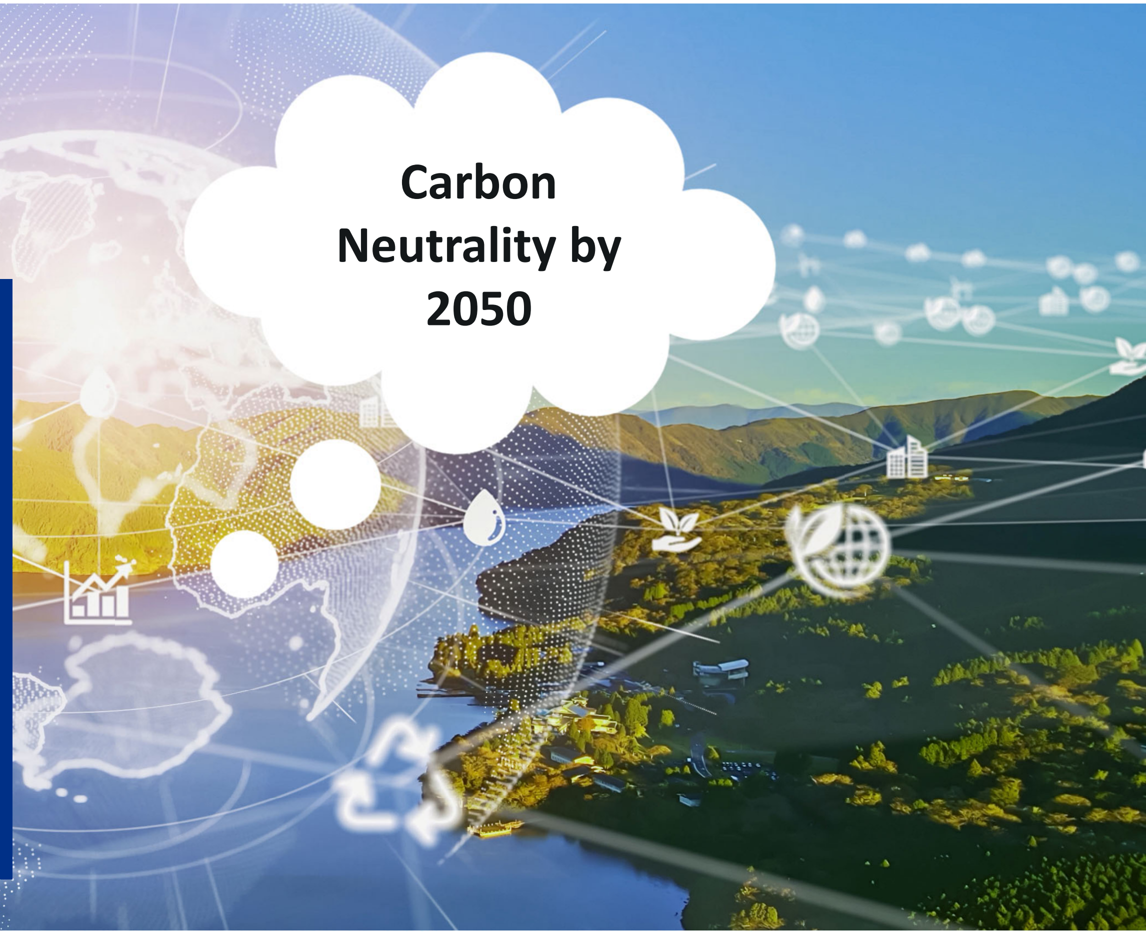
How to Optimize Water Infrastructure Planning and Design with Decarbonization in Mind

Governor’s Conference on the Future of Water in Kansas 2024



Ghina Yamout, PhD, Env-SP, EIT

November 14, 2024

Why are We Talking About Decarbonization?
Energy Water Nexus

- Water and wastewater are energy intensive, accounting for approximately 5% of GHG emissions globally, or equivalent to the emissions from the entire shipping industry.

- Water Withdrawals in the US (NAWI):

Power
42%

Agriculture
40%

Municipal
12%

Industry
5%

Resource
Extraction 1%

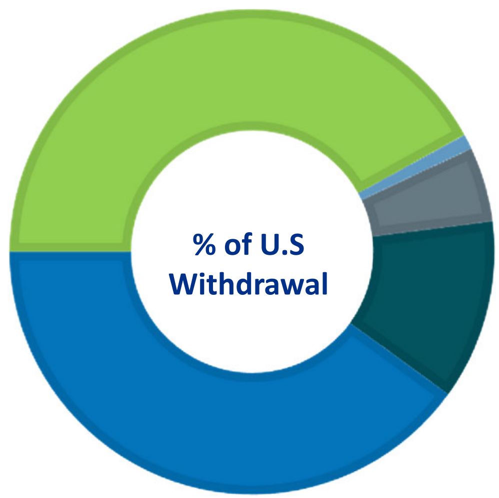


Figure 3: Overview of water withdrawals in the United States

Source: National Alliance for Water Innovation (NAWI) Master Technology Roadmap (nrel.gov)

Why are We Talking About Decarbonization?
Energy Water Nexus

- Treat Wastewater
- Pump water from underground aquifers
- Convey water from one location to another
- Treat water to make it drinkable or other potable use
- Heat and cool water for manufacturing
- O&G Production
- Energy generation

Source: E. R. Jones et al.: Country-level and gridded estimates of wastewater production. Earth Syst. Sci. Data, 13, 237–254, 2021

Energy Water Nexus Drives "Costs"
Types of Water and Wastewater Infrastructure Investments

Drinking Water Treatment Plants

Wastewater Treatment Plants

Biosolids Treatment Facilities

Water Collection/ Distribution Networks

GHG Emission Accounting

Operations

Construction

Rehabilitation

Decarbonization

Energy Water Nexus Drives "Costs"
Water Source & Quality Drives Energy Consumption

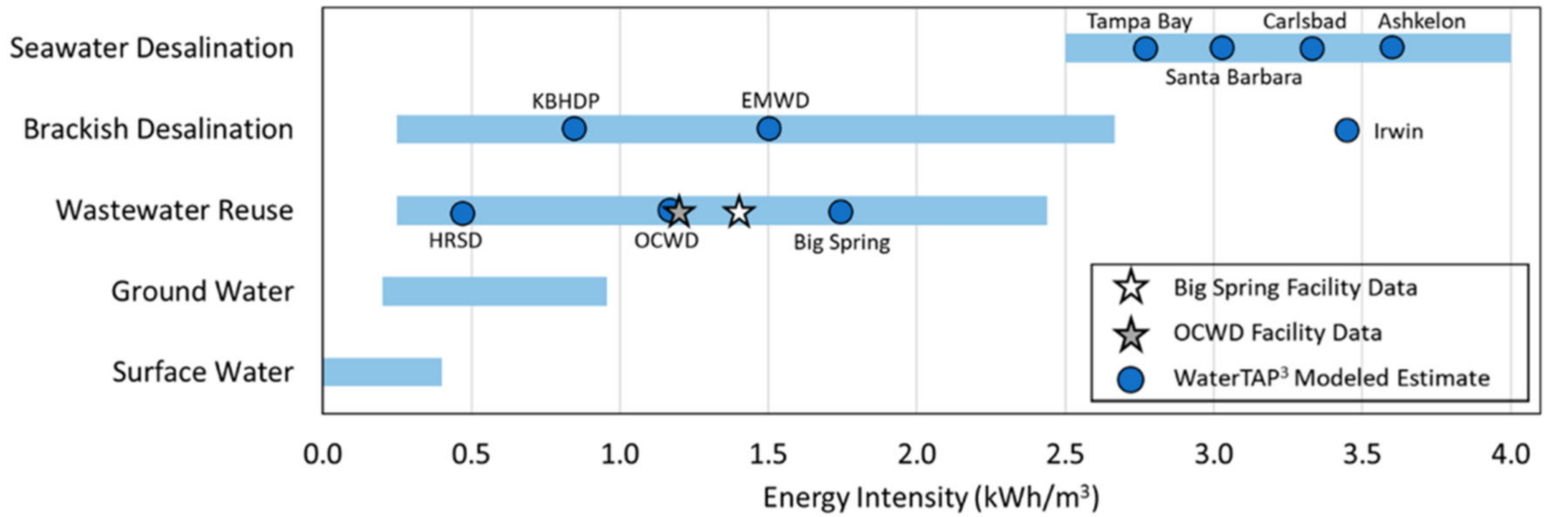


Figure 10. Energy intensity of production of potable water from treatment of different source water options including the model estimates from WaterTAP[3] and specific values for two water reuse facilities.

Source: Giammar et al. ACS ES&T Engineering 2022 2 (3), 489-507. DOI: 10.1021/acsestengg.1c00351

Why are We Talking About Decarbonization?
Energy Water Nexus

- Wastewater treatment
- Pump water from underground aquifers
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- Energy generation

Decarbonization is required to minimize and/or mitigate GHG emissions from:

- Energy production and use
- Embodied carbon footprint of capital investment for water supply
  - Development and treatment
  - Conveyance / delivery
- Operations and maintenance (Process)

Optimize monitoring and treatment to reduce these emissions, particularly biogenic fugitive

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- Heat and cool water for manufacturing
- O&G Production
- Energy generation

5% → 10%

70% of these GHG emissions is caused by wastewater treatment. And this doesn't even consider the 50% of wastewater that is released to the environment without treatment.

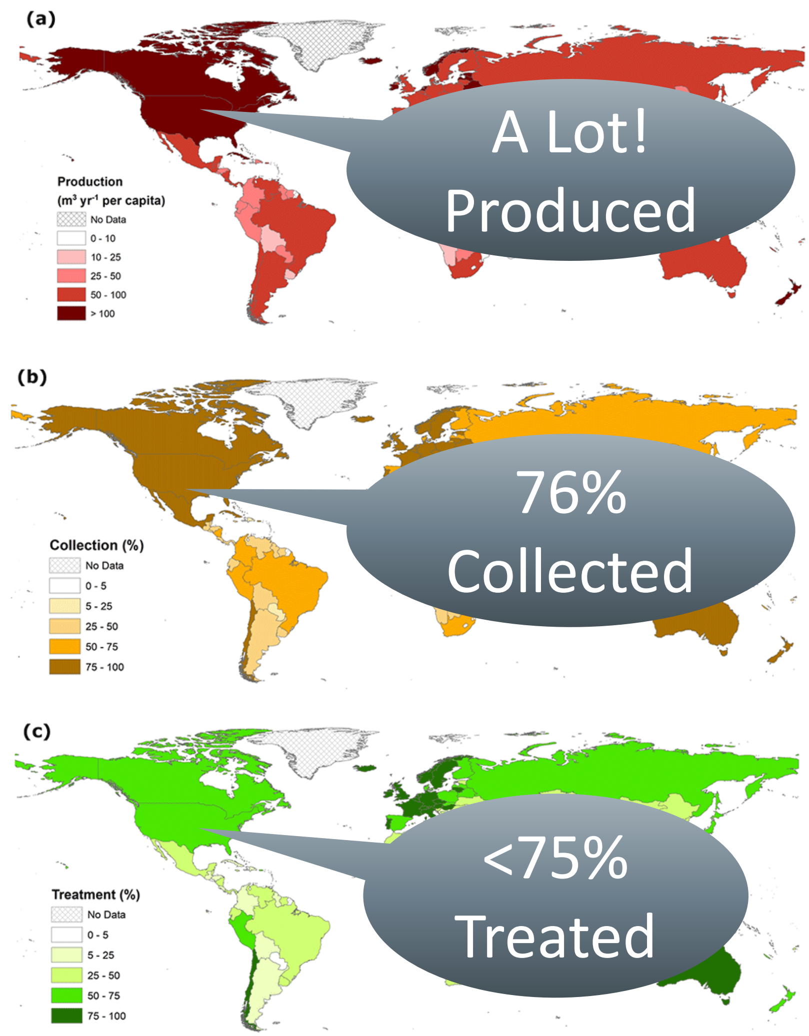
Source: E. R. Jones et al.: Country-level and gridded estimates of wastewater production. Earth Syst. Sci. Data, 13, 237–254, 2021

