United States Environmental Protection Agency

Environmental Accounting for the Urban Water System: Past, Present and Future

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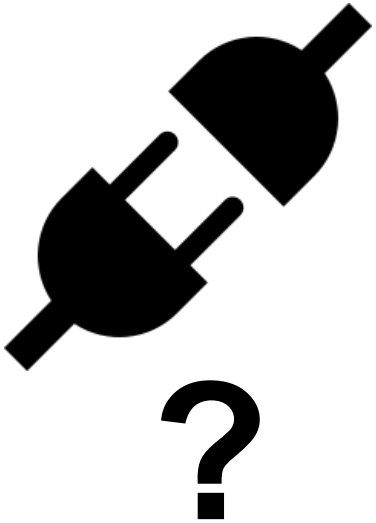
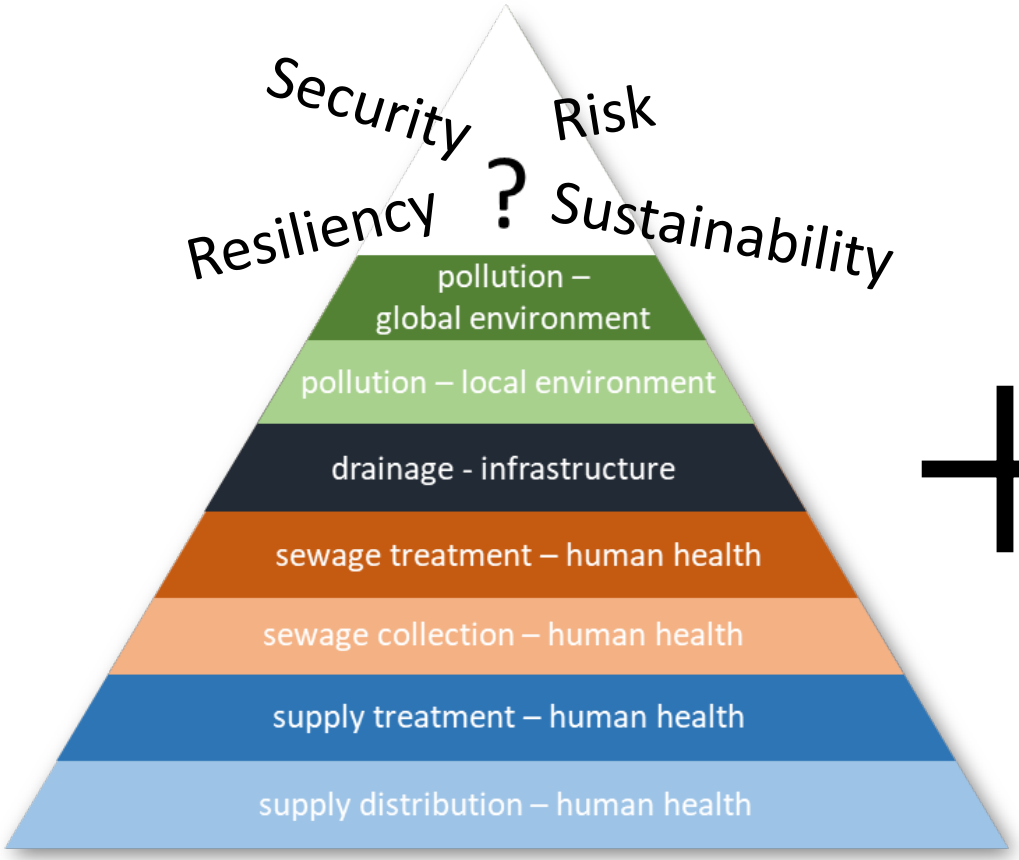
Introduction

- Societies develop services to meet collective needs – problems beget solutions
- Solutions come with costs, which are often externalized in time or space
- At the societal level, the expansion of services (solutions) results in system complexification, which requires additional resources



https://lunchbuddiesplus.files.wordpress.com/2013/01/what-can-i-do.jpg
https://pixabay.com/en/idea-light-bulb-lit-bright-lights-1651681/

