NC STATE UNIVERSITY

Circular Economy in the Water and Sanitation Sector in the US

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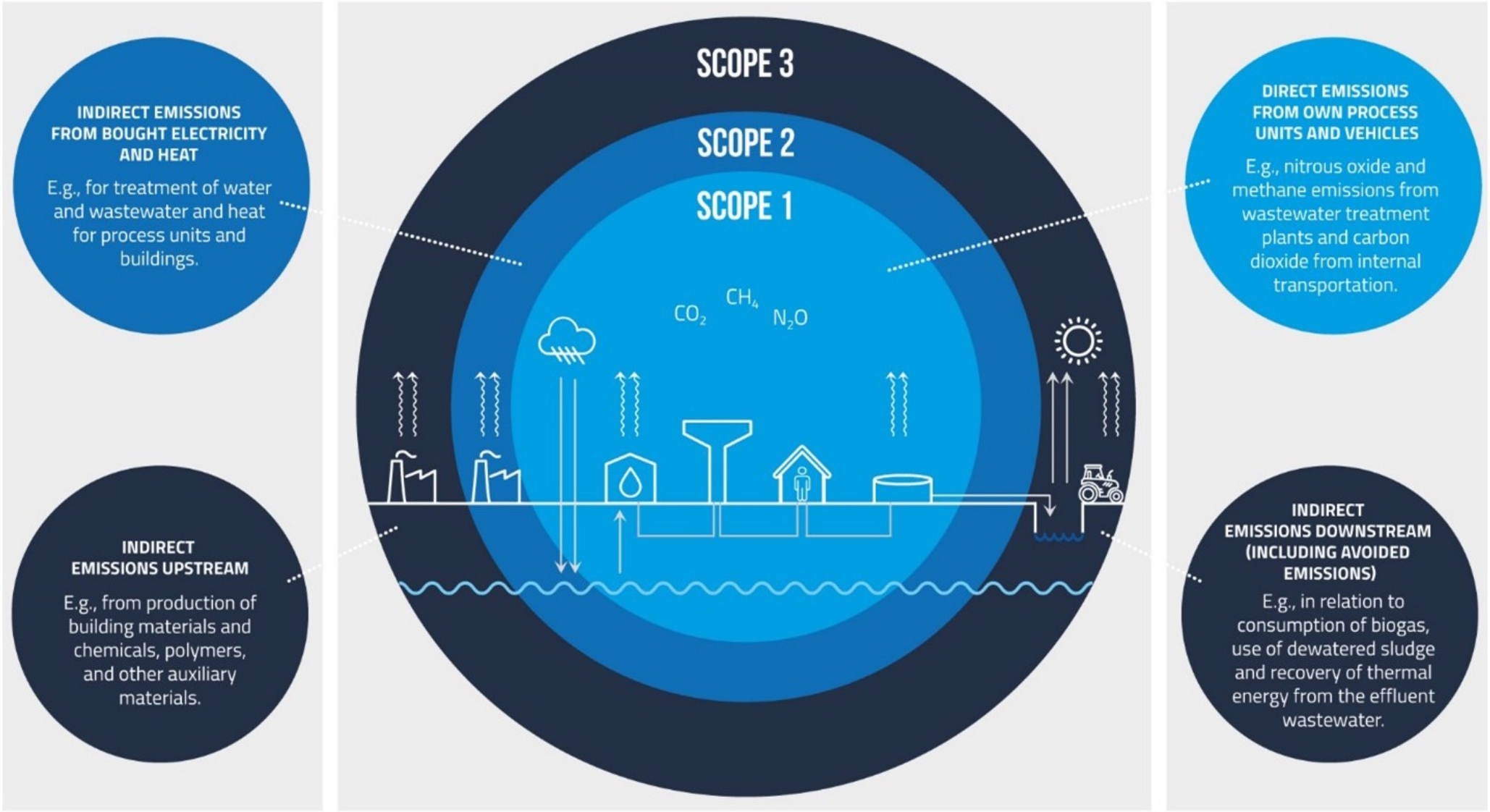
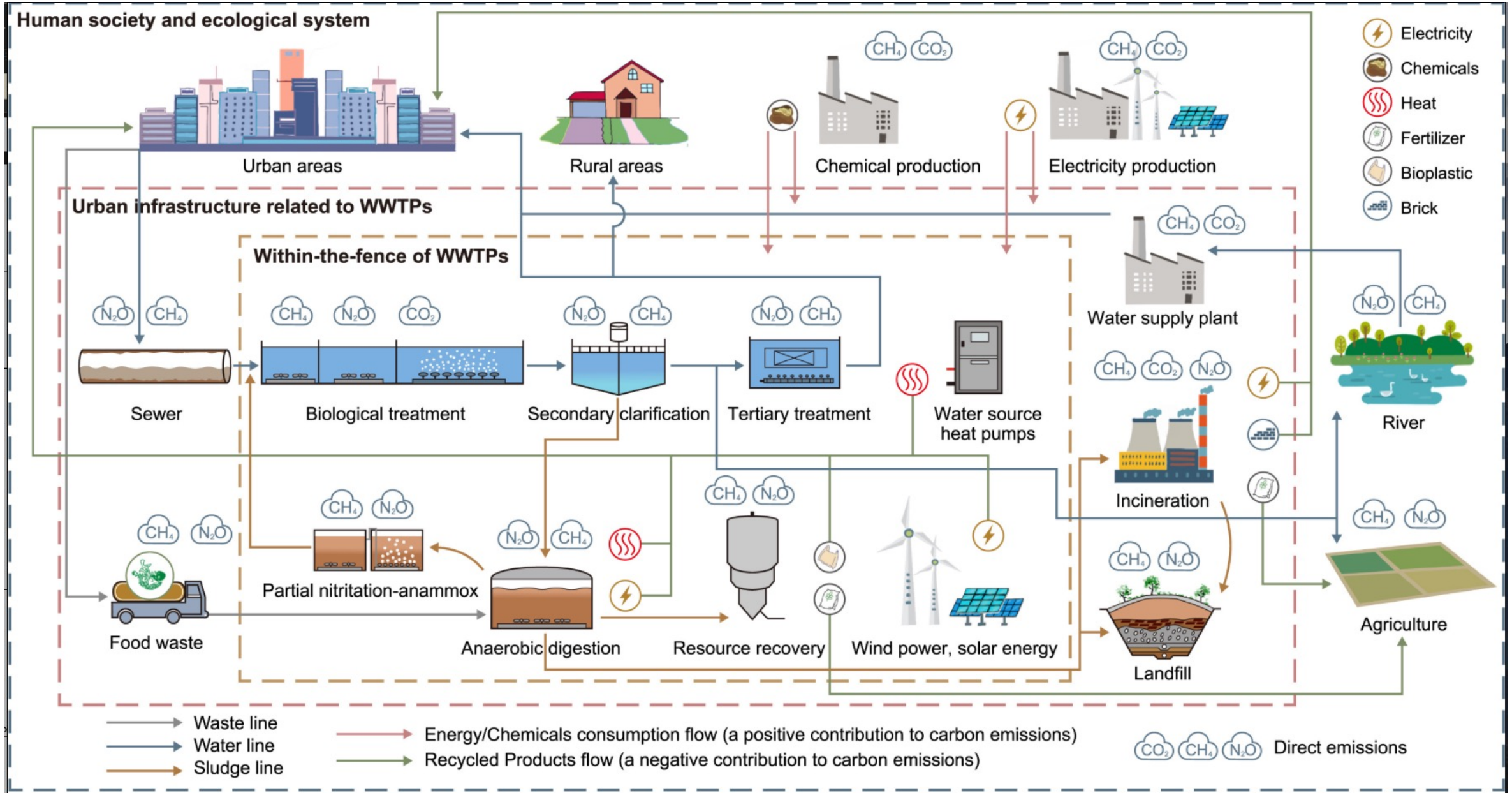
Glenn E. and Phyllis J. Futrell Distinguished Professor of Civil, Construction, and Environmental Engineering
Alumni Distinguished Undergraduate Professor
University Faculty Scholar

