Integrating a Sustainability Framework with Assessment of Treatment and Resource Recovery Technologies

Qiong (Jane) Zhang
Associate Professor
Department of Civil and Environmental Engineering
University of South Florida

Prepared for NSF Metrics Workshop
Date: May 16, 2016

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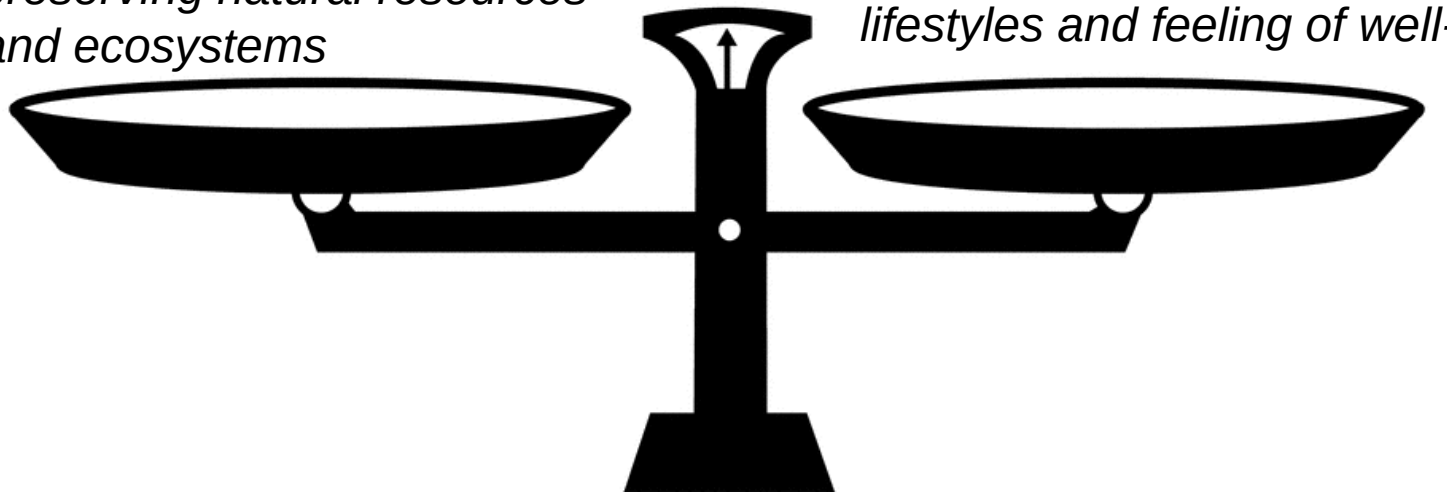
Sustainability

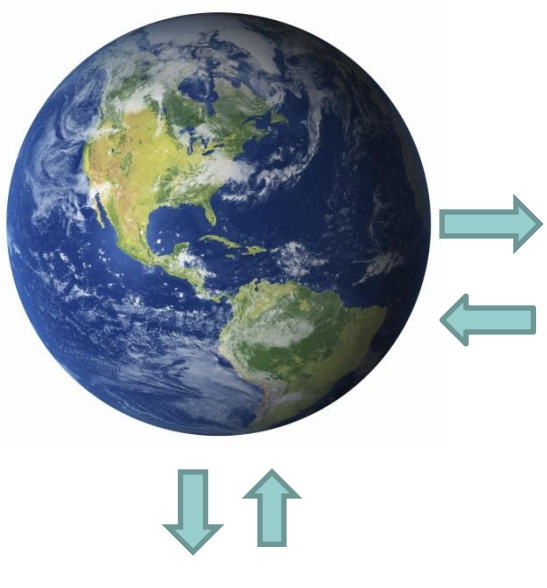
- Ability to be sustained
- What to be sustained?