Needs and costs – the urban water system



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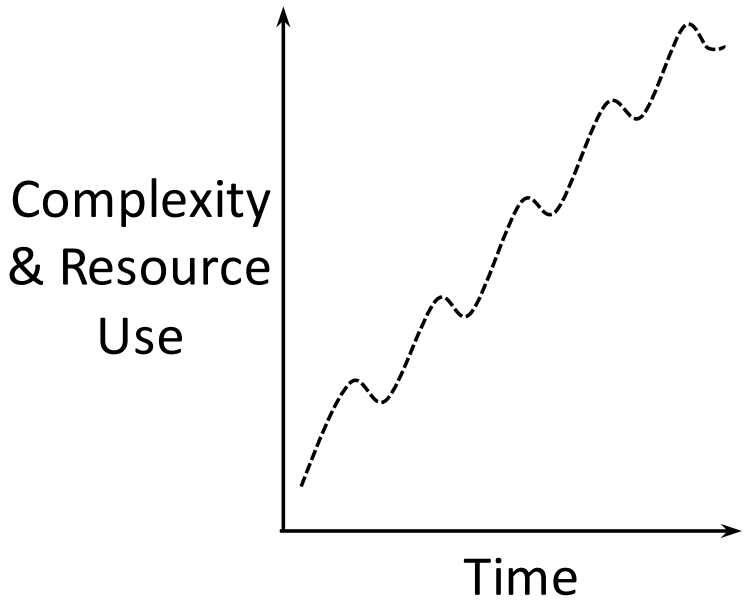
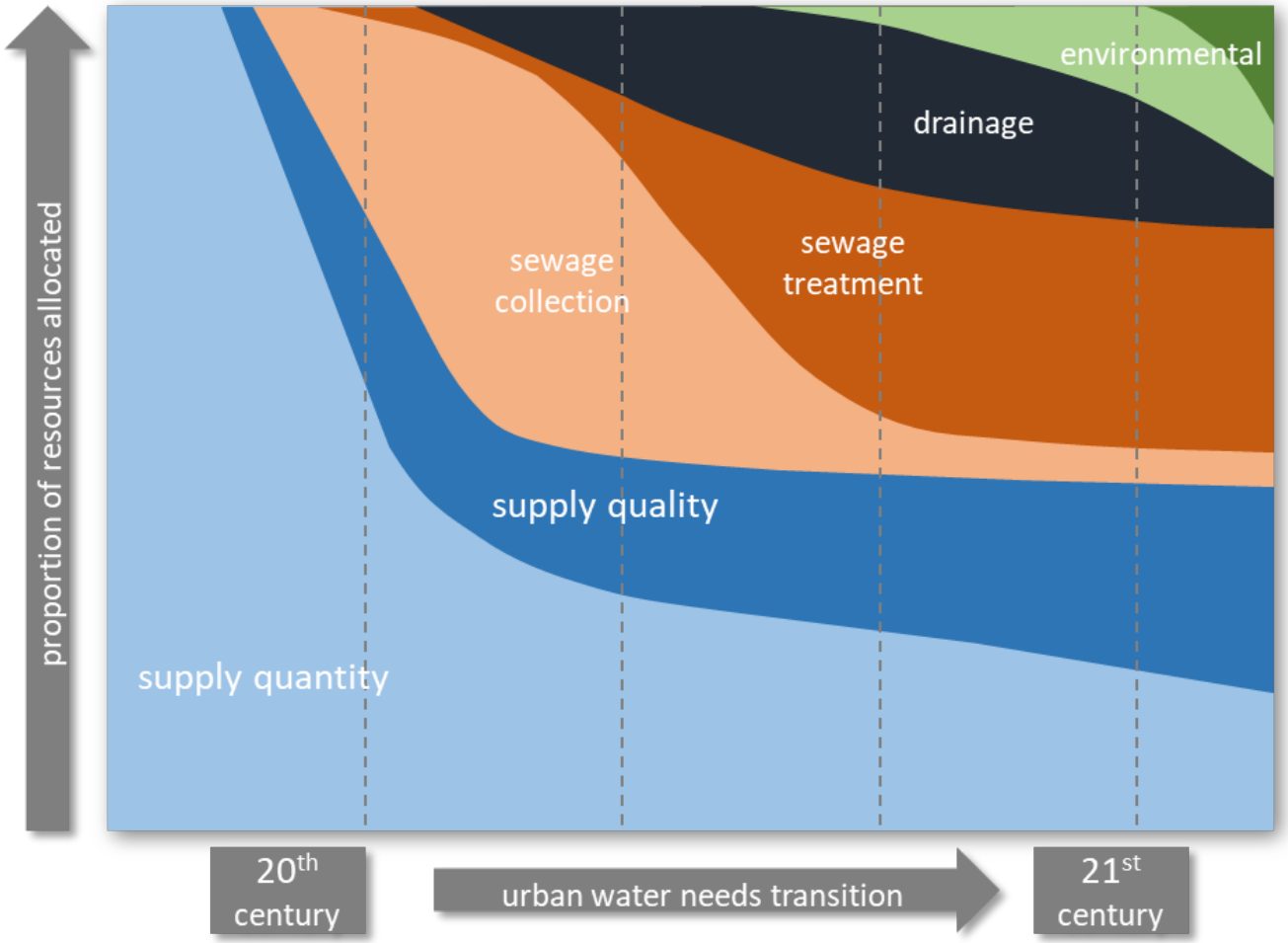
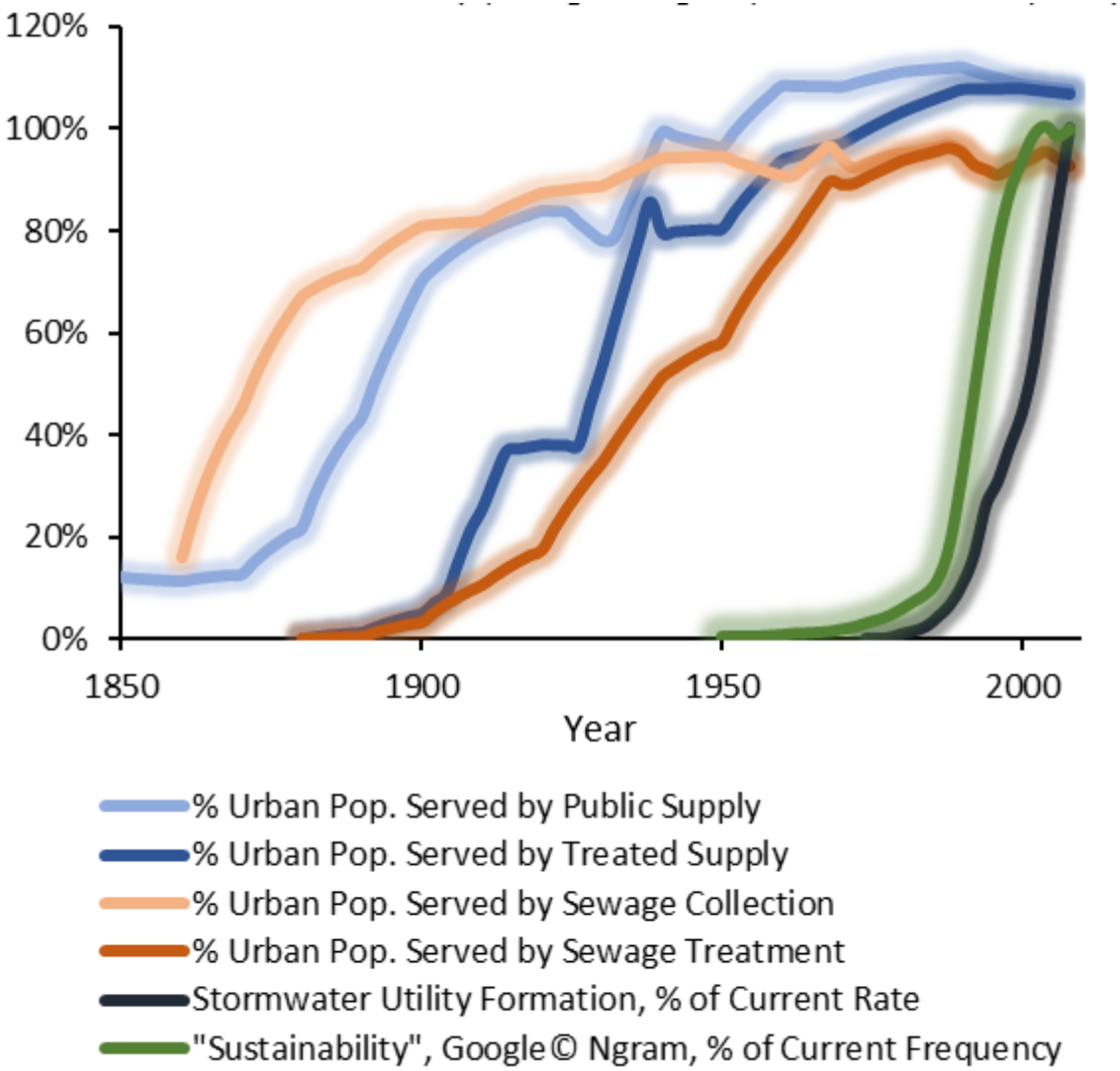


