Integrated Water and Wastewater Infrastructure: Technologies and System Configurations

Qilin Li

[1]*Civil and Environmental Engineering, Rice University*

[2] *Nanosystems Engineering Research Center for Nanotechnology Enabled Water Treatment*
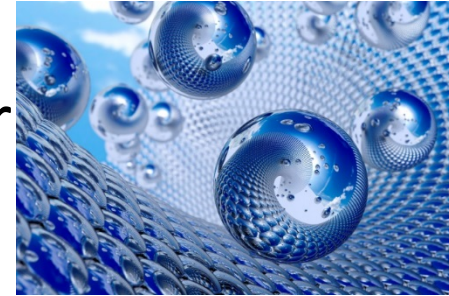