preserving natural resources and ecosystems

the human need to improve lifestyles and feeling of well-being



Sustainability at Different Scale

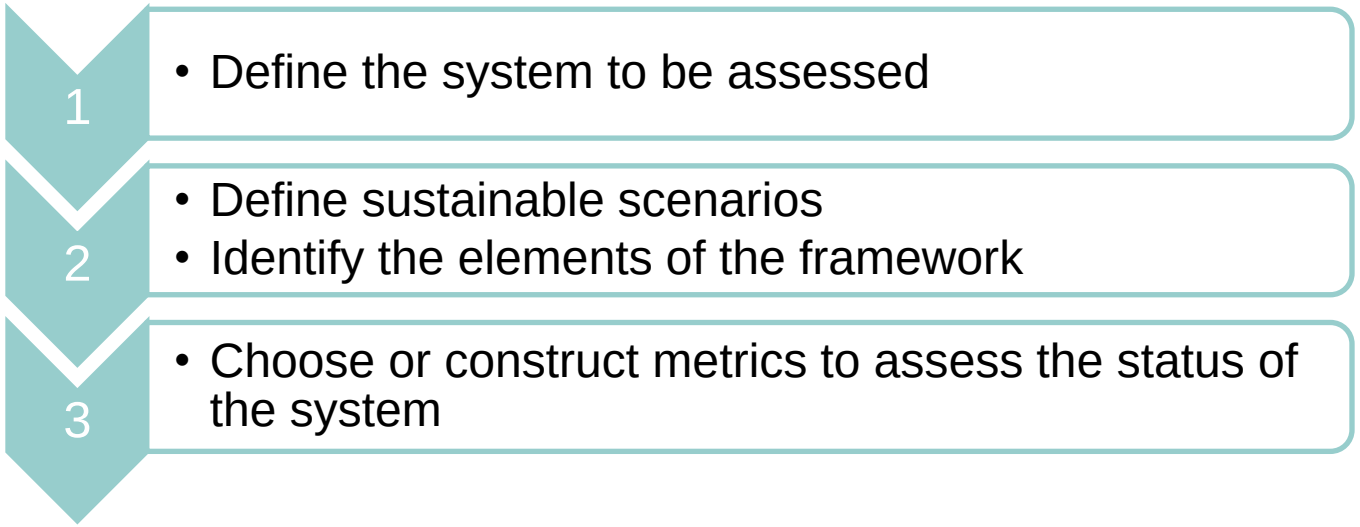


https://en.wikipedia.org/wiki/Tampa_Bay_Area

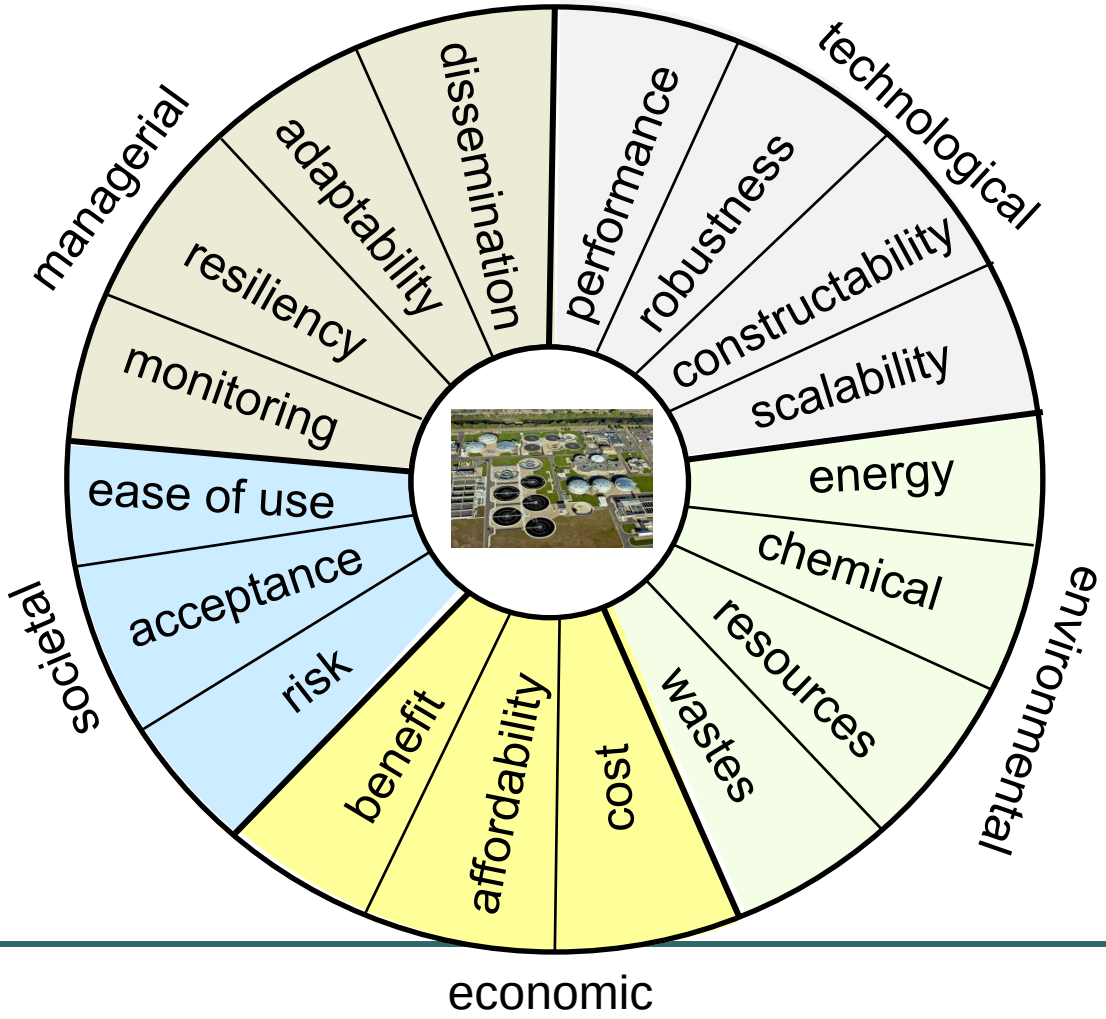
Image obtained from google earth

Sustainability Framework

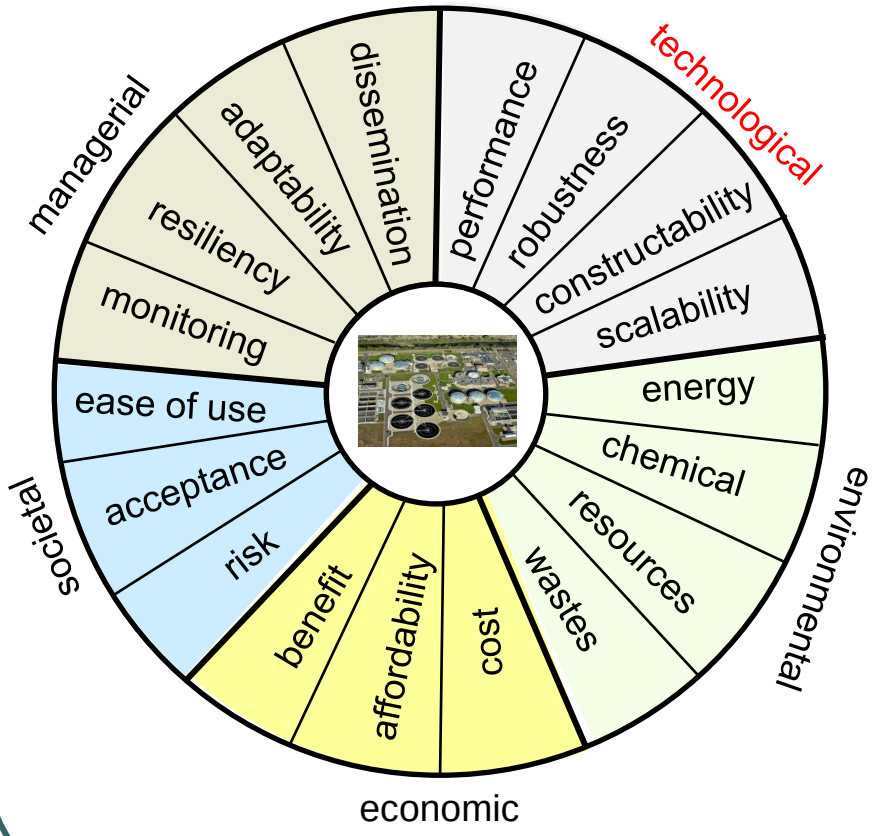
- A way to organize thinking about sustainability
- An organized structure informing the evaluation of activities or technologies