Global Wastewater - Volumes

- 63% of globally produced wastewater is captured

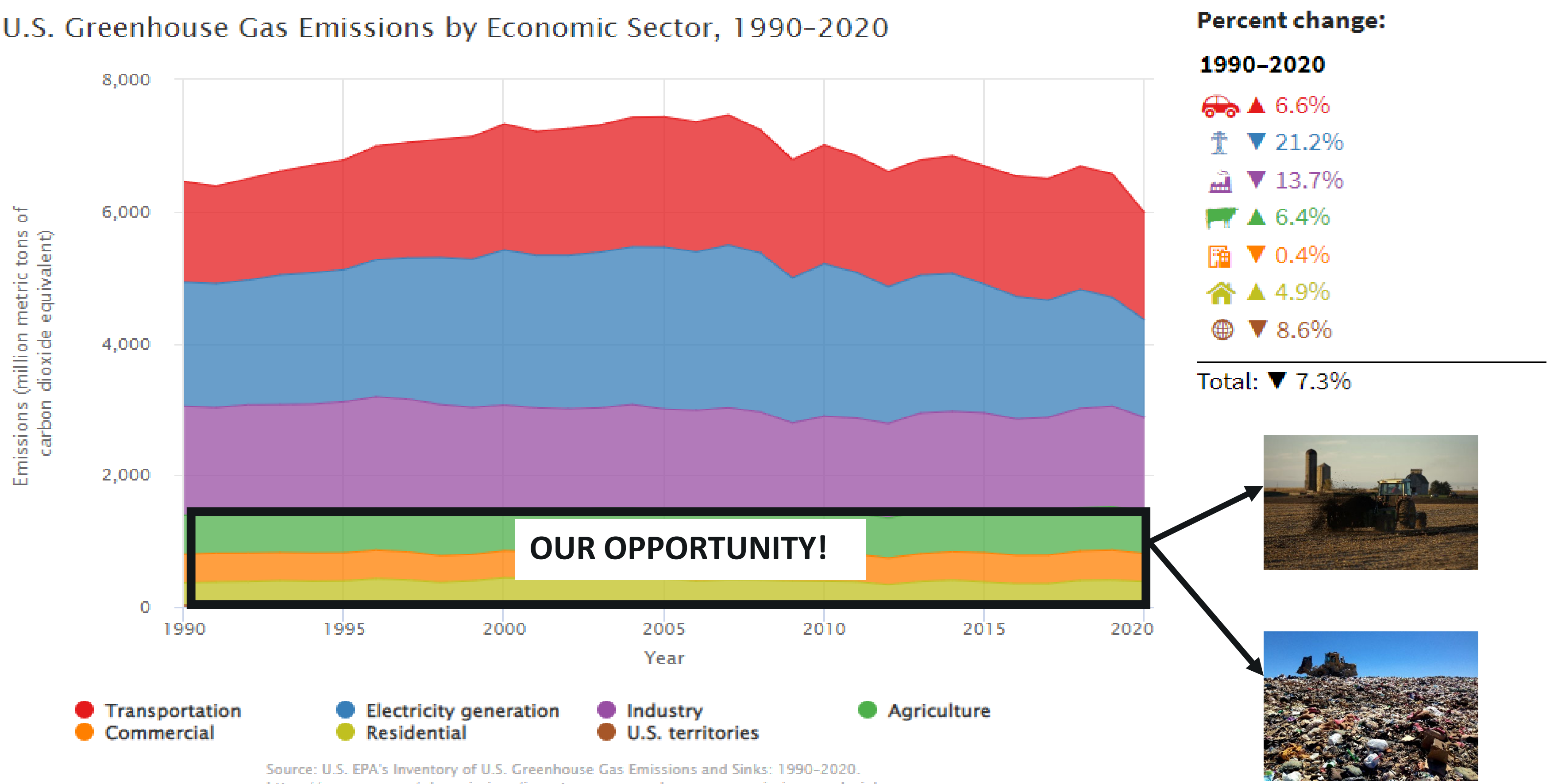
- 52% of globally produced wastewater is treated

  - 109,159 WWTPs in the world, representing 129 countries , serving 34.7% of world population
  - 14,748 WWTPs in US alone (serving 76% US population)



Source: E. R. Jones et al.: Country-level and gridded estimates of wastewater production. Earth Syst. Sci. Data, 13, 237–254, 2021

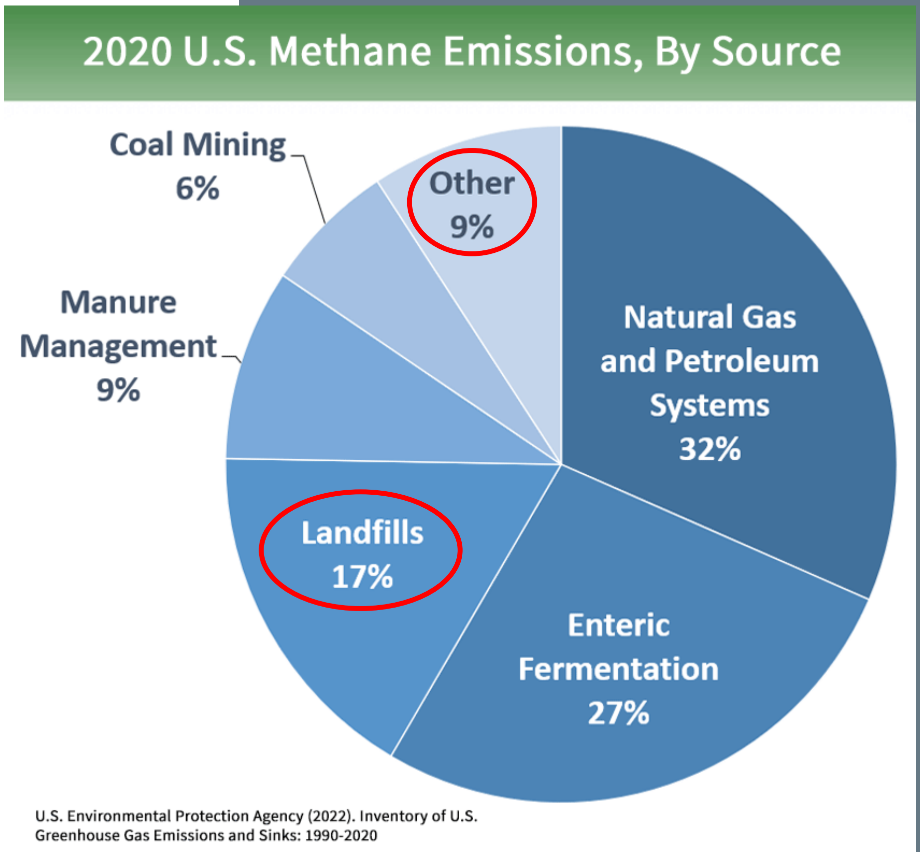
How Does the Wastewater Sector Contribute to GHG Emissions?



Source: U.S. EPA's Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2020.
https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks

Methane (CH_4)

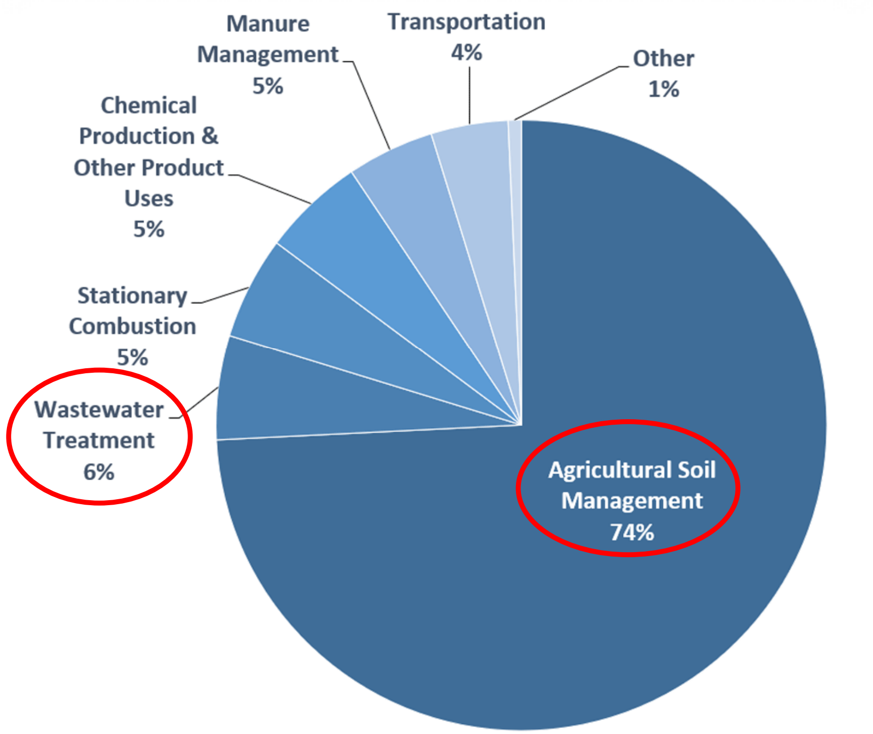
- **Greenhouse gas (GHG)** 20-25 times more potent than CO_2
- Accounts for **11% of all U.S. GHGs** from human activities
- Approximately **20% of CH_4 emissions** due to landfills and WWTP processes



Nitrous Oxide (N_2O)

- **300 times** more potent than CO_2
- Accounts for **7% of all U.S. GHGs** from human activities
- Approximately **80% of N_2O emissions** due to wastewater treatment and agricultural soil management

2020 U.S. Nitrous Oxide Emissions, By Source



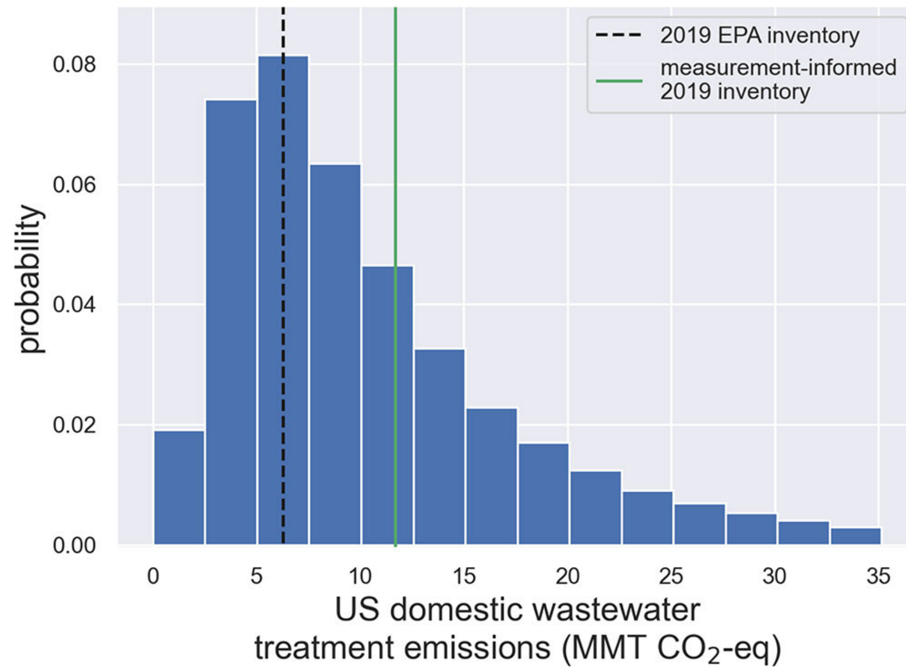
U.S. Environmental Protection Agency (2022). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2020

US Wastewater - Emissions

- 63 Different utilities compared to EPA and IPCC underestimate CH4 emissions by a factor of 2 (leaky anaerobic digestors)
  - Emission Rates
  - Emission Factors

- Wastewater treatment plants equipped with anaerobic digesters account for less than 10% of all treatment plants in the U.S.

- Most of those plants are large facilities that, combined, treat around 55% of the wastewater in the country



Distribution of US emissions from domestic wastewater treatment, excluding septic systems. For reference, the expected value (mean) of the lognormal distribution (green solid line) and the current US EPA inventory (dotted black line) are shown.

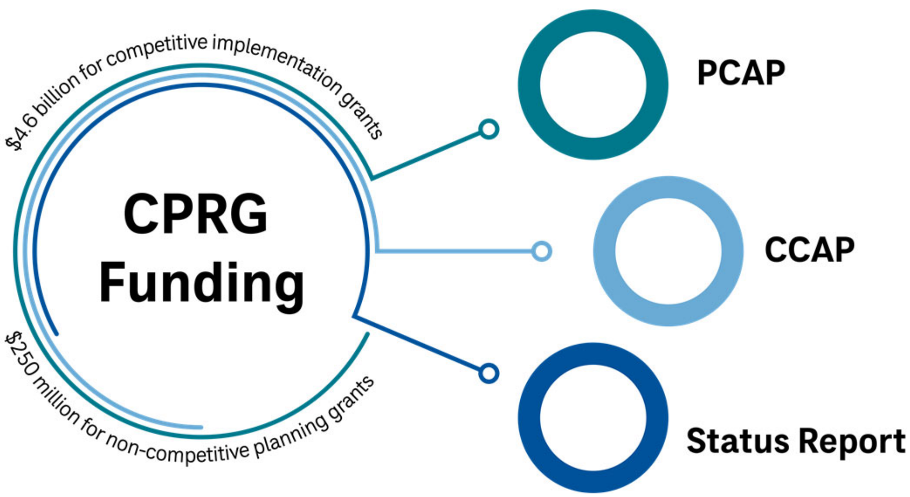
Source: *Underestimation of sector-wide methane emissions from United States wastewater treatment*

Why are We Talking About Decarbonization at the Kansas Governor's Conference?