We can use the ”Scopes Framework” in Circularity



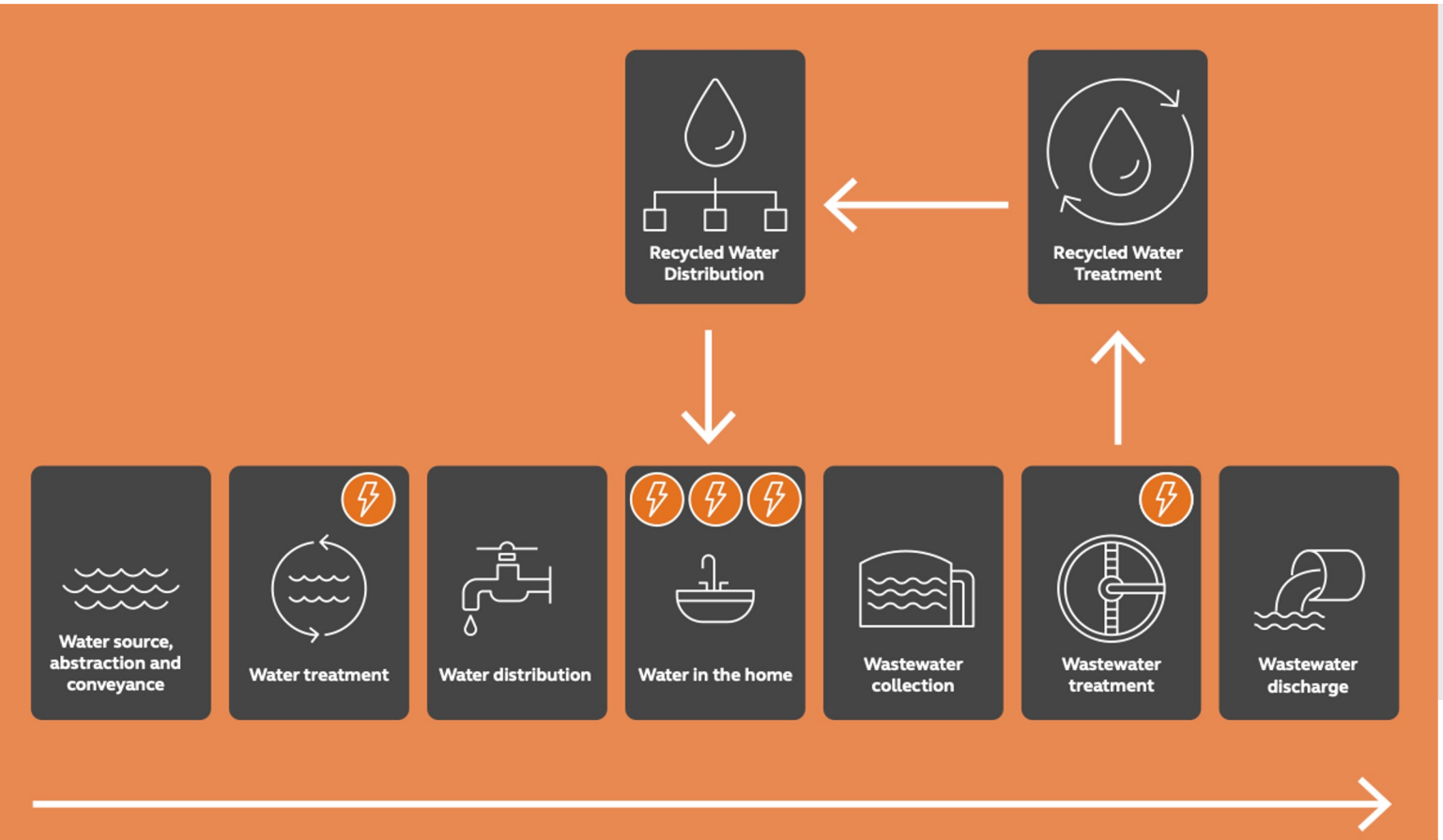
Illustrating Boundaries and Scopes

(Li et al., Carbon neutrality of wastewater treatment - A systematic concept beyond the plant boundary, Env. Science and Ecotech., 2022)



Centralized Water Infrastructure

Water and Sanitation INFRASTRUCTURE NEEDS TO BE SUSTAINABLE – FROM LINEAR TO CIRCULAR



- Energy
- Greenhouse gas emissions
- Hydrologic cycle disruption
- Capital & operation expenditures

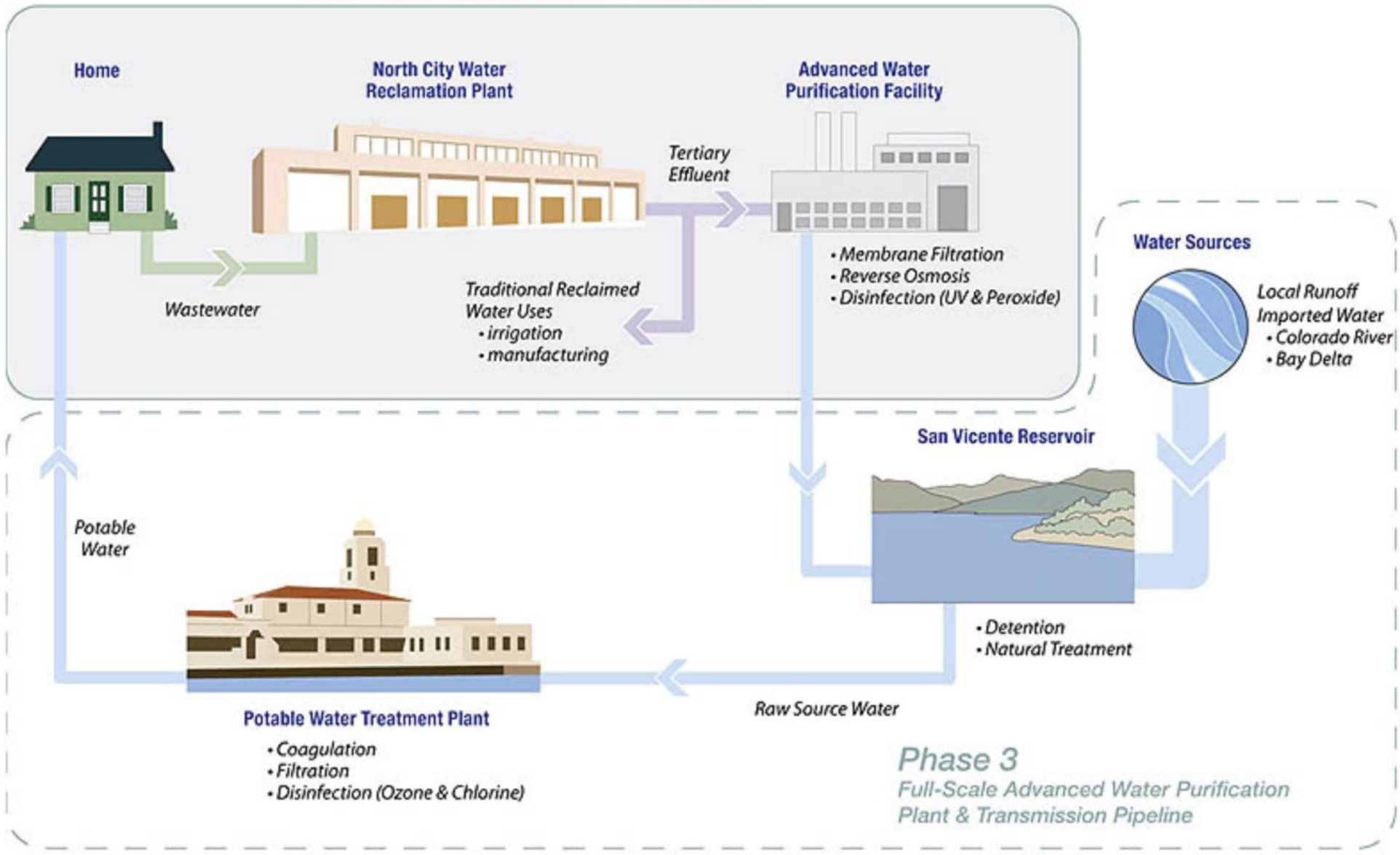
ARCADIS. Water-Energy-Carbon Nexus in our Homes. 50L Home.

City of San Diego's

Demonstration Project

Water Purification Demonstration Process

Phase 2 *Demonstration-Scale Project*



California is leading in DPR

California Takes Next Key Step: Implementing Direct Potable Reuse

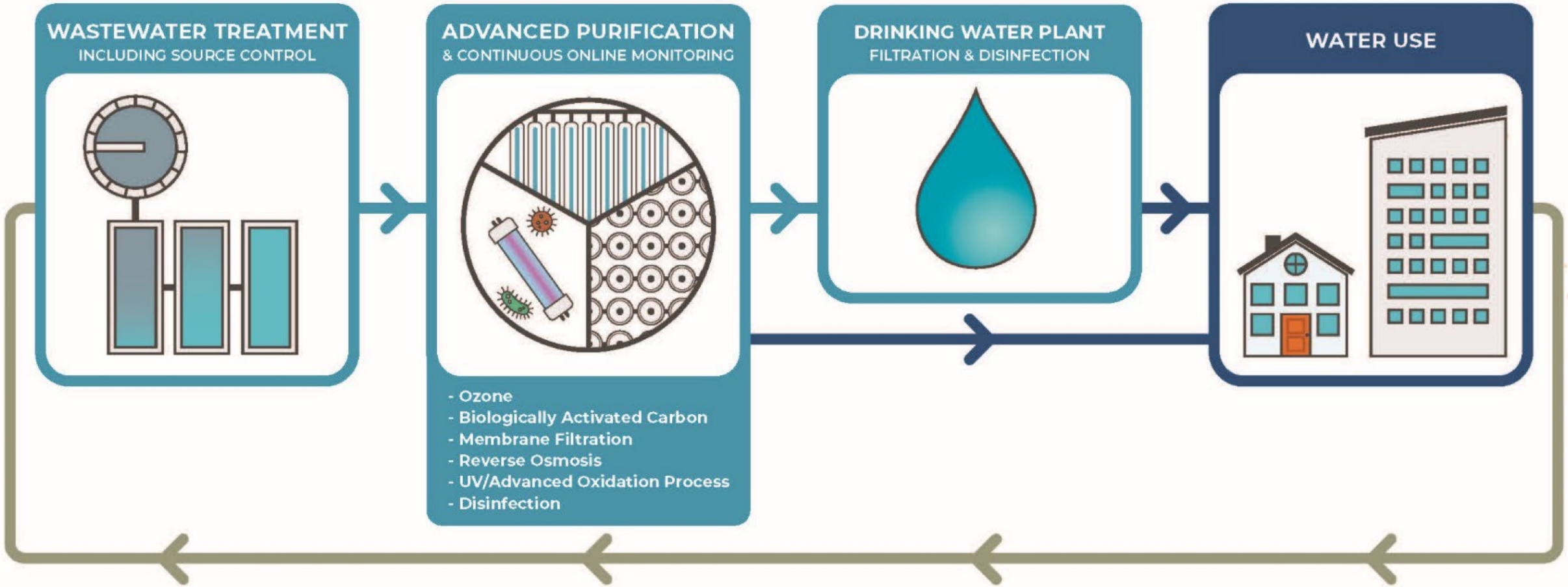
Date: August 12, 2024

For Immediate Release

Sacramento, CA – Following years of research, collaboration, and public engagement, California's Office of Administrative Law (OAL) approved OAL File No. 2024-0624-02S – the Direct Potable Reuse Regulations – and filed with the Secretary of State on August 6, 2024. This is the next critical step in the evolution of using recycled water as a safe and reliable water supply for Californians. The regulations will take effect on October 1, 2024.