A Sustainability Framework

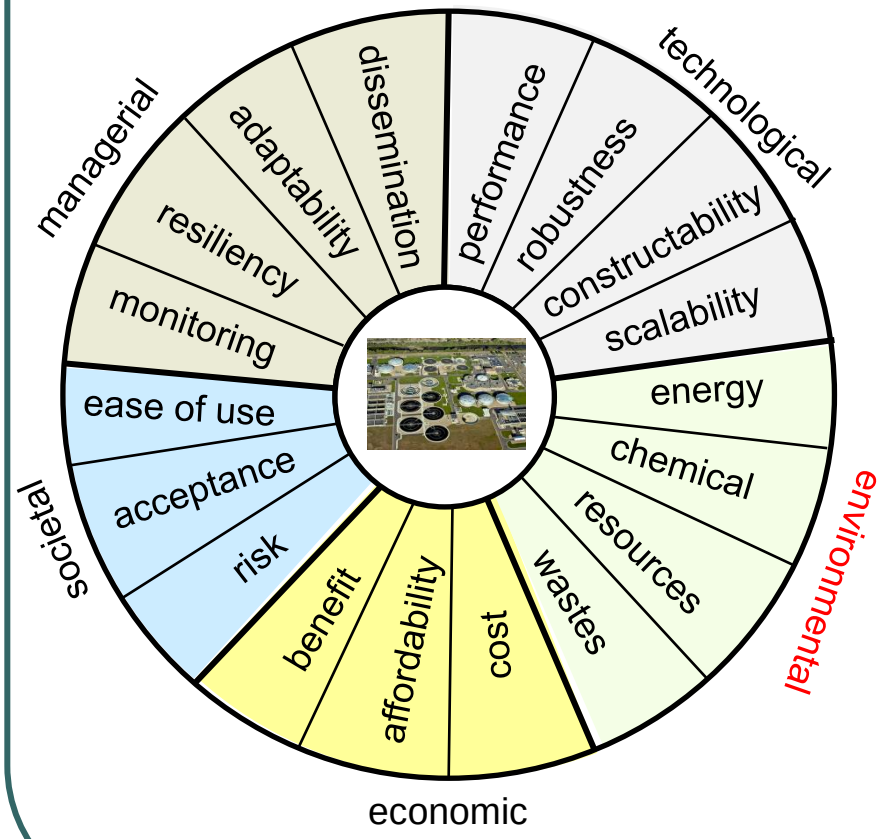


Assessment Framework



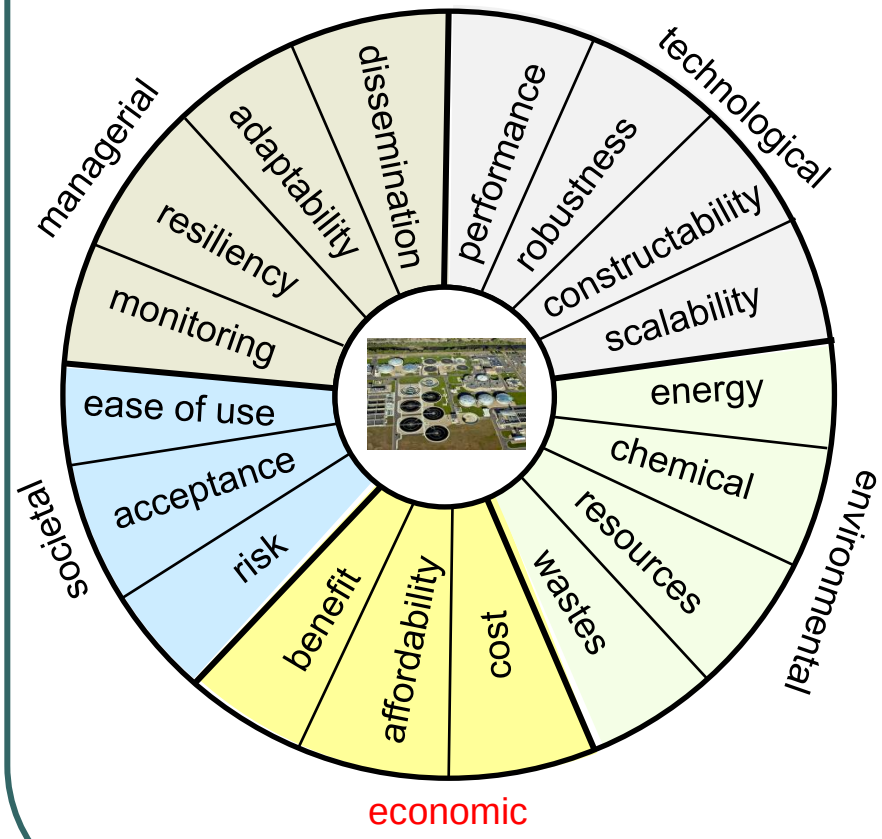
Definition	Metric
treatment effectiveness	removal of targeted contaminants
ability to cope with fluctuations in the influent	ratio of the SD of effluent quality to the SD of influent quality
ease of construction	time and labor needed for construction
possibility to implement the technology in various scales	the range of applicable scales

Assessment Framework



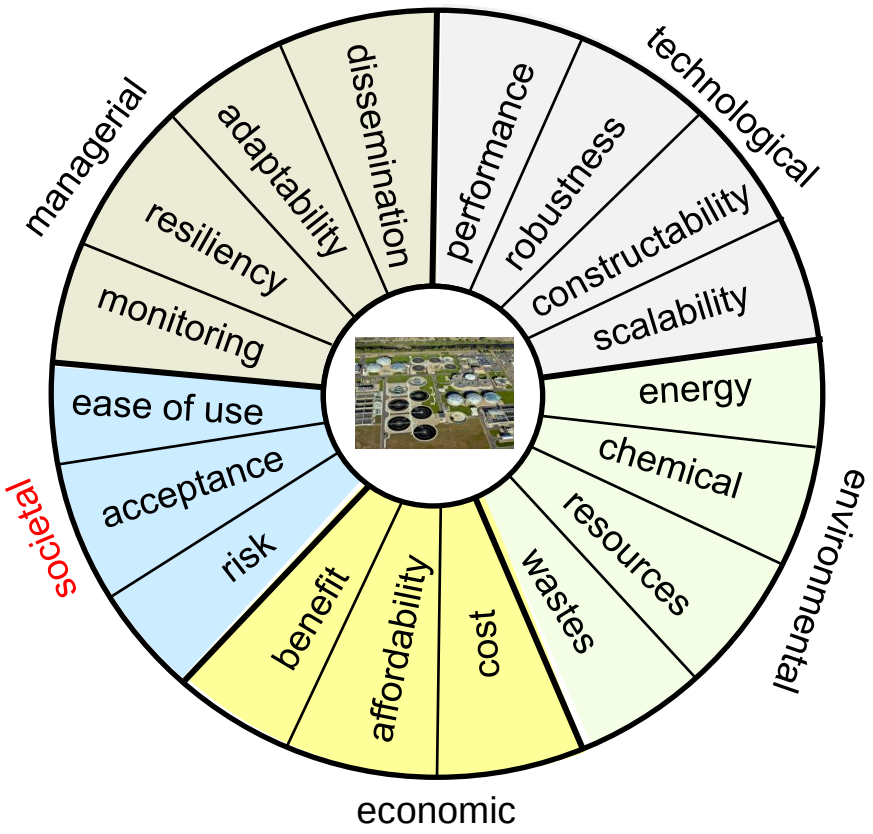
Definition	Metric
energy consumption rate	electricity consumed per unit water treated
chemical use rate	mass and type of chemical used per unit water treated
resources recovered	amount and type of resources recovered per unit water treated
gas, liquid and solid waste	amount and type of waste generated per unit water treated

Assessment Framework



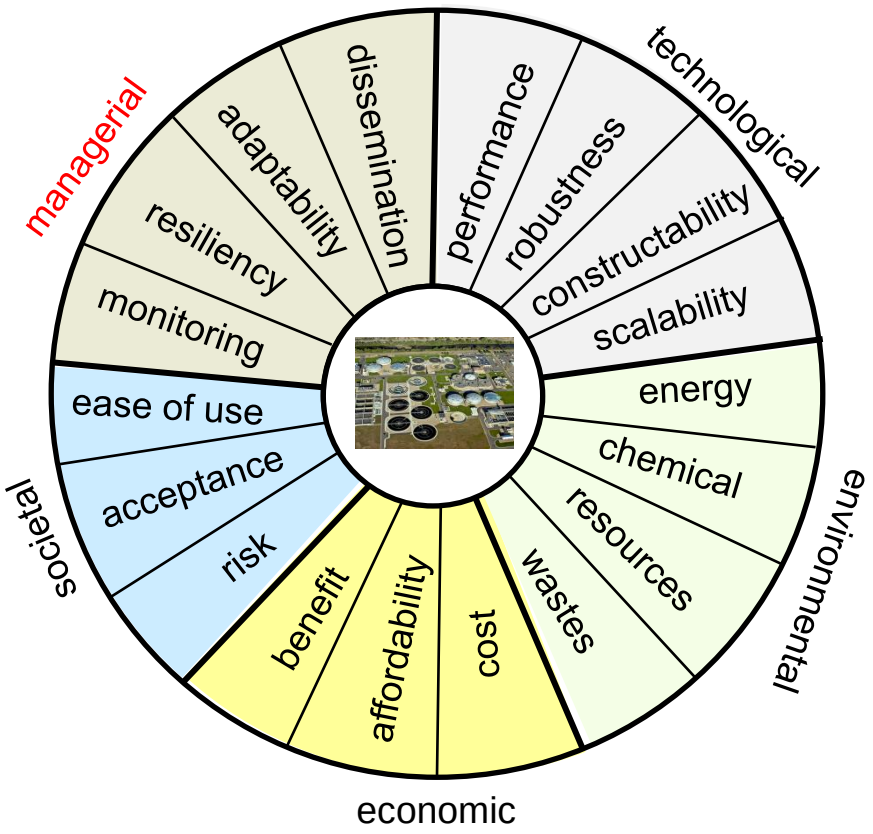
Definition	Metric
cost over the life of technology for targeted performance	life cycle cost per unit water treated
ability to afford the technology	ratio of the cost of technology to the financial ability
cost savings/profit from resource recovery	The ratio of cost savings/profit to total cost

