Comprehensive Building Water System Water Quality, Thermal & Mechanical Goals

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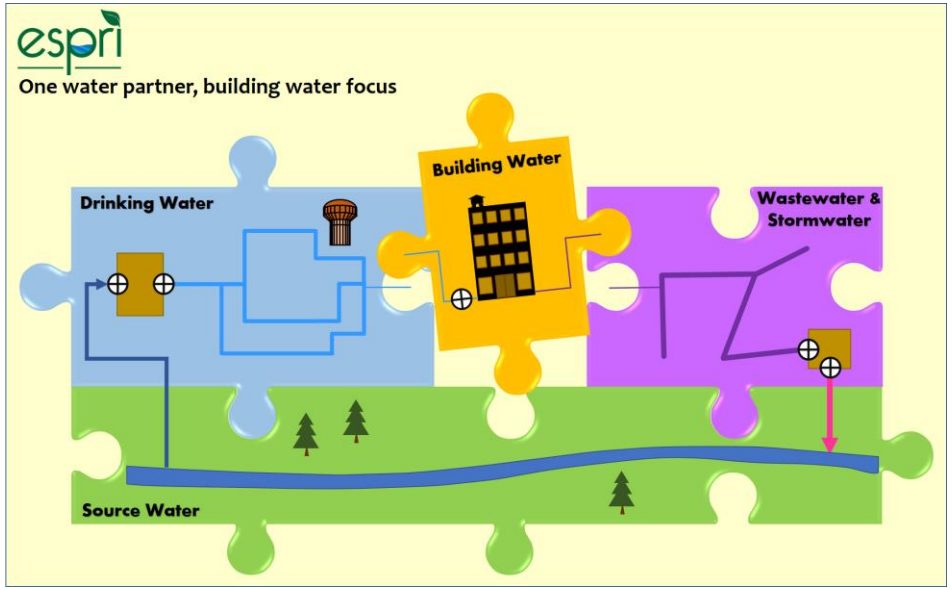
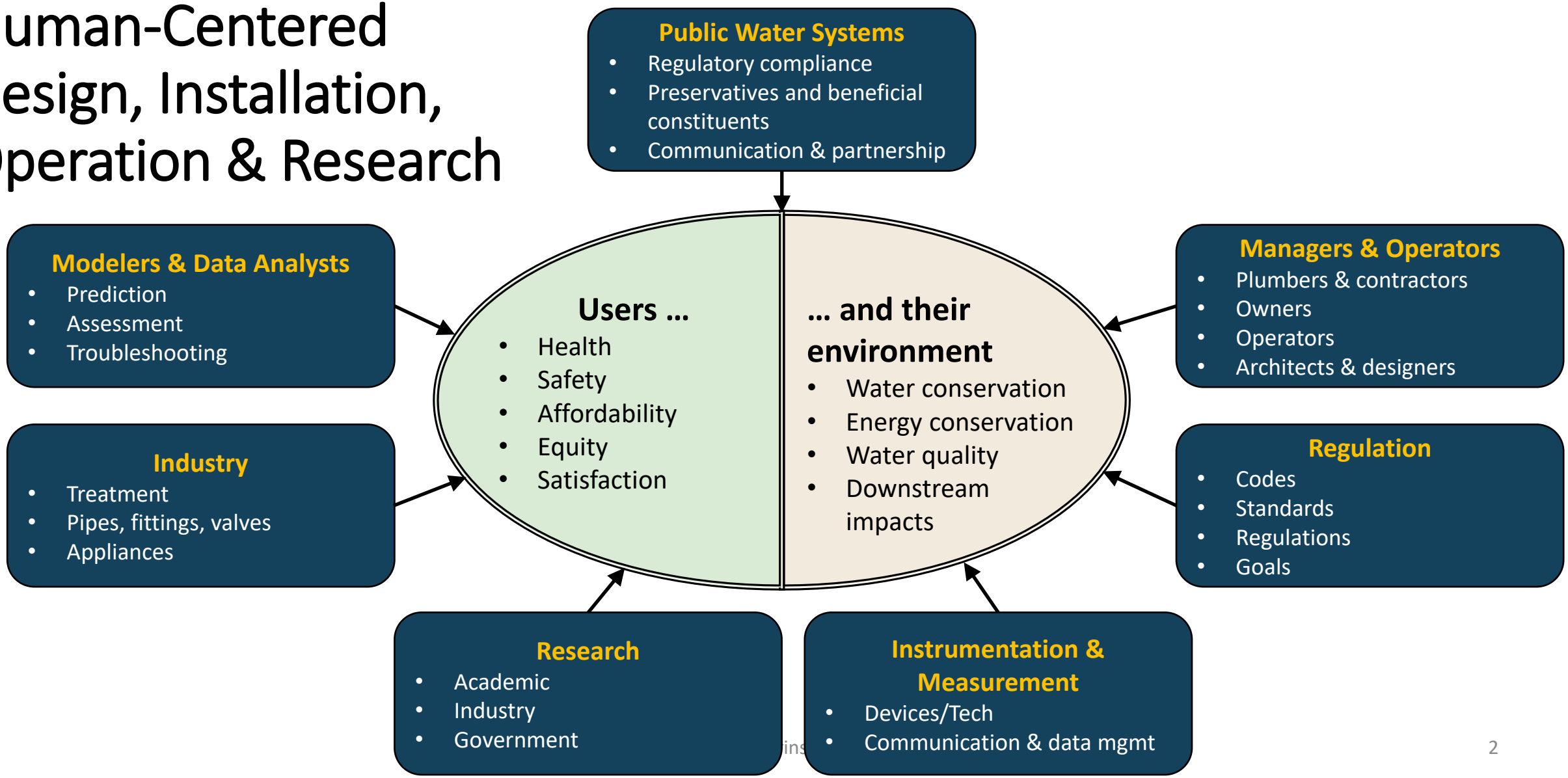