GHG Reduction Measures Funding & Policy Drivers

CLIMATE POLLUTION REDUCTION GRANTS

U.S. Environmental Protection Agency



Kansas Department of Health and Environment (KDHE) Emissions Reduction and Mitigation Plan (E-RAMP)

- Reduce ambient air pollution and impacts while supporting the creation of quality jobs and lowering energy costs.
- Empower neighborhoods community-driven solutions.

2024 Kansas City Reginal Priority Action Plan (PCAP) (Mid-America Regional Council, MARC) and KC Regional Climate Action Plan (2021)

- Building energy efficiency and renewable energy;
- Transportation alternatives and technologies;
- Urban greening;
- Agriculture, food and waste systems innovation;
- Cross-sector measures that help build capacity for action

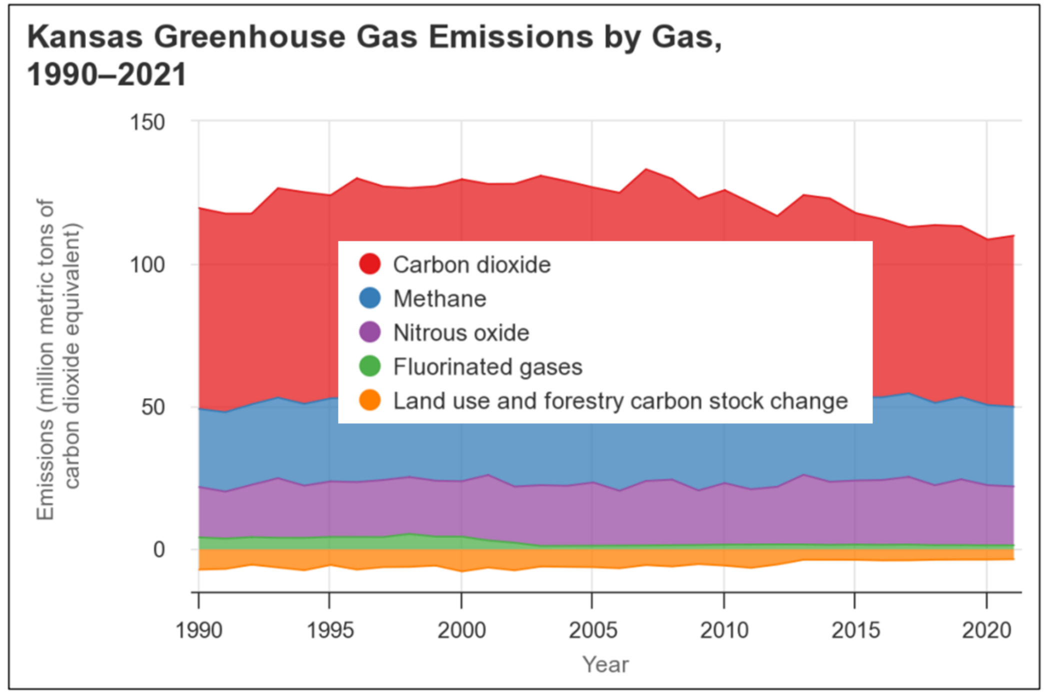
Develop pipeline of municipal implementation projects and framework for local climate policy and operational initiatives

Identify decarbonization, GHG/carbon reduction projects to take advantage of future implementation funding

Identify sustainable co-benefits and best practices for equitable implementation

Why are We Talking About Decarbonization at the Kansas Governor's Conference?
KDEH Emissions Reduction and Mitigation Plan (E-RAMP)

- Funded by Climate Pollution Reduction Grant (CPRG)
  - Part of the Inflation Reduction Act (IRA)
  - Funding received in June 2023.
- Funding to states, local governments, tribes and territories to create plans to reduce GHG emissions and improve carbon sinks.
- Planning Phase: State received $3M
  - Priority Action Plan due by March 2024
  - Comprehensive Action Plan due Summer 2025
  - Status Report(s) due with final report in 2027
- Implementation Phase (April 2024 and beyond)
  - Competitive grant for ~$4.3 billion in funding, from EPA
  - Eligibility based upon inclusion in plans developed during Planning phase



Source: U.S. EPA's Inventory of U.S. Greenhouse Gas Emissions and Sinks by State: 1990–2021. https://www.epa.gov/ghgemissions/state-ghg-emissions-and-removals

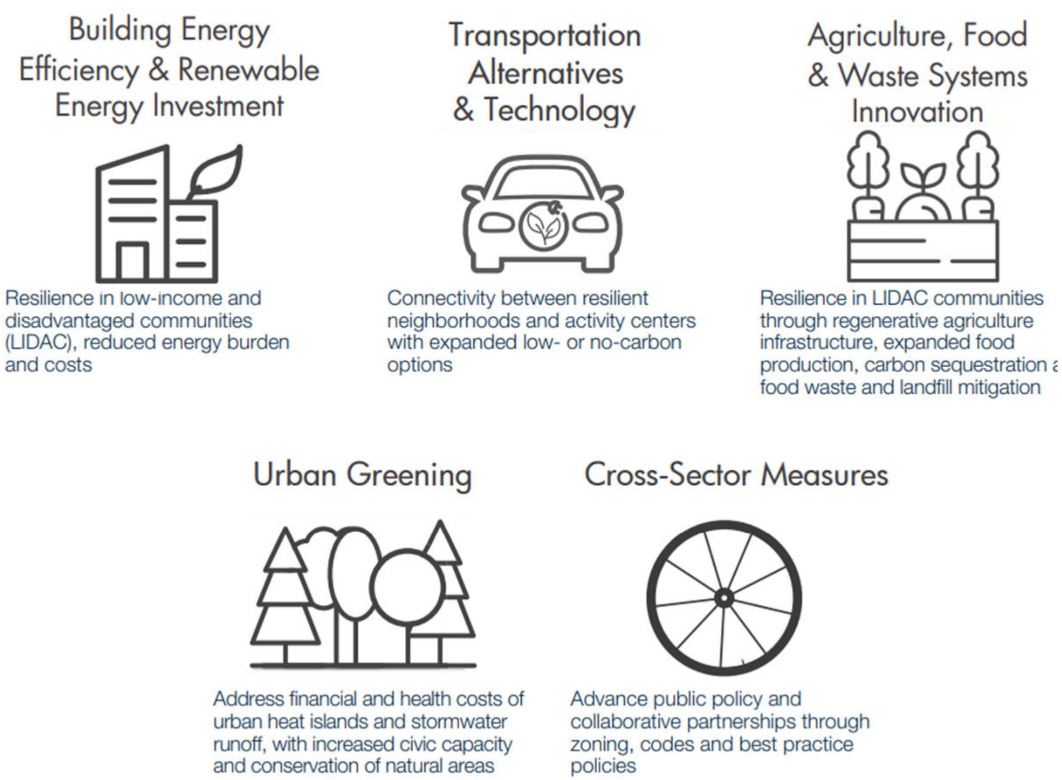
Total (Source) Emissions	118.9	126.1	112.8	112.4	107.7	109.0
Carbon Sink Net Total	-6.4	-5.5	-2.8	-2.7	-2.7	-2.6
Net Emissions (Sources and Sinks)	112.5	120.6	110.0	109.7	105.0	106.4

Source: Kansas Emission Reduction and Mitigation Plan

Why are We Talking About Decarbonization at the Kansas Governor’s Conference?

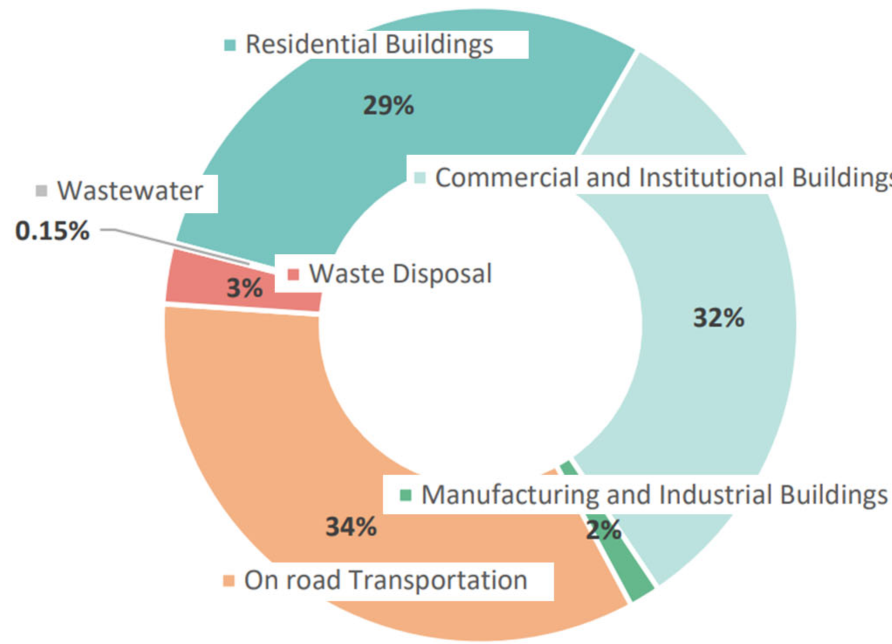
MARC Kansas City Regional Priority Climate Action Plan (PCAP)

PRIORITY ACTION AREAS



Source: Regional Priority Climate Action Plan

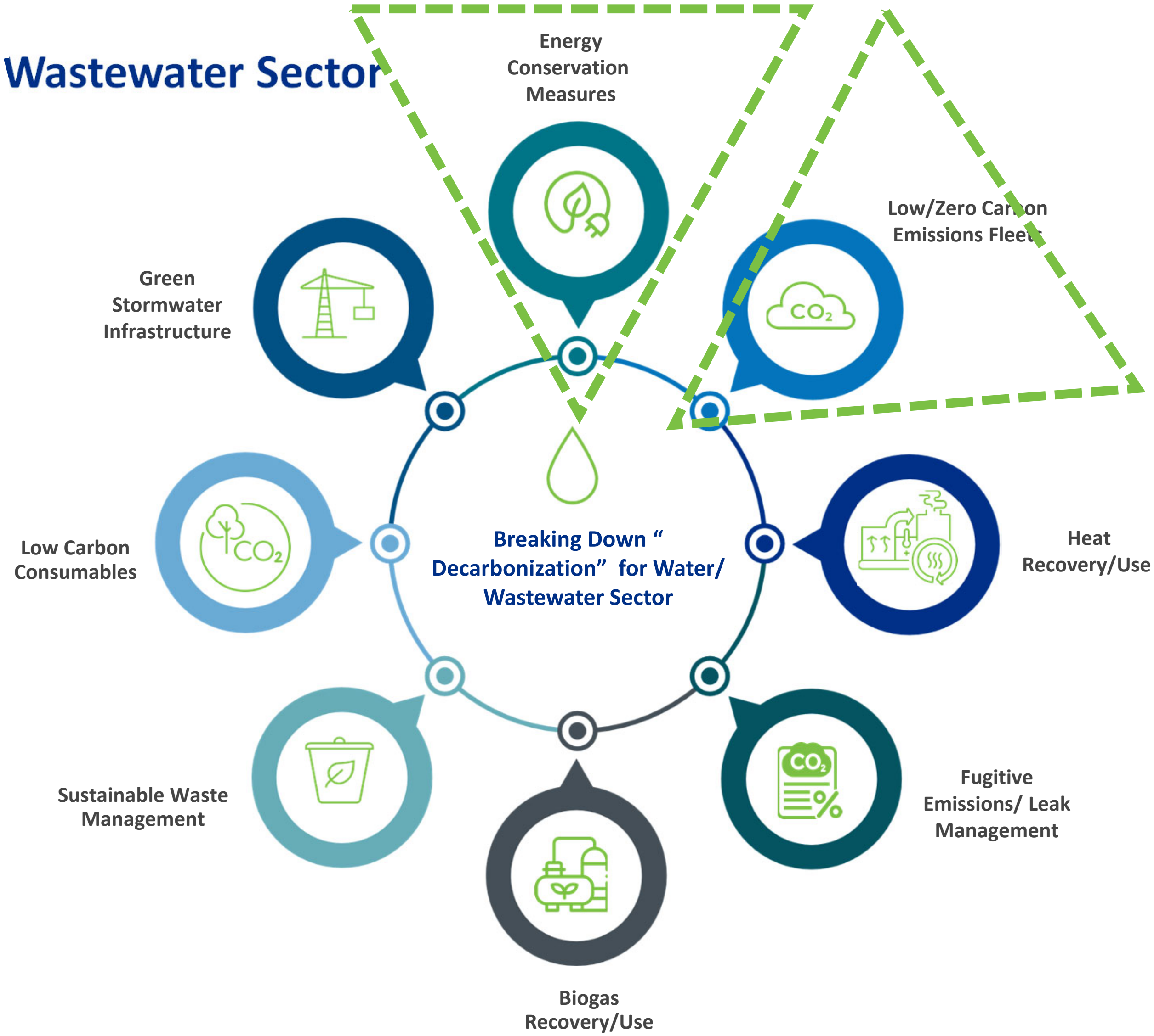
GHG INVENTORY (2015/2020)



