An Integrated Model of Urban Water-Wastewater-Stormwater-Energy Systems

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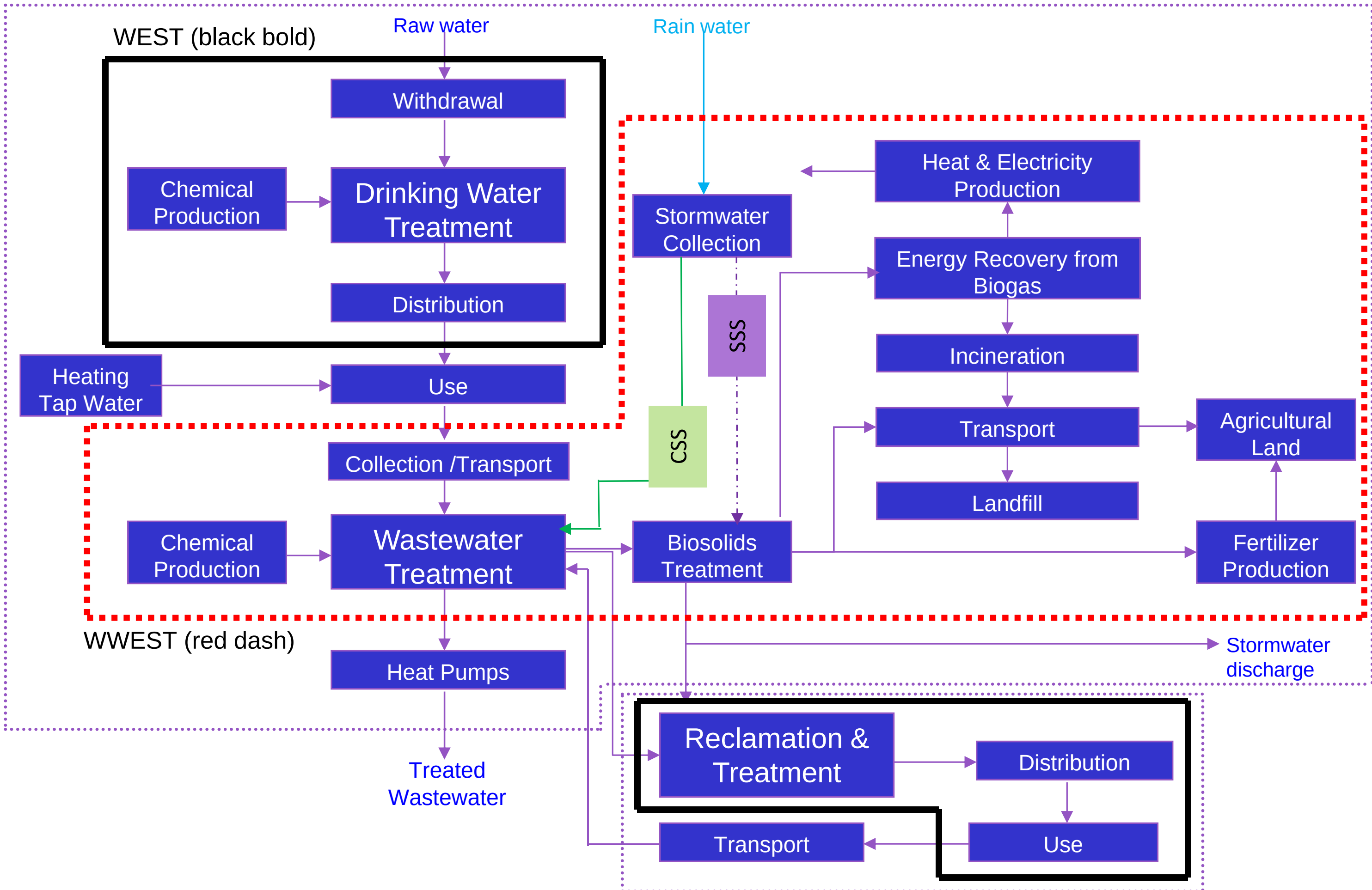
Urban Water-Wastewater-Stormwater System



CSS: Combined sewer and stormwater
SSS: Separate sewer and stormwater

Method: Life-cycle Assessment (LCA)

To help us:

Target improvements Benchmark utility performance Educate consumers Set design goals Evaluate technology performance Identify tradeoffs Prioritize investments Enable more sustainable solutions Inform planning and policy