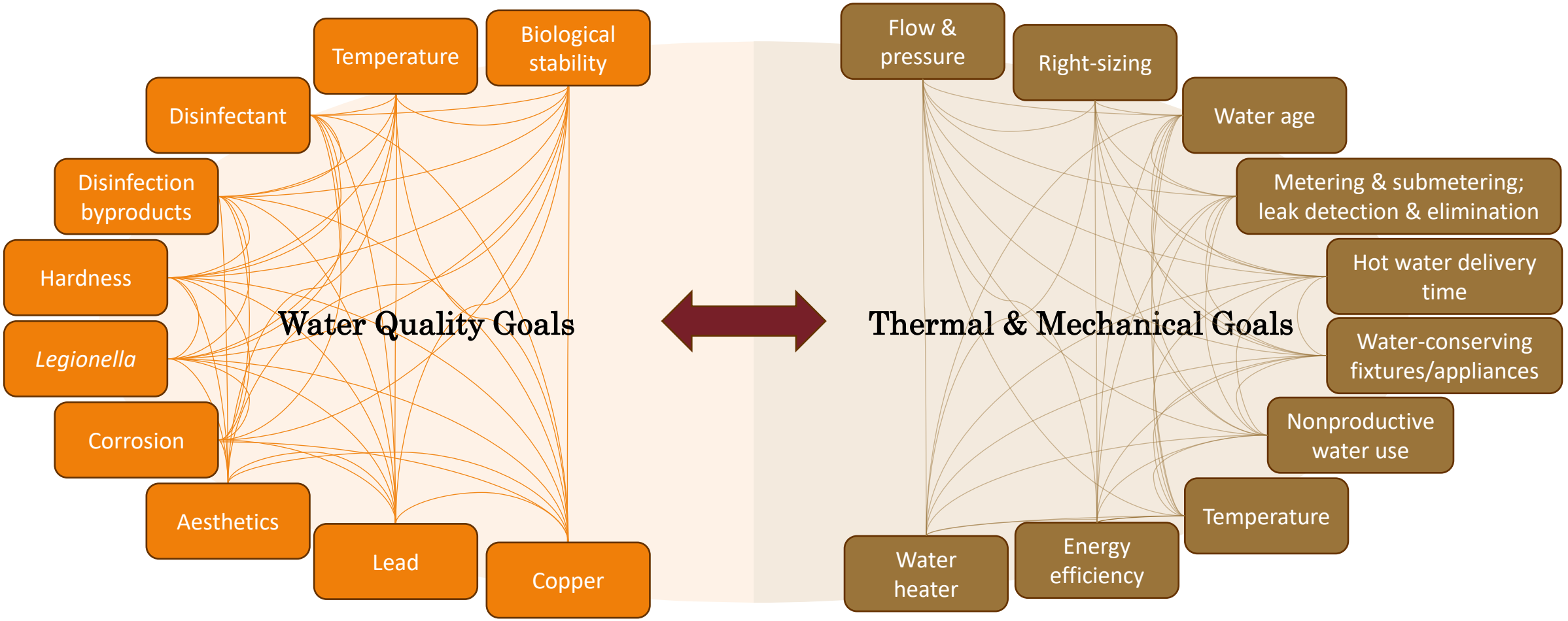
Human-Centered Design, Installation, Operation & Research



The Building Water System Goals Effort

- *Subject matter scope – The Water Energy Nexus*
  - Water conservation
  - Energy conservation
  - Water quality
  - Focused on processes in buildings and how they can be better controlled/managed
- *Building water system scope*
  - Single family residences goals addressed through design and installation goals
  - Limited set of goals applies to systems with limited occupant exposures (e.g., warehouses)
  - Buildings with susceptible/sensitive occupants and users
  - All other buildings
- *The panel*
  - Academics
  - Government agencies and labs
  - Consultants
  - Non-profits/NGOs
  - Industry
- *Methodology and timeline*
  - Twenty goals spanning water quality and thermal/mechanical performance
  - Small groups of subject matter experts assigned to each goal
  - First draft anticipated Q2 2024

Goals Overview



What are Goals? Why Goals Instead of Standards, Regs & Code?