Source: Greenhouse-Gas-Inventory-for-the-Kansas-City-Region_Final.pdf

Decarbonization of Water and Wastewater Sector
Technology Portfolio

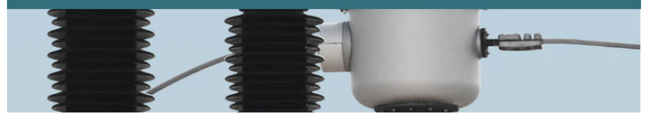
ENERGY CONSERVATION



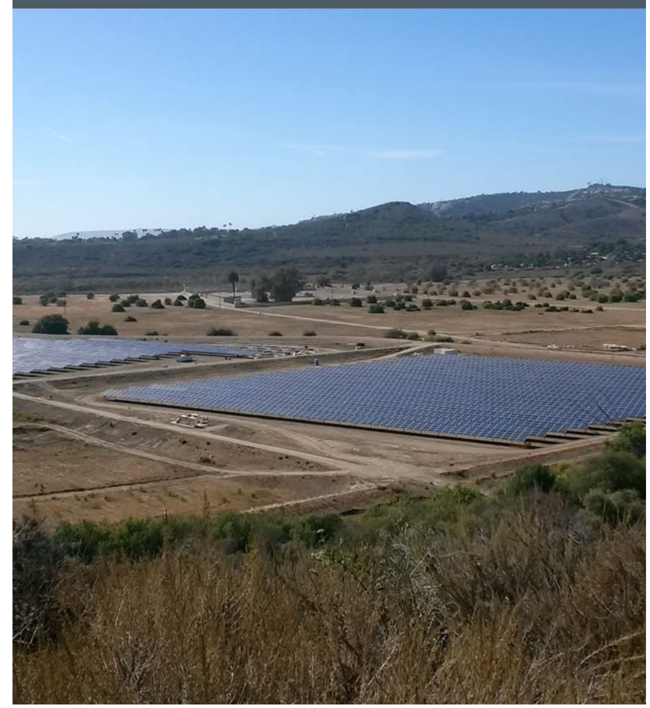
Energy Conservation Measures and Low Carbon Fuels
Decarbonization Value Engineering

Energy Efficiency
Operational Footprint Consolidation, Leaking Water Pipe Reduction

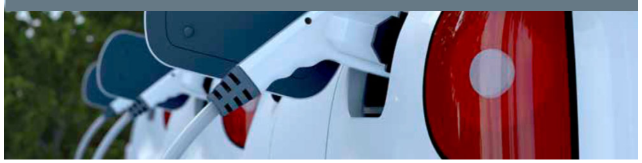
Power Systems/Utility Analysis
Arc Flash, Load Flow, Coordination/Protection



Microgrid
Distributed Energy Resources



Fleet Transition
EV, Fuel Cell



Renewable Energy
Hydrogen, Wind, Solar, Hydro, RNG/Biogas

Energy Storage
Battery, Hydrogen

Geothermal
Building Heating/Cooling

Energy Conservation Measures and Low Carbon Fuels

Decarbonization Value Engineering – National Examples

Mayor Henry and City Utilities Highlight Investments in Solar Panels on Wet Weather Ponds

Posted on September 19, 2023

For immediate release: September 19, 2023

CITY UTILITIES
WATER THAT WORKS

SUSTAINING
FORT WAYNE
FOR TODAY AND TOMORROW

“A reduction of approximately 20% or 4,600 tons per year in greenhouse gas emissions and the carbon footprint of the facilities is expected."

Doug Fasick, Fort Wayne Chief Sustainability Officer

Source: https://utilities.cityoffortwayne.org/mayor-henry-and-city-utilities-highlight-investments-in-solar-panels-on-wet-weather-ponds/
Source: https://www.fwbusiness.com/fwbusiness/article_33cb0f3a-22e0-541b-b524-7dc1562dd9a6.html

MCB CAMP PENDLETON UPGRADING ENERGY SECURITY

8 AUG 2020 | Curtis Hill, Marine Corps Installations West

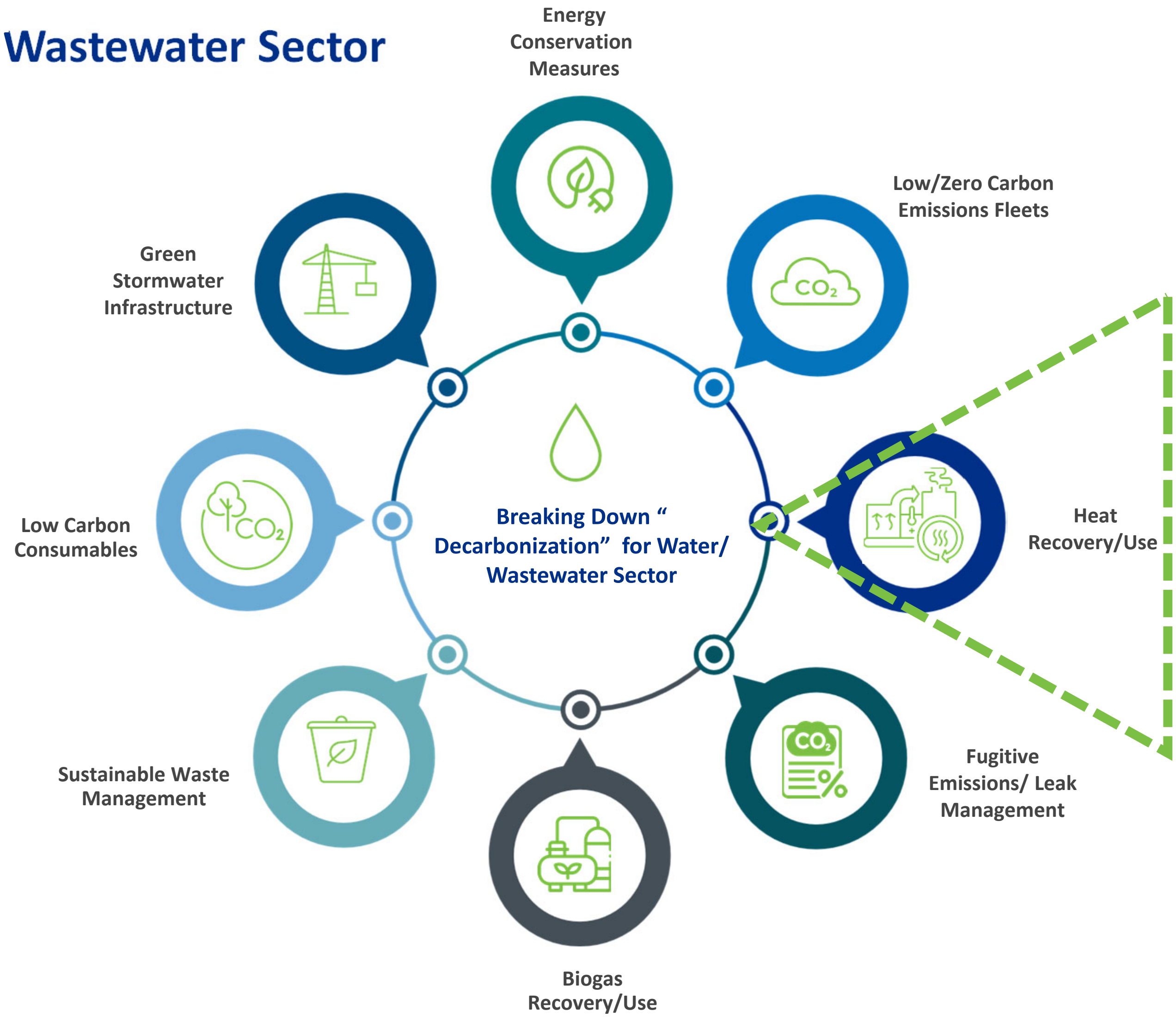
Three of Camp Pendleton’s major substations and advanced WTPs

- **Install/repair meters**
- **LEDs**
- **High efficiency boilers**
- **Energy efficient transformers**
- **Retro commissioning of hundreds of base buildings and the installation of supervisory, control and data acquisition (SCADA) system**
- **Microgrid**

Source: https://www.mciwest.marines.mil/Media-Room/Stories/Article/Article/2324199/mcb-camp-pendleton-upgrading-energy-security/

Decarbonization of Water and Wastewater Sector
Technology Portfolio

HEAT RECOVERY

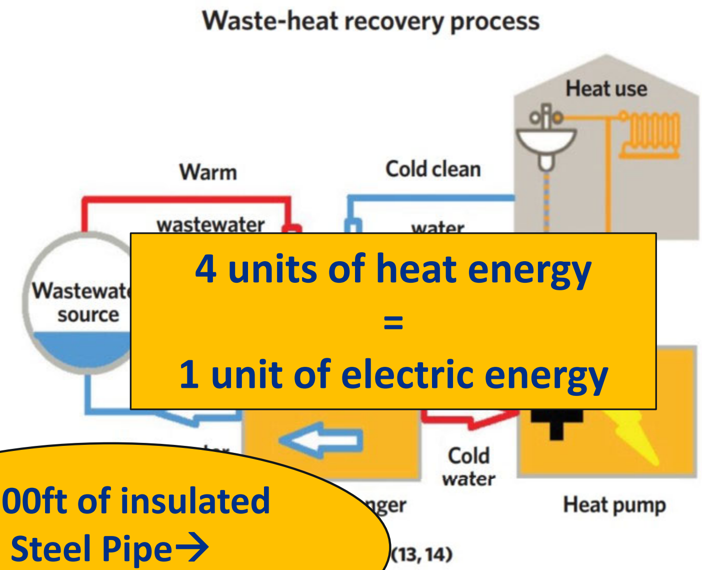


Heat Recovery and Use

- Effluent captured
- Heat extracted before discharge
- Heat pump reclaims heat energy
- Distribute heat energy for heating facility and to community