Expected urban water expenditures through time



Actual urban water expenditures through time



Transition of urban water services in the US, normalized to US urban population (supply and sanitation) or 2008 value (stormwater utility formation and Google © Ngram)

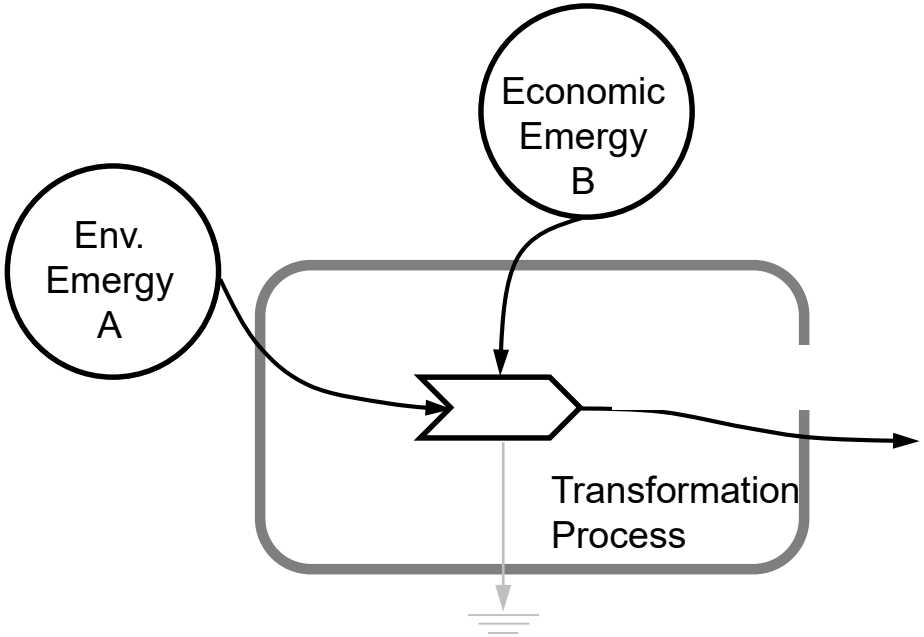
Resource cost quantification

Emergy – the available energy of one form that is used up in transformations directly and indirectly to make a product of service

$$Em = \sum_{i=1}^{i=n} UEV_i \, x_i$$

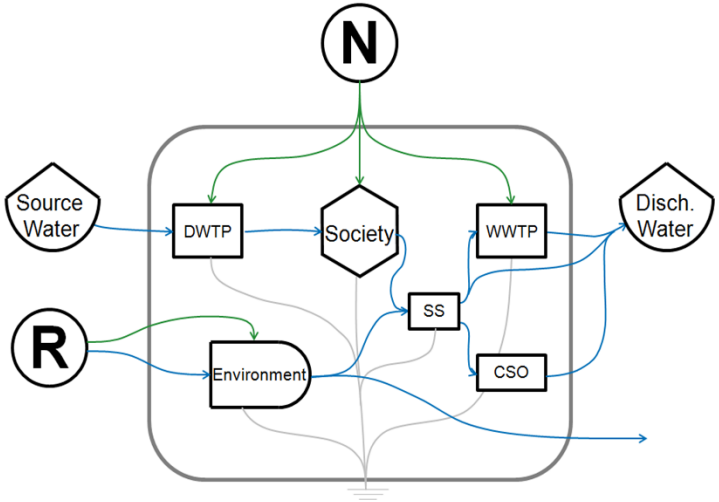
where:

Em = Emergy (solar emjoule, or sej)
UEV = Unit Emergy Value (sej/unit)
x = unit of flow (J, g, $, etc.)



Cincinnati urban water infrastructure - *Present*

Arden et al., *pending submission*. Resource Use of an Urban Water System: An Emergy Accounting Approach. *Water Resources Research*.