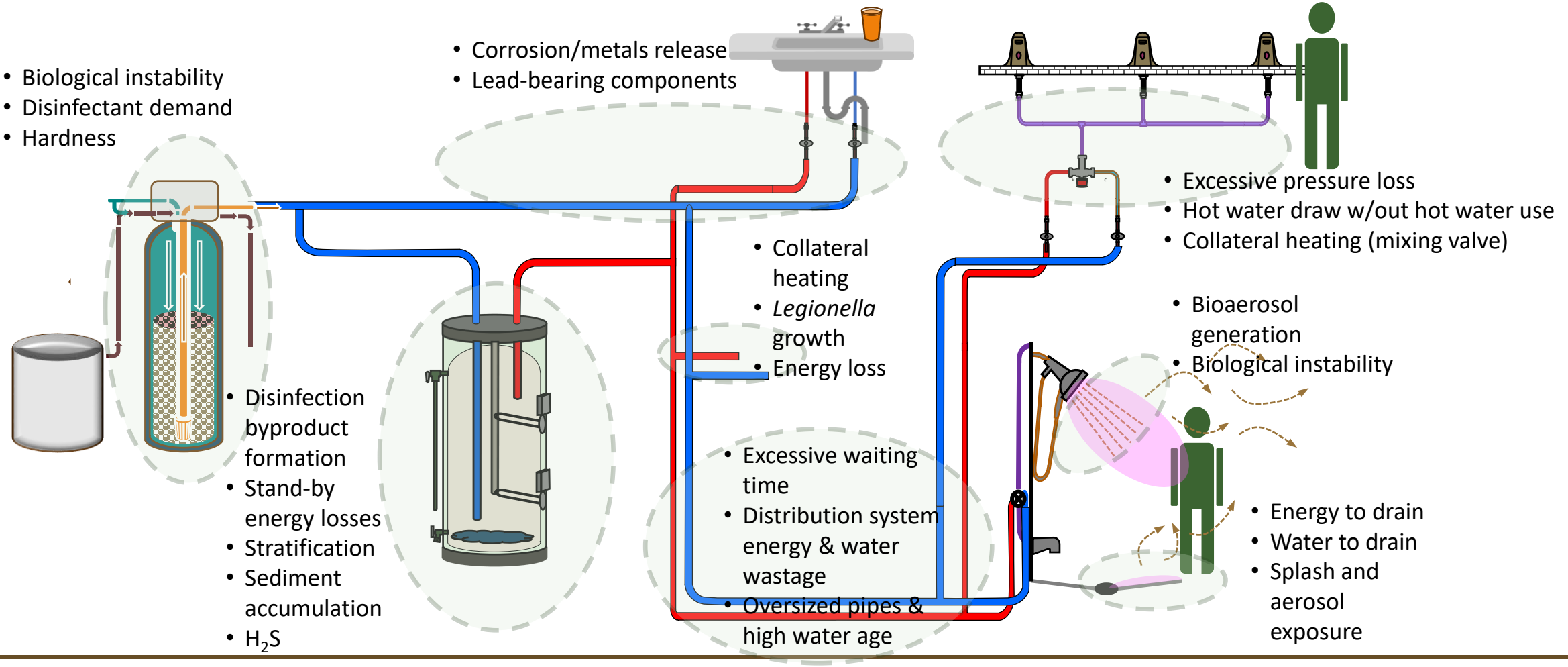
Goals

- Goals are:
  - Measurable and actionable
  - Positive
    - Meeting a goal is an achievement; meeting standards is a requirement with penalties for failure
  - Design criteria
  - Operational limits
- Goals can be set to drive innovation and establish value proposition

Standard, Regulations and Code

- Standards, regulations and code
  - Set a floor for performance (no incentive to strive for more)
  - Need to be developed by an authority with jurisdiction
  - Are much more difficult to develop than goals
- EPA has been advised to play a more active role in premise plumbing – stay tuned!

A 60 Second System Assessment



Interconnected Goals – *Legionella*

- Growth suppression or promotion
- Select for thermotolerant orgs
- Accelerated disinfectant decay
- Collateral heating and local instability

Temperature

- Growth on media
- Organic carbon production
- Disinfectant decay and demand
- Scale & sediments – OPPPs ecological niche

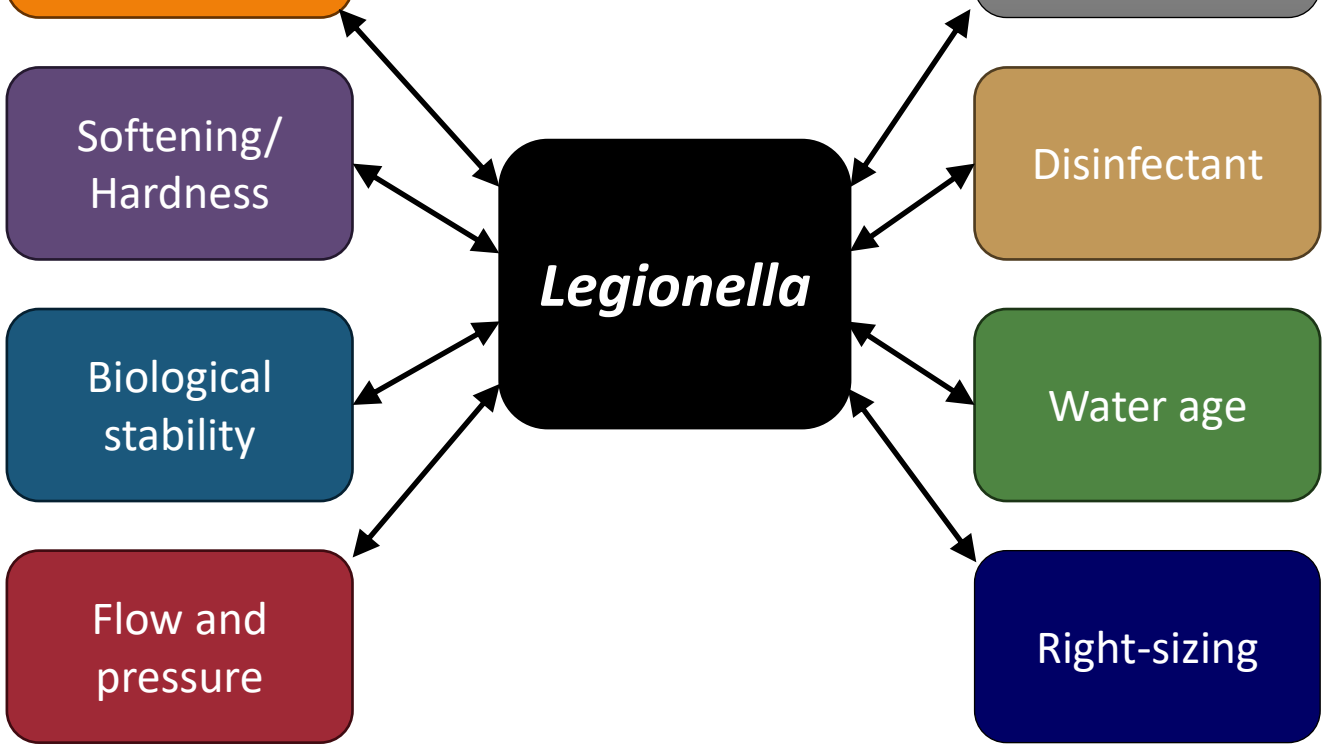
Softening/ Hardness

- Microbial community structure (e.g., conditions favoring protozoan hosts)
- Selection for tolerant strains/isolates

Biological stability

- Biofilm scouring or dead zones
- Water turn-over (distribution network and fitting/valve residence time distribution)

Flow and pressure



Corrosion

- Release of nutrients
- Habitat
- Disinfectant demand

Disinfectant

- Antagonistic to OPPPs
- Important determinant of microbial community structure
- May select for resistant organisms
- Disinfectant demand and decay