Avon, CO WWTP

Warm Treated Effluent



4 units of heat energy = 1 unit of electric energy

3,500ft of insulated Steel Pipe→ 3 buildings

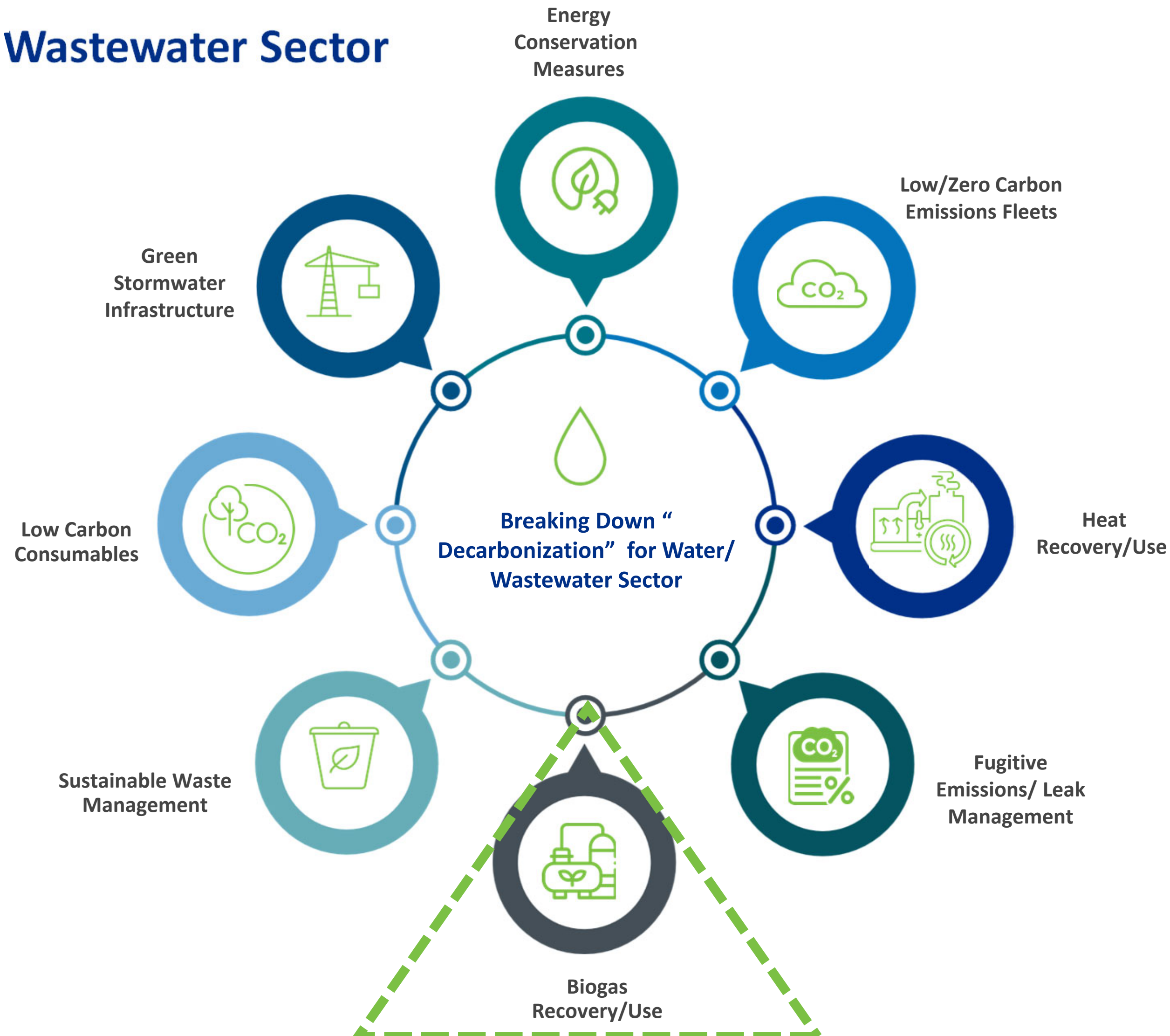
Cooler Treated Effluent

agle Rive

Source: https://www.cibsejournal.com/general/londons-hidden-energy-source-recovering-heat-from-sewage/

Decarbonization of Water and Wastewater Sector
Technology Portfolio

BIOGAS RECOVERY



Biogas Recovery/Use
Boiler Utilization of Biogas

- **Boilers combust biogas to produce heat**
  - Process heating
  - Building heating
  - Fluctuations in seasonal demands
- **Boiler burners can be configured for low pressure**
- **Biogas conditioning for H2S removal can be required**

BIOFUEL VALUE
(+) Market value of BTUs as natural gas
(–) Maintenance costs
(?) Social cost of carbon savings

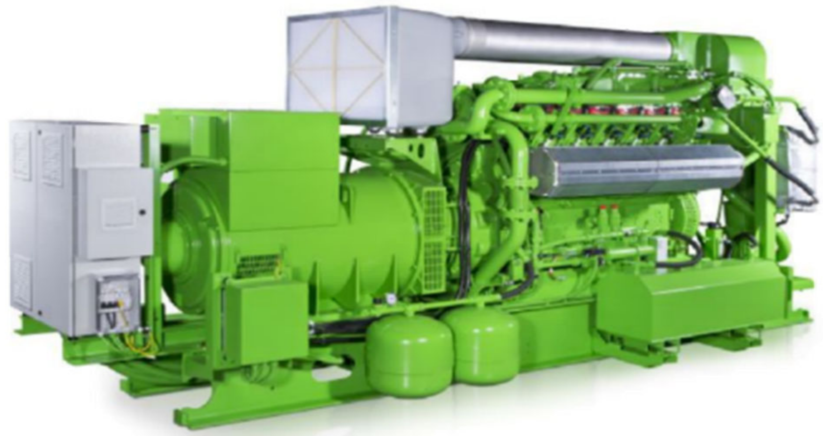
Organic waste (sewage sludge, agricultural residues, food waste)

Anerobic Process

Renewable fuel as Biogas

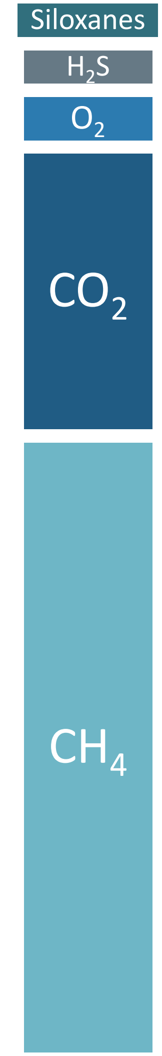
Biogas Recovery/Use
Biogas Utilization in CHP

- **Cogeneration of biogas produces heat + power**
  - Process heating
  - Building heating
  - Electricity to offset grid purchases
- **Requires higher biogas pressure 200 – 350 millibar (~3-5psig)**
- **Some biogas conditioning is required**
  - Moisture removal (chilling biogas)
  - Hydrogen sulfide treatment (reduction of corrosion/sox emissions)
  - Siloxane treatment



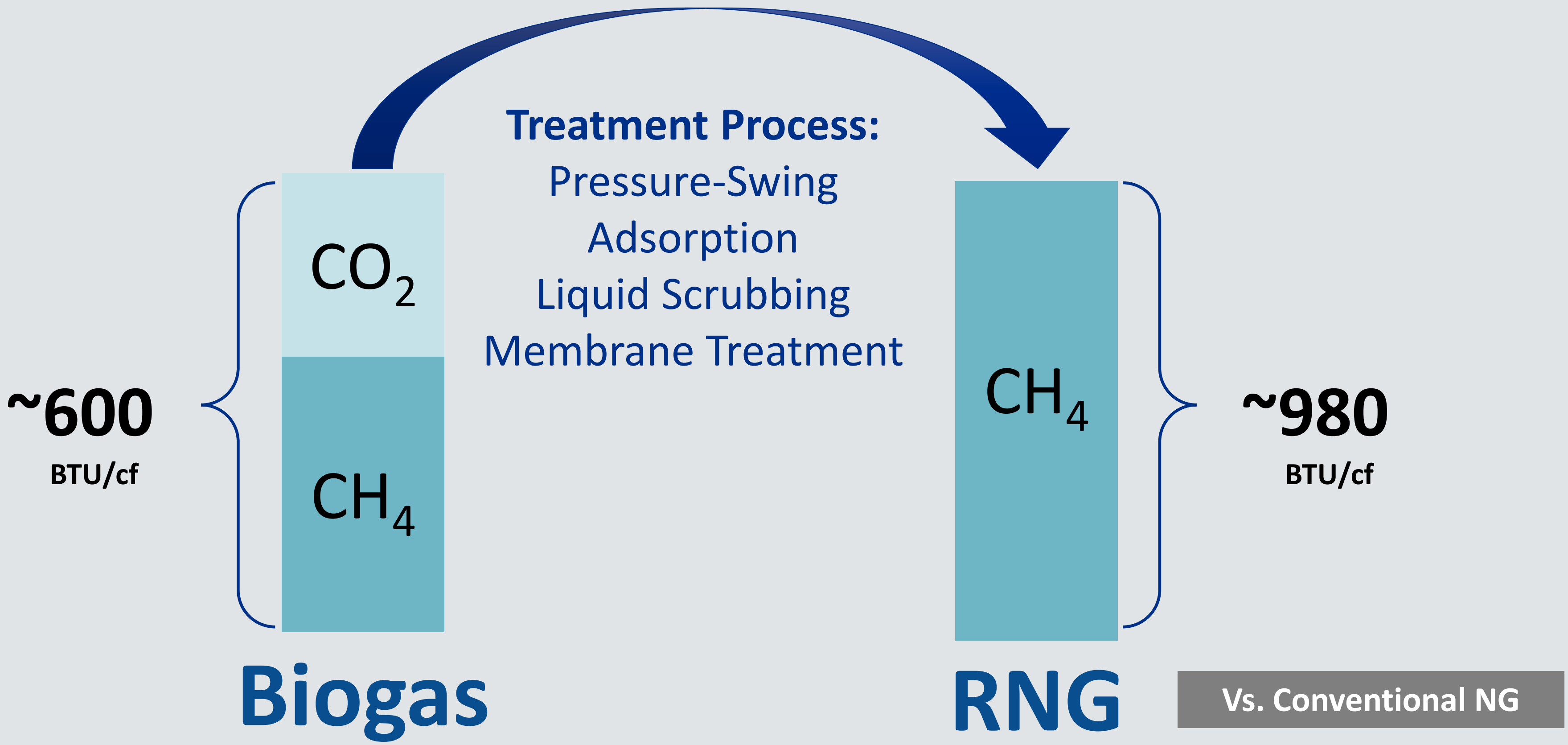
BIOFUEL VALUE

(+) Market value of BTUs as natural gas
(+) Market value of electricity to offset grid purchases
(–) Maintenance costs of cogen
(–) Maintenance costs of gas treatment
(?) Social cost of carbon savings



Biogas Recovery/Use

Biogas → Renewable Natural Gas (RNG) → Buildings + Fleet



Biogas Recovery/Use

Spire and KC Water announce Kansas City RNG-from-wastewater partnership

- **Spire and KC Water are partnering on Kansas City, Missouri's first renewable natural gas (RNG) facility, a project that will capture methane emissions from the wastewater treatment process to generate renewable energy.**
  - Repurpose biogas generated from the city's Blue River Wastewater Treatment Plant into RNG, and the new facility is expected to be complete in 2025.
  - Reduce GHG emissions by approximately 20,000 tons of CO2 equivalent per year.
  - Generate approximately $1 million (€910.9k) of revenue for KC Water per year.
  - Produce 0.3 billion cubic feet (BCF) of natural gas a year which would be enough energy to supply 4300 homes in the Kansas City region with natural gas.

Rendering of Blue River Biosolids & Future Biogas Facilities

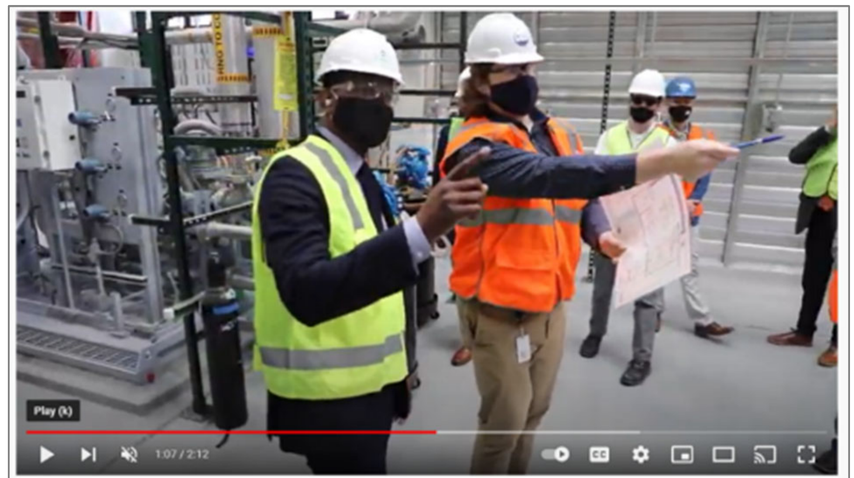
NGI

Source: KC Water

Source Spire and KC Water announce Kansas City RNG-from-wastewater partnership | Bioenergy Insight Magazine

Biogas Recovery/Use & Sustainable Waste Management
City of Des Moines Bioenergy Program Overview