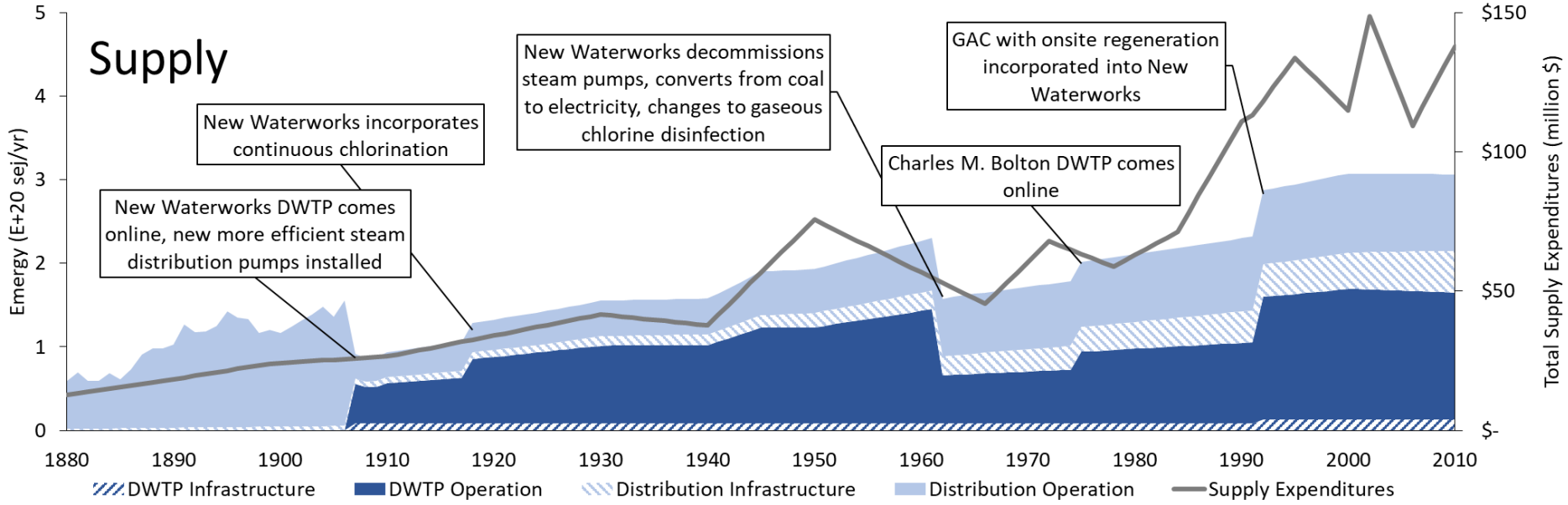
Cincinnati urban water infrastructure - *Present*

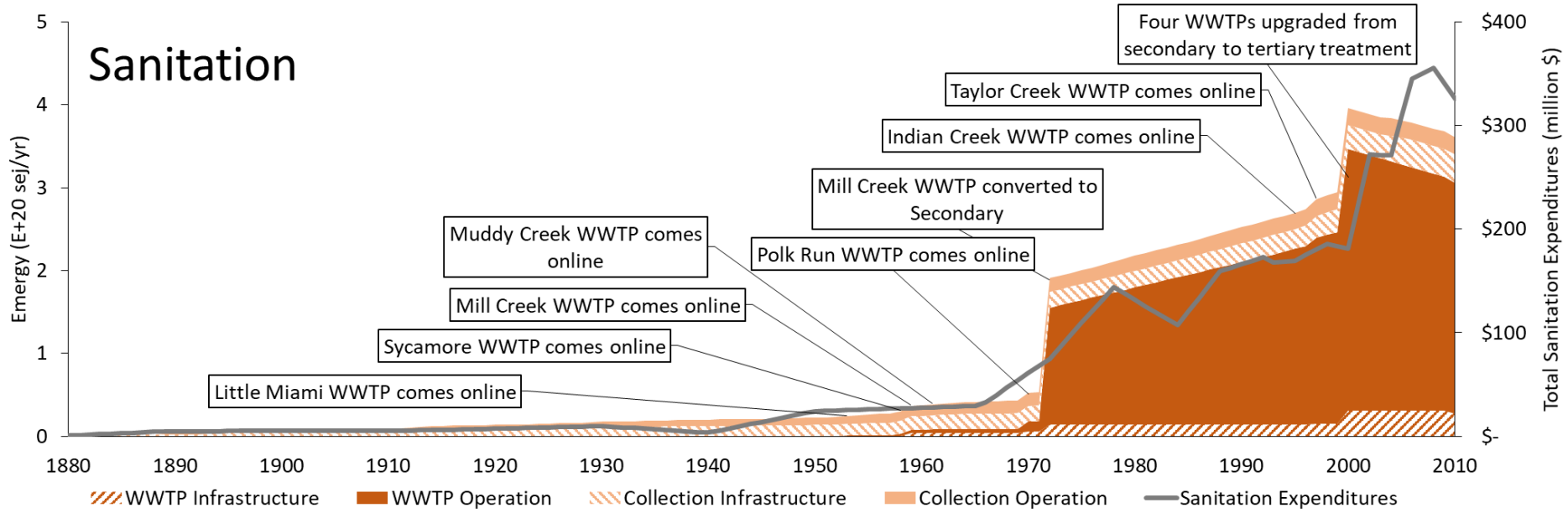
- Functional unit:
  - Drinking water: m^3 finished water delivered to consumer
  - Wastewater: m^3 of wastewater treated
- Unit processes based on data received from project partners