Data Collection and Sources

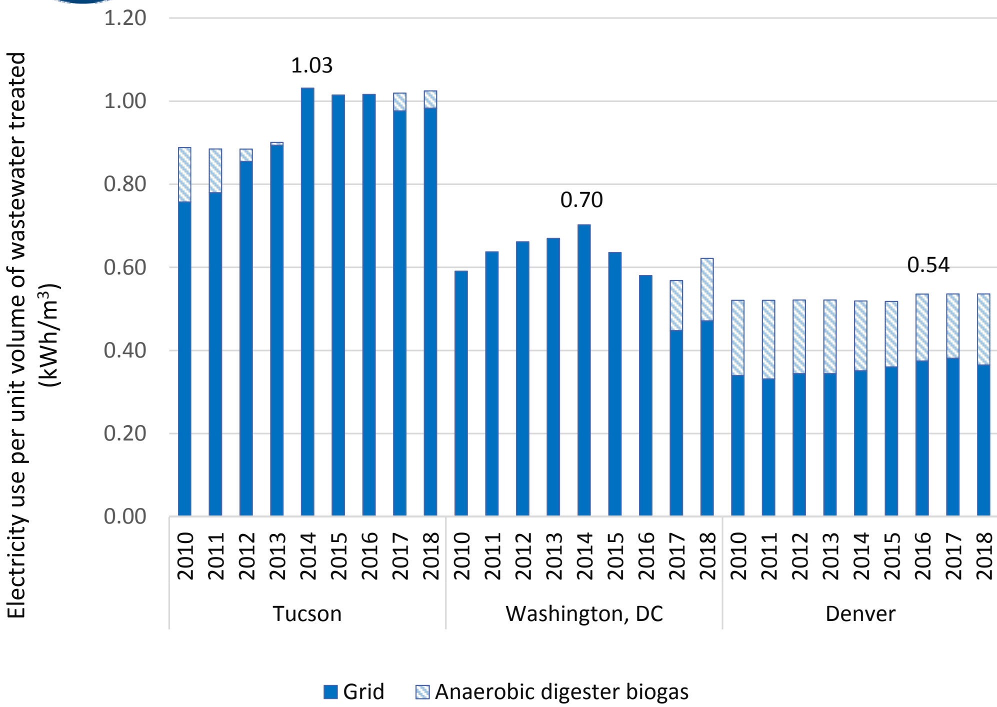
Data requirements of life-cycle assessment of urban water systems:

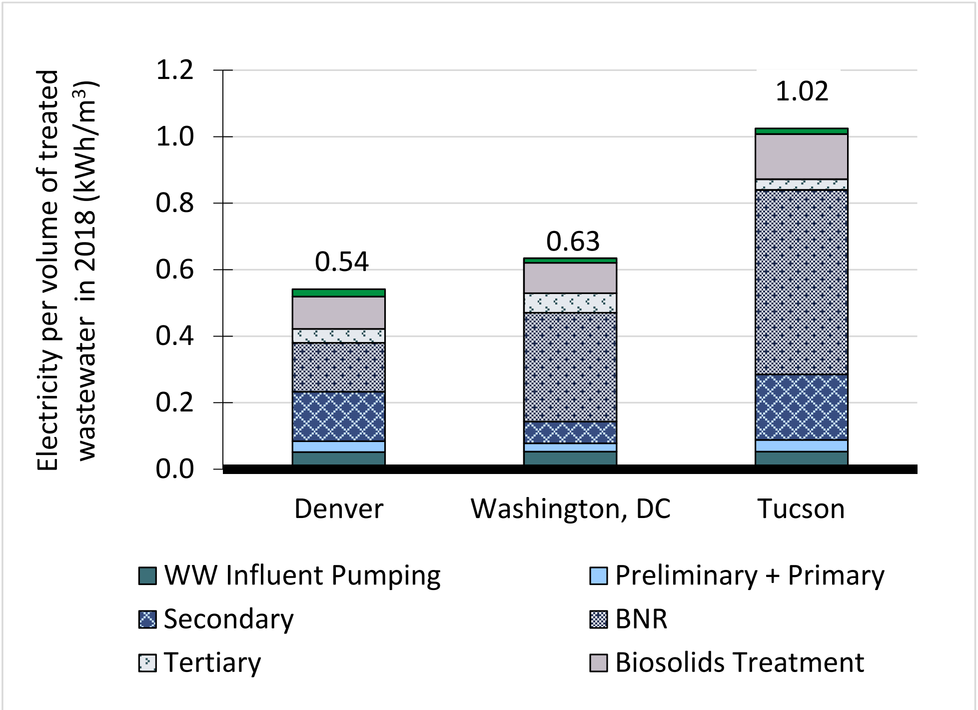
- Infrastructure construction and maintenance of water and wastewater systems.
- Energy consumption for operation of water (WT) and wastewater treatment (WWT) plants.
- Manufacturing and transportation of treatment chemicals.
- Electricity and heat generation from biogas as a result of anaerobic digestion at WWT plants.
- End-of-life options for biosolids (landfill vs. fertilizer for agriculture).
- Influent characteristics and effluent quality requirements.
- Population characteristics.
- Water consumption and wastewater generation rates.
- Water savings programs.