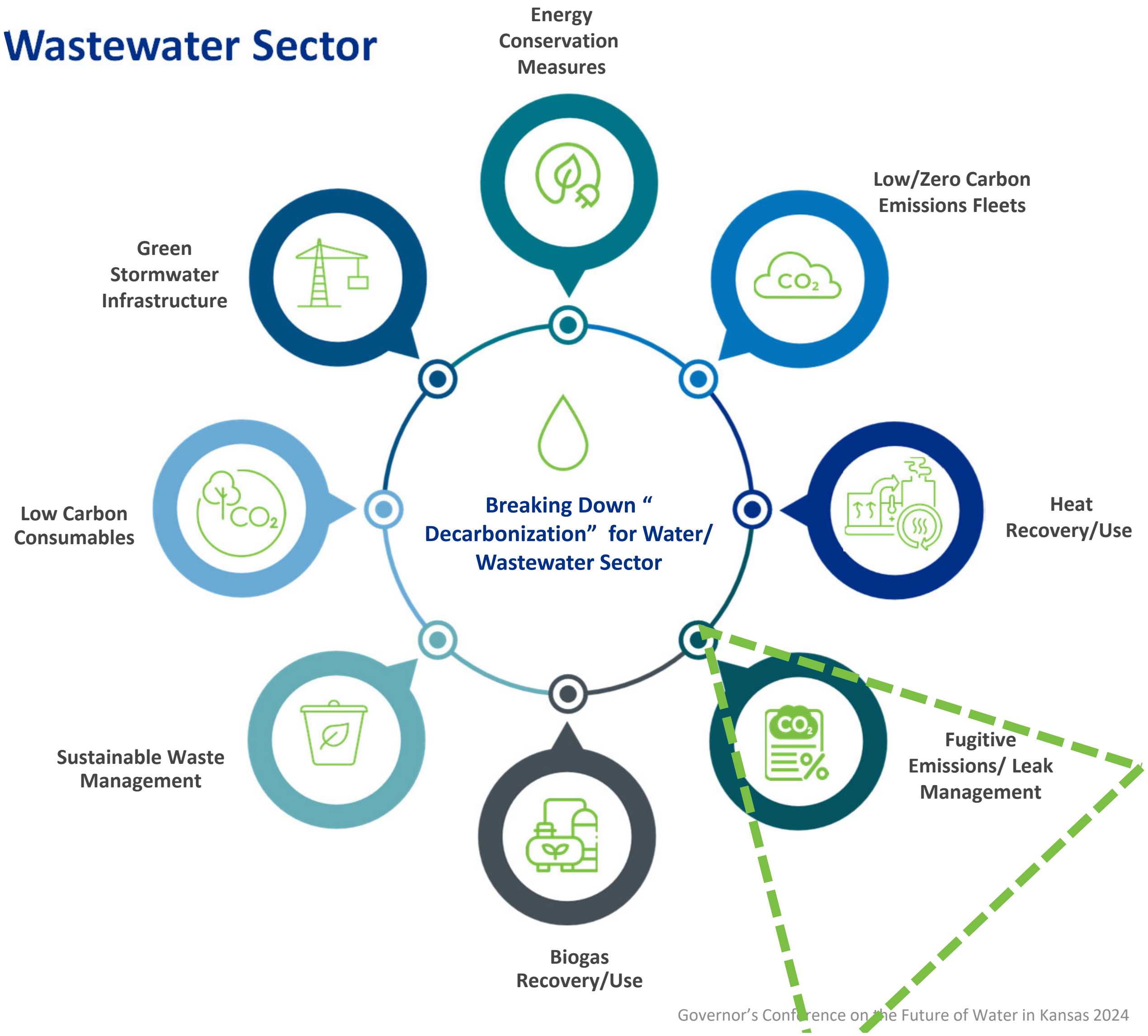
- Conversion of 80 MGD of municipal wastewater + 21,000 tanker trucks/yr of hauled waste into **renewable energy**
- Provides natural gas for 5,500 homes/day
- Organic waste tipping fees: ~$1-$1.5M/yr
- Renewable natural gas value: ~6.5M/yr
- Anticipated payback of ~3-4 years
- Local News Coverage & City Press Release
- EPA Administrator – Michael Regan Visited WRA



EPA Administrator Visits WRA

Decarbonization of Water and Wastewater Sector
Technology Portfolio

FUGITIVE EMISSIONS



Optimize Monitoring and Treatment Process to Address Fugitive Emissions

RETURN TO ISSUE | < PREV | ANTHROPOGENIC IMPACT... | NEXT >

Underestimation of Sector-Wide Methane Emissions from United States Wastewater Treatment

Daniel P. Moore, Nathan P. Li, Lars P. Wendt, Sierra R. Castañeda, Mark M. Falinski, Jun-Jie Zhu, Cuihong Song, Zhiyong Jason Ren, and Mark A. Zondlo*

Cite this: *Environ. Sci. Technol.* 2023, 57, 10, 4082–4090
Publication Date: February 27, 2023
https://doi.org/10.1021/acs.est.2c05373

Environmental Science & Technology

"An increasing percentage of U.S. waste methane (CH_4) emissions come from wastewater treatment (10% in 1990 to 14% in 2019), although there are limited measurements across the sector, leading to large uncertainties in current inventories."

Optimize Monitoring and Treatment Process to Address Fugitive Emissions

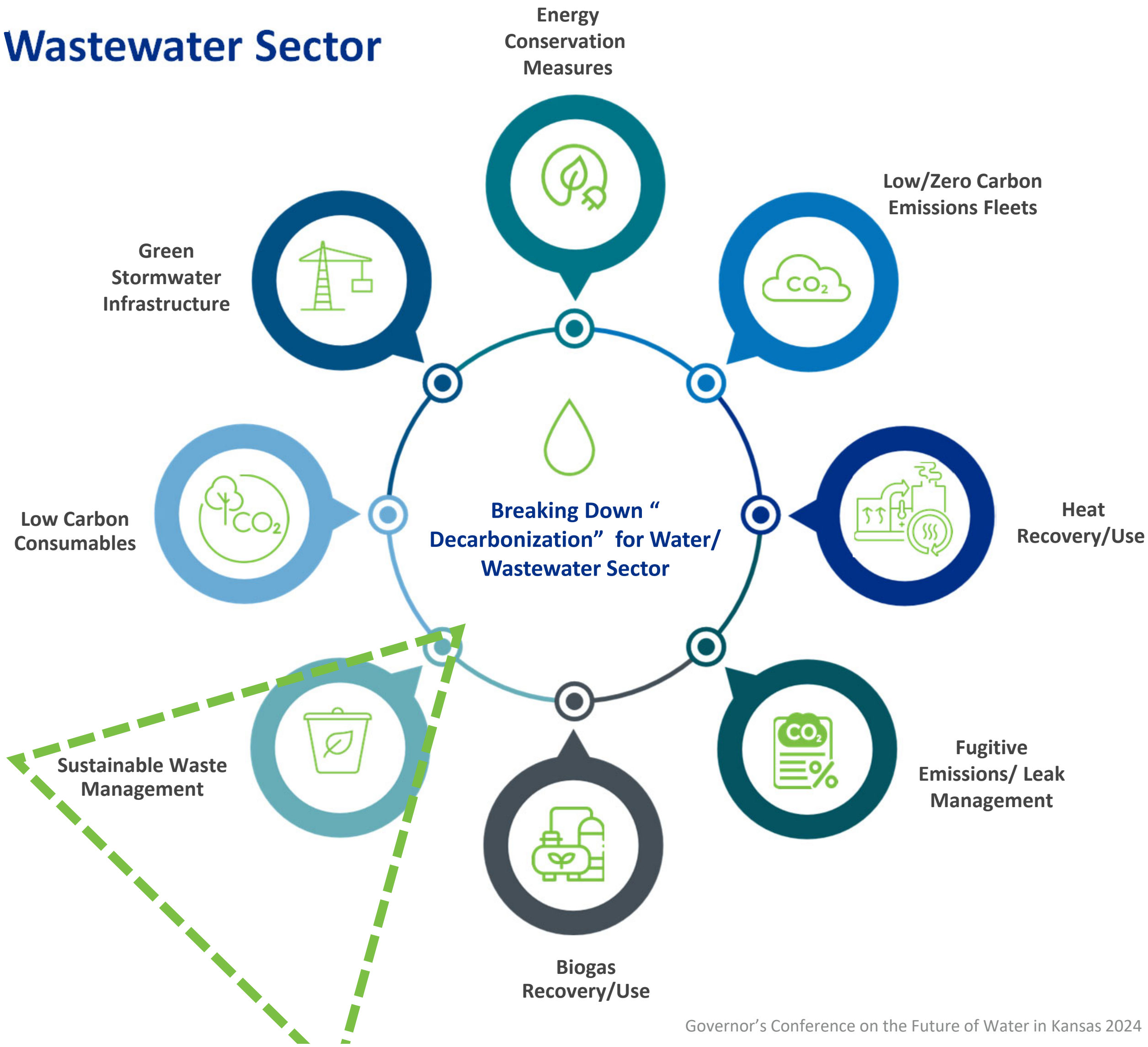
3-D Modeling of Wastewater N2O Liquid Concentration

Source: Experts in Computational Fluid Dynamics for Process Optimization | AM-Team

- Fugitive emissions are finicky
  - GHG emission composition and concentrations vary plant wide, and sometimes within a storage basin/reservoir
  - Seasonally and temporally influenced
- *Monitoring* and *Mitigation* technologies are novel and undergoing active testing globally
  - Catalytic treatment of $N_2$0 to N_2 and O_2 under high temperature (NACAT project Envidan, Jeannette Madsen Denmark)
  - Algal-bacterial consortium (Wuhan Unv. Of Technology of China)
  - Adaptive dynamic $N_2$0 model (Kruger Veolia, 8 WWTPs, other)
  - $N_2$0 Monitoring Program Changi Water Reclamation Plant (2045 Net Zero, Pathways, Singapore National Water Agency)

Decarbonization of Water and Wastewater Sector
Technology Portfolio

WASTE/ WASTEWATER MANAGEMENT



Sustainable Waste Management
Opportunity for Biosolids Industry

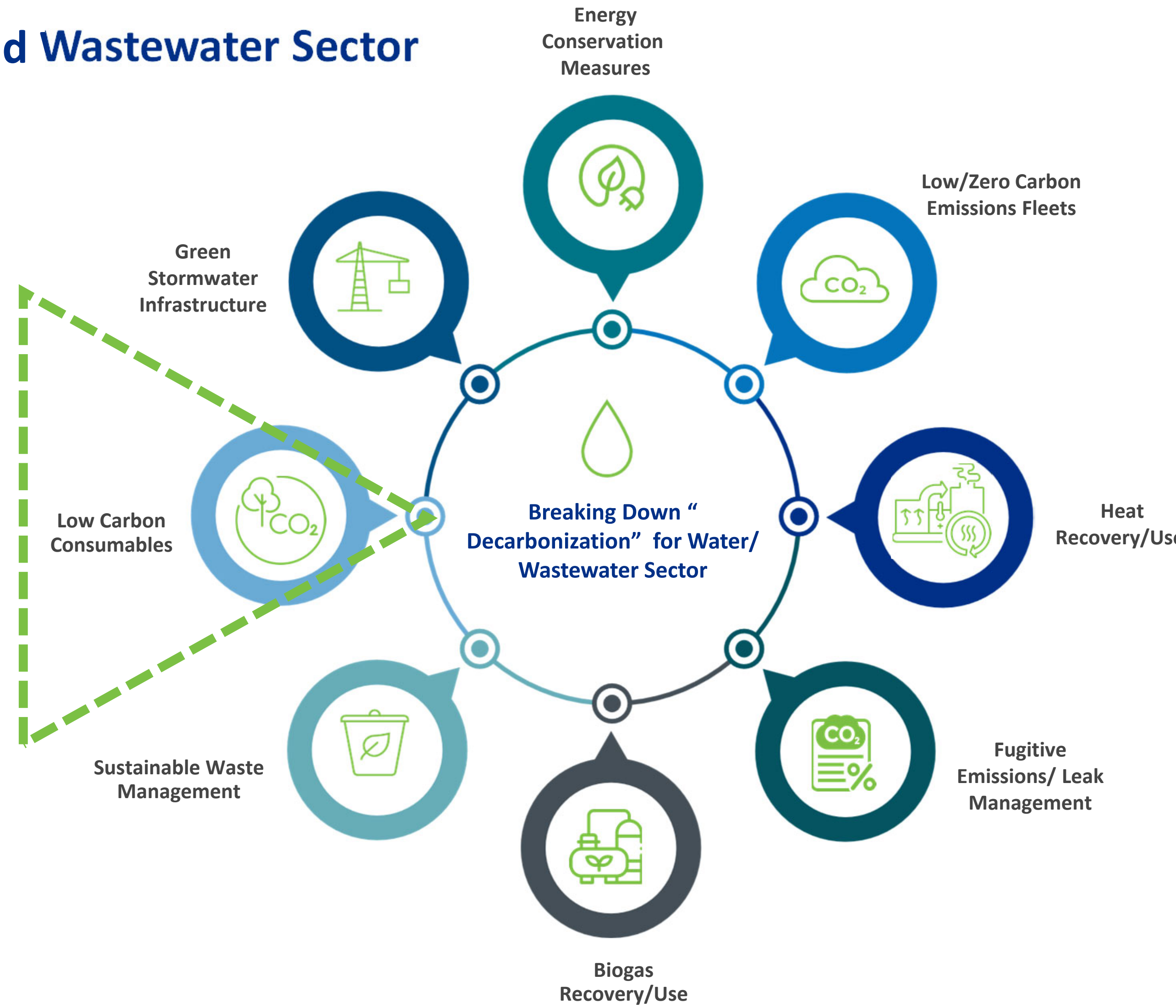
- **Landfills – 2% of all U.S. emissions**
- **Agricultural Soil Management – 5% of all U.S. emissions**
- **Local Impact**
  - WWTP processing and landfills often #1 source of GHGs for municipalities who own these assets
- **Emissions Profile dependent on Process Decisions**
  - Anaerobic Digestion and Sludge Drying can reduce net GHG emissions at moderate sized WRRFs
  - Residuals end use method has significant impact on emissions