Parameter	unit	GCWW DWTP	MSDGC WWTP
Year of Inventory		2011	2011
Year Plant Built		1906	1959
Annual Volume Treated	m^3	123,560,247	157,615,342
Distribution/Collection Network Piping	km	5,045	2,731
Geographic Area Served	km^2	--	344
Number of People Served	ppl.	724,000	518,000
Assumed Building, Tank and Pipe Lifetime	yr	100	100
Assumed Pump and Motor Lifetime	yr	25	25

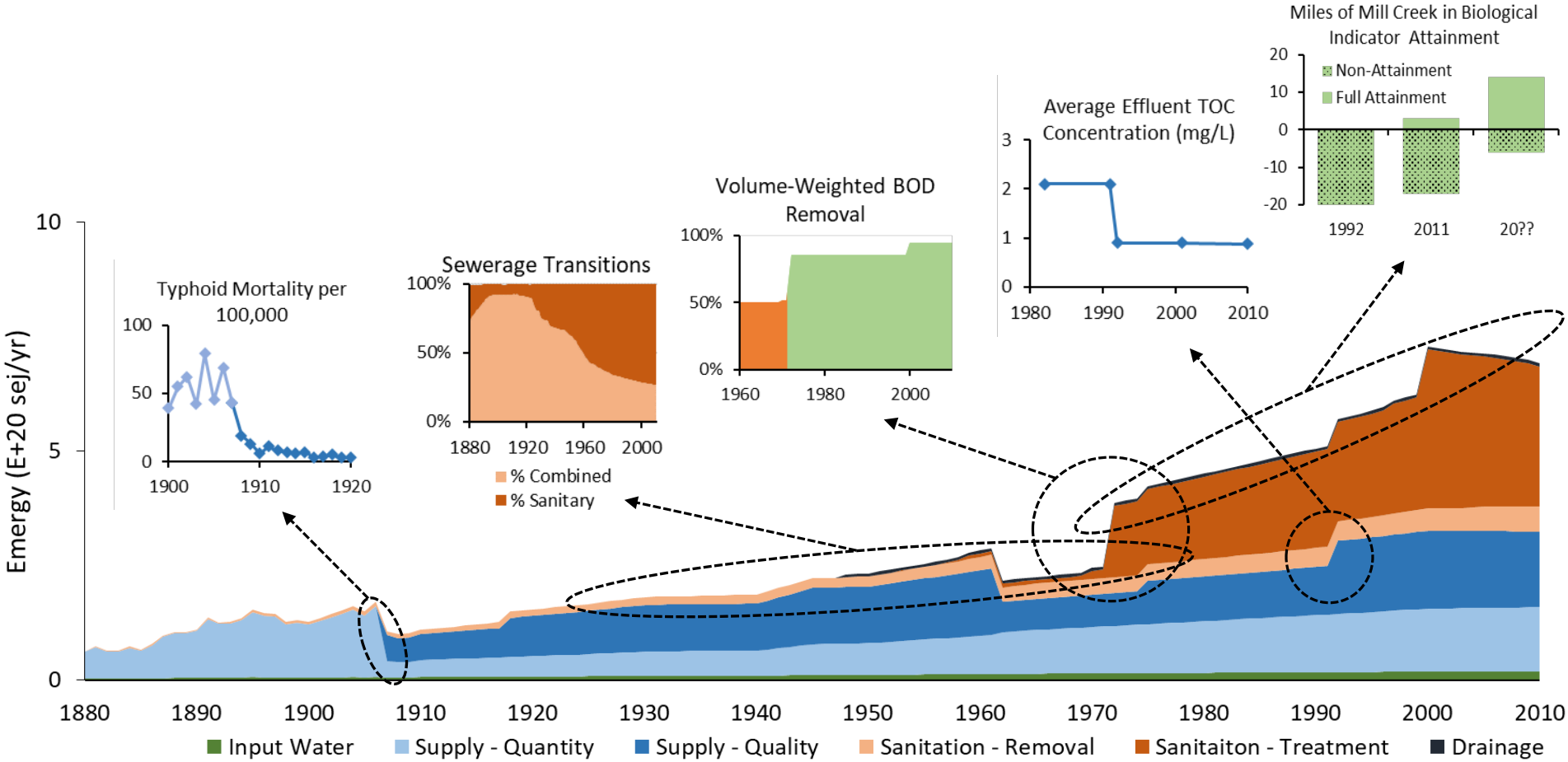
Cincinnati urban water infrastructure - *Past*

- Historical Process Inventories
  - Sources: City annual reports, academic theses, semi-regular government inventory documents, books, utilities correspondence
  - Distribution System (1866-present – pipe material, size, length)
  - Drinking Water Treatment Plants (first 1909, second 1965, continual upgrades)
  - Collection System (1865-present – pipe material, size, length)
  - Wastewater Treatment Plants (seven total, first 1957, 6 more online through present, continual upgrades)
- Inventories compiled, consistent UEV library used through time
- Economic costs adjusted to 2015 dollars