Direct potable reuse is a practice which uses multiple phases of proven advanced water treatment technology to transform recycled water into safe, reliable purified water, for blending directly into a community's existing drinking water system.

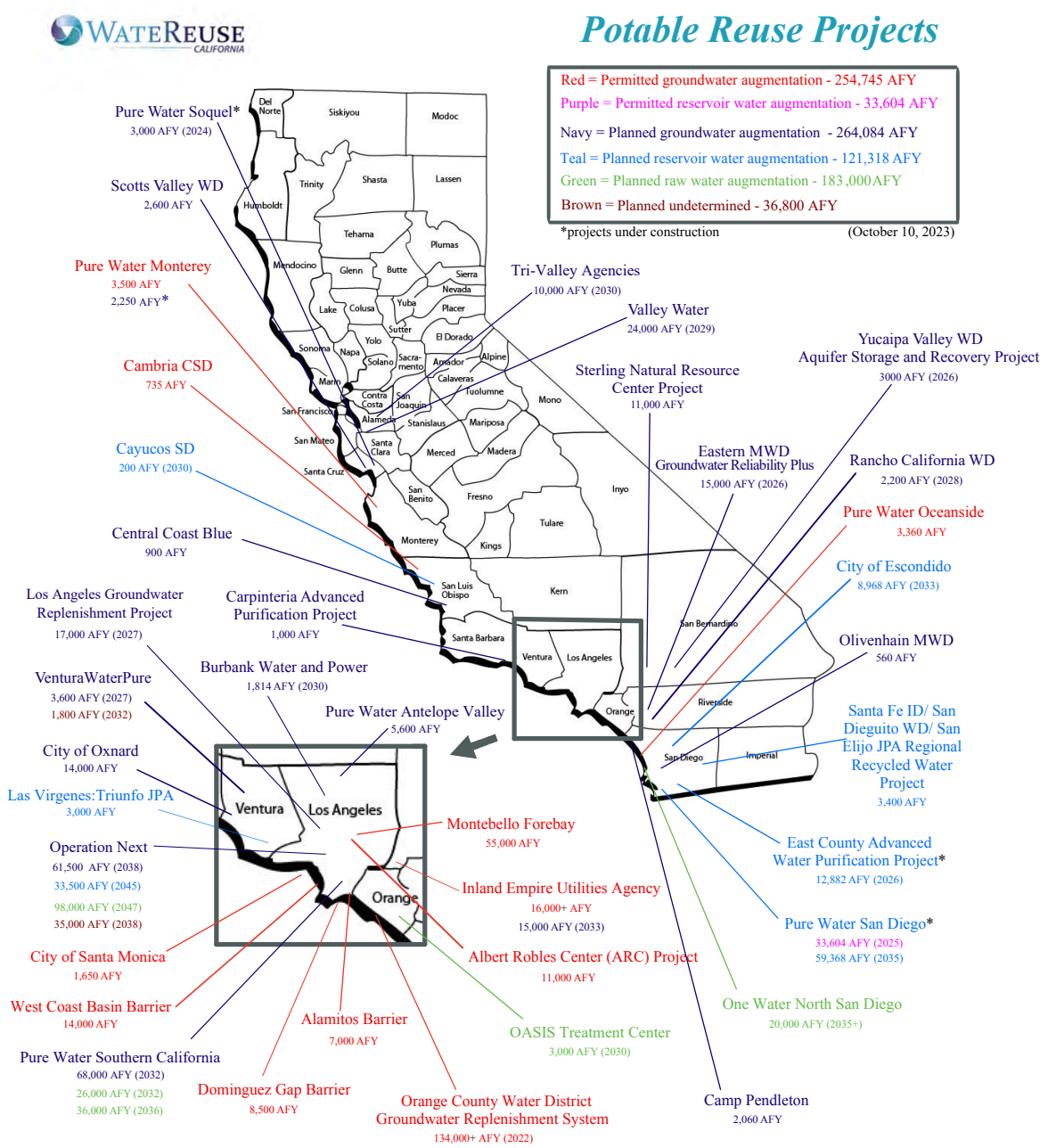
DIRECT POTABLE REUSE STEPS



Direct Potable Reuse treatment steps described by Cailfornia regulations announced in Dec 2023.
Final purified water meets all drinking water standards and stringent regulations for emerging contaminants.

CCG/Winter 2024

Potable Reuse Projects in CA



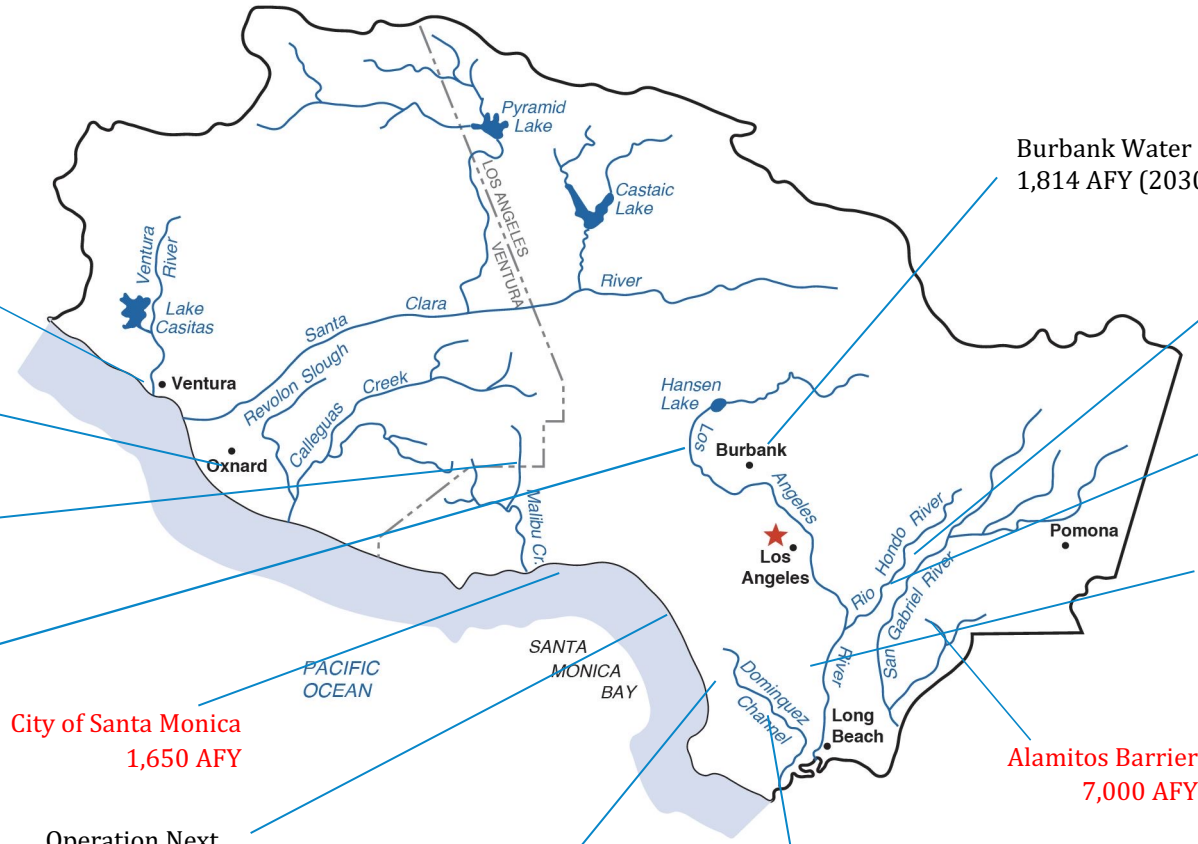
1 AFY = 3377 liters/day

+ Volume indicated reflects facility online factor and may be less than volume permitted.