Assessment Framework



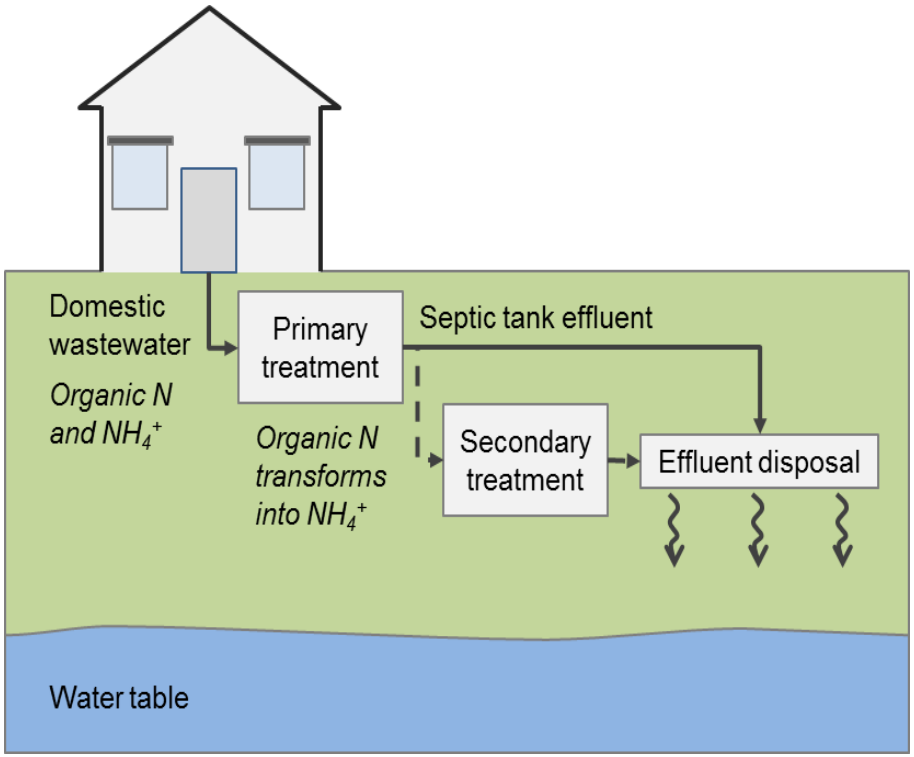
Definition	Metric
awareness of risk	rating from survey
acceptance of technology and risk	rating from survey
competence and information requirements	rating from survey

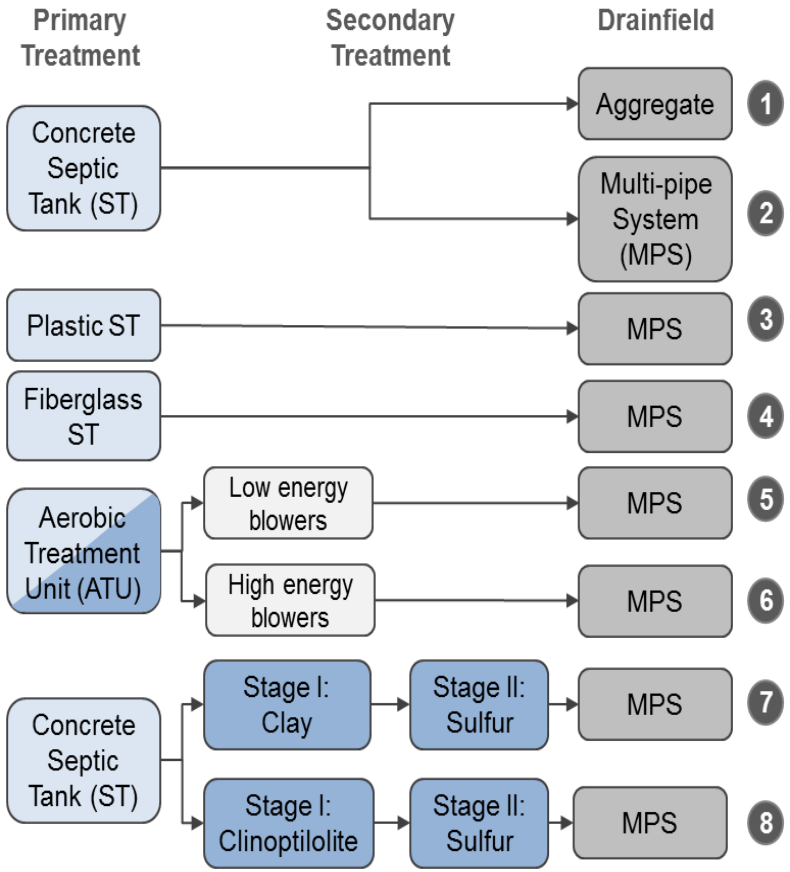
Assessment Framework



Definition	Metric
monitoring status and data management	automatically, semi-automatically or manually, data organization and storage
preparedness for hazard	emergency response plan
resource adequacy	sufficient labor and experts
methods for information dissemination	visitor tour, official website