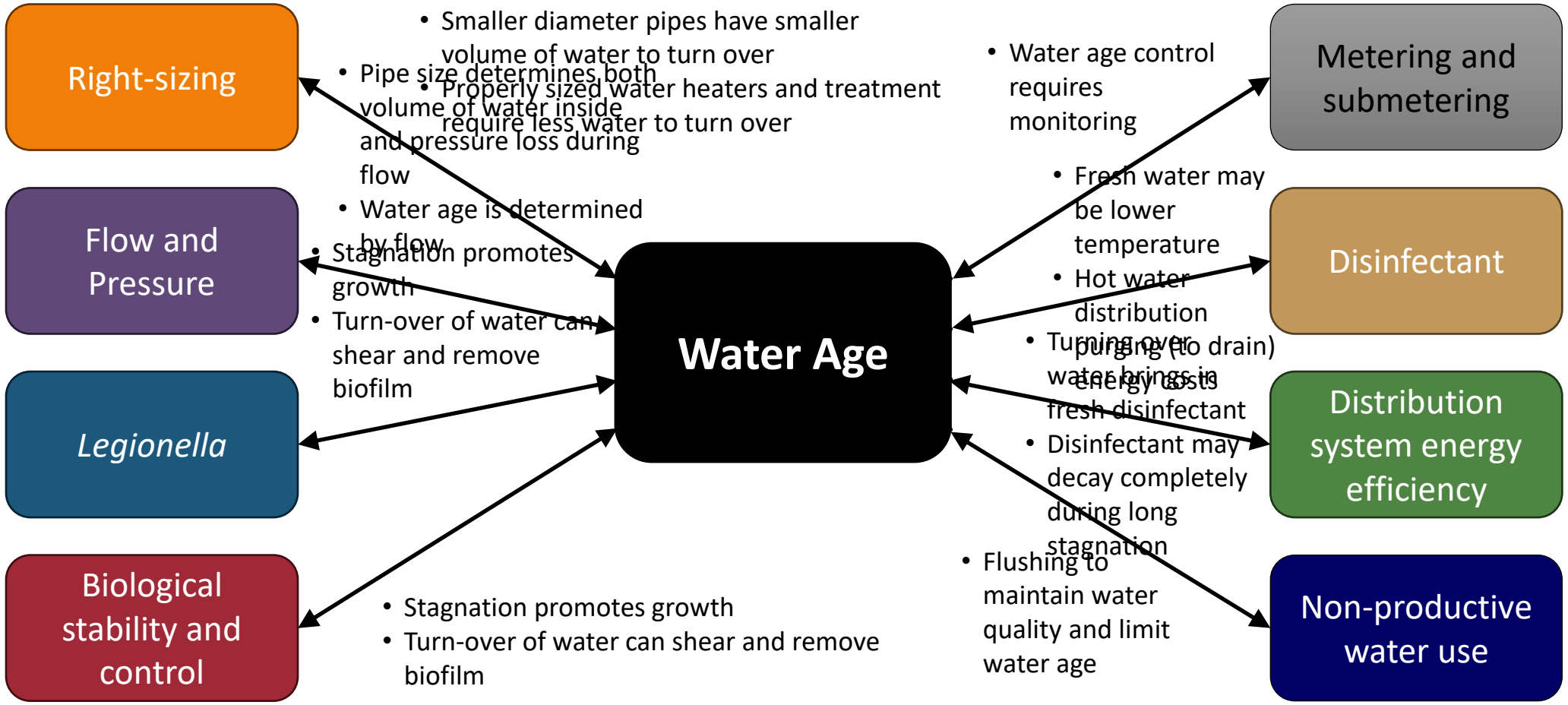
Water age

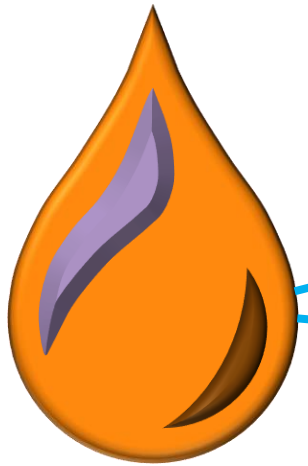
- Biofilm growth
- Biofilm mechanical properties

Right-sizing

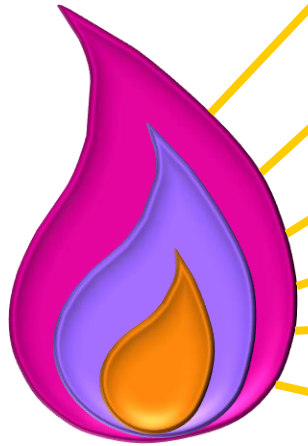
- Surface area for biofilm growth
- Water turn-over and velocity

Interconnected Goals – Water Age





Wasted Water



Wasted Energy

Water and energy use impacts	*Water quality impacts*
System flushing for water quality control Flush to drain	Reduced DBP formation & pathogen amplification
Water to drain waiting for hot water (branch) Waste to drain	Oversized pipes, long pipe runs, high water age, disinfectant demand
Cool down heat loss between draws	Temperature frequently or always in OPPPs growth range
Collateral heating (tank to distribution)	Temperature in segments favors pathogen growth
Pipe & fitting heat transfer during draws	
Water heater temperature higher than intended delivery temperature	High temperature controls pathogen growth

Water Quality Goals

Water Supply

OPPPs

THMs

HAAs

HANs

Taste and odor

Mn

Fe

Cu

Pb ≈ 0

Organic Carbon (OC)

