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Overview of Resource Recovery-based Sustainable Water Systems: Life Cycle Assessment Updates from US EPA's Safe and Sustainable Water Resources Research Program

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Office of Research and Development
National Exposure Research Laboratory
National Risk Management Research Laboratory

United States Environmental Protection Agency

EPA’s Safe and Sustainable Water Resources (SSWR) Research Program

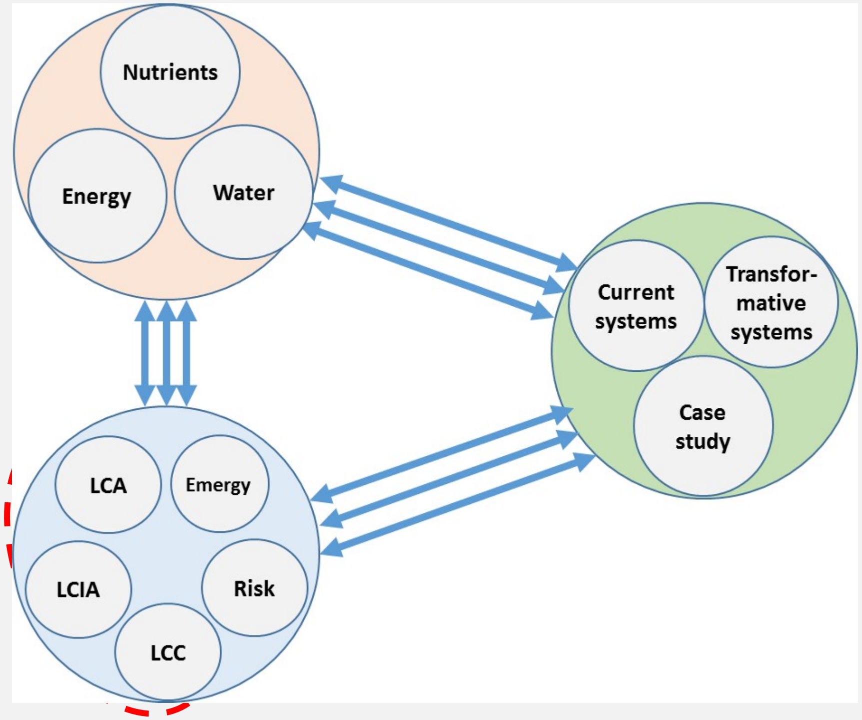
- Watershed Sustainability
- Nutrients
- Green Infrastructure and Stormwater
- Water Systems

Water System Analyses

1. Development of a transformative technology toolkit library

2. Metrics, tools improvement, and expansion

3. System analyses comparing conventional and transformative community water systems and applications in community-based case studies



Water System Analyses

- LCA and LCCA for current centralized water and wastewater systems
  - Greater Cincinnati region (GCWW and MSD)

- Resource recovery-based community system
  - *Small-scale WWRF in NY (energy recovery via co-digestion, water reuse, nutrient recovery via composting)*
  - *Medium-scale WWRF in MA (expanded energy recovery via co-digestion, nutrient recovery via pellet land application)*

- Evaluation of alternative scenarios for decentralized non-potable water reuse systems (mixed wastewater and graywater, scale, source separation of wastes, treatment approach)
  - *San Francisco, CA and other stakeholders (from knowledge to application)*

- Emergency response options *(Atmospheric water generation, single-serve single use bottled water, multi-serve reusable jugs)*

Why are Cities Interested?

- Water resource stress (quantity-drought)
- Water resource stress (quality – safety)
- Drinking water quality (pathogens, DBPs, PFOS/PFOA)
- Wastewater treatment (eutrophication)
- Combine sewer overflow (CSO)
- Storm water management (flooding)
- Aging infrastructure (rated as "D+")
- Financial burden ($540 billion gap in next 20 years)

"Siloed" water management approaches.

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Centralized Treatment Resources

- S Cashman, A Gaglione, J Mosley, L Weiss, N Ashbolt, T Hawkins, J Cashdollar, X Xue, X Ma, and S Arden. Environmental and Cost Life Cycle Assessment of Disinfection Options for Municipal Drinking Water Treatment. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-14/376, 2014. https://nepis.epa.gov/Exe/ZyPDF.cgi/P100LHTP.PDF?Dockey=P100LHTP.PDF