Potable Reuse Projects: Los Angeles Regional Board

Existing: 93,350 AFY

Planned: 407,714 AFY = 1,377 MLD



Ventura Pure Water
3,600 AFY (2027)
1,800 AFY (2032)

City of Oxnard
14,000 AFY (2030)

Las Virgenes: Triunfo JPA
3,000 AFY (2029)

Los Angeles Groundwater Replenishment Project
17,000 AFY (2027)

City of Santa Monica
1,650 AFY

Operation Next
61,500 AFY (2038)
35,000 AFY (2038)
33,500 AFY (2045)
98,000 AFY (2047)

West Coast Basin Barrier
14,000 AFY

Dominguez Gap Barrier
4,700 AFY
8,500 AFY (2024)

Alamitos Barrier
7,000 AFY

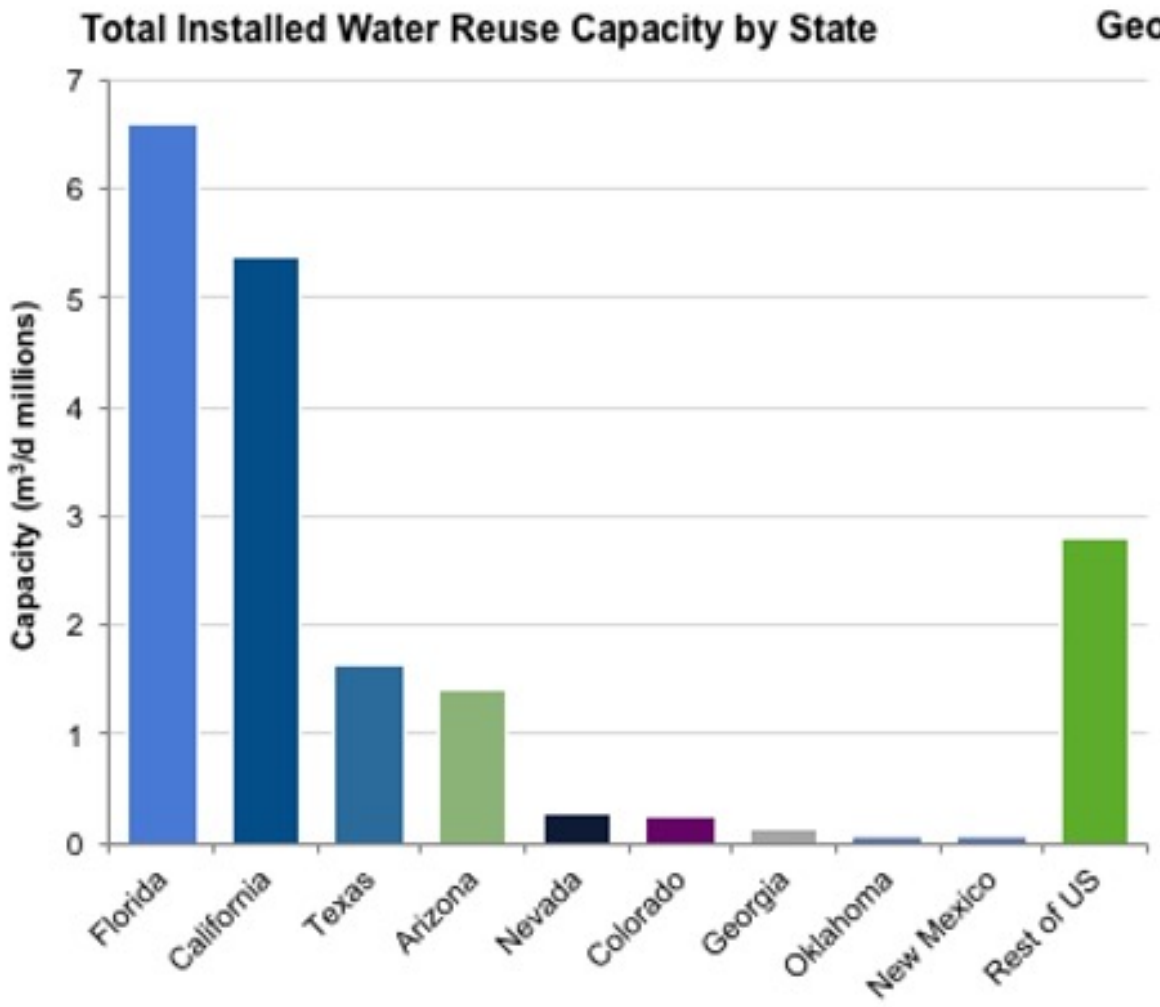
Pure Water Southern California
68,000 AFY (2032)
26,000 AFY (2032)
36,000 AFY (2036)

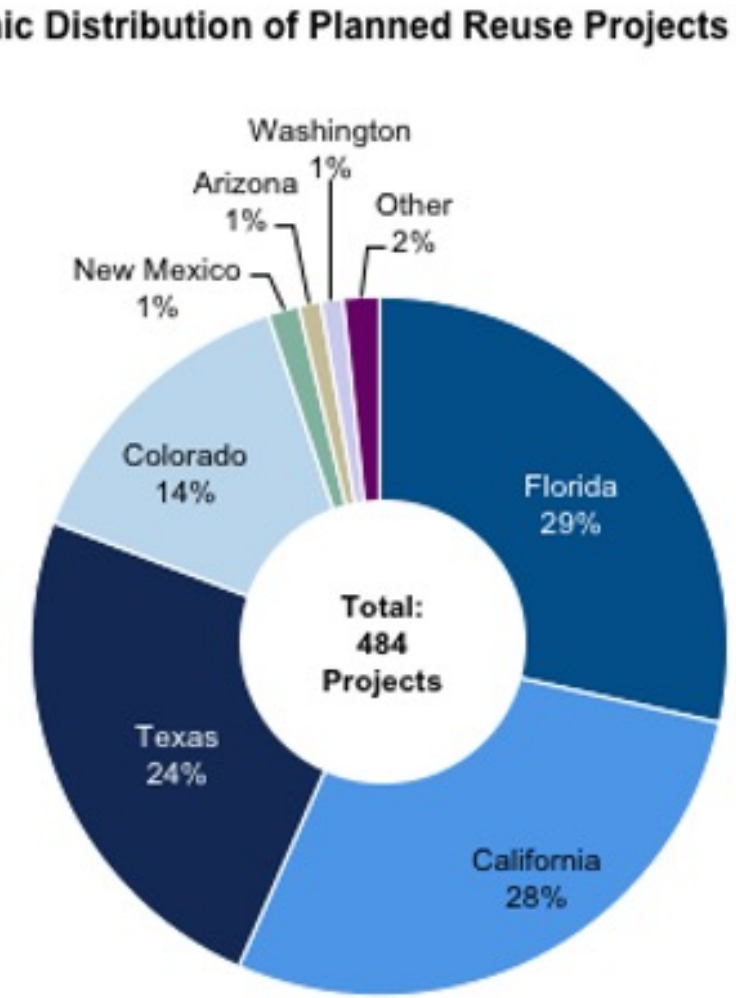
Montebello Forebay
55,000 AFY

Albert Robles Center
Project 11,000 AFY

Burbank Water and Power
1,814 AFY (2030)


Tenino
LOTT Cleanwater Alliance
Airway Heights
Ephrata
Yelm
Quincy
Chehalls
Royal City
Portland Clean Water Services
SFPUC
Valley Water
Soquel Creek Water District
Pure Water Monterey
Cambria
OneWater Nevada
Ventura
Las Virgenes
West Basin Water Recycling Plant
Montebello Forebay, County Sanitation Districts of Los Angeles County
Dominguez Gap Barrier, Los Angeles
Inland Empire Utility Authority
Alamitos Barrier, Water Replenishment District
Los Angeles Groundwater Replenishment Project
Water Replenishment District ARC
OCWD & OCSD Groundwater Replenishment System
Padre Dam
Eastern Municipal Water District
Scottsdale
Water Campus
Cloudcroft
San Diego Pure Water
Aurora Prairie Waters
Anapahoe County
Big Spring,
Colorado River Municipal Water District
Wichita Falls
North Texas Municipal Water District
Tarrant Regional Water District
Abilene
El Paso Water Utilities
Hueco Bolson Recharge Project,
El Paso Water Utilities
Loudoun County
Upper Occoquain Service Authority
Hampton Roads
Sanitation District
Raleigh
Franklin
Gwinnett County
Clayton County
JEA
Daytona Beach
Altamonte Springs pureALTA
Clearwater
Hillsborough County SHARP
West Palm Beach
Hollywood
Town of Davie
Miami-Dade
Indirect Potable Reuse
Direct Potable Reuse





Bluefield Research, 2016

THE PRICE OF WATER: 2015

Combined water, sewer and stormwater prices for households in 30 major U.S. cities.

Water prices pay for treating, pumping, and delivering water, while sewer prices cover the cost of cleansing the water that goes down the drain.

Sewer prices are often higher than water prices because more energy and chemicals are required for treatment. Following the Clean Water Act, the federal government gave grants for new treatment plants during the 1970s and 1980s. Over the past three decades, however, new spending has been cut for local sewer infrastructure.

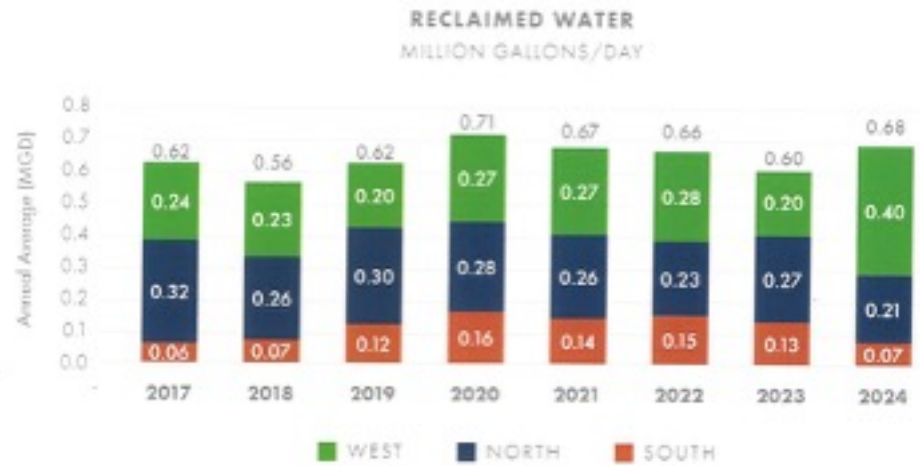
Stormwater fees are not included in every city's monthly bill. Some cities use general tax revenues to pay for projects to reduce polluted runoff from streets and parking lots. However, these projects must then compete for funds with other departments like police and schools.