VOCs

Hardness

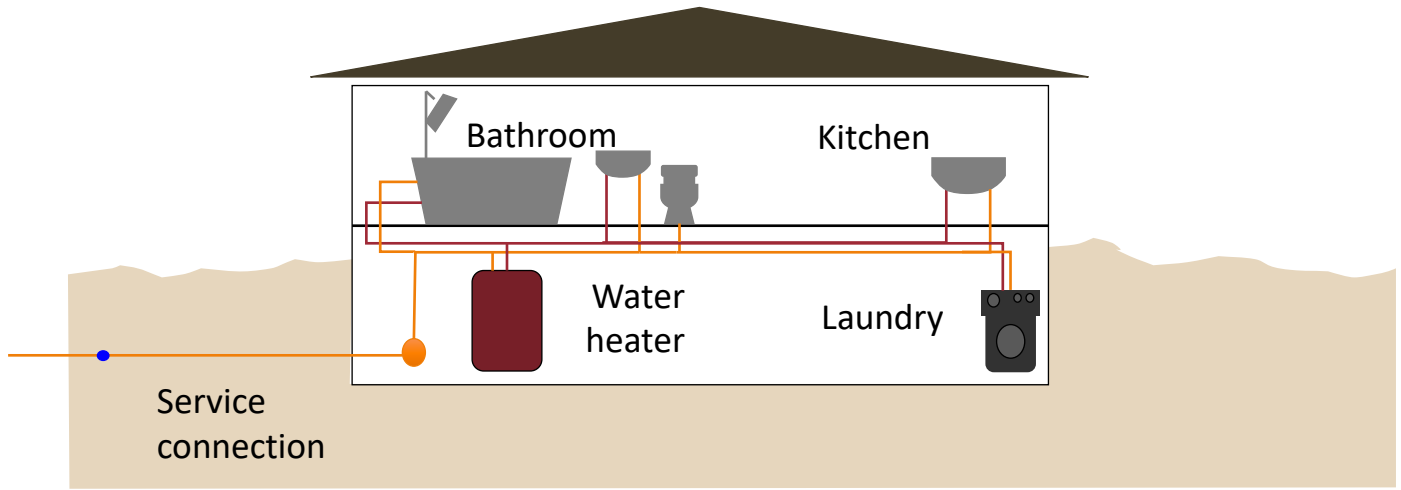
Chloride

Nitrifying bacteria

Nitrate

Residual

Corrosion inhibitor



Points of Use

OPPPs ± Δ OPPPs

THMs ± Δ THMs

HAAs ± Δ HAAs

HANs ± Δ HANs

T&O ± Δ T&O

Mn ± Δ Mn

Fe ± Δ Fe

Cu ± Δ Cu

Δ Pb

OC ± Δ OC

VOCs ± Δ VOC

Building water system "surcharge"

OPPP: Opportunistic Premise Plumbing Pathogen
THM: Trihalomethane
HAA: Haloacetic acid
HAN: Haloacetonitrile
VOC: Volatile Organic Compound

Biological Water Quality Goals

Goal Category	Draft goals

Legionella pneumophila	• Except for residential BWSs, a water management plan that includes:
	  • Periodic *L. pneumophila* or *Legionella* spp. ***monitoring***
	  • ***Control*** of factors related to *Legionella* control (temperature, disinfectant, water age, corrosion)
	  • Control assessed according to CDC guidance on interpretation of *Legionella* monitoring data

Biological stability and control	• Individual Heterotrophic Plate Count (***HPC***) results are within 1 log of the 12-month geometric mean of HPC results for the same location and • The 6-month HPC geometric mean is within 0.5 log of the baseline HPC geometric mean. • Water ***temperature*** is maintained within limits specified in temperature goal. • ***Disinfectant*** residual concentration is maintained within limits in disinfectant goal. • Opportunity for application of advanced microbial assays such as ATP, qPCR, flow cytometry, next generation sequencing, community analysis

Temperature (with flow, the most common factors among goals)

Goal Category	Draft goals
Temperature	• Cold water temperature ≤ 19.4°C (67°F) • Water temperature in water heaters ≥ 60°C (140°F) • Hot water temperature in recirculation loops and in plumbing upstream of mixing/tempering valves ≥ 55°C (131°F) • Water temperature delivered to fixtures ≤ 48°C (120°F) (minimize scalding risk)

Chemical and Aesthetic Water Quality Goals

Goal Category	Draft goals
Lead	• Primary goal -– Lead is ***below 10 ppb*** (subject to revision) at all drinking water taps, and below 1 ppb at all drinking water taps in schools and daycare facilities. • Only lead-free (per the Reduction of Lead in Drinking Water Act [RLDWA]) components in the BWS; exclusions for toilets, bidets and other fixtures not associated with oral ingestion • Periodic lead ***monitoring*** for building water systems installed prior to 2011
Copper	• ***Copper < 1.0 mg/L*** from fixtures associated with oral ingestion (MCLG) • No signs of copper staining or colored water or pinhole leaks, and verifying in new construction that copper piping has passivated
Disinfection byproducts	• TTHM and HAA5 concentrations ***at fixtures*** do not exceed EPA regulatory limits • ***Cannot be met with existing technology***

Chem and Aesthetic WQ (2)

Goal Category	Draft goals
Disinfectant	• Where disinfectant is required, meets the greater of ***0.2 mg/L*** or regulatory minimum in flushed cold water tap nearest the entry point • Disinfectant below the Maximum Residual Detection Level (MRDL) everywhere • ***Detectable*** at all flushed cold taps unless alternative biological control strategy is in place • Cold water disinfectant concentration at flushed fixtures ***≥80%*** of concentration in the building supply

Aesthetics	• ***Materials*** chosen to not be negatively affected by the water supply
	• System designed to facilitate flushing
	• Cross connections will be protected from backflow.
	• Occupant ***complaints*** for tastes, odors and color/particles/sediment are ***investigated***
	  • Remediation if complaints are result of building water system materials & processes
	  • Otherwise, reported to the water supplier

Chem and Aesthetic Goals (3)

Goal Category	Draft goals
Corrosivity	• Systems designed with compatible materials • Periodic monitoring; metals (copper, iron) are not more than 120% of metals in supply • Research need: predictive corrosion indices
Hardness	• Hardness < 150 mg/L as $CaCO_3$ • Water softener sized properly, operated properly and monitored to ensure that softening is not a source of opportunistic pathogens, organic carbon and does not deplete cold water disinfectant

Thermal Goals

Hot Water Thermodynamics and Heat Transfer

Net energy to Heat and Distribute Water

Water Heating

Energy to raise water temperature

- **Water heater inefficiency**
- **Recirculation pump energy consumption**
- **Water heater stand-by losses**

Distribution

Energy in water delivered for beneficial use

- **Energy in water flushed to drain**
- **Pipe wall heat loss during use**
- **Cooldown in distribution**
- **Collateral heating**

Thermal Goals (1)

Goal Category	Draft goals
Distribution system energy efficiency	• Primary goal: distribution system energy losses < 10% of total water heating energy consumption (***modeling and model development essential to meeting this goal***) • Secondary goal: distribution system energy losses < 5% of total water heating energy consumption • Ongoing monitoring and data analysis to document distribution system energy losses
Hot water waiting time	• Primary Goal: Hot water delivery to fixture within 15 seconds • Secondary Goal: Instantaneous hot water

Thermal Goals (2)

