Decentralized Water Infrastructure for Growing Urban Neighborhoods: Environmental, Social, and Financial Implications

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Abstract

• Purpose
  • Evaluate financial, environmental, and social impacts of decentralized water technologies (on-site/shared systems) based on multiple neighborhood growth scenarios

• Study Area
  • Bankhead: low-income neighborhood where water affordability is a critical issue

• Methods
  • System dynamics incorporating land-use dynamics, fixture retrofitting, water demand projection, and impacts of decentralized water technologies

• Results
  • Decentralized technologies have potential to reduce potable water demand up to 44%
  • Shared rainwater and graywater systems can be sustainable and economically viable solutions to meet increasing water demand in a growing urban neighborhood
Sustainable Urban Water Management (SUWM)

• Principles of SUWM
  • Incorporate a number of alternative water sources
  • Distribute decentralized treatment plants across urban areas
  • Integrate supply, sewer disposal, and stormwater as components of a system
  • Consider multiple sustainability indicators of system performance

Conventional urban water cycle
(“take, make, waste approach”)

Sustainable urban water cycle
Rainwater & wastewater reuse
Decentralized Urban Water Technologies

• Types of Technology
  • Rainwater harvesting / Graywater reuse / Wastewater recycling

• Scales
  • On-site / Semi-centralized (Shared)

• Benefits
  • Increased efficiency of resource use and reduced ecological footprint
    • 30-60 % decrease in water demand; reduced water treatment and transfer costs
  • Enhanced water security through source diversification and multiscale networks
    • Lower capital intensity and shorter construction time; rapid respond to external shocks
  • Better opportunities to adjust the water system to local conditions
    • Low-tech, low-cost, and flexible service boundary
Study Area

• Challenges in Atlanta Water Management
  • Growing population and urban sprawl
    • 2.5 million more residents within the next 25 years (Atlanta Regional Commission)
  • Lack in diversity of water supply options
    • A single water source, Lake Lanier, supplies over 70% of metropolitan water demand
  • Nation’s highest combined water price
    • $325.52 estimated monthly water bill for a typical four-person family
  • Tristate water wars
    • Inter-state dispute concerning the use of two shared river basins (Alabama & Florida)
  • A century-old infrastructure system
Study Area

- Bankhead Neighborhood
  - Low income & low density neighborhood
  - Old housing stock
  - Abandoned homes & vacant parcels

<table>
<thead>
<tr>
<th></th>
<th>Bankhead</th>
<th>Atlanta</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>6,873</td>
<td>455,004</td>
</tr>
<tr>
<td>% Black</td>
<td>80.7%</td>
<td>52.6%</td>
</tr>
<tr>
<td>Unemployment rate</td>
<td>20.1%</td>
<td>10.4%</td>
</tr>
<tr>
<td>Median HH income ($)</td>
<td>33,433</td>
<td>60,730</td>
</tr>
<tr>
<td>% Home ownership</td>
<td>26.0%</td>
<td>42.6%</td>
</tr>
<tr>
<td>Vacancy rate</td>
<td>34.2%</td>
<td>18.1%</td>
</tr>
</tbody>
</table>

Data: American Community Survey 5-year Estimates (2012-2016)
Assumption:
New plumbing code that requires all newly constructed residential & commercial units to be equipped with water-conserving technologies
Testing Scenarios

<table>
<thead>
<tr>
<th>Growth scenarios</th>
<th>Types of technology</th>
<th>Implementation scales</th>
</tr>
</thead>
<tbody>
<tr>
<td>S#1: Slow growth</td>
<td>Rainwater system (Outdoor-use only)</td>
<td>Individual (on-site)</td>
</tr>
<tr>
<td>S#2: Projected growth</td>
<td>Rainwater system (Outdoor + Indoor use)</td>
<td></td>
</tr>
<tr>
<td>S#3: Rapid growth</td>
<td>Graywater system</td>
<td>Decentralized (shared)</td>
</tr>
<tr>
<td></td>
<td>Combined system</td>
<td></td>
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</table>