Case Study Applications and Results

- Analysis of urban water use and possible wastewater generation reduction in three representative U.S. cities: https://iopscience.iop.org/article/10.1088/1748-9326/ab8dd8
- Tucson (Arizona), Denver (Colorado), and Washington, DC were chosen for their distinct locations, climatic conditions, raw water sources, wastewater treatment technologies, and electric power mixes.
- We evaluated electricity consumption and greenhouse gas (GHG) emissions associated with wastewater flows from residential and commercial water use for the period 2010-2018.
- Contributions of unit wastewater treatment processes and electricity sources to the overall emissions are considered.
- We have found that the cities have seen reductions in water consumption and wastewater generation, energy demand, and emissions – despite growing populations.
- Introduction of biosolids digestion at wastewater plants has led to significant local electricity supply and reductions in GHG emissions.
- This study highlights the variability observed in water and wastewater systems and the opportunities that exist with water savings to allow for wastewater generation reduction, recovering energy from onsite biogas, and using energy-efficient wastewater treatment technologies.

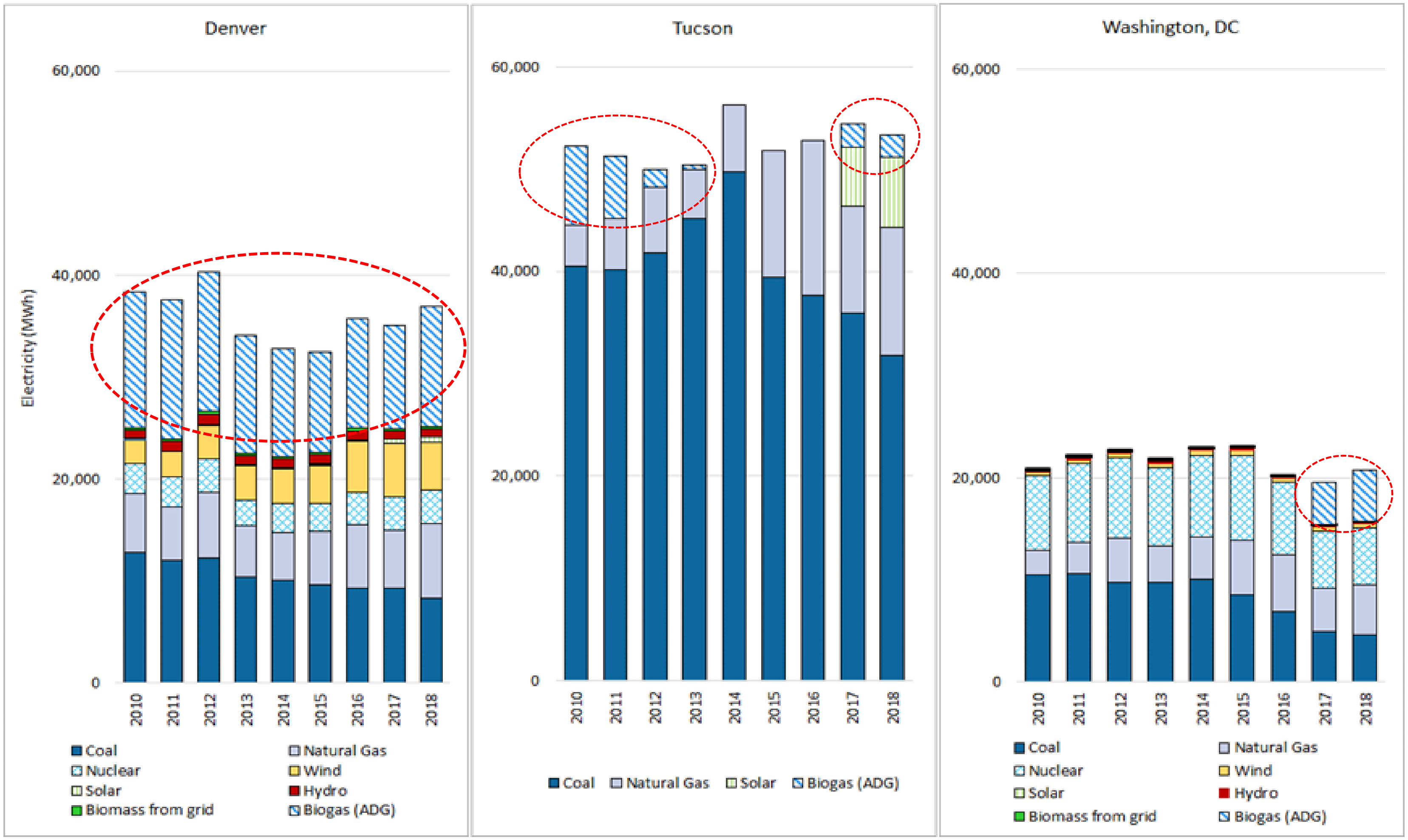
Case Study Results





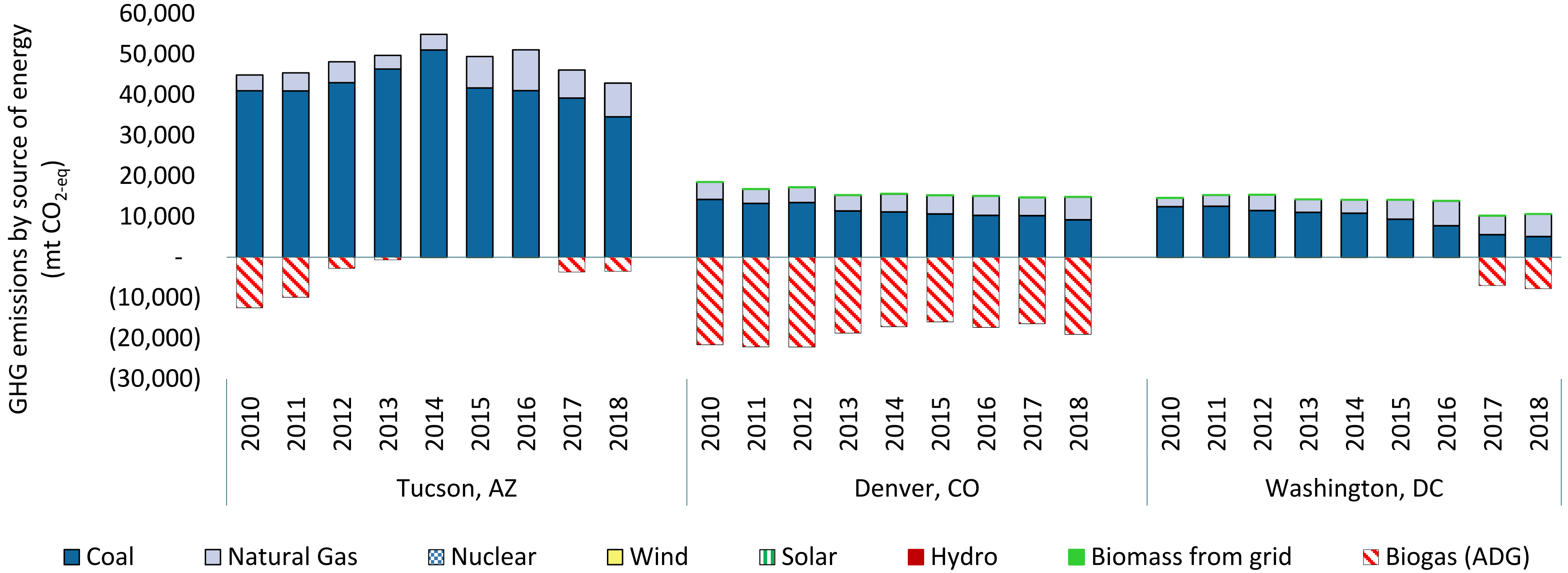
Electricity intensity of wastewater treatment plants from 2010 to 2018 showing grid-sourced and anaerobic digester gas-derived electricity