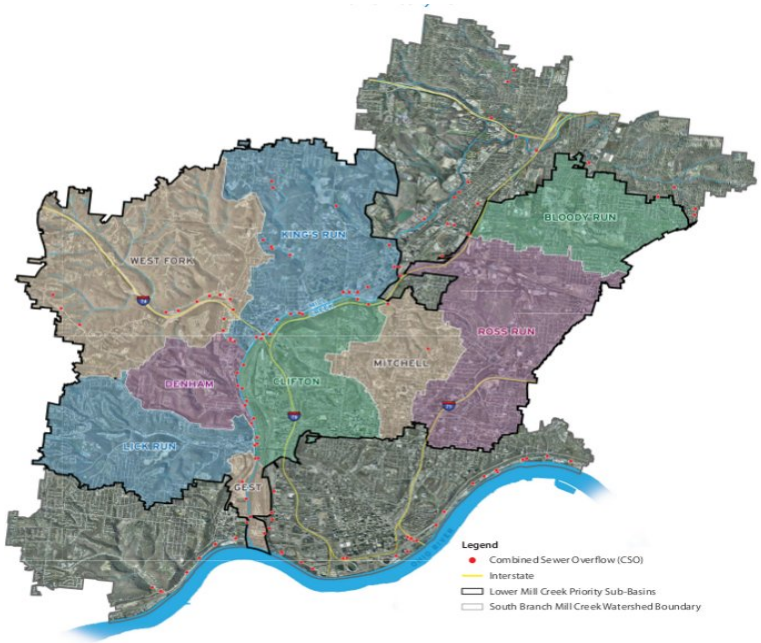

Supply
New Waterworks DWTP comes online, new more efficient steam distribution pumps installed
New Waterworks incorporates continuous chlorination
New Waterworks decommissions steam pumps, converts from coal to electricity, changes to gaseous chlorine disinfection
Charles M. Bolton DWTP comes online
GAC with onsite regeneration incorporated into New Waterworks
Emergy (E+20 sej/yr)
Total Supply Expenditures (million $)
0
1
2
3
4
5
$-
$50
$100
$150
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
DWTP Infrastructure
DWTP Operation
Distribution Infrastructure
Distribution Operation
Supply Expenditures

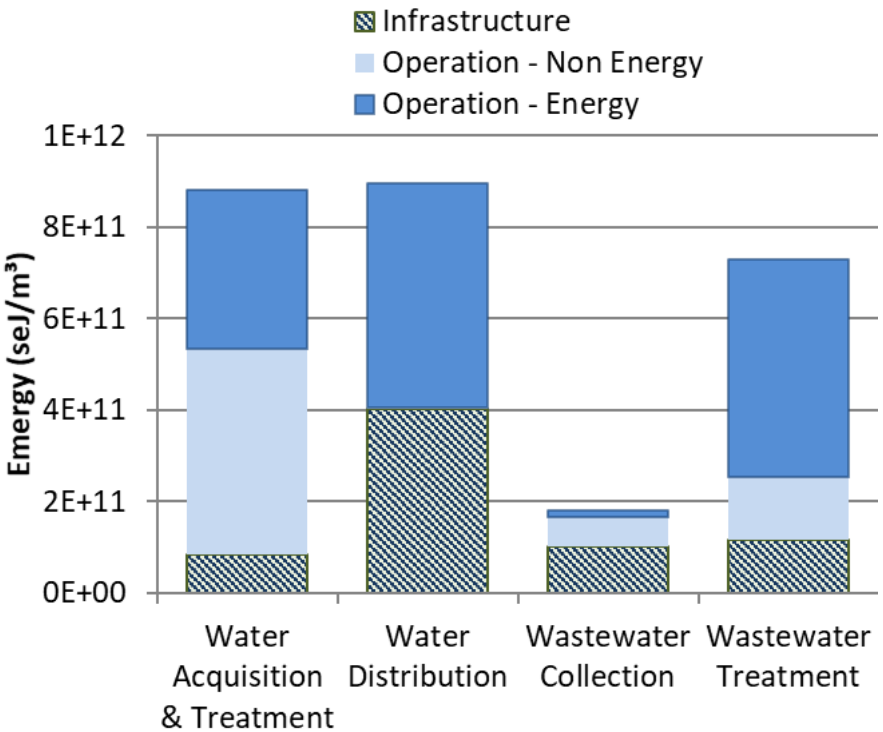

Sanitation
Little Miami WWTP comes online
Sycamore WWTP comes online
Mill Creek WWTP comes online
Muddy Creek WWTP comes online
Polk Run WWTP comes online
Mill Creek WWTP converted to Secondary
Indian Creek WWTP comes online
Taylor Creek WWTP comes online
Four WWTPs upgraded from secondary to tertiary treatment
Emergy (E+20 sej/yr)
Total Sanitation Expenditures (million $)
0
1
2
3
4
5
$-
$100
$200
$300
$400
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
WWTP Infrastructure
WWTP Operation
Collection Infrastructure
Collection Operation
Sanitation Expenditures