- **Neighborhood Growth Scenarios**

<table>
<thead>
<tr>
<th>Growth scenarios</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>S#1: Slow growth</td>
<td>Land-use patterns and the vacancy rate will remain unchanged</td>
</tr>
<tr>
<td>S#2: Projected growth</td>
<td>The vacancy rate will decrease from 34.15% to 4.3%</td>
</tr>
<tr>
<td>S#3: Rapid growth</td>
<td>Benchmarking to another TOD neighborhood (Lindbergh)</td>
</tr>
</tbody>
</table>
Results: Population & Employment Change

Projected Population

Projected Employment

Slow growth  Projected growth  Rapid growth

Slow growth  Projected growth  Rapid growth

+11.3%  +61.7%  +141.8%

+12.2%  +63.1%  +358.4%
Results: Water Consumption Projection

Estimated Monthly Water Demand

- Slow growth
- Projected growth
- Rapid growth

-7.6% (Annual: -0.15%)
+34.3% (Annual: 0.69%)
+153.5% (Annual: 3.07%)
Results: Effect of Fixture Retrofitting (Water consumption per unit)

Monthly average water consumption in CCF (1CCF = 748 gallon)

- Single family: -19.5%, 6.06 CCF in 2018, 4.97 CCF in 2043, 4.88 CCF in 2068
- Multifamily: -20.7%, 4.42 CCF in 2018, 3.55 CCF in 2043, 3.50 CCF in 2068
- Commercial: -9.4%, 21.73 CCF in 2018, 19.86 CCF in 2043, 19.68 CCF in 2068
Results: Effect of Decentralized Technologies (Reduced water demand)

- Potable water reduction by technologies (Projected growth, on-site)
Results: Effect of Decentralized Technologies (Reduced water demand)

- Comparison between on-site and shared infrastructures (Projected growth, Combined system (RW+GW))
Results: Effect of Decentralized Technologies (Reduced wastewater)

- % wastewater reduction (Projected growth, Graywater (on-site))
Results: Effect of Decentralized Technologies (Reduced water bill)

• Estimated annual water bill (Projected growth, on-site technologies)

![Annual water bill (US$, 2018)](chart)

Water affordability criteria
(3% of household median income)
Results: Financial Implications of Decentralized Technologies

- Cost-Benefit analysis results for on-site technologies

<table>
<thead>
<tr>
<th>Technology</th>
<th>Single-family unit</th>
<th>Multifamily unit</th>
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<tbody>
<tr>
<td></td>
<td>NPV (US$)</td>
<td>BC-ratio</td>
</tr>
<tr>
<td>Rainwater (outdoor)</td>
<td>-327</td>
<td>0.93</td>
</tr>
<tr>
<td>Rainwater (indoor)</td>
<td>-1,156</td>
<td>0.87</td>
</tr>
<tr>
<td>Graywater</td>
<td>-2,347</td>
<td>0.77</td>
</tr>
<tr>
<td>Combined</td>
<td>-5,900</td>
<td>0.57</td>
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</tbody>
</table>
Results: Fiscal Impacts of Decentralized Technologies

- Annual revenue from potable and wastewater bill (Projected growth)
Results: Fiscal Impacts of Decentralized Technologies

- Annual revenue from potable and wastewater bill (Rapid growth)

![Graph showing estimated total water bill and its components from 2018 to 2068]
Conclusion

- Decentralized water infrastructures are an effective solution to sustainable water management for growing urban neighborhoods.
  - Ecological benefits
    - Reduce 16.6 - 47.2% potable water consumption
    - Reduce 31.1 – 45.8% wastewater production
  - Social benefits
    - Greater water accessibility for households and businesses in low-income neighborhoods

- On-site water-conserving technologies may increase fiscal pressure of city’s water department because of reduced service revenues.
  - For a growing city, increased water demand offsets the reduction in per capita water bill
  - Shared infrastructure is a better solution for a city in terms of effectiveness, efficiency, and fiscal control