Image Source

Image Source

Decarbonization of Water and Wastewater Sector
Technology Portfolio

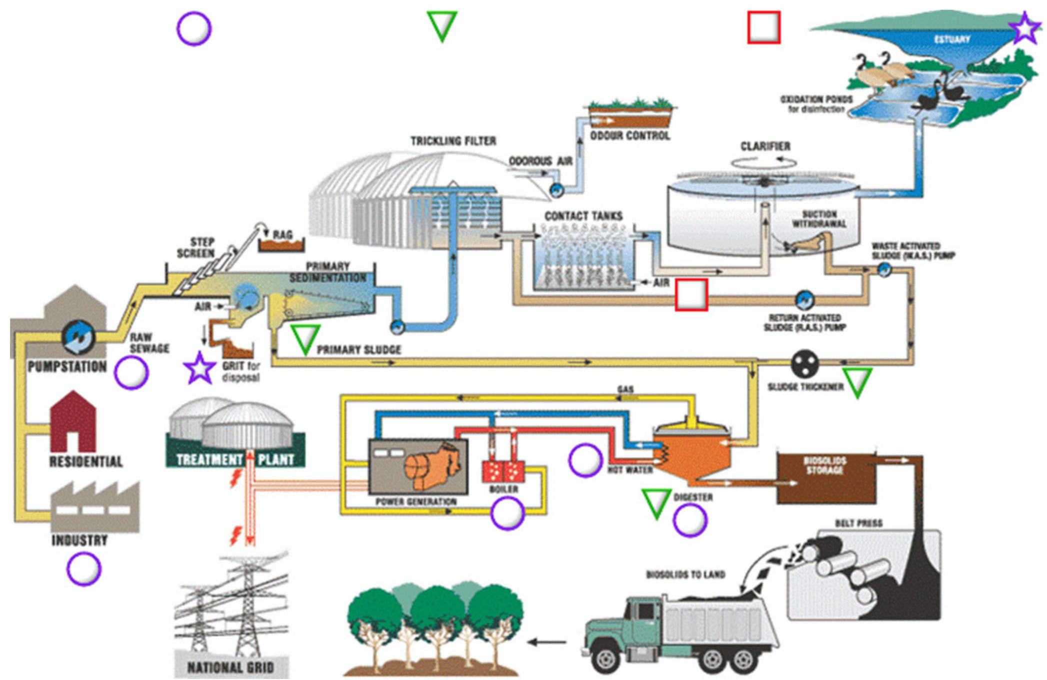
LOW CARBON CONSUMABLES



Low Carbon Consumables and Treatment Processes
GHG Lifecycle Assessment

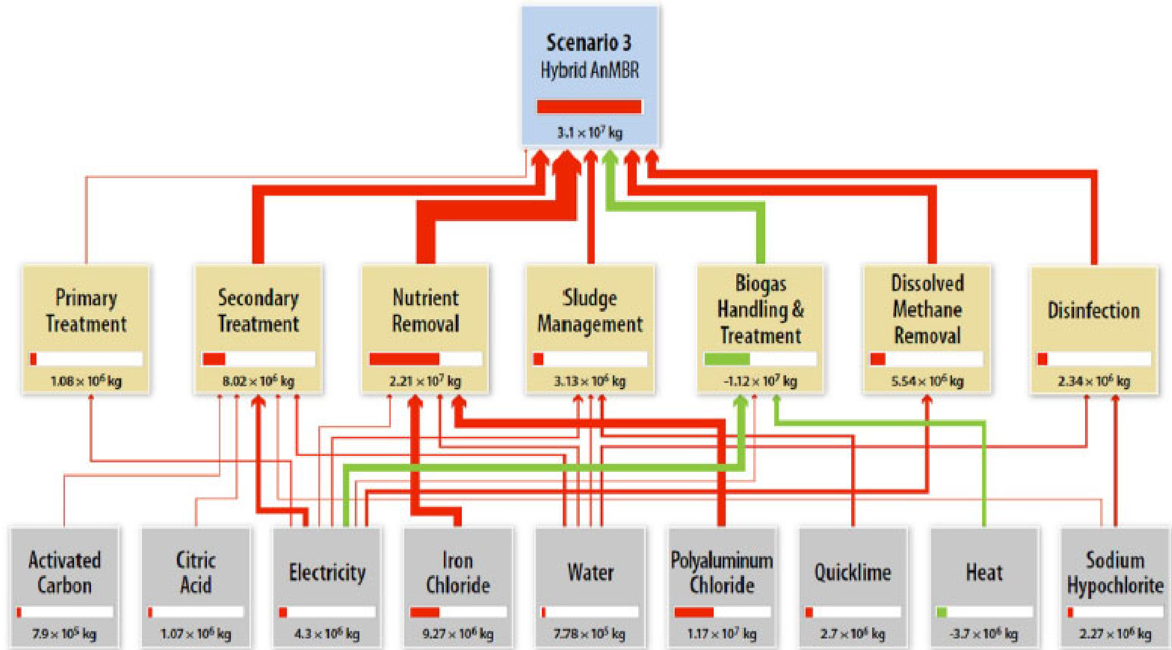
- **Water Research Foundation (WRF) 5188** Establishing Industry-Wide Guidance for Water Utility Lifecycle Greenhouse Gas Emission Inventories
- **Commenced December 2023!**
- **PI:** David Ponder, U.S. Water Alliance
- **Team**: Princeton University, Brown and Caldwell, Cobalt Water Global, GHD, Jacobs, Northern Tilth, Stantec, and CDM Smith
- Keep a look out for tools and resources!

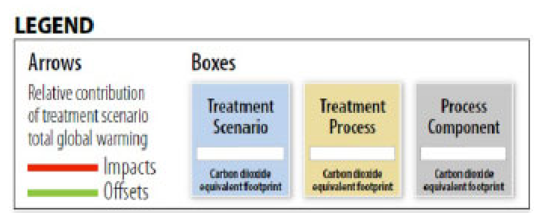
  Website: https://www.waterrf.org/research/projects/establishing-industry-wide-guidance-water-utility-life-cycle-greenhouse-gas



Low Carbon Consumables and Treatment Processes
GHG Lifecycle Assessment

- **Process innovations, e.g.,**
  - ABAC, PND, MABR all promise to reduce aeration
  - Solids fermentation is meant to reduce need for carbon purchasing
  - Microaeration could reduce the need for scrubbers
  - UVC-LED could be a game changer one day
- **Example: AnMBR treatment**
  of domestic wastewater may be more energy efficient and sustainable than conventional treatment with:
  - Primary sedimentation with anaerobic digestion
  - Alternative processes for dissolved methane removal
  - Biological sulfide removal
  - Biogas recovery as energy source





Evans, P., Doody, A., Harclerode, M., Vila, P., Parameswaran, P., Lim, K., ... & Maga, S. (2018). Anaerobic Membrane Bioreactor (AnMBR) for sustainable wastewater treatment. *Project ER-201434. Department of Defense Environmental Security Technology Program Final Report.*

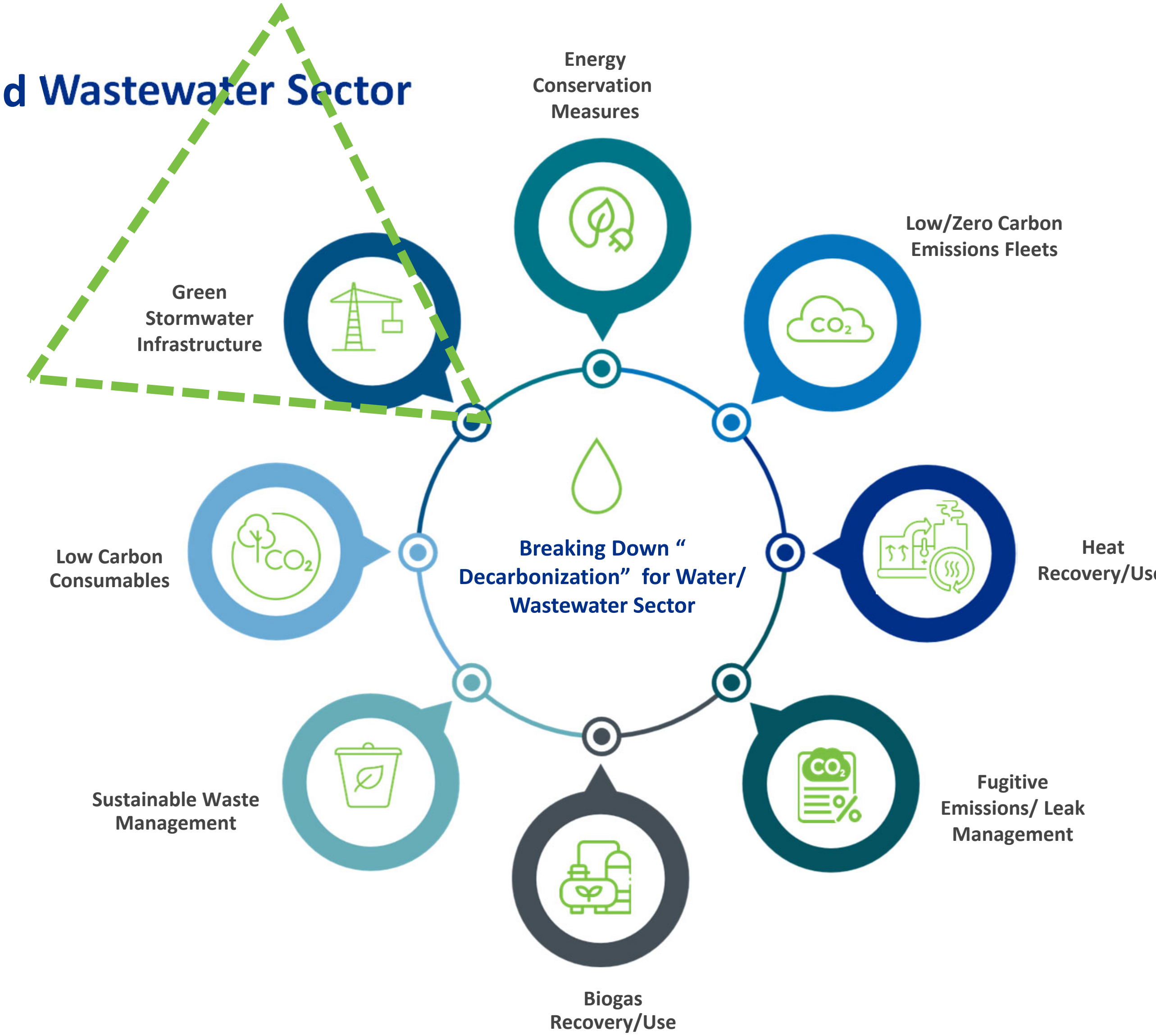
Low Carbon Consumables
Cement, Steel, Asphalt

GSA's Interim IRA Low Embodied Carbon Material Requirements, based on EPA's Interim Determination, set global warming potential (GWP) limits for IRA-funded asphalt, concrete, glass, and steel.

Example: Cementitious Material

Material Description	Carbon Reduction Potential	Advantages	Disadvantages
Baseline Type I/II Cement	0.82kg CO_2/kg of cement	• Industry Standard and widely applied over the US • Used extensively in transportation systems	• Carbon intensive production • Higher permeability; lower durability
Alter #1 Type 1L	10-15%	• Uses less energy which reduces greenhouse gas emissions • Eco-friendly substitution for OPC (Ordinary Portland Cement) without compromising performance • Lower carbon footprint • Improved early strength profile • Sulfate resistance comparable to OPC • Equal performance compared to OPC	• Requires precise mixture or else compromised • Slight increase heat of hydration
Alter #2 Type 1L + 30% Fly Ash	22%	• Reduced energy consumption • Reduced emissions • Reduced temperature in massive concrete	• Slow strength development • Longer set time • Poor air content control
Alter #3 Type 1L + 50% slag	39-48%	• Alternative use for slag over landfill • Lower heat of hydration • Improved long term strengths • Reduced permeability	• Lower the percentage, the lower the strength • Poor early compressive strength • Cannot be applied in areas with cold weather

Decarbonization of Water and Wastewater Sector
Technology Portfolio



GREEN STORMWATER INFRASTRUCTURE

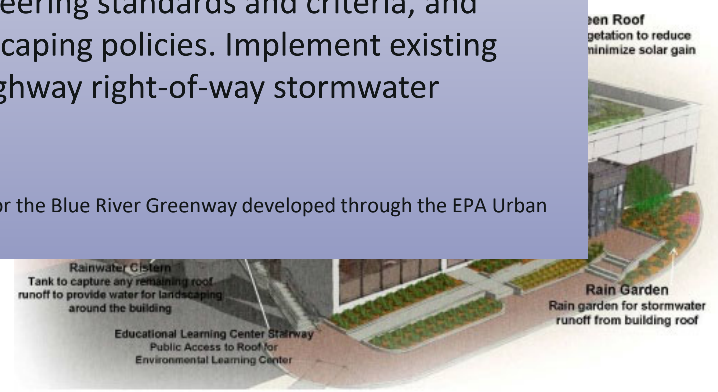
Green Stormwater Infrastructure
Water Quality Reduces Carbon!