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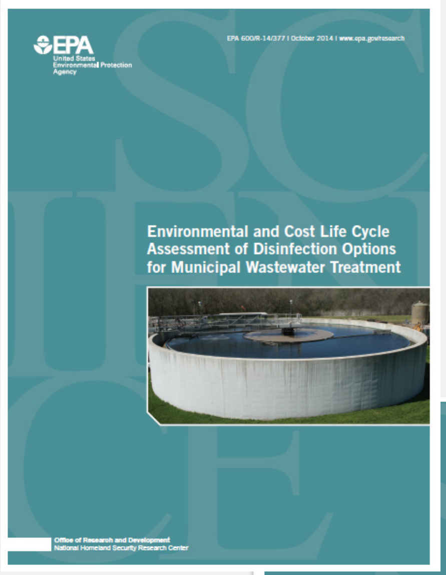
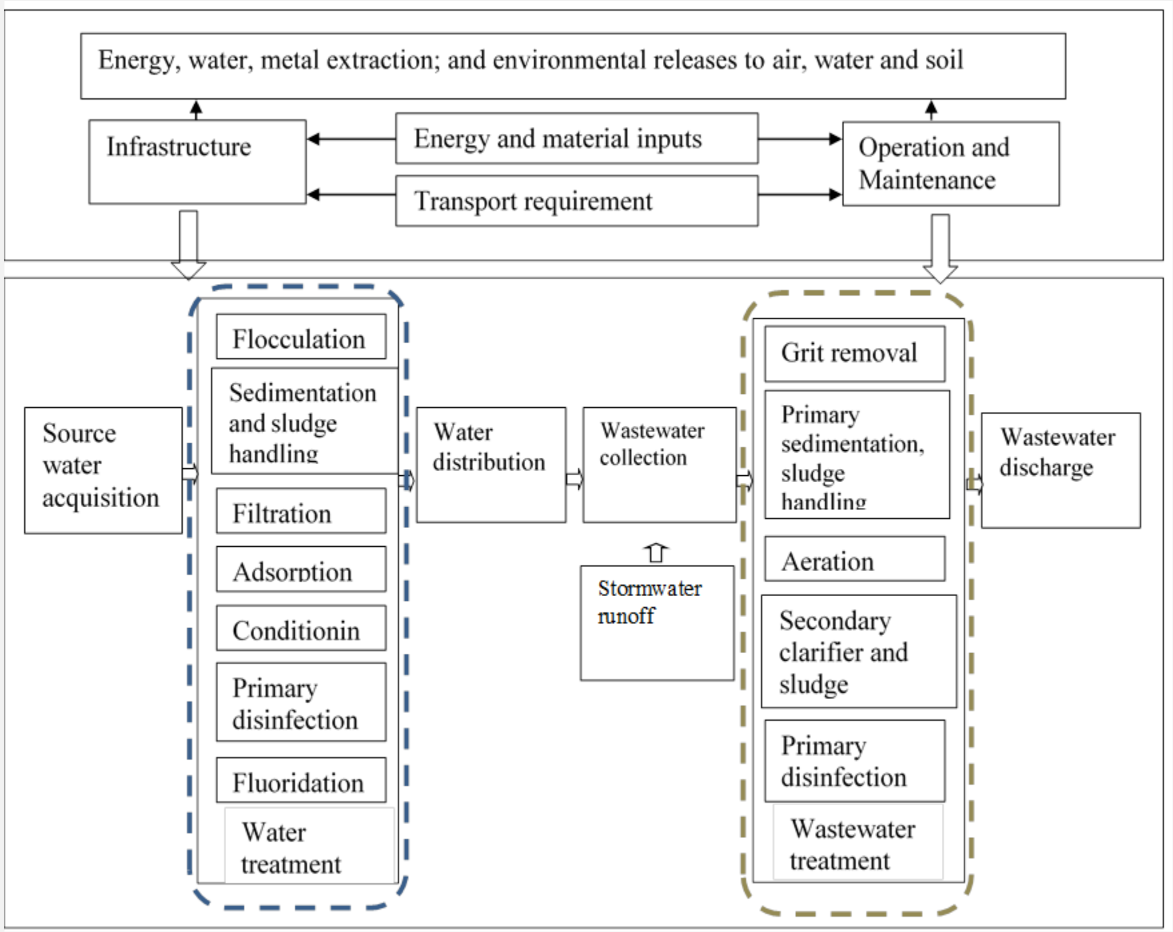
- X Xue, S Cashman, A Gaglione, J Mosley, L Weiss, X Ma, J Cashdollar, J Garland. Holistic Analysis of Urban Water Systems in the Greater Cincinnati Region: (1) Life Cycle Assessment and Cost Implications. Water Research, 2018 *(Accepted)*.



Centralized Treatment Unit Process Coverage

- Functional unit = cubic meter of water delivered to consumer, which is subsequently treated.
- Unit processed based on data received directly from utilities in the Greater Cincinnati region.



From Xue et al., 2018 (Accepted)