Rates current as of April 1, 2015.
Monthly bill calculated for a family of four using 100 gallons per person per day.
Source: Circle of Blue research, based on utility water rates.

circle of blue

RECLAIMED WATER

Reclaimed Water is distributed in three service areas and offsets potable demand by providing highly-treated wastewater for irrigation and cooling towers. It's also used on-site at our water reclamation facilities for cleaning equipment.



In summer months, reclaimed irrigation is 17% of overall billed irrigation and helps offset potable peak water day usage.


HACH
SC4500
12:27
1676426
0.727
TRB
NTU


LIMIT
25
THIS AREA
OBSERVED BY
COMMUNITY WATCH
CITIZENS
CALL CARY POLICE
911
DO NOT
DRINK


CALL CARY POLICE
911
THIS SITE IRRIGATED
WITH RECLAIMED WATER
DO NOT
DRINK
No tome
de esta agua.
Este sitio es regado con
agua regenerada.
CARY

WaSH Infrastructure needs to be:

SUSTAINABLE: FROM LINEAR TO CIRCULAR

- Energy
- Greenhouse gas emissions
- Hydrologic cycle disruption
- Capital & operation expenditures

Vision 75:50

75% reduction in water use

From ~260 to 50 L/cap/day

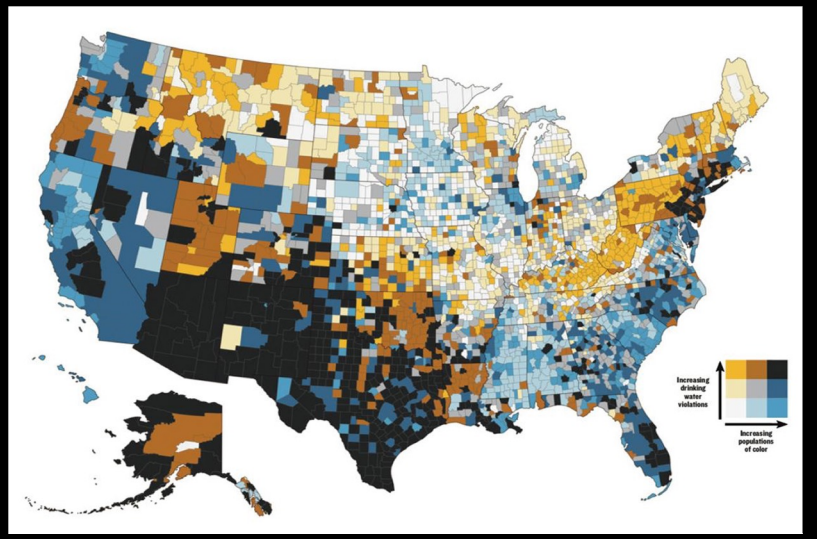
50% reduction in energy

From 17.5 to 8.5

RESILIENT

- Risk of catastrophic failure
- Physical and financial inflexibility
- Aging pipes & failing infrastructure

EQUITABLE



LOWER INCOME, PEOPLE OF COLOR HAVE LESS SAFE WATER

WHAT IS NEEDED

Transitioning…to a more integrated 21st century water system…

"will require significant changes in infrastructure, institutions, and professional practice"

GT Daigger (NAE), Visions for 2050, ASCE 2012

…Need ***"radical innovation"*** to overcome ***"institutional momentum"*** (Sunk Cost Effect)…and ***"incremental improvement"***

Rabaey et al., Water Research 185, 2020

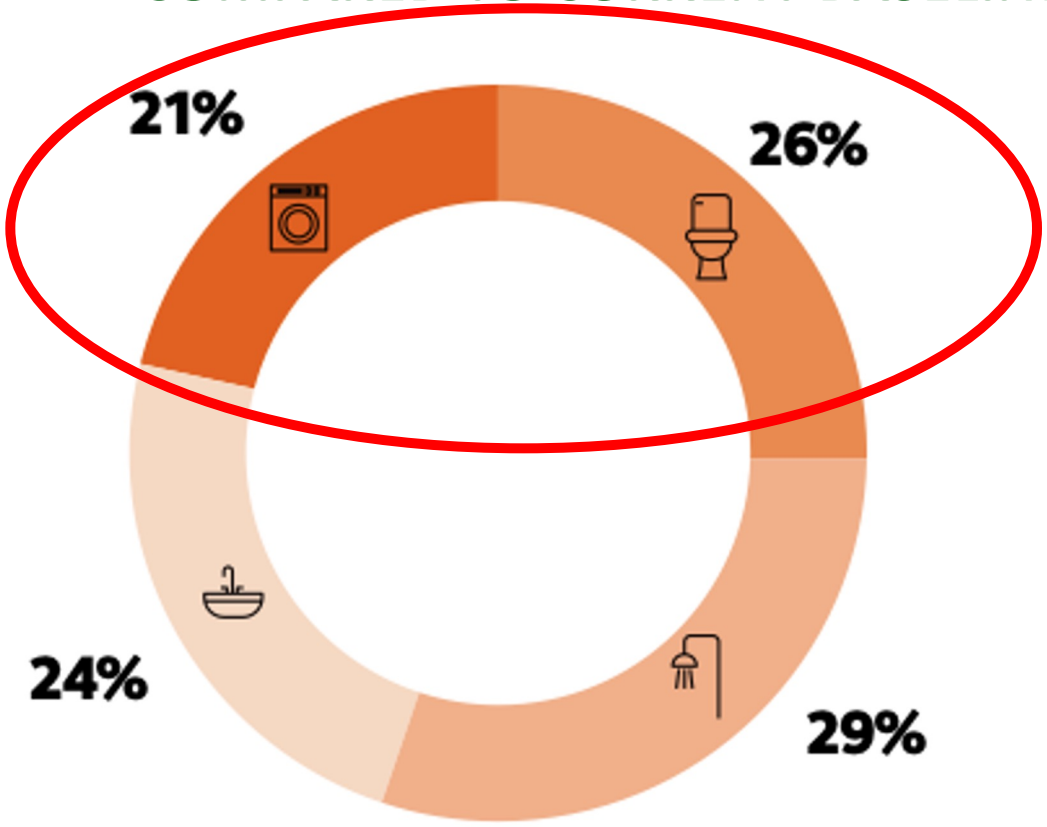
THE 75:50 GOAL

75% reduction in water use

50% reduction in energy & GHG emissions

75% REDUCTION IN WATER USE

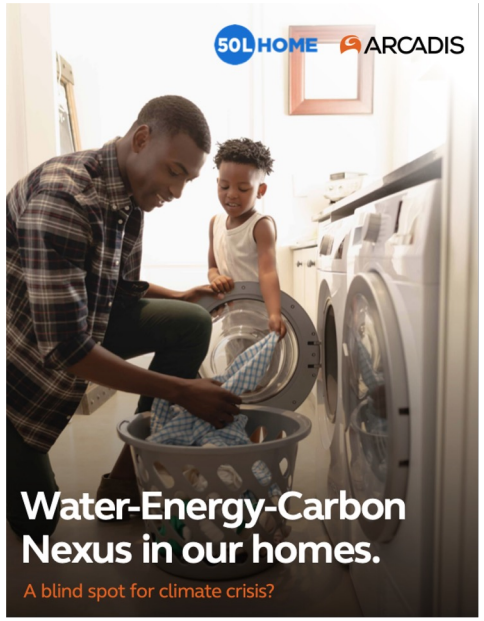
COMPARED TO CURRENT BASELINE (262 L/cap/day to 50 L/cap/day)



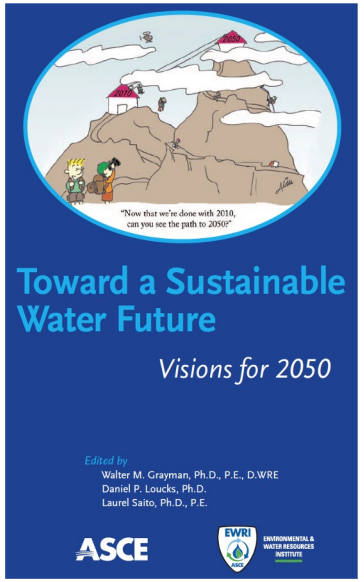
Average water use in the home (with internal leaks included)[57]

Average Water System Water Loss = 16%

EPA, Water Audits and Water Loss Control for Public Water Systems



50% REDUCTION IN ENERGY AND ASSOCIATED GHGs



CENTRALIZED

8W for transport ($1M to $10M per km, + pumping)