A history of costs and benefits

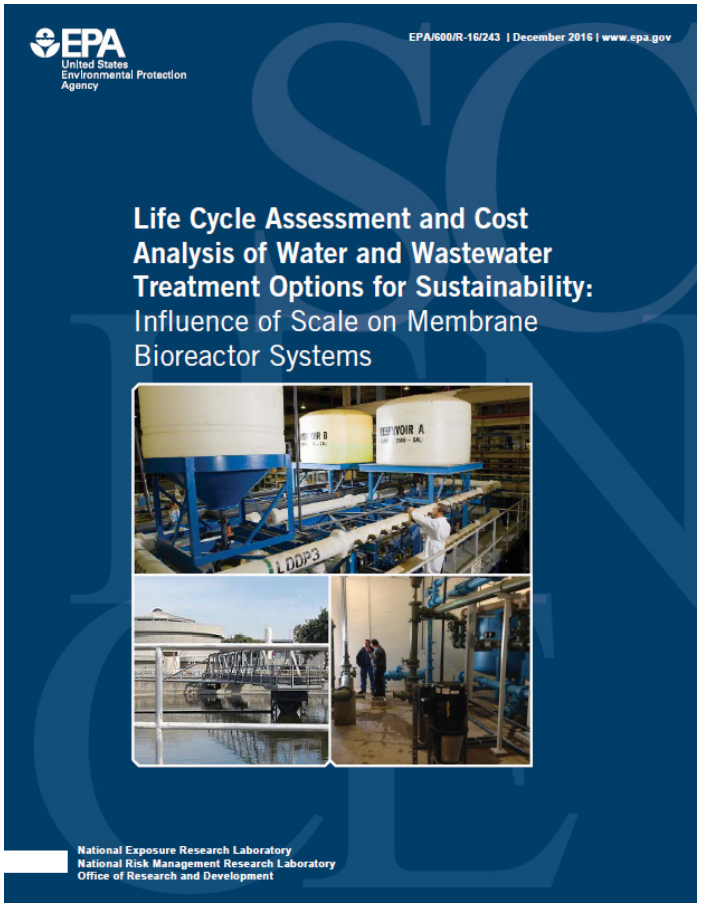


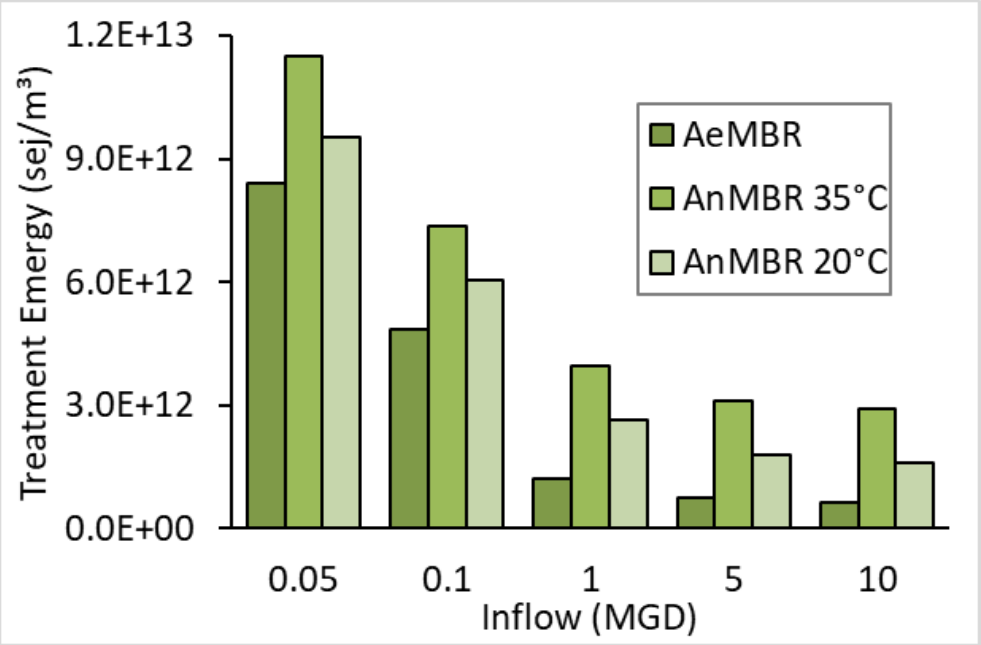
Cincinnati urban water infrastructure - *Present*