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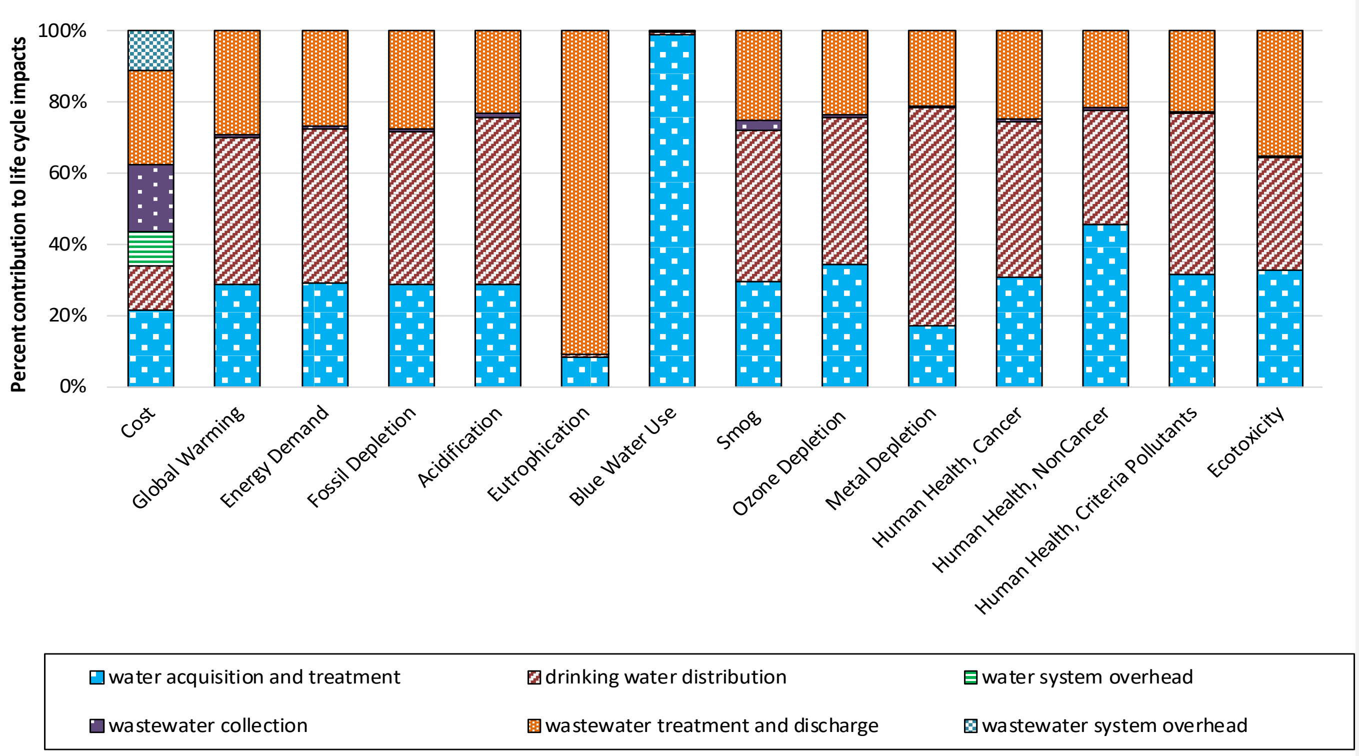
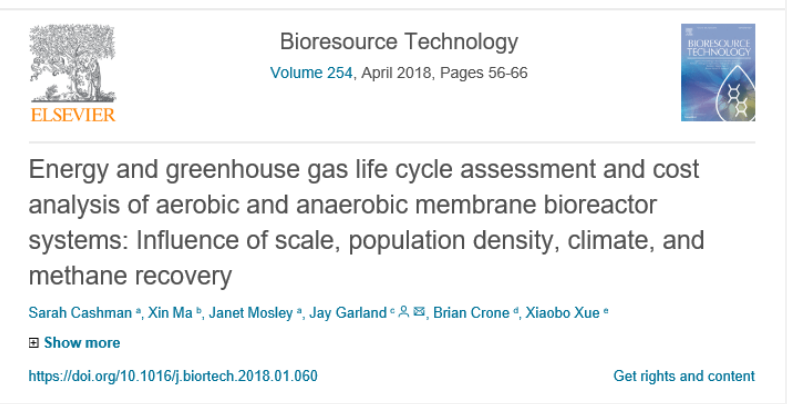
Analysis of Complete Municipal Water System

Results by Underlying Drivers



From Xue et al., 2018 (Accepted)

Onsite Non-potable Water Systems Resources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Bioresource Technology
Volume 254, April 2018, Pages 56-66

Energy and greenhouse gas life cycle assessment and cost analysis of aerobic and anaerobic membrane bioreactor systems: Influence of scale, population density, climate, and methane recovery

Sarah Cashman [a], Xin Ma [b], Janet Mosley [a], Jay Garland [c], Brian Crone [d], Xiaobo Xue [e]

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- S Cashman, X Ma, J Mosley, JL Garland, BC Crone, X Xue. Energy and greenhouse gas life cycle assessment and cost analyst of aerobic and anaerobic membrane bioreactor systems: Influence of scale, population density, climate, and methane recovery. Bioresource Technology, 2018. https://www.sciencedirect.com/science/article/pii/S0960852418300749. ORD-018382.

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- B Morelli, S Cashman, Cissy Ma, J Garland, D Bless, M Jahne. Life Cycle Assessment and Cost Analysis of Distributed Mixed Wastewater and Graywater Treatment for Water Recycling in the Context of an Urban Case Study. EPA report: EPA/600/X-18/280, 2018. *Under Clearance*.

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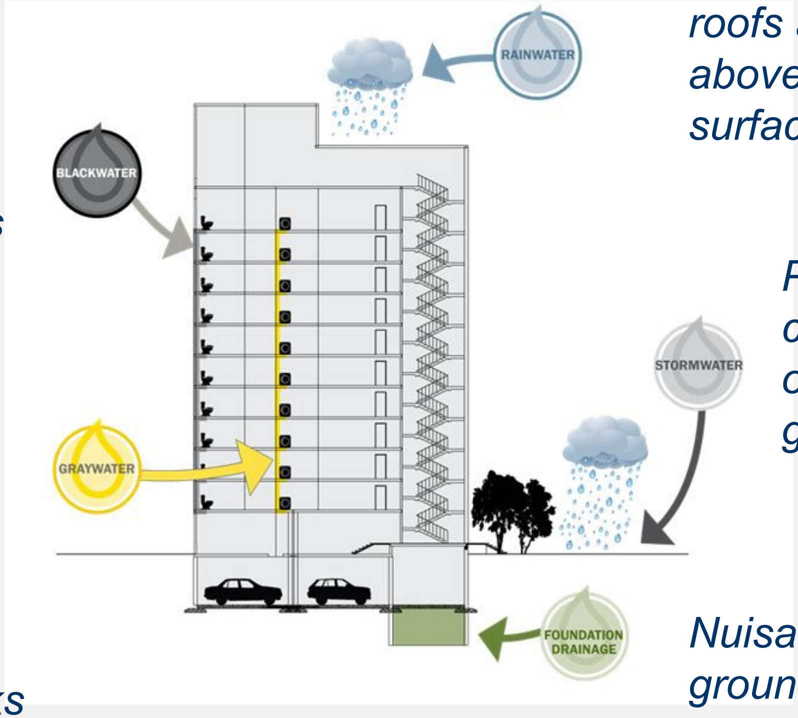
Buildings Produce Water