Goal Category	Draft goals

Water heating & recirc	• Water heater type
	  • Primary goal: Water Heater is ***Energy Star*** certified
	  • Primary goal: Water heater is ***right-sized*** and consistent with anticipated usage
	  • Secondary goals: ***demand flexibility***, preference for heat pump or condenser types
	• Monitoring and maintenance
	  • WH performance ***monitoring***; automated fault detection and diagnostics preferred
	  • Maintenance & monitoring scheme to maintain operational efficiency & integrity
	  • Annual maintenance including tank ***flushing***/sludge removal, heat exchanger & anode rod ***maintenance***
	• Recirculation
	  • Thermal losses to non-flowing branches minimized via ***heat traps***, downward branch ***orientation*** or other measures
	  • Recirculation loops meet temperature goals

Mechanical/Hydraulic Goals

Draft Hydraulic Goals (1)

Category	Draft goals

Flow & Pressure	• Consistently deliver water at plumbing fixtures meeting target flow and pressure per fixture specifications
	  • Target range for flow and pressure met @ fixture @ both static flow & peak conditions
	  • Residual pressure showerheads at rated flow is 40 psi or greater.
	  • Pressure loss across shower/tub valves should not exceed 8 psi at the rated flow
	  • Pressure loss across faucets (including mixing) should not exceed 5 psi at rated flow
	• Hydraulic modeling or other pre-installation analysis is performed to ensure that pressure and flow targets are met from the outset of beneficial use.
	• Pressure maintenance
	  • Valves, fittings, appurtenances, and equipment should be selected to minimize pressures loss while not negatively impacting water age. This has pressure and flow benefits and potentially will conserve energy (lower pumping energy).
	  • R&D to reduce pressure losses for valves & fittings
	• Systems designed to prevent crossover; crossover detection & control conducted regularly
	• Continuous commissioning

Draft Mechanical/Hydraulic Goals (2)

Goal Category	Draft goals

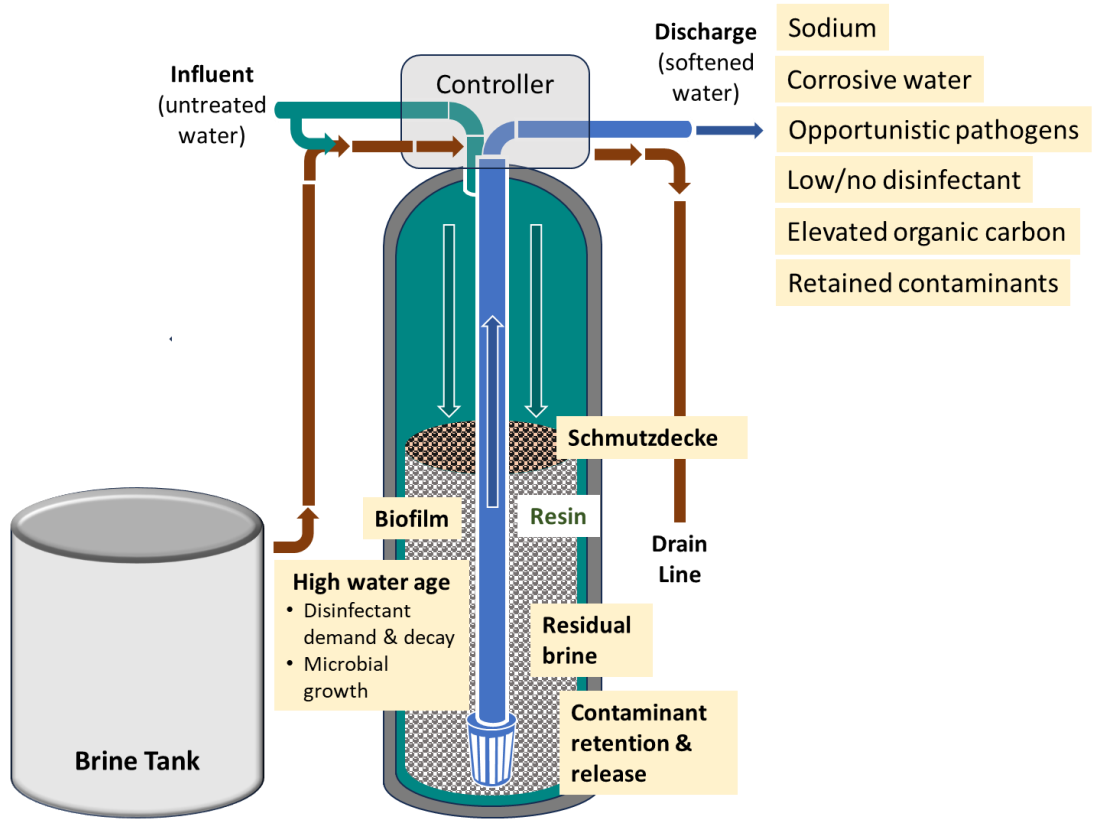
Water age	• Maximum water age is
	  • ≤ 1 day for all building potable water system (BWS) components for health care facilities or facilities used by immunocompromised or sensitive populations and
	  • ≤ 3 days for all BWS components for other BWSs
	• Purging/flushing to meet water age goal does not cause failure meeting nonproductive water use goals

Monitoring & Leak Detection	• Flow metering and submetering; data analytics and system performance assessment • Leak detection program in place and documented