Application to Wastewater Treatment





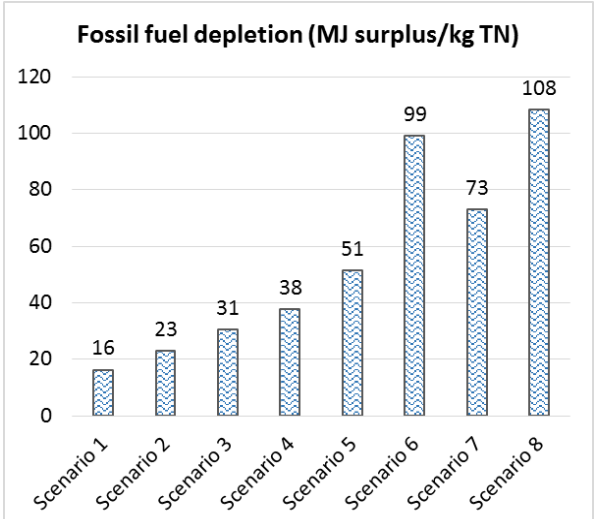
Nancy Diaz-Elsayed

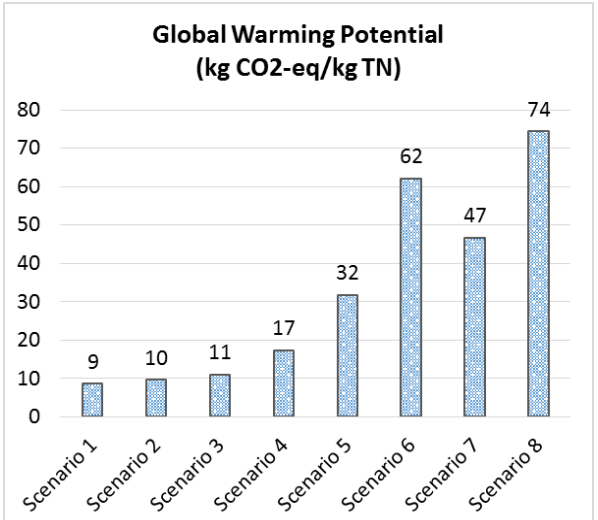
reclaim
water • nutrients • energy

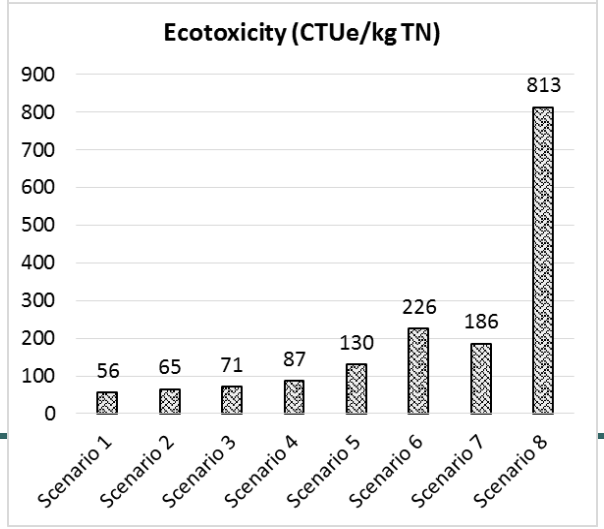
Technical Performance

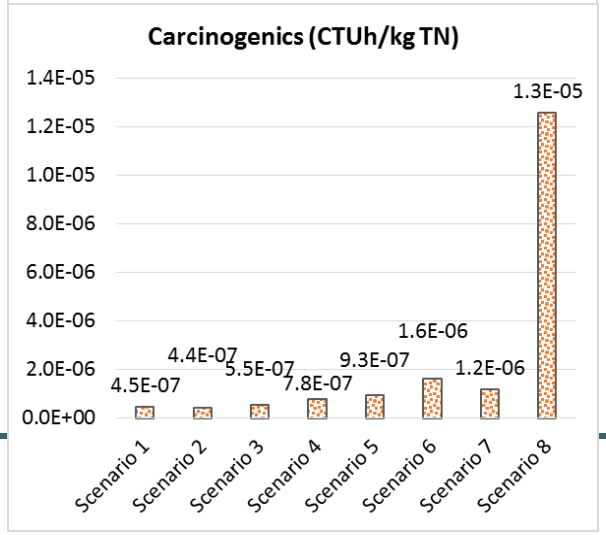
	Unit	Scenario 1	Scenarios 2-4	Scenarios 5-6	Scenario 7	Scenario 8
TN in influent	[mg/L]	77.4	77.4	77.4	77.4	77.4
TN in effluent	[mg/L]	77.4	77.4	25.5	2.1	2.2
TN at 100 cm below DF	[mg/L]	38	53	12	0.1	0.1
TN removed	[mg/L]	39	24	65	77	77
Percent TN removed	[-]	50%	31%	84%	99%	99%
Lifetime TN removed	[kg]	315	199	540	639	639