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

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

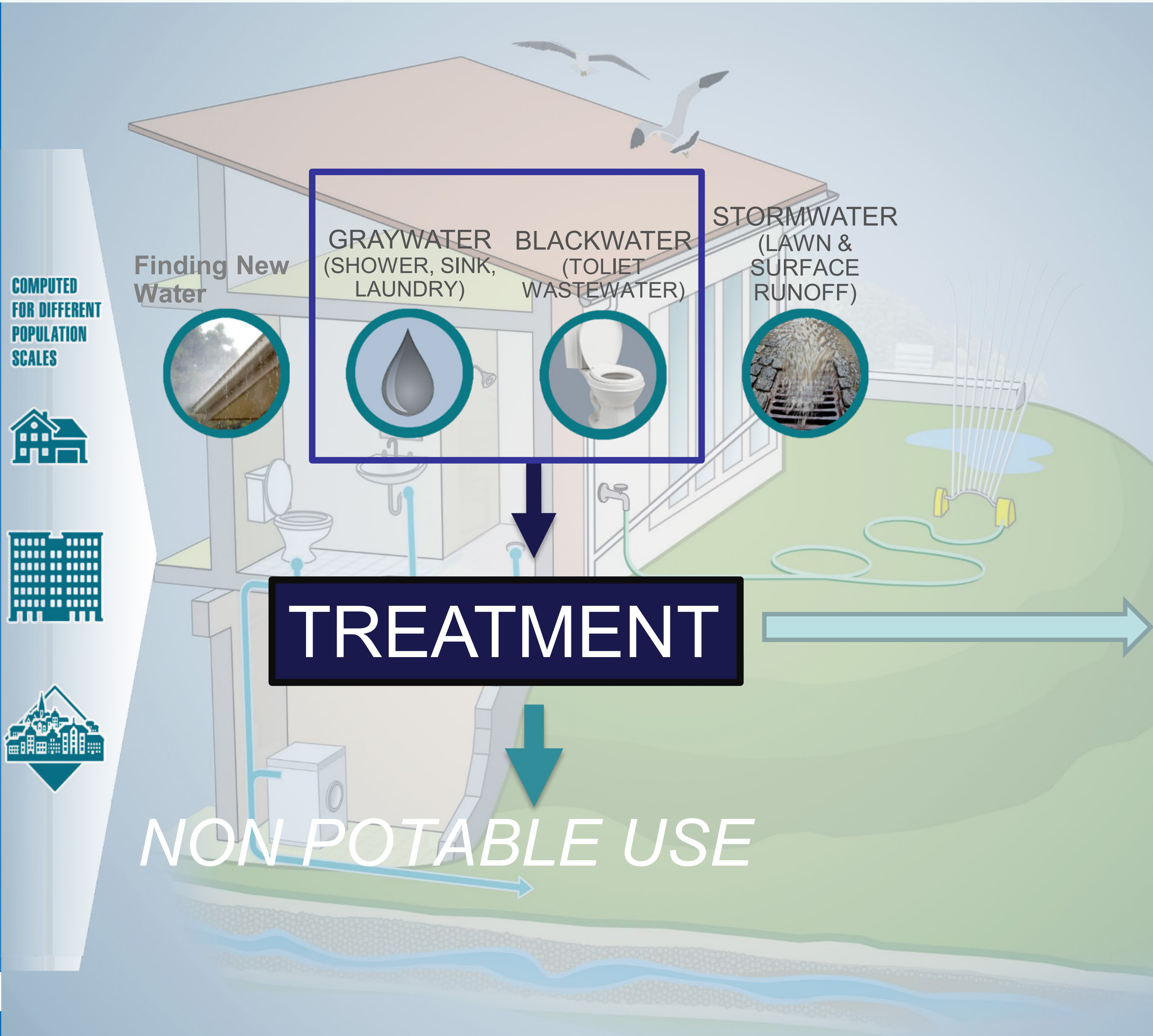


Precipitation collected from roofs and above-grade surfaces

Precipitation collected at or below grade

Nuisance groundwater from dewatering operations

FINDING NEW WATER
Alternative Water Reuse