Electricity demand per m^3 of wastewater in 2018



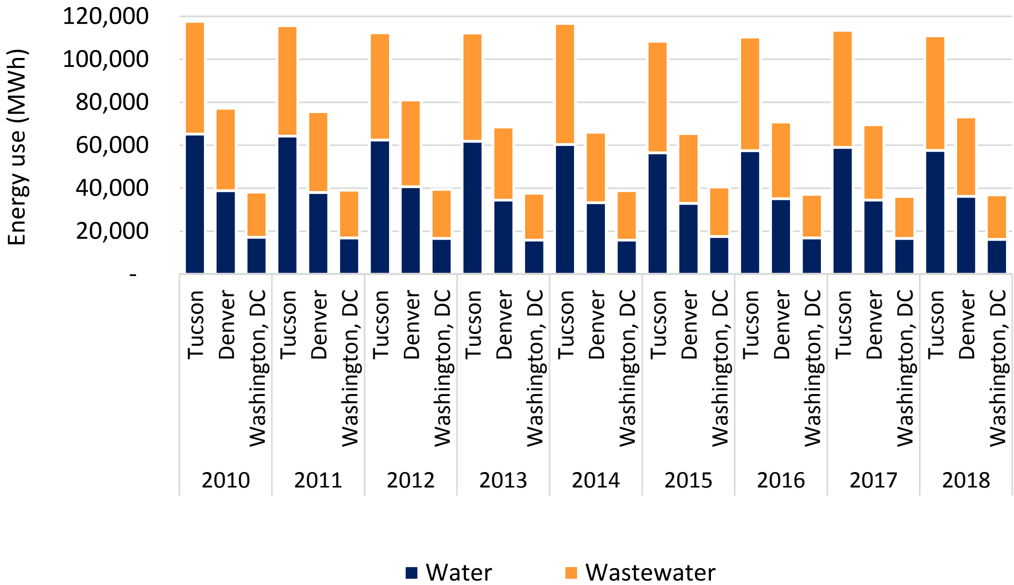
Electricity consumption of wastewater treatment plants disaggregated by source of electricity.
Biogas (ADG: anaerobic digester gas) contributions are circled.

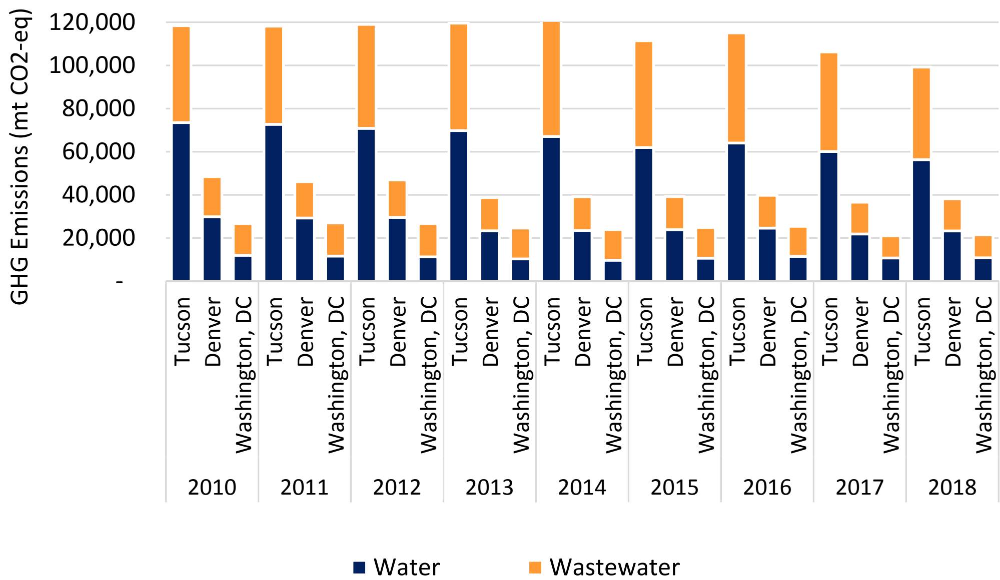
GHG Emissions by Source of Electricity



- In Denver and Washington, DC, the electricity generated using anaerobic digester gas (biogas) replaces the electricity grid mix comprised mostly of coal and natural gas.
- GHG emissions could be further lowered with increased onsite biogas utilization for electricity, as well as renewable sources.

Energy Use and GHG Emissions of Urban Water Systems in Case-Study Cities





- There is significant variability between the GHG emissions associated with water consumption versus wastewater treatment processes from one city to another. Local and regional analyses are necessary.
- An electricity grid mix with predominantly fossil fuel sources contributes to considerably higher GHG emissions profiles (e.g., in Tucson).
- Wastewater treatment plants that use anaerobic digestion can support onsite combined heat and power generation and lower their GHG emissions, thus helping transform wastewater treatment into a resource-recovery system.

Findings and Future Research Direction

- Water and wastewater systems and stormwater management have major impact on energy use and GHG emissions in the urban water cycle.
- Understanding the energy use, energy generation potential, and emissions reduction potential of both water and wastewater systems is important for future decision-making processes.
- Significant technological, energy, and emissions differences have been observed between cities.
- Future research goal: Estimate the use of energy and related GHG emissions for the urban water cycle at the U.S. national level by taking into consideration variability of treatment technologies and climatic differences at regional/city scale.

Acknowledgments:

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