Environmental Metrics

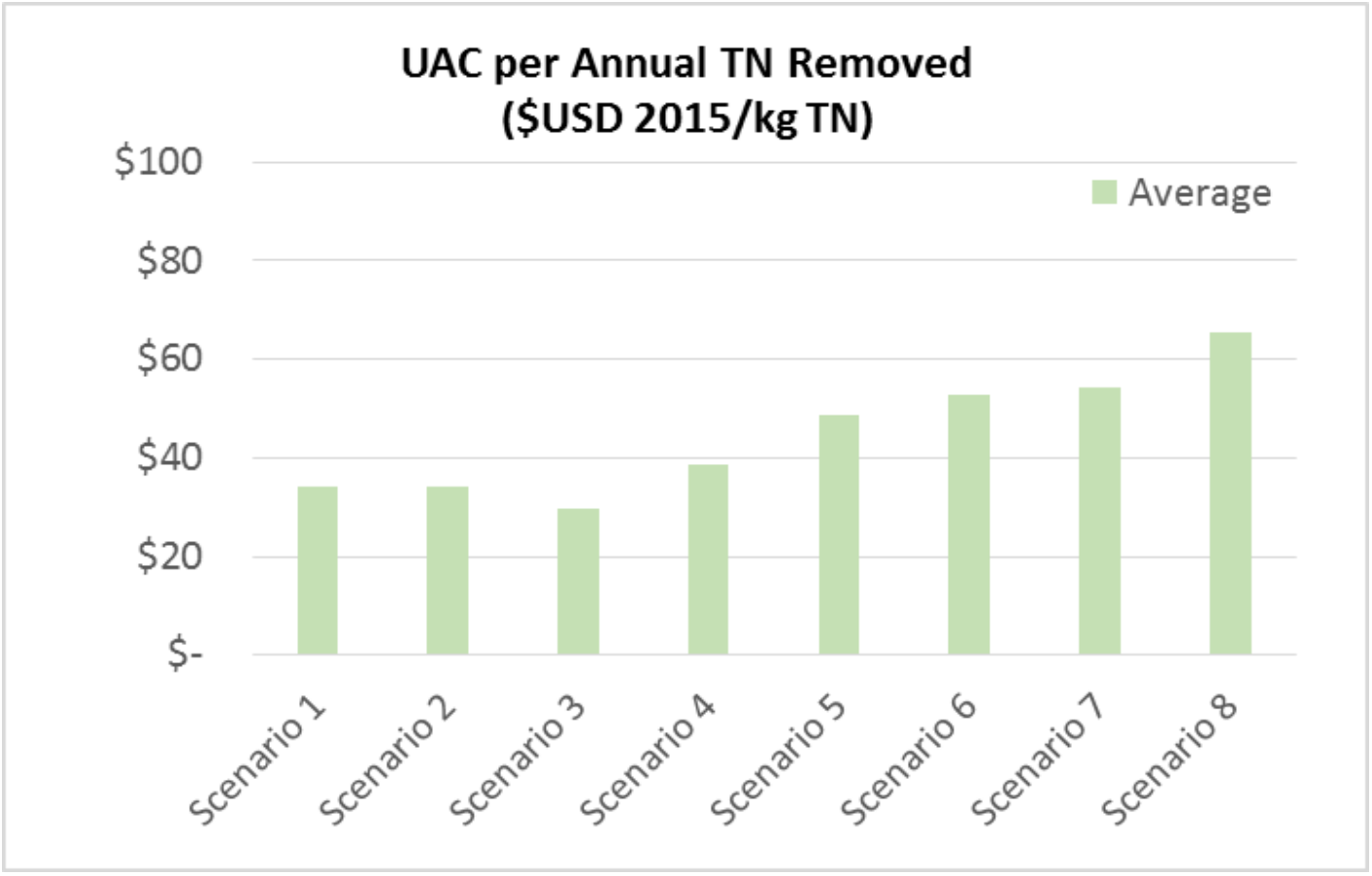




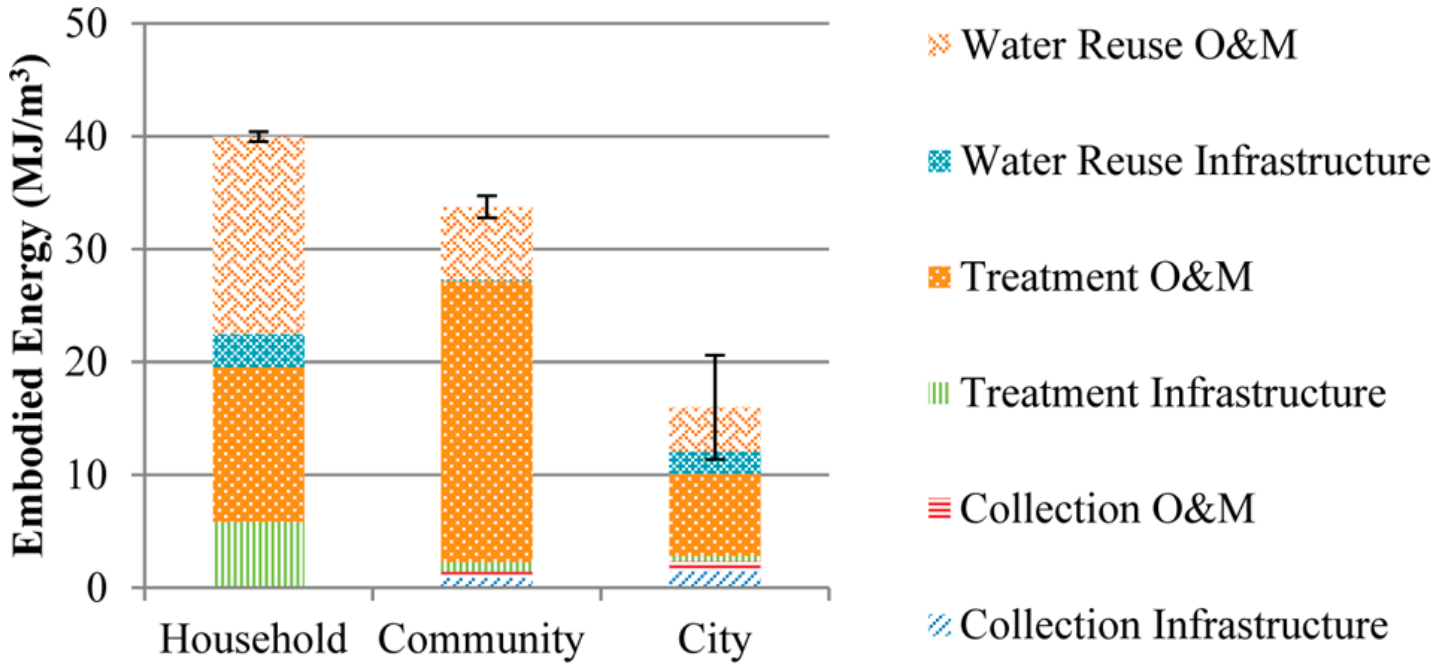




Economic Metric



Application to Wastewater Resource Recovery



Pablo K. Cornejo

Ref: **Cornejo** et al. (2016) ***Environ. Sci. Technol.***, DOI: 10.1021/acs.est.5b05055

reclaim
water • nutrients • energy

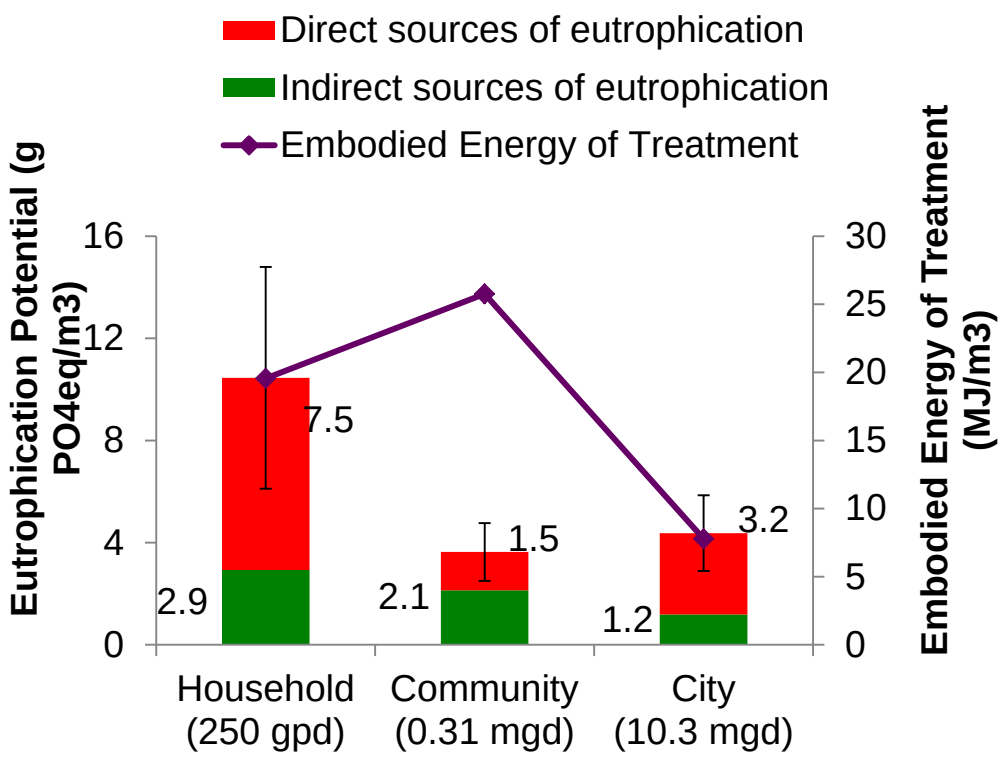
Embodied energy of resource recovery

- Water reuse
  - Dominant form of resource recovery at all scale (16-25% offset)
  - Greatest benefits at the household scale
- Integrated Resource Recovery
  - City scale provides greatest percent offset of embodied energy (49% offset)
  - Embodied energy offsets = embodied energy of treatment (city scale)

Embodied Energy Reduction potential of resource recovery strategies, MJ/m^3 (% of total)

Description	Household	Community	City
Water Reuse - Potable Water Offsets	7.2 (18%)	5.5 (16%)	4.0 (25%)
Nutrient Recycling - Fertilizer Offsets	1.3 (3%)	0.2 (1%)	0.8 (5%)
Energy Recovery - Energy Offsets	-	-	3.0 (18%)
Integrated Resource Recovery Offsets	8.5 (21%)	5.7 (17%)	7.8 (49%)

Eutrophication potential trends & Trade-offs



- Decreases from household to community scale
  - Shifts in nutrient removal
- Direct sources
  - Highest at household scale
  - Lowest at community scale
- Trade-offs of nutrient removal
  - Eutrophication potential lower
  - Higher embodied energy of treatment