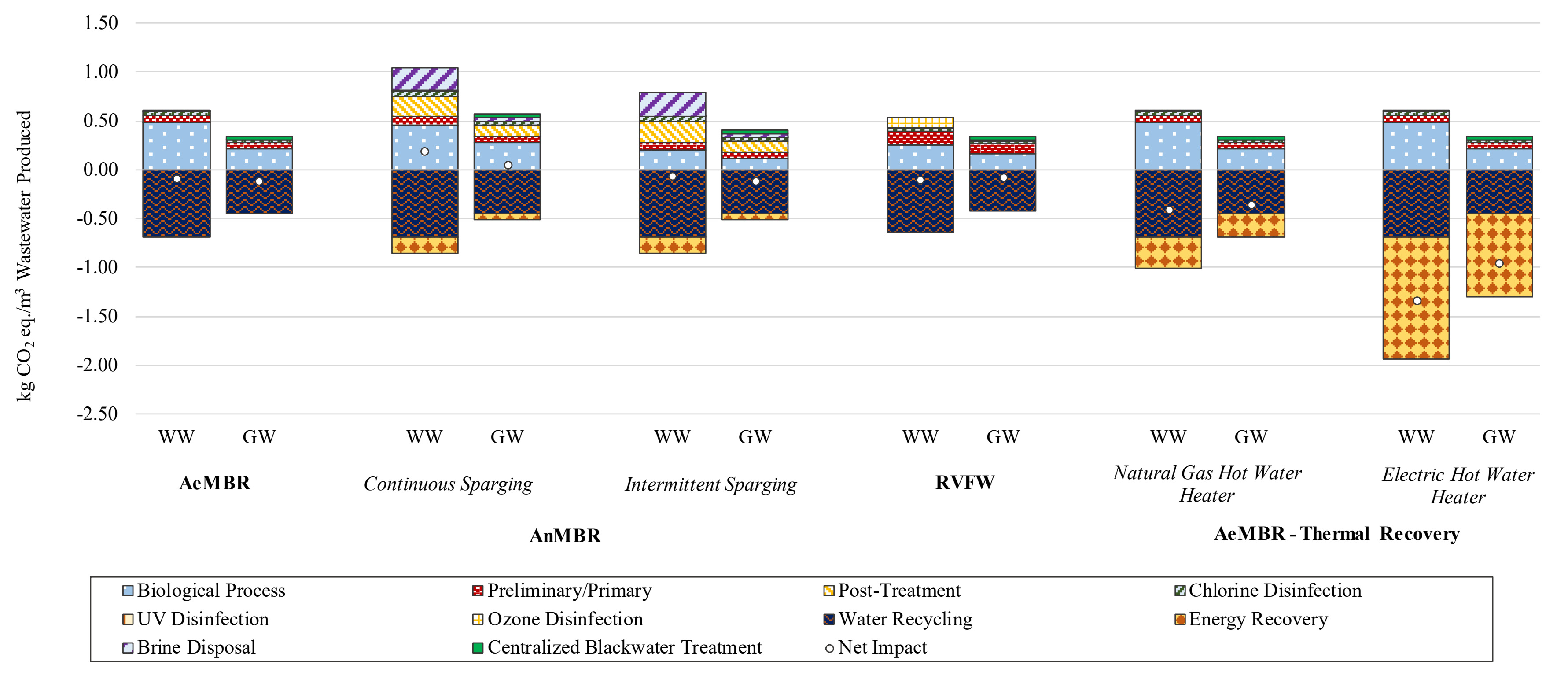
Aerobic Membrane Bioreactor (AeMBR)

Mesophilic Anaerobic MBR (AnMBR)

Psychrophilic AnMBR

Recirculating Vertical Flow Wetland

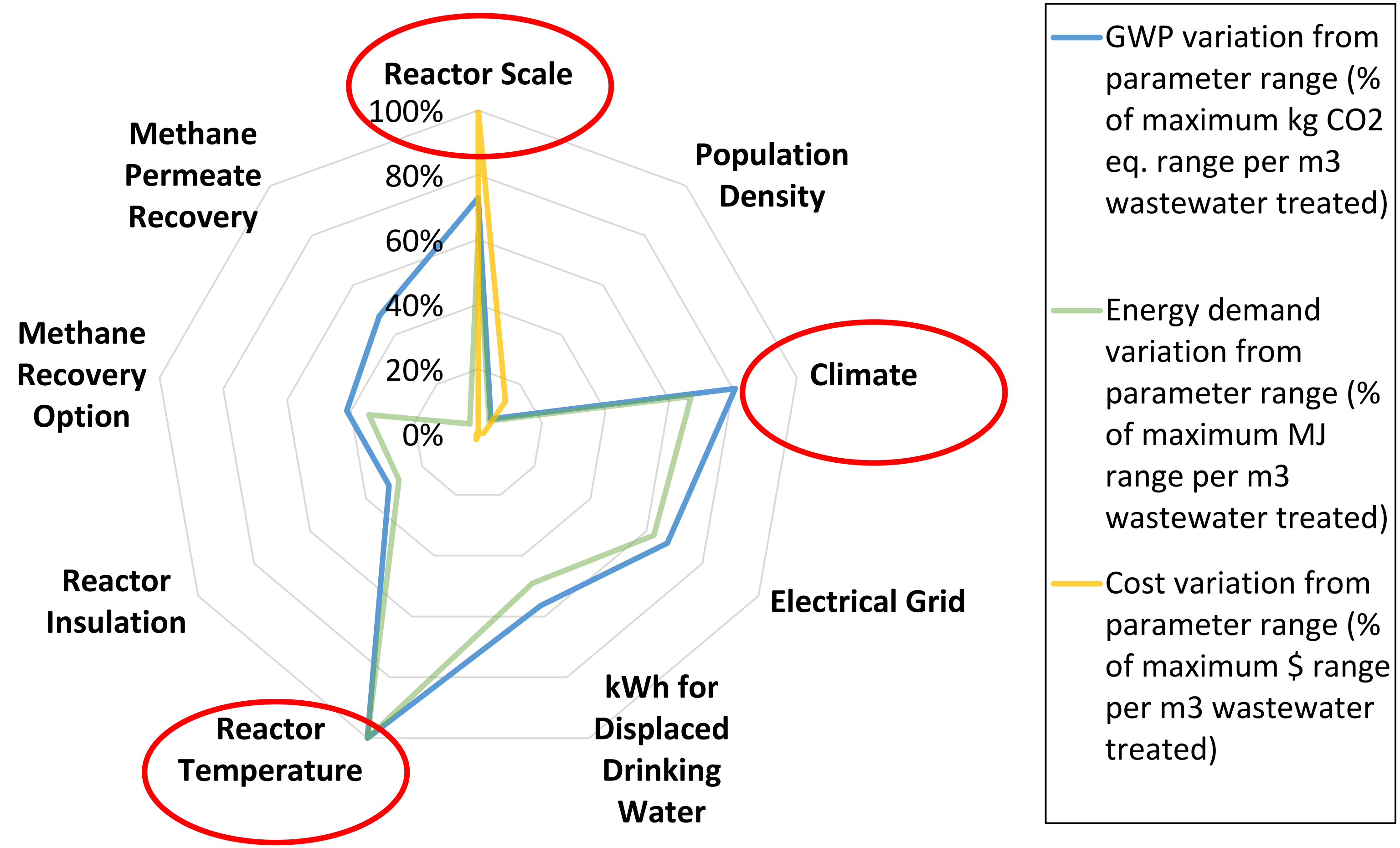
Life Cycle Impacts for Building Scale Mixed Wastewater and Graywater Treatment Technologies – Full Utilization of Treated Water (Global Warming Potential)