4.5W for water treatment

5W for wastewater treatment

17.5W total

NEW MODEL

0.8W Minimize energy for transport

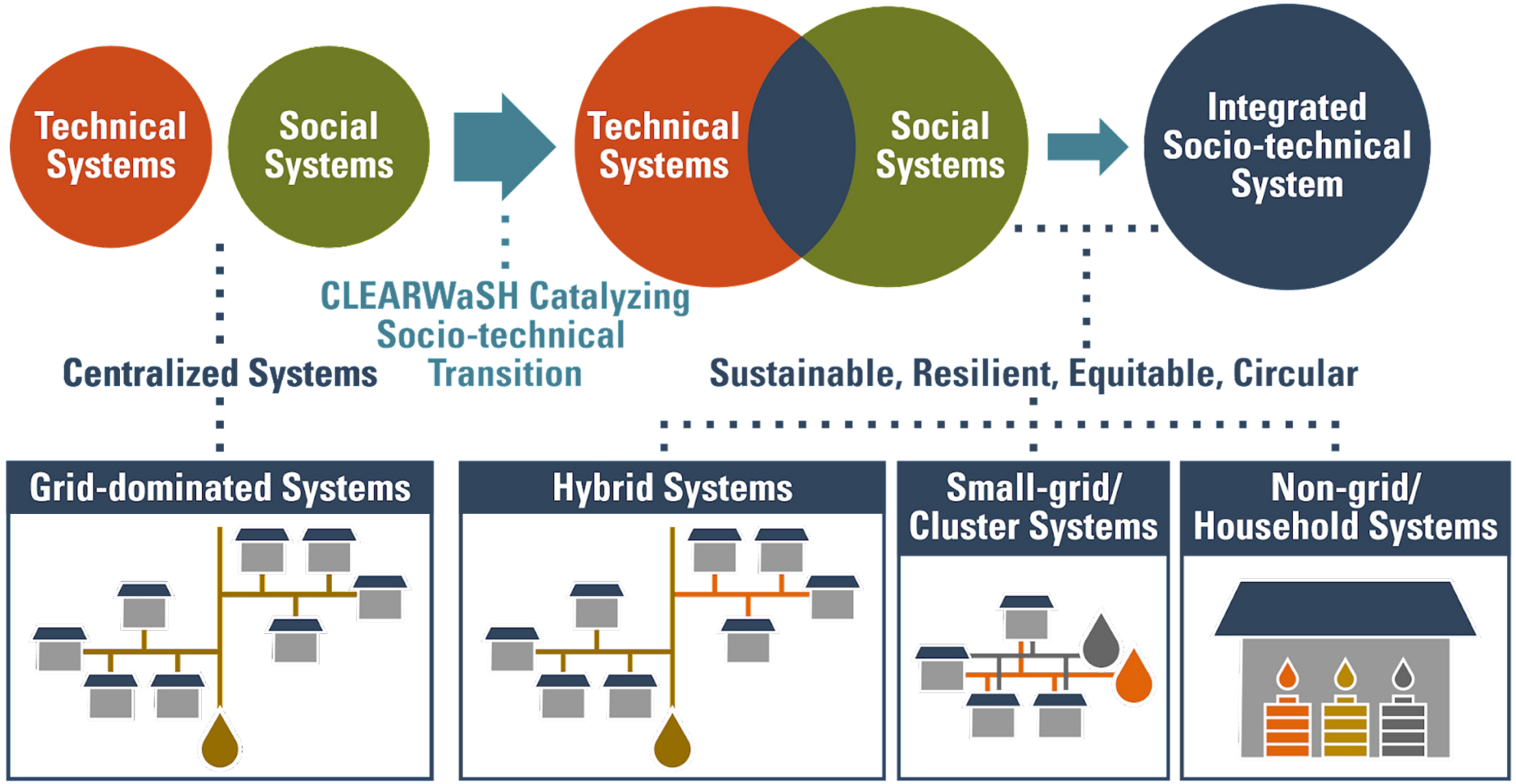
4.5W for water treatment

5W for wastewater treatment

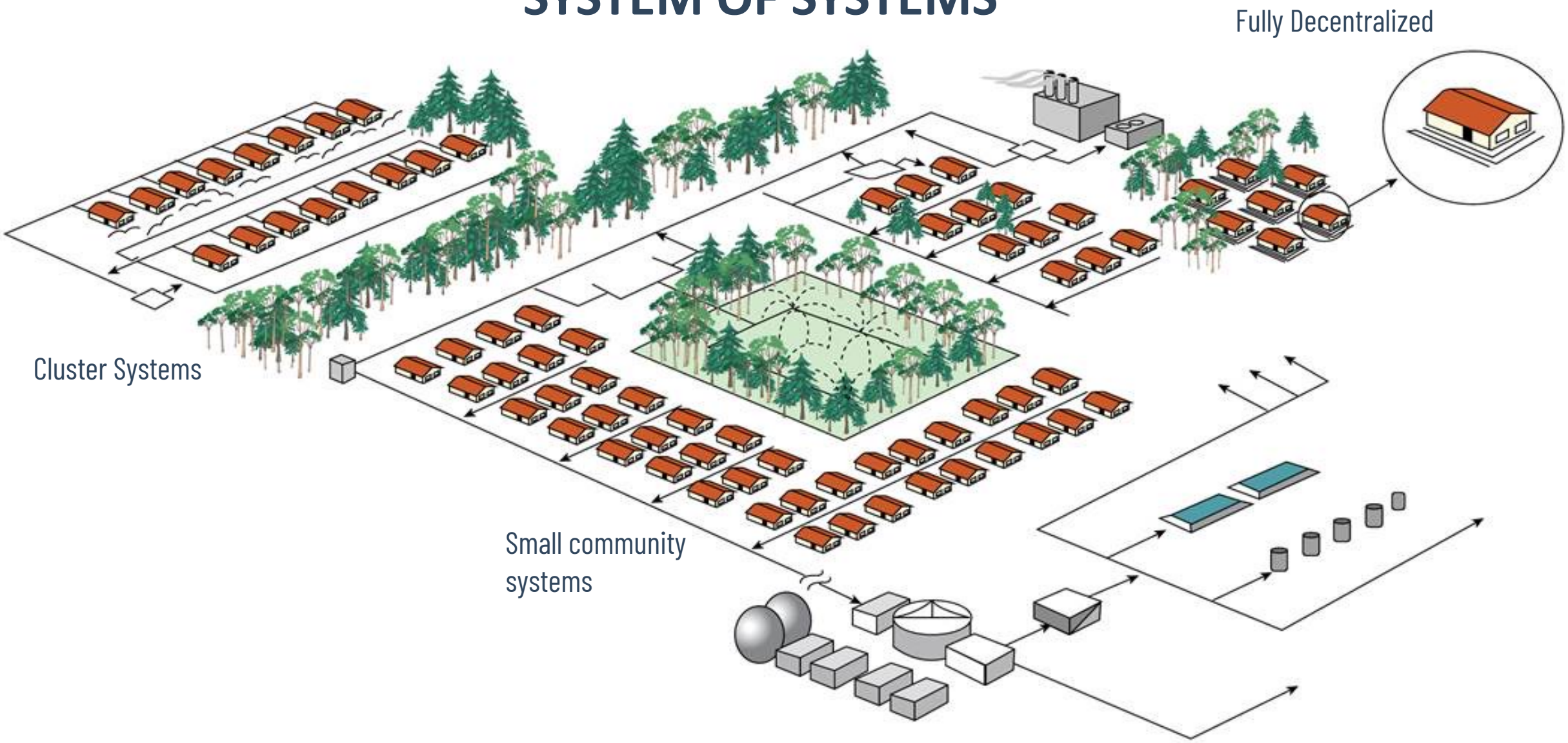
10.3W = 41.1% reduction

Daigger, 2009

TRANSITIONING TO AN INTEGRATED WaSH SOCIO-TECHNICAL SYSTEM



SYSTEM OF SYSTEMS



Adapted from Tchobanoglous and Leverenz, 2013

OPTIMIZE INHERENT ADVANTAGES OF DECENTRALIZED/DISTRIBUTED SYSTEMS

ECONOMIC

- Avoiding long pipes & pumps (25% less in CapEx, 40% less in OpEx)
- Flexibility to meet new demand
- Good jobs within local communities

ENVIRONMENTAL

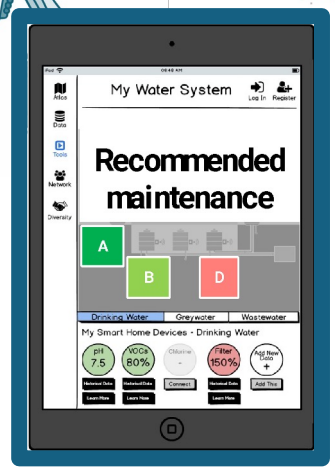
- Reduce the energy footprint for water movement
- Extend regional supplies by recycling water onsite
- Allow opportunities for resource recovery, green spaces

SOCIAL

- Improve community resiliency to catastrophic events
- Increase local control/tailoring of treatment to meet purpose
- Address the inequity gap

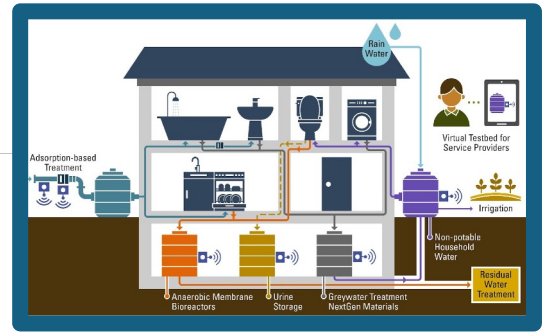
DIGITALIZED & SCALE-ADAPTABLE WATER & WASTEWATER SYSTEM THAT DELIVERS CLEAN DRINKING WATER & HANDLES WASTEWATER THAT IS SUSTAINABLE, RESILIENT, & EQUITABLE COMPARED TO EXISTING SOLUTIONS