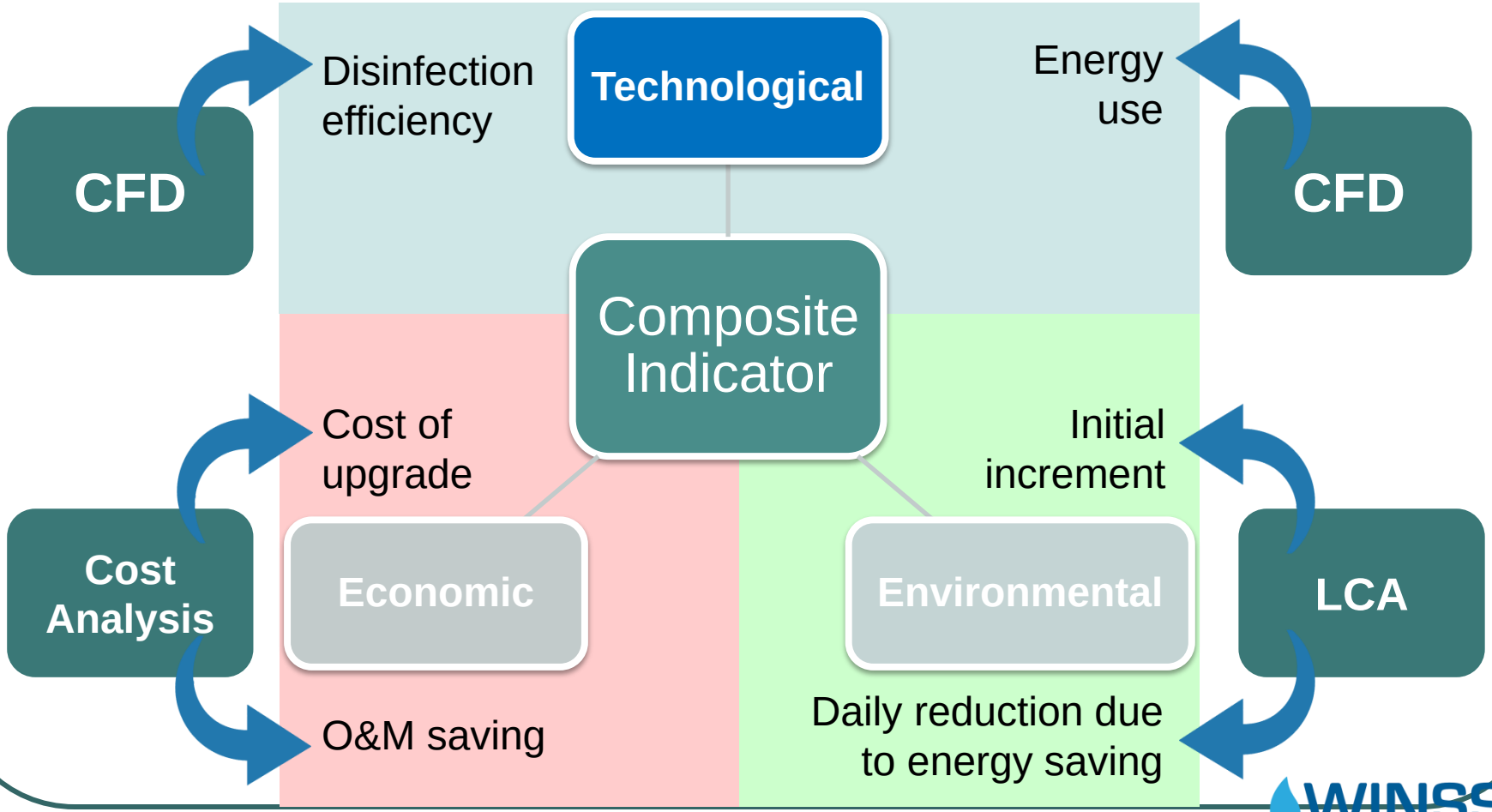
Eutrophication potential of resource recovery

- Integrated offsets - comparable at all scales
- Water reuse (potable water offsets) - Decrease with scale
  - % of water reclaimed lowest at city scale, less potable water offsets
- Nutrient recycling (fertilizer offsets) - Increase with scale
  - Increased biosolids production with increased scale, more fertilizer offsets

Eutrophication potential reduction of resource recovery strategies, g PO_4eq/m^3 (% of total)

Description	Household	Community	City
Water Reuse - Potable Water Offsets	0.7 (7%)	0.6 (16%)	0.4 (10%)
Nutrient Recycling - Fertilizer Offsets	0.1 (1%)	0.2 (6%)	0.4 (8%)
Energy Recovery - Energy Offsets	-	-	0.02 (0.4%)
Integrated Resource Recovery Offsets	0.8 (8%)	0.8 (22%)	0.8 (18%)