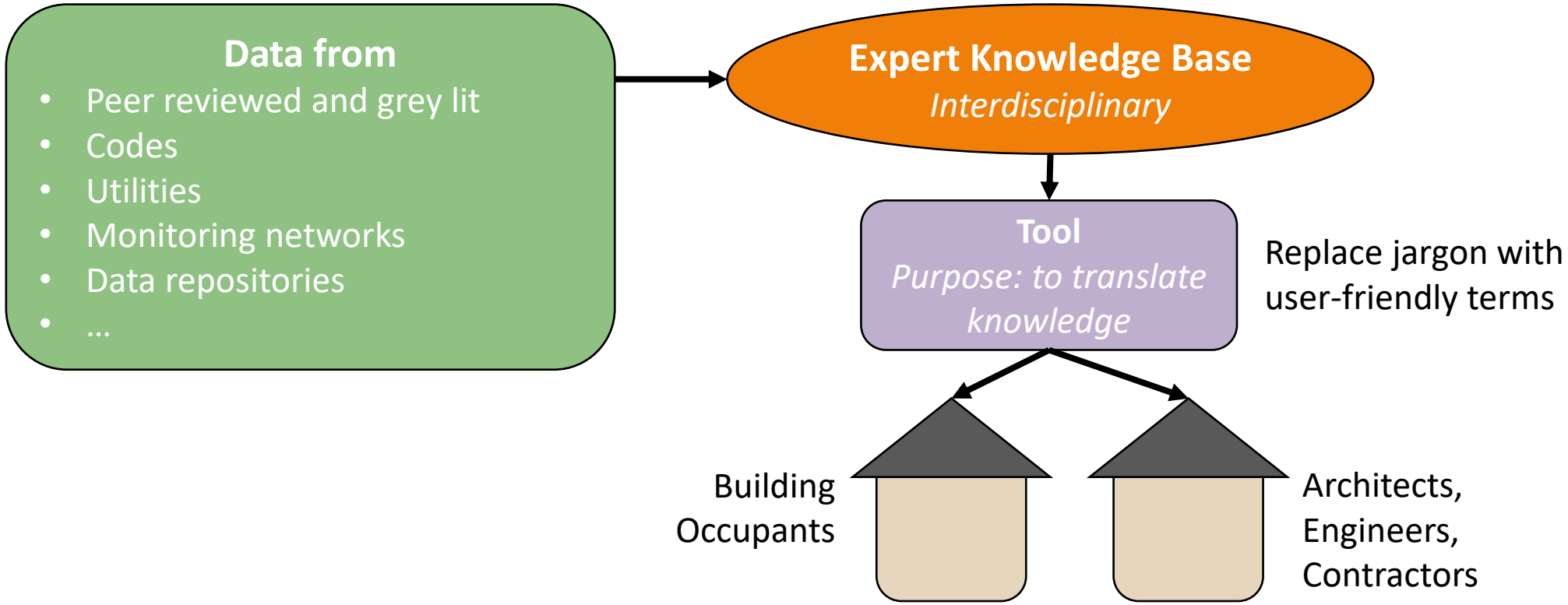
Some Emerging Technology Needs & Opportunities

- Water softeners that preserve biological& chemical water quality
- Disinfection byproduct reduction/treatment for hot water systems
- Low head loss, high scour valves and fittings
- Point of use copper removal
- Low-cost, high-res, networked flow, temp & water quality monitoring plus advanced data analysis and diagnostics
- Advanced water system models
  - Flow/pressure
  - Thermal/temperature
  - Water quality

Water softener hazards analysis & controls assessment



Top Priority R&D from NSF Hot Water Innovations Workshop (Katherine Alfredo, U S Florida, PI)