WaSH CIRCUIT RIDER



BBUWP, Alabama
Imperial Valley, CA

COMMUNITY ORGANIZATION



Cluster of off-grid homes with decentralized systems

Small centralized treatment plant serving cluster of homes

Small cluster networked system

DIGITALIZATION

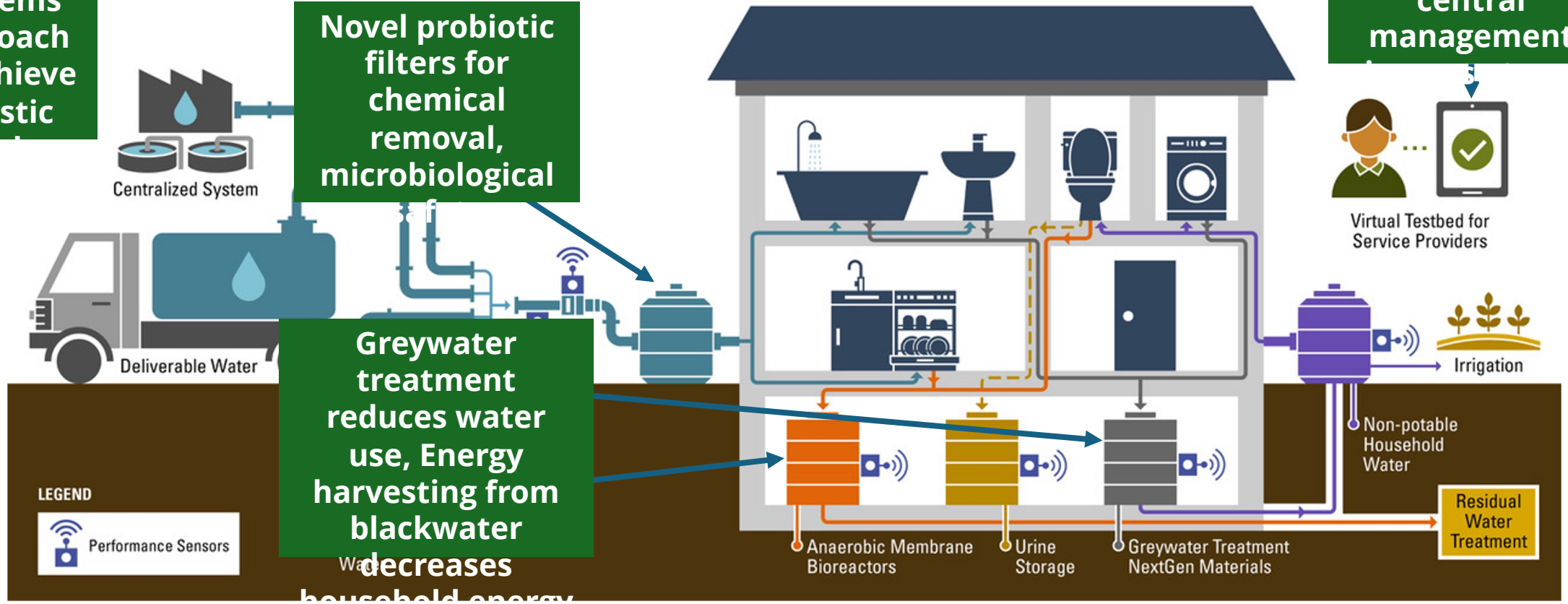
OVERALL SYSTEM OPTIMIZATION

TECHNICAL INNOVATIONS DEVELOPED & TESTED THROUGH COMMUNITY-ENGAGED ENGINEERING WITH HOUSE OF THE FUTURE OF WATER

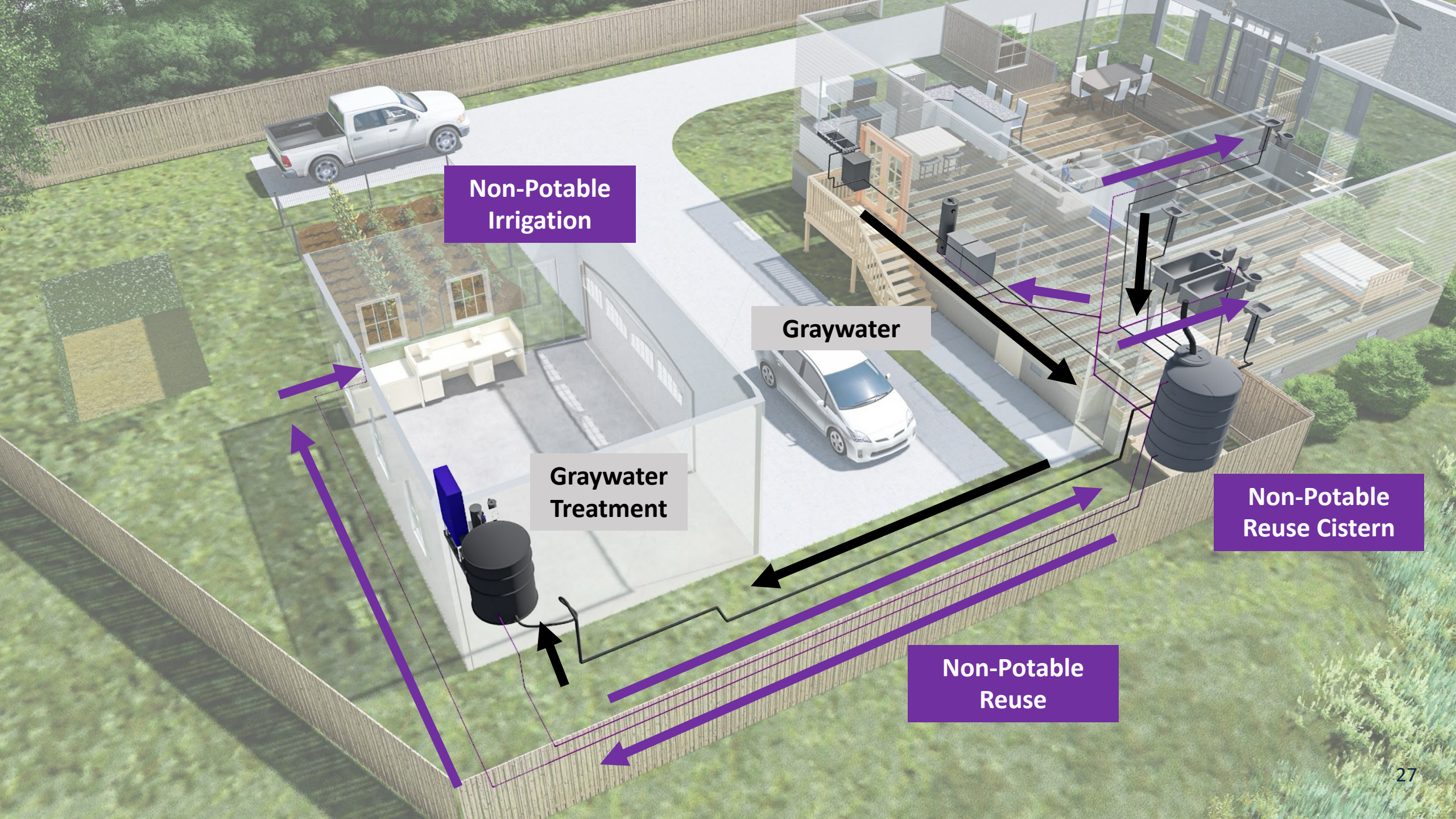
Systems approach to achieve holistic

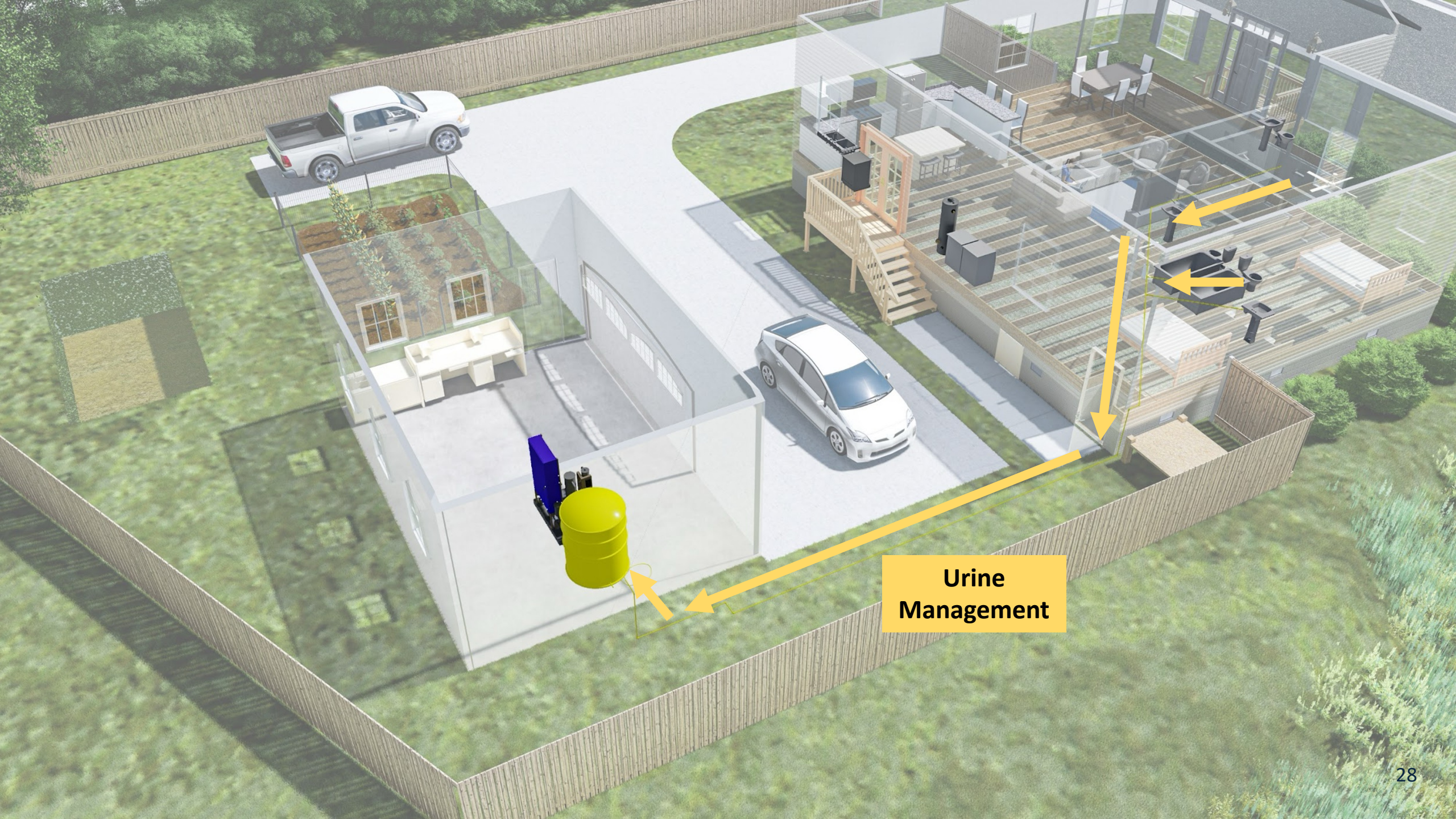
Novel probiotic filters for chemical removal, microbiological