Application to Drinking Water Treatment

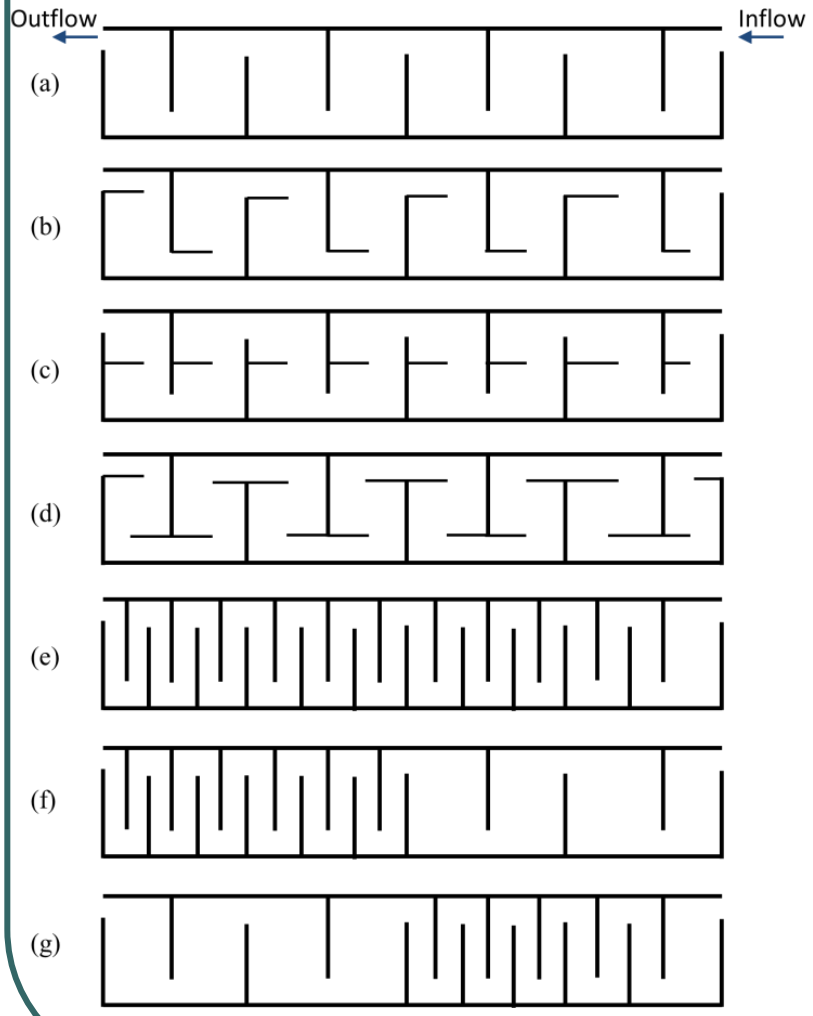


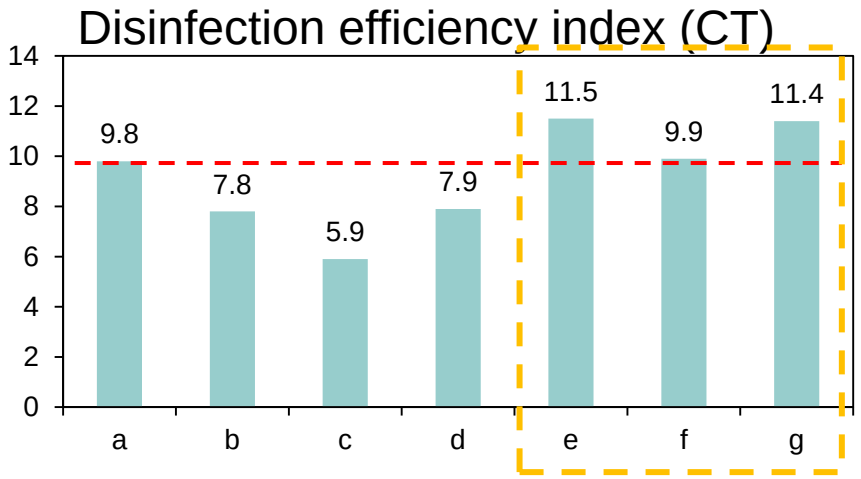
Jie Zhang

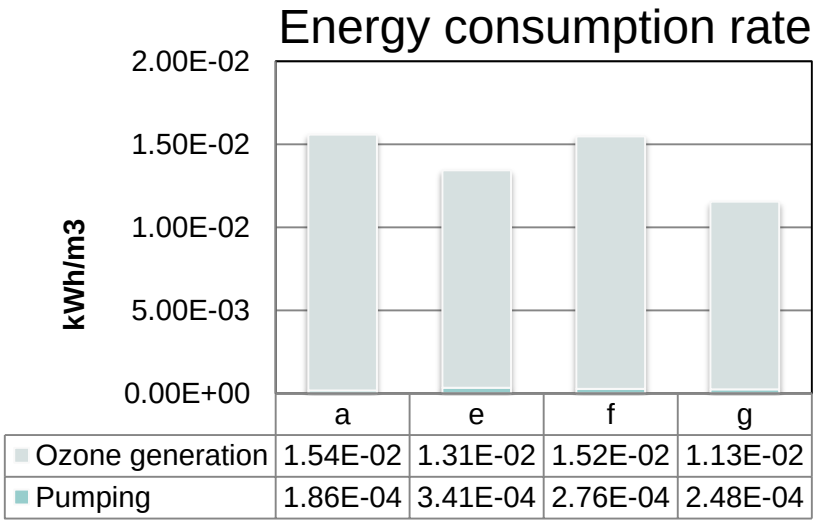
Ref: **Zhang** et al. (2016) ***Water Research***, in revision

WINSSS
Water Innovation Network for Sustainable Small Systems
A National Center for Innovative Small Drinking Water Systems

Sustainability Assessment of Design

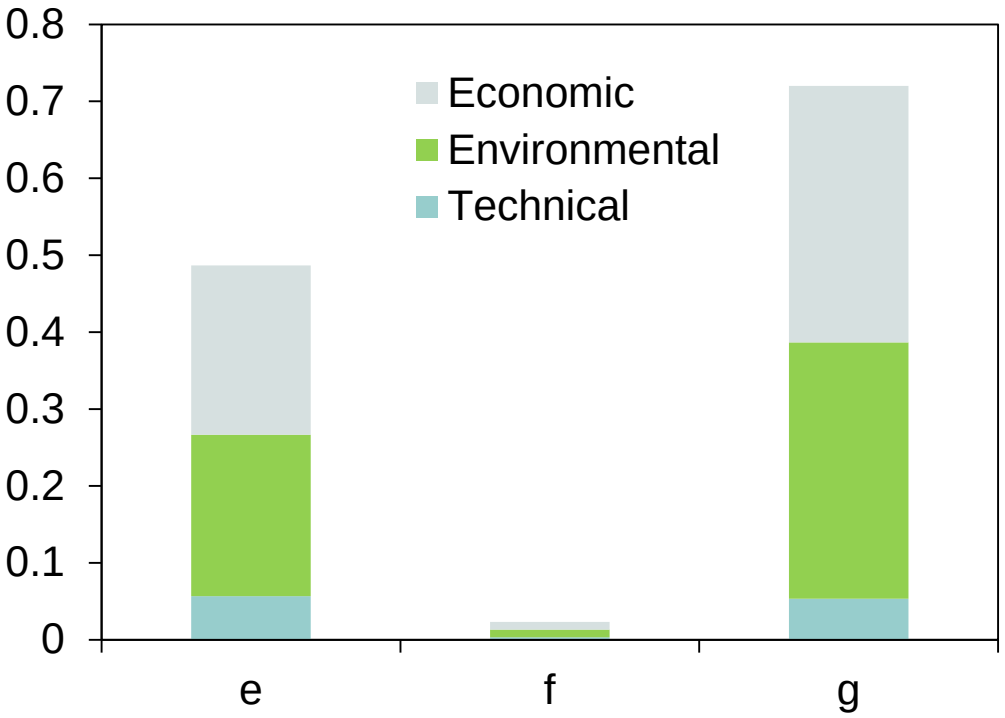




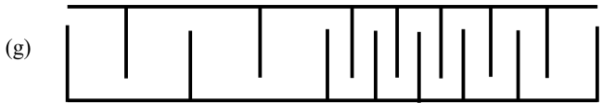


	a	e	f	g
Ozone generation	1.54E-02	1.31E-02	1.52E-02	1.13E-02
Pumping	1.86E-04	3.41E-04	2.76E-04	2.48E-04

Sustainability Assessment of Design



- Upgrade to configuration (g) would be the most sustainable option



$$\mathrm{COT} = \left(\frac{\text{Cost of upgrade}}{\text{Operation \& maintenance saving per day}}\right)/Q$$

$$\mathrm{EIOT} = \left(\frac{m \cdot E_m}{P_s \cdot E_e}\right)/Q$$

$$\mathrm{CTI_n} = \frac{\mathrm{CT}}{\mathrm{CT_{ref}}} - 1$$

$$\mathrm{EIOT_n} = \frac{\mathrm{EIOT_{ref}}}{\mathrm{EIOT}}$$

$$\mathrm{COT_n} = \frac{\mathrm{COT_{ref}}}{\mathrm{COT}}$$

Key Points

- Include environmental, societal and managerial metrics in addition to technological and economic metrics.
- Involve stakeholders to determine key indicators.
- Framework can be flexible in application.
- Environmental impacts offset can be used as one indicator for resource recovery.

Acknowledgement

- National Science Foundation Partnerships for International Research and Education (PIRE) grant (No. 1243510)
- EPA RAINmgt nutrient center grant (No. 83556901)
- EPA WINSSS center grant (No. 83560201)
- Research group