WW = Wastewater
GW = Graywater

From Morelli et al, 2018 (Under Clearance Review)

Example Influence of Parameters on Study Outcome: psychrophilic AnMBR



From Cashman et al. (2017)

Resource Recovery Studies

- B Morelli, S Cashman, X Ma, J Garland, D Bless, J Cashdollar. Environmental Life Cycle Assessment and Cost Analysis of Bath, NY Wastewater Treatment Plant: Potential Upgrade Implications. EPA Report EPA/600/R-17/207, 2017. https://cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryId=338074

- B Morelli, S Cashman, X Ma, J Garland, J Turgeon, L Fillmore, D Bless, M Nye. Effect of Nutrient Removal and Resource Recovery on Life Cycle Cost and Environmental Impacts of Small Scale Wastewater Resource Recovery Facility. Sustainability, 2018 (Under Review).

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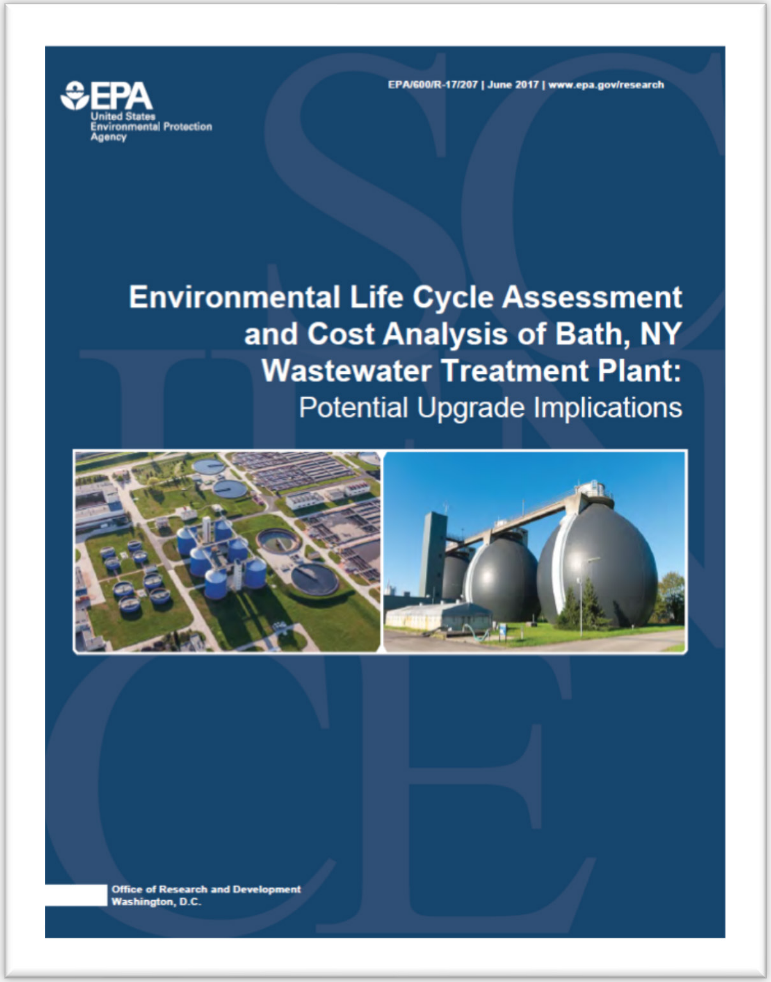
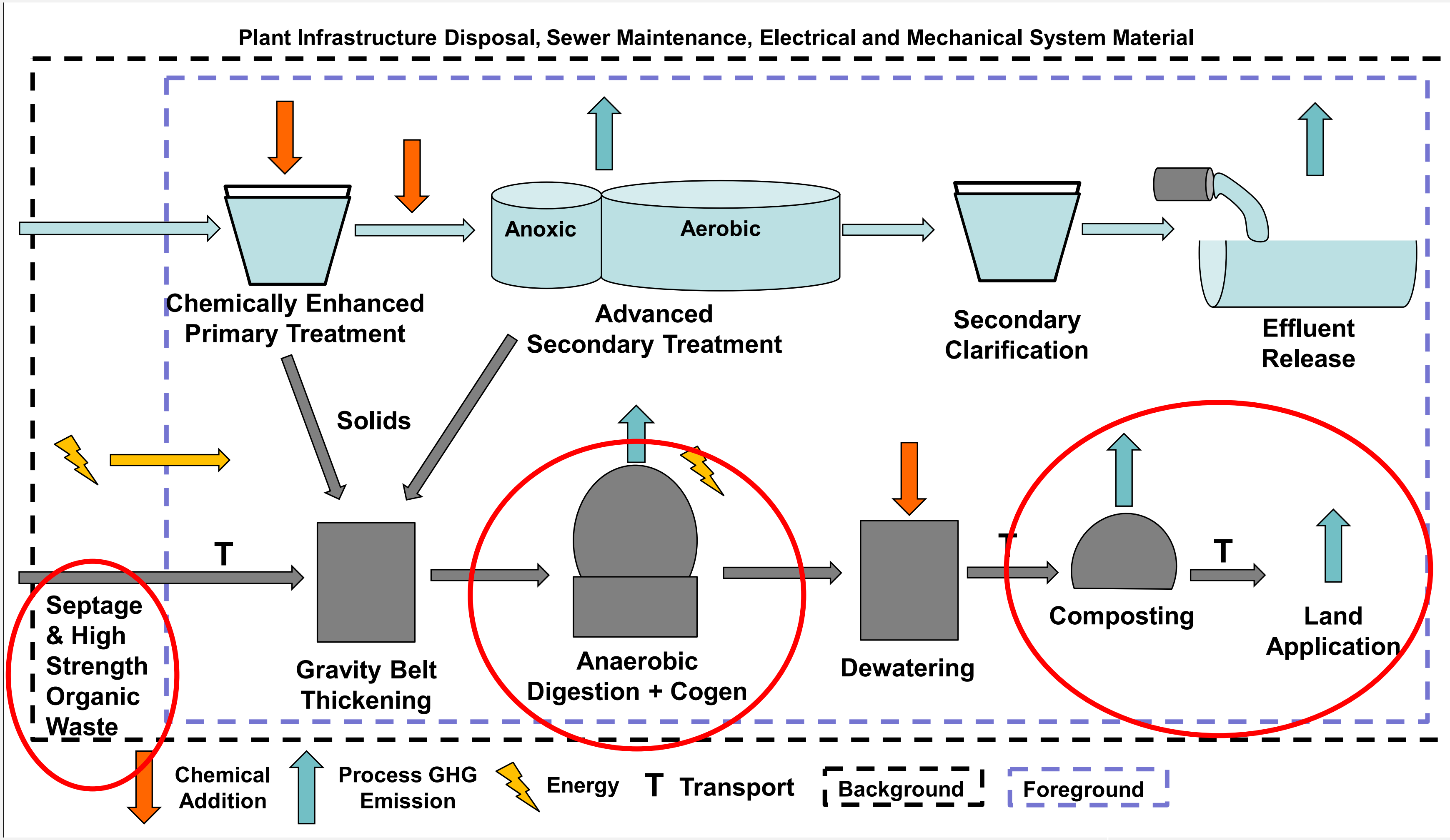
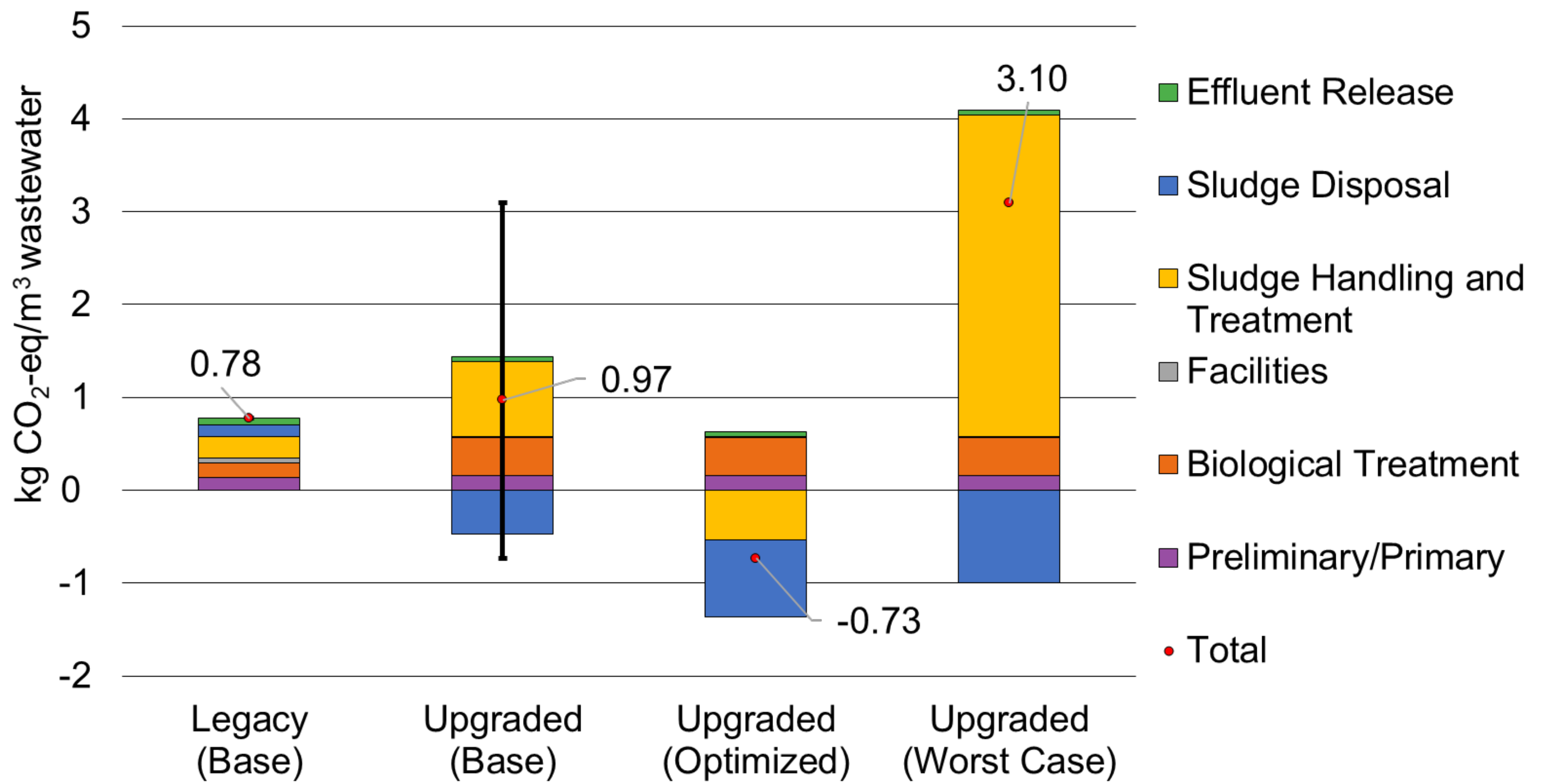