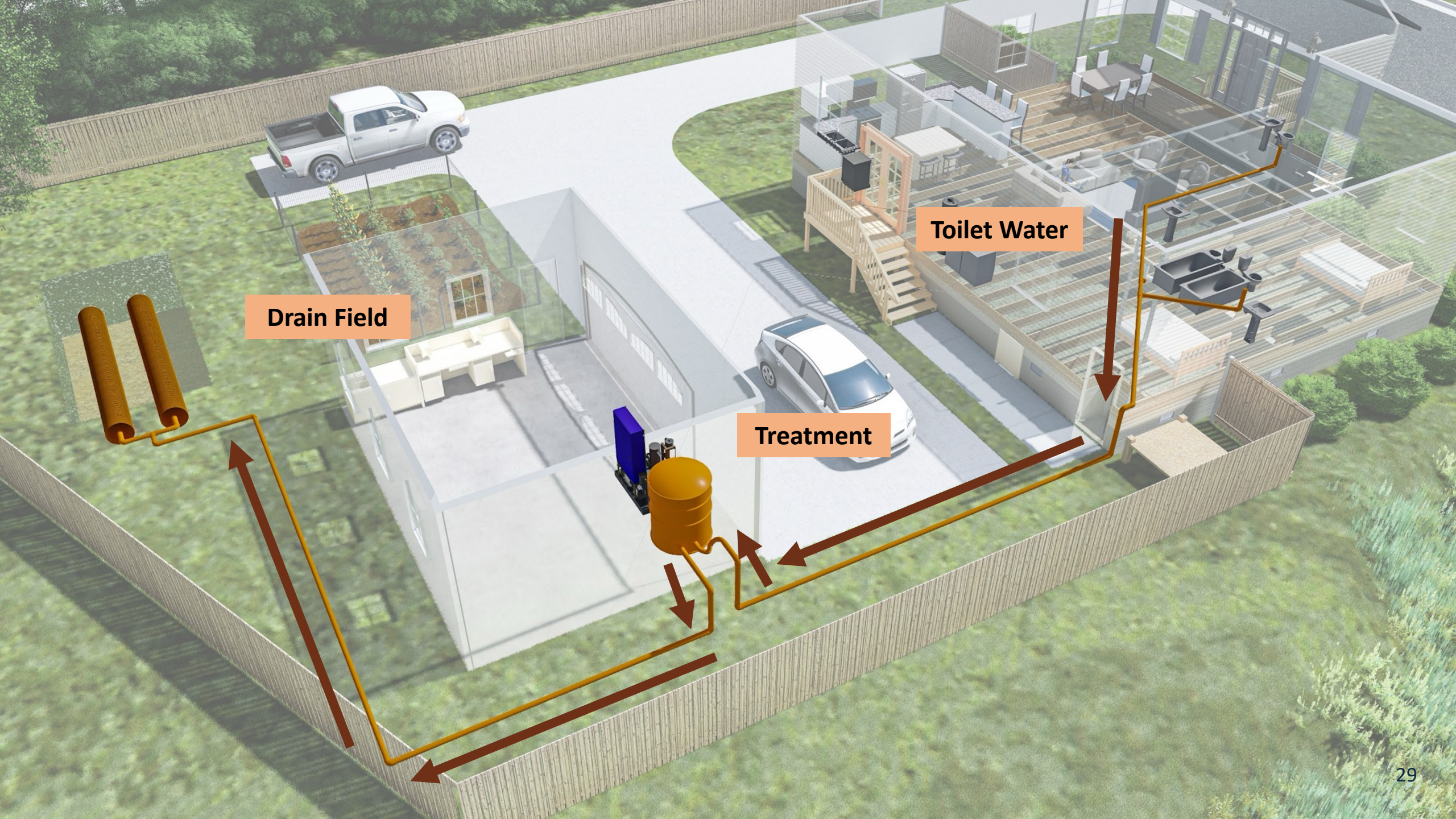
Novel sensors connected to iPhone app & central management



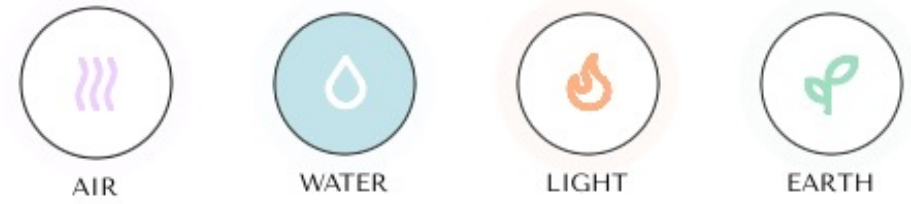
Greywater treatment reduces water use, Energy harvesting from blackwater decreases household energy

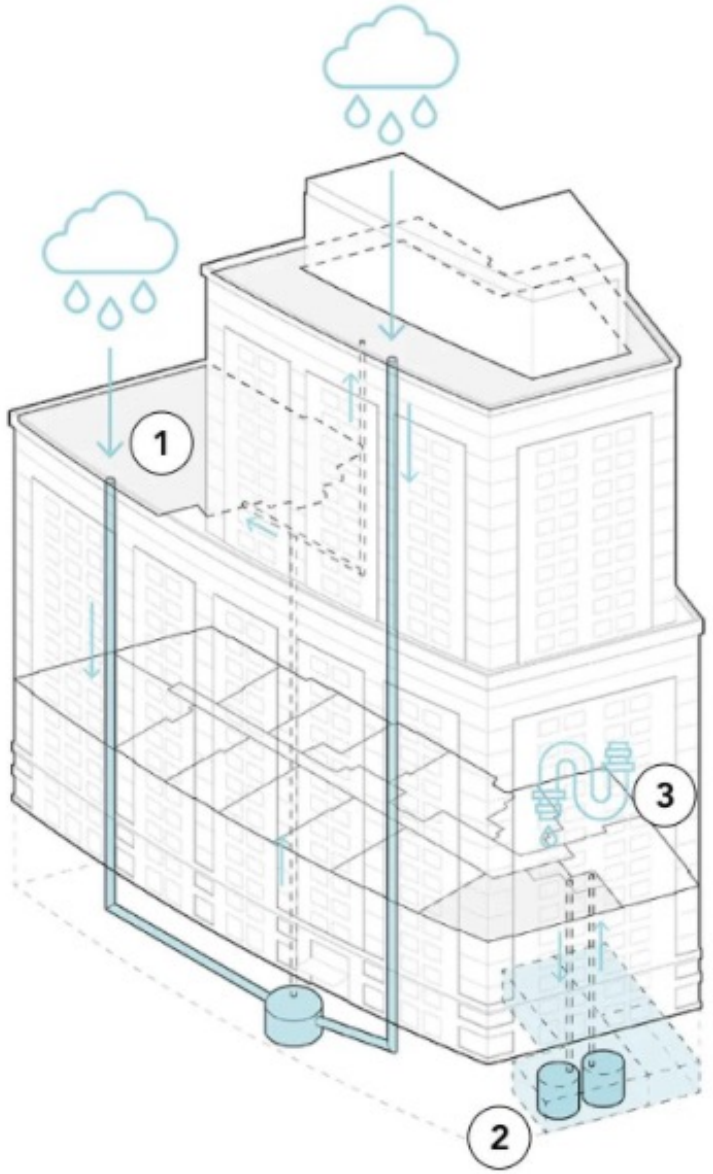

Non-Potable Irrigation
Graywater
Graywater Treatment
Non-Potable Reuse Cistern
Non-Potable Reuse


Urine
Management


Drain Field
Toilet Water
Treatment

Solaire Building, New York City





295 apartments, 25,000 gallons/day (94,500 liters/day)

We need policy changes and mindset shifts

- Get the **data**
    - Accurate census in the US and globally
    - Linking various databases
- Remove **regulatory barriers**
- Increase support for alternative **technologies**
- Nurture long-term relationships with **communities**
- Develop innovation ecosystems – various **stakeholders**
- Re-think the engineering and science **workforce**
- **Always ASK: Who will benefit?**

CLEARWaSH