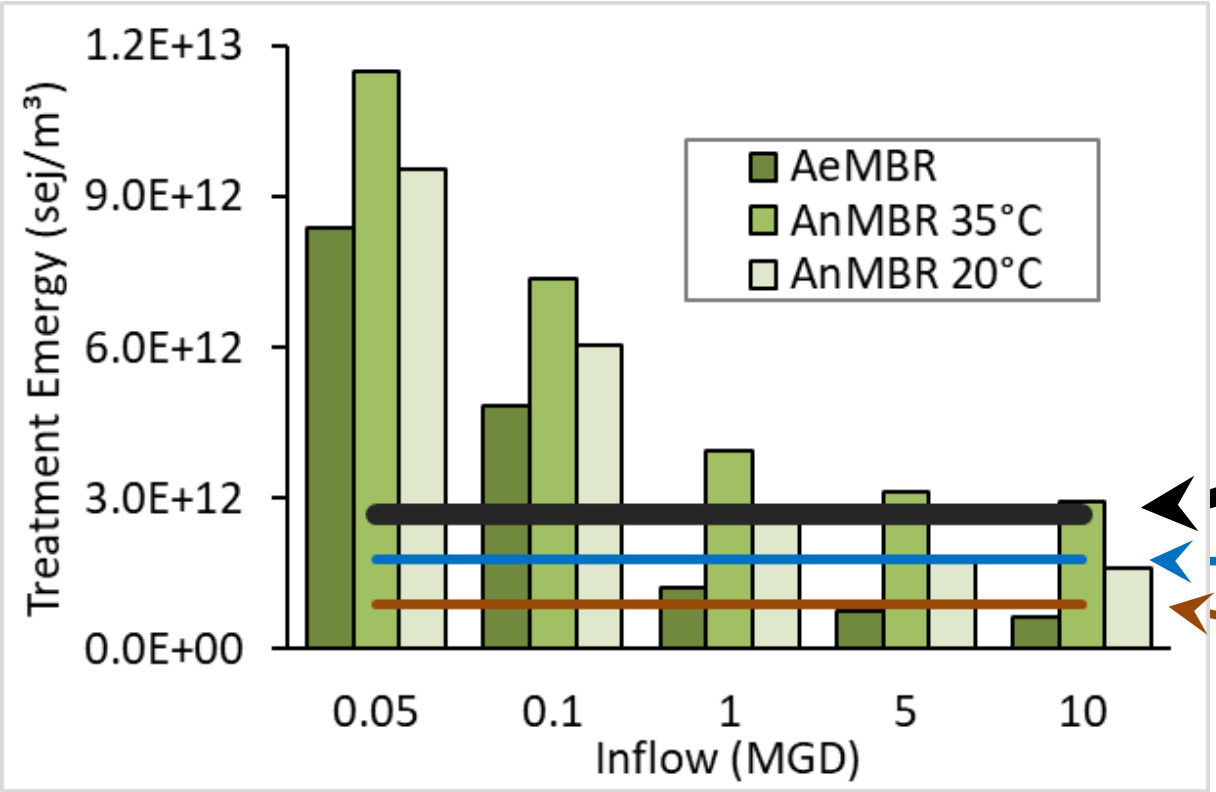


Cincinnati urban water infrastructure - *Future*





Cincinnati urban water infrastructure - *Future*



Combined

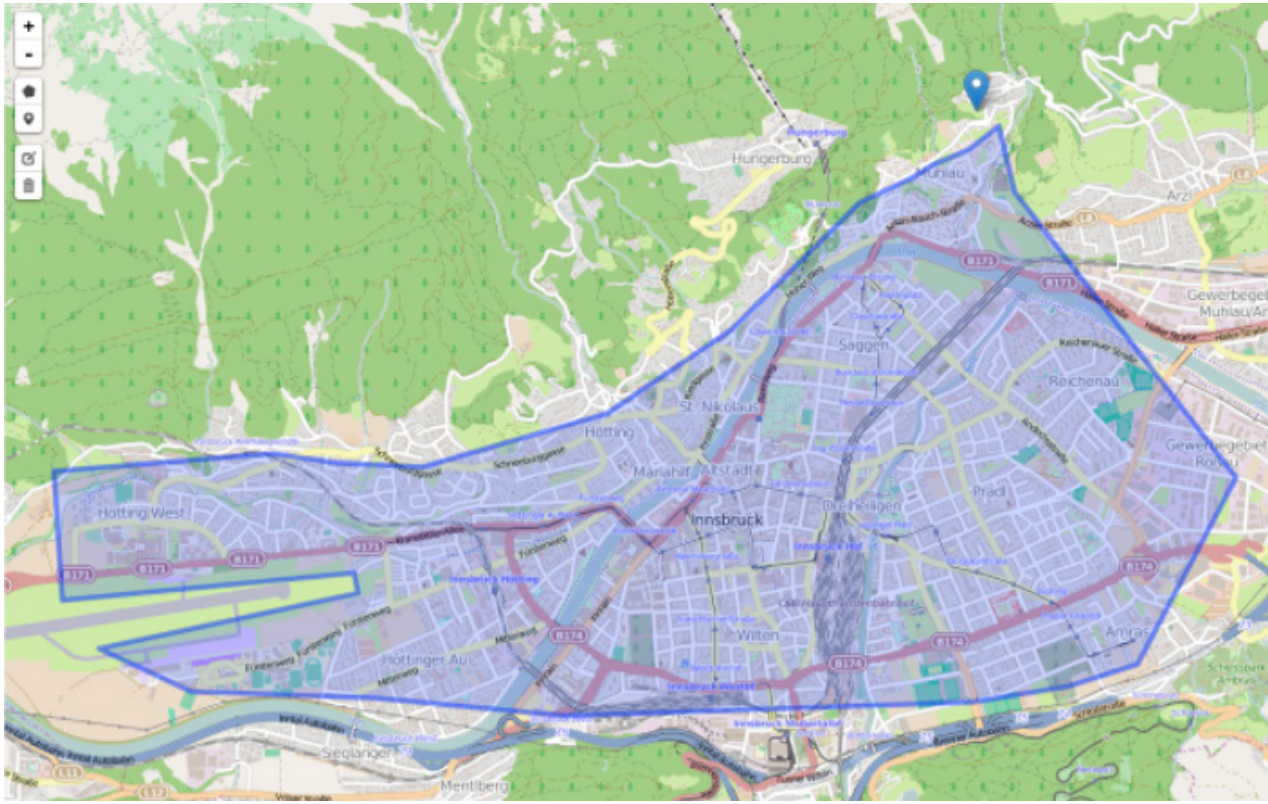
Drinking Water

Wastewater

Cincinnati urban water infrastructure - *Future*

Input Data

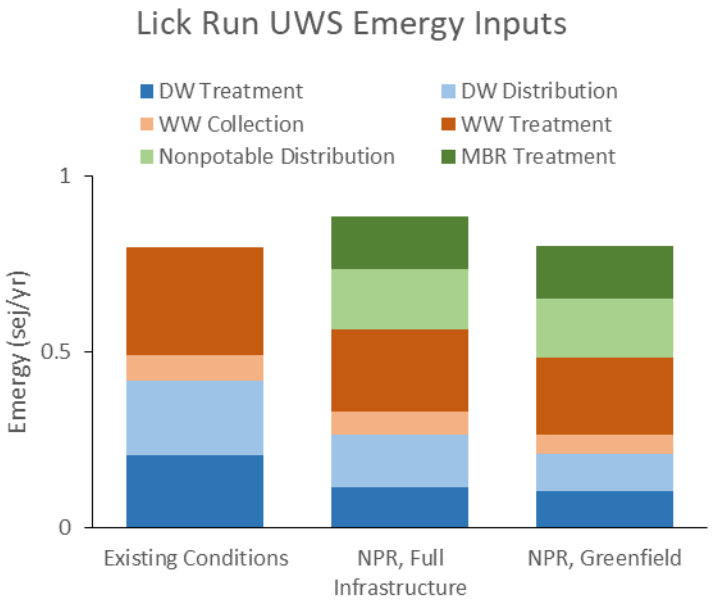
- DEM, 1 meter resolution ~100 meter cell size
- OpenStreets map
- Total demand (lps)
- Definition of project area
- Definition of water source locations
- Some dials to turn
- Output – EPANET2 .inp file



Cincinnati urban water infrastructure - *Future*

Incremental Approach – Assumptions:

- Only a small fraction of the service areas affected, so that resource costs of existing services remain approximately the same
- Affected service areas are in representative zones of existing demand
- Potable demand decreased to 20%



Acknowledgements

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