Potential Upgraded Treatment System (Bath, NY)



From Morelli et al. (2017)

Bath, NY Plant Upgrade Global Climate Change Potential



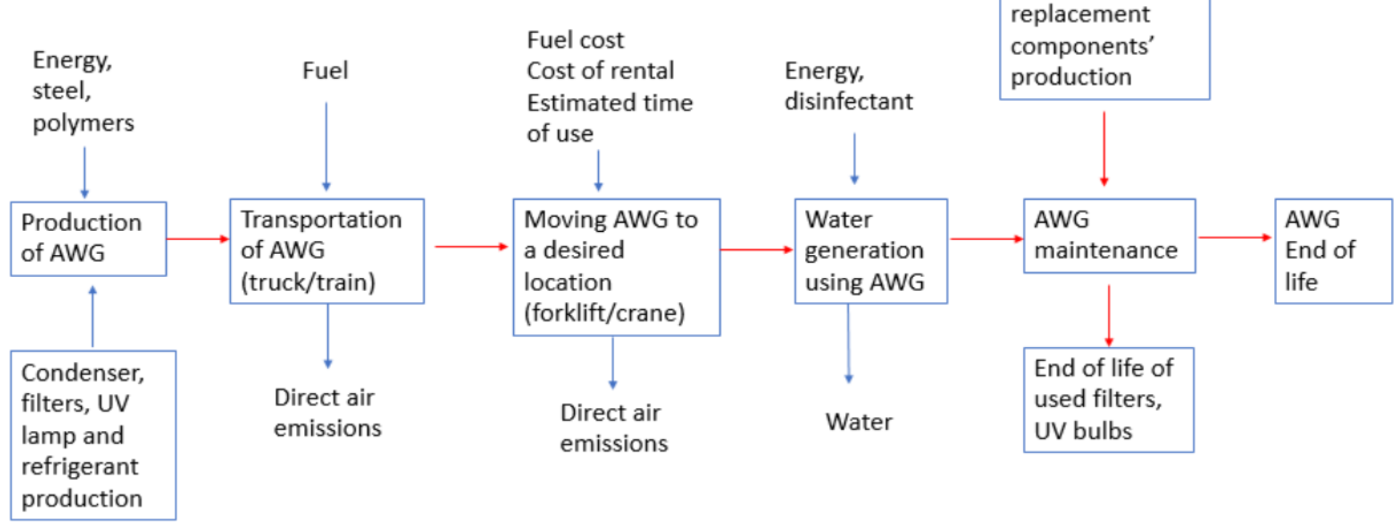
* Error bar on the Upgraded (Base) scenario reflects the full range of results across all feedstock, anaerobic digestion, and end-of-life scenarios.

From Morelli et al. (2017)

Emergency Response Potable Water Options

- Atmospheric Water Generator (AWG) in 3 scales (large scale, medium scale and home/office scale)
- Bottled Water
  - Single use 16.9 oz bottles in a 24 pack
  - Multi-use 5 gallon jug

System Boundary – AWG General



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Next Steps

- Compile a "Toolkit" inventory of transformative alternative unit processes used in resource-recovery-based water system design
- Develop Smart Water Management Evaluation Tool to compare quantitative impacts of different alternatives and make balanced decisions
- Allow dynamic generation of LCA and LCCA results through selection of key regional and technological parameters.

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  - Michael Jahne, USEPA, National Exposure Research Laboratory
  - Brian Crone, USEPA National Exposure Research Laboratory
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  - Janet Mosley, Eastern Research Group, Inc.
  - Sam Arden, Eastern Research Group, Inc.
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  - Michael Nye, USEPA, National Exposure Research Laboratory
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  - Michael Jahne, USEPA, National Exposure Research Laboratory

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