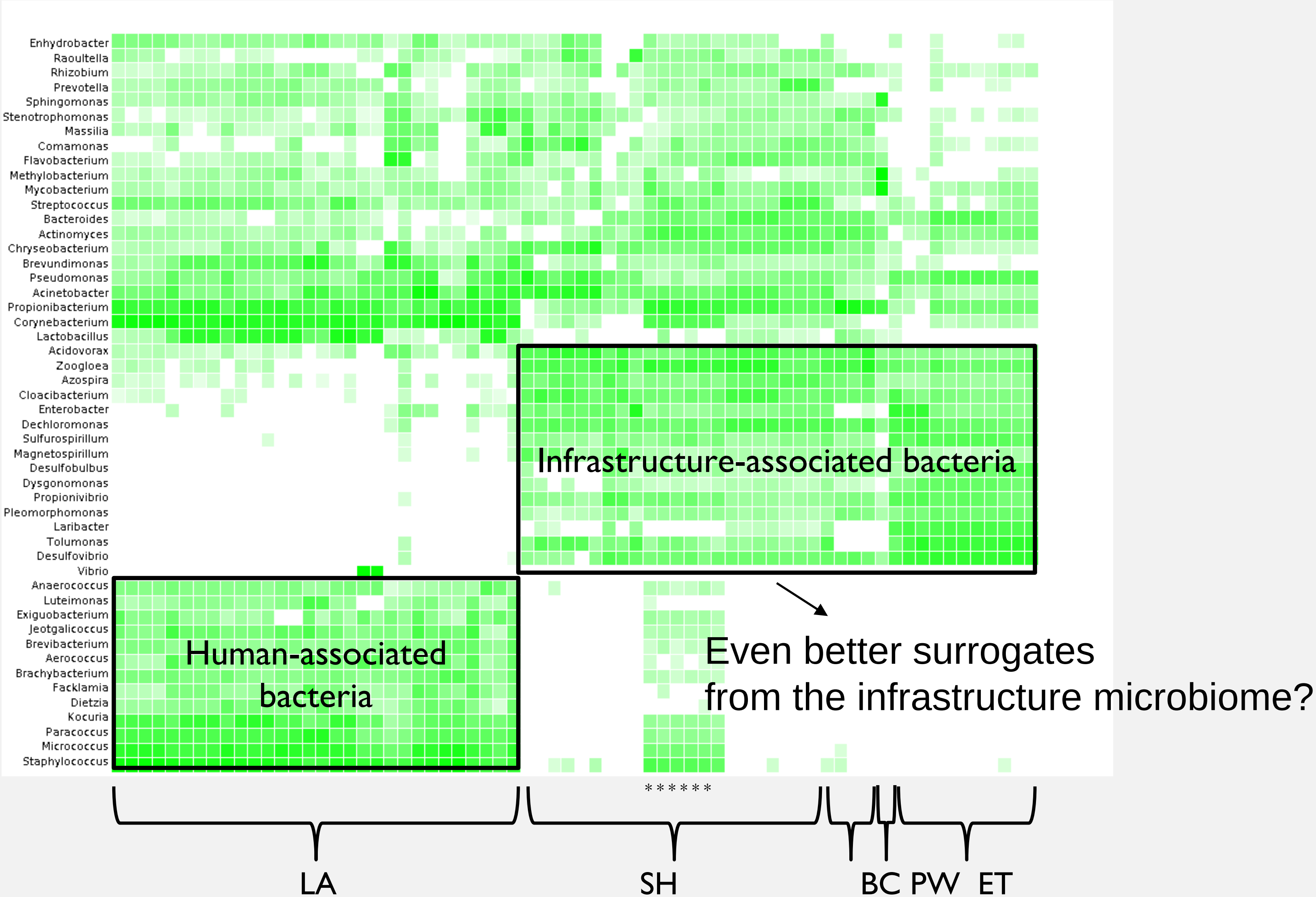
Good surrogates will have a dynamic range that extends above the line

Skin bacteria may be more suitable than fecal indicators



Zimmerman et al. 2014. *Environmental Science and Technology* 48, 7993

Analysis of "Graywater" Microbiome



Keely et al. 2015. *Journal of Applied Microbiology* 119: 289

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Summary of Monitoring

- Framework emphasizes on-line monitoring to best protect public health

- "Off-line" biological measurements for validation
  - Typical surrogates (fecal indicators) limited
    - Too dilute (or)
    - Wrong target

- Evaluation of the microbiome provides new surrogates
  - Working on both bacteria and viruses
  - Produce new standard methods
  - Potentially on-line biological sensors

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Impact

- **Immediate**
  - Log reduction targets incorporated to:

    Guidebook for Developing and Implementing Regulations for Onsite Non-potable Water Systems (December 2017)

    Providing public health agencies direct guidance on what treatment will ensure water can be recycled safely

- **On-going**
  - Defining more effective biological targets for monitoring performance & developing associated standard methods
  - Comparing cost/benefits of different non-potable reuse approaches to inform design

Resources for Additional Information

- http://uswateralliance.org/initiatives/commission/resources
  - All the documents produce by the National Blue Ribbon Commission
- www.epa.gov/water-research/water-research-webinars
  - An upcoming webinar on the topic with more detail and panel discussion with Commission members

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