Projected green stormwater infrastructure installations associated with future growth and redevelopment trends in the metro: **restore 40,880 acres in regional riparian corridors and install 13,200 acres of nature-based green infrastructure solutions** including streetside and site-scale green stormwater infrastructure and landscape restoration.

Riparian forest/wetland protection and restoration will sequester approximately 9.6 million mtCO2e by 2050.

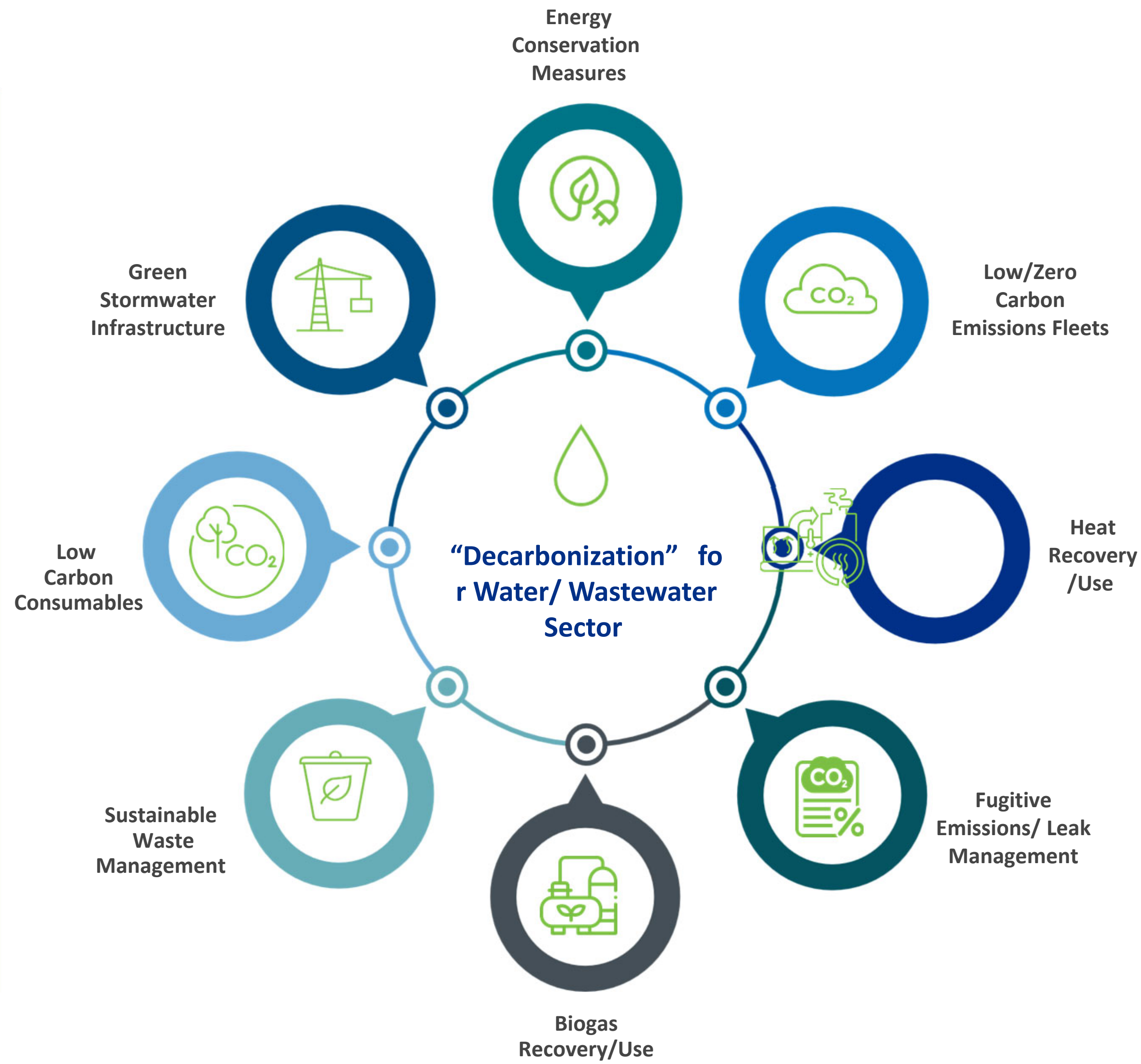
These benefits will accrue contingent upon the implementation of cross-sector measure CS-1 through the regional adoption of new stormwater engineering standards and criteria, and related stream setback, tree protection and native landscaping policies. Implement existing green corridor, trail, urban heat island reduction, and highway right-of-way stormwater management and restoration plans and projects.

Source: Kansas City PCAP and Heartland Conservation Alliance's Water Equity Roadmap for the Blue River Greenway developed through the EPA Urban Waters Federal Partnership



Future Decarbonization Perspective

- Policy, funding, and societal drivers are prevalent
- Key decarbonization actions in cross-discipline value engineering
- As the electrical grid “greens”, operational GHG emissions will draw more attention
- Businesses will be attracted to low-cost green energy regions for sustainable operations
- Population growth will put increased demand on water and wastewater systems
- Being proactive in water/wastewater decarbonization is good for people, planet, profit



Voluntary Carbon Market Integrity Initiative (VCMI)


University of Colorado **Boulder**

Mortenson Center in Global Engineering & Resilience

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The Climate Crisis is a Water Crisis

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March 19, 2024

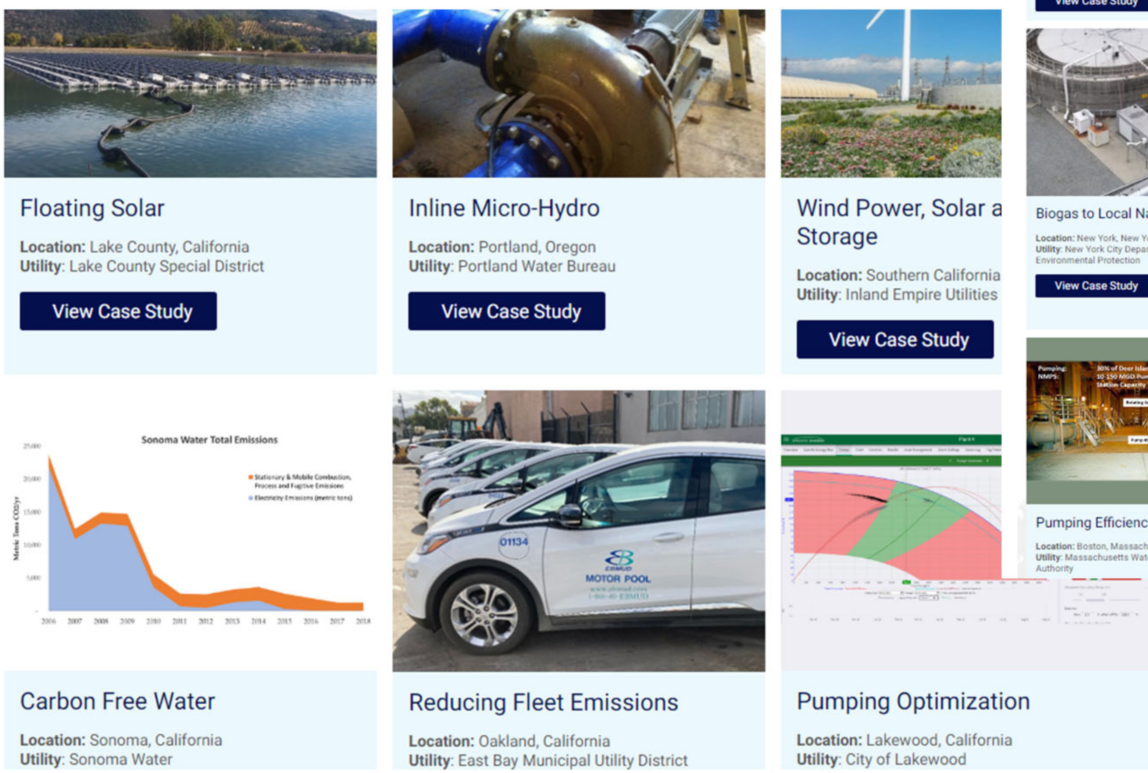
Why Water Must Be at the Heart of Climate Action

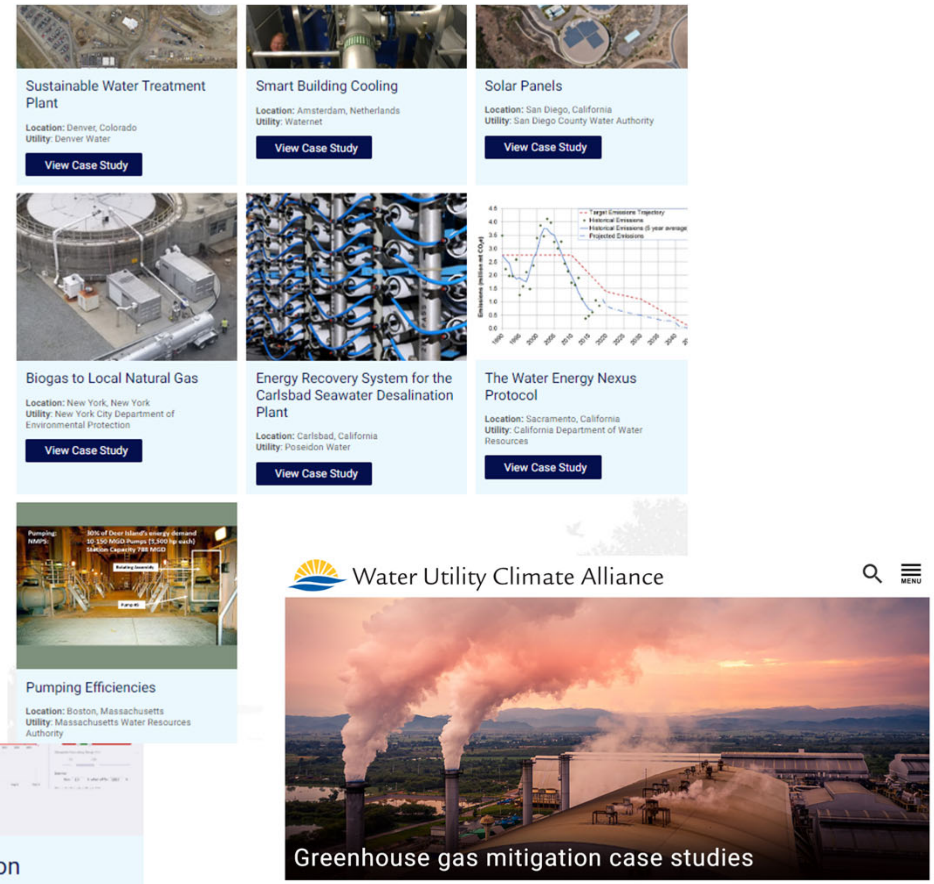
The Mortenson Center in Global Engineering & Resilience at the University of Colorado Boulder along with Castalia Advisors were commissioned by WaterAid's Resilient Water Accelerator (RWA), the Voluntary Carbon Market Integrity Initiative (VCMI), and HSBC to discover an achievable pathway to creating a green, resilient future for global water supplies supported by voluntary carbon markets.

- Mortenson Center in Global Engineering & Resilience at the University of Colorado Boulder and Castalia Advisors commissioned by WaterAid's Resilient Water Accelerator (RWA)
- Project types:
  - Wastewater treatment (e.g., biogas power generation plant)
  - Community safe water supply
  - Reduced grid emissions for utilities (e.g., piped water loss reduction, pumping efficiency, renewable power sources)
  - Industrial and domestic wastewater treatment (e.g., biogas utilization, desludging)
  - Blue carbon (e.g., sequester CO_2 from wetlands, such as mangroves and seagrass)
  - Watershed restoration
- Integrity
  - 3rd party verification
  - Commitment letter to mitigate double counting

Water Utility Climate Alliance (WUCA) Funding Guidance & Case Study Initiative

- Greenhouse Gas Mitigation (GHG) Community of Practice, Inflation Reduction Act Guide/FAQ + Continuation of GHG Case Studies





Thank You

To learn more, please reach out to:

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Any Questions?