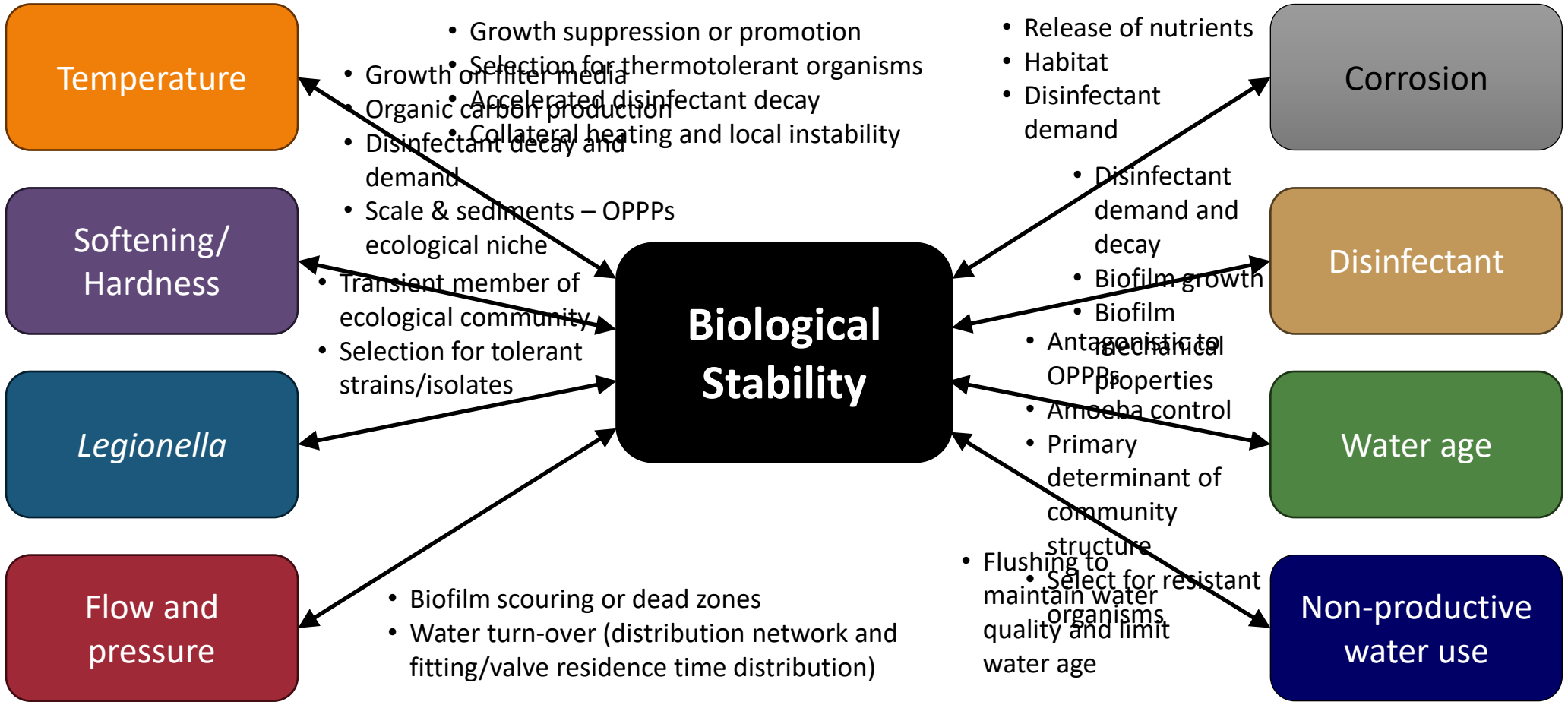


Discussion Topics

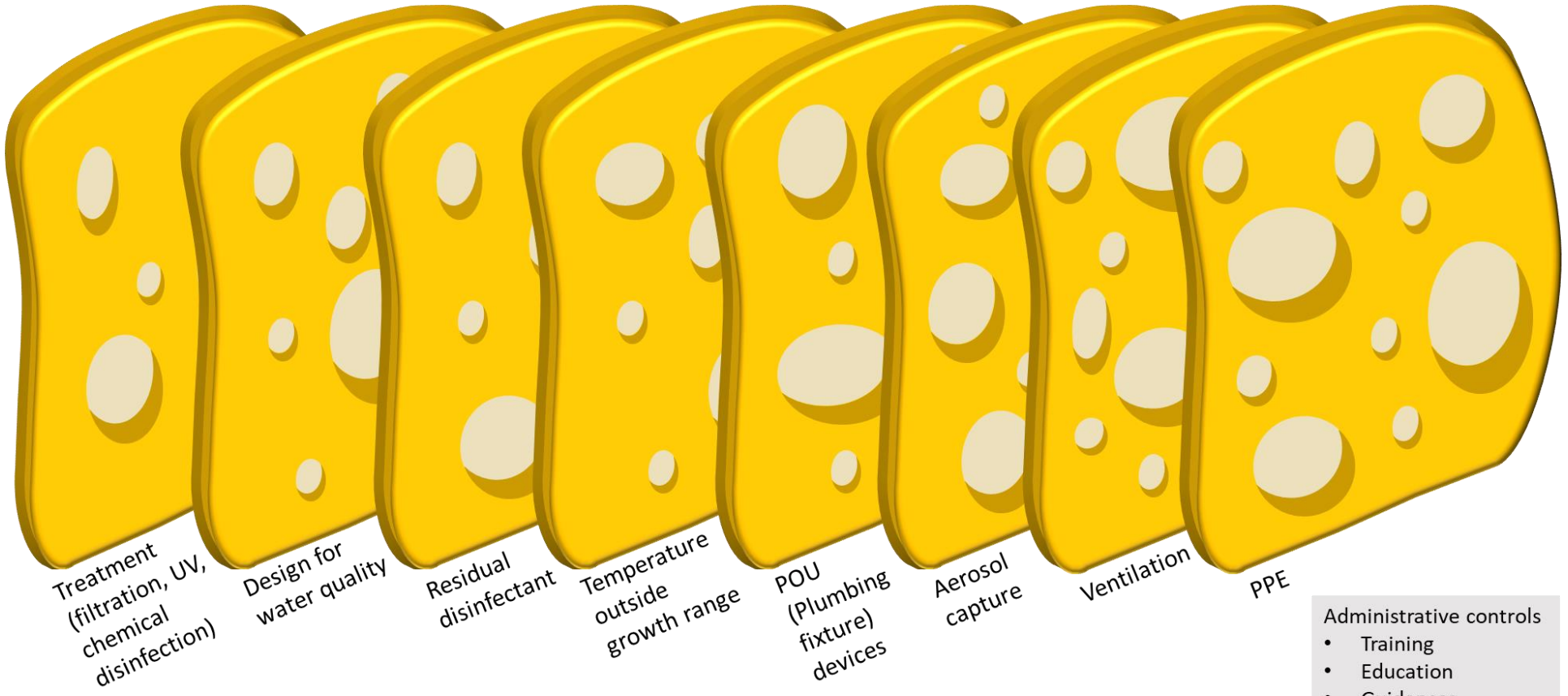
- Overall assessment of the goals
  - Should any be added or deleted?
  - Are they realistic? Aggressive enough?
- What are the priority
  - Research areas?
  - Innovation needs?
- How can these goals be integrated with other building performance standards/guidances/requirements? Should they?

Extra Slides for Discussion

Interconnected Goals – Biological Stability



Multiple Barriers & Managing Building Latent Risks



Barriers must be

- *Distributed through the system*
- *Highly reliable*

Administrative controls

- Training
- Education
- Guidances
- Code
- Occupational safety

CDC Protocol for interpreting *Legionella* monitoring data

Concentration indicates that *Legionella* growth appears:

Uncontrolled	Poorly controlled	Well controlled			
≥10 CFU/mL† in potable water **OR** ≥100 CFU/mL in non-potable water	1.0–9.9 CFU/mL in potable water **OR** 10–99 CFU/mL in non-potable water	Detectable to 0.9 CFU/mL in potable water **OR** Detectable to 9 CFU/mL in non-potable water	No *Legionella* detected in a single round of testing	No *Legionella* detected in multiple rounds of testing	No *Legionella* detected in multiple rounds of testing with methods that detect viable and non-viable bacteria of any *Legionella* species

Change in concentration over time indicates that *Legionella* growth appears:

Uncontrolled	Poorly controlled	Well controlled			
100-fold or greater increase in concentration (e.g., 0.05 to 5 CFU/mL)	10-fold increase in concentration (e.g., 0.05 to 0.5 CFU/mL)	*Legionella* concentration steady (e.g., 0.5 CFU/mL for two consecutive sampling rounds)	No *Legionella* detected in a single round of testing	No *Legionella* detected in multiple rounds of testing	No *Legionella* detected in multiple rounds of testing with methods that detect viable and non-viable bacteria of any *Legionella* species

Extent indicates that *Legionella* growth appears:

Uncontrolled	Poorly controlled	Well controlled			
Detection in multiple locations AND a common source location‡ **OR** Detection across many locations within a water system	Detection in a common source location that serves multiple areas **OR** Detection in more than one location within a water system	Detection in a few of many tested locations within a water system	No *Legionella* detected in a single round of testing	No *Legionella* detected in multiple rounds of testing	No *Legionella* detected in multiple rounds of testing with methods that detect viable and non-viable bacteria of any *Legionella* species

Type of *Legionella* (species and serogroup) associated with Legionnaires' disease:

Highly Associated	Less Associated
Detection in multiple locations AND a common source location‡ **OR** Detection across many locations within a water system	Detection in a common source location that serves multiple areas **OR** Detection in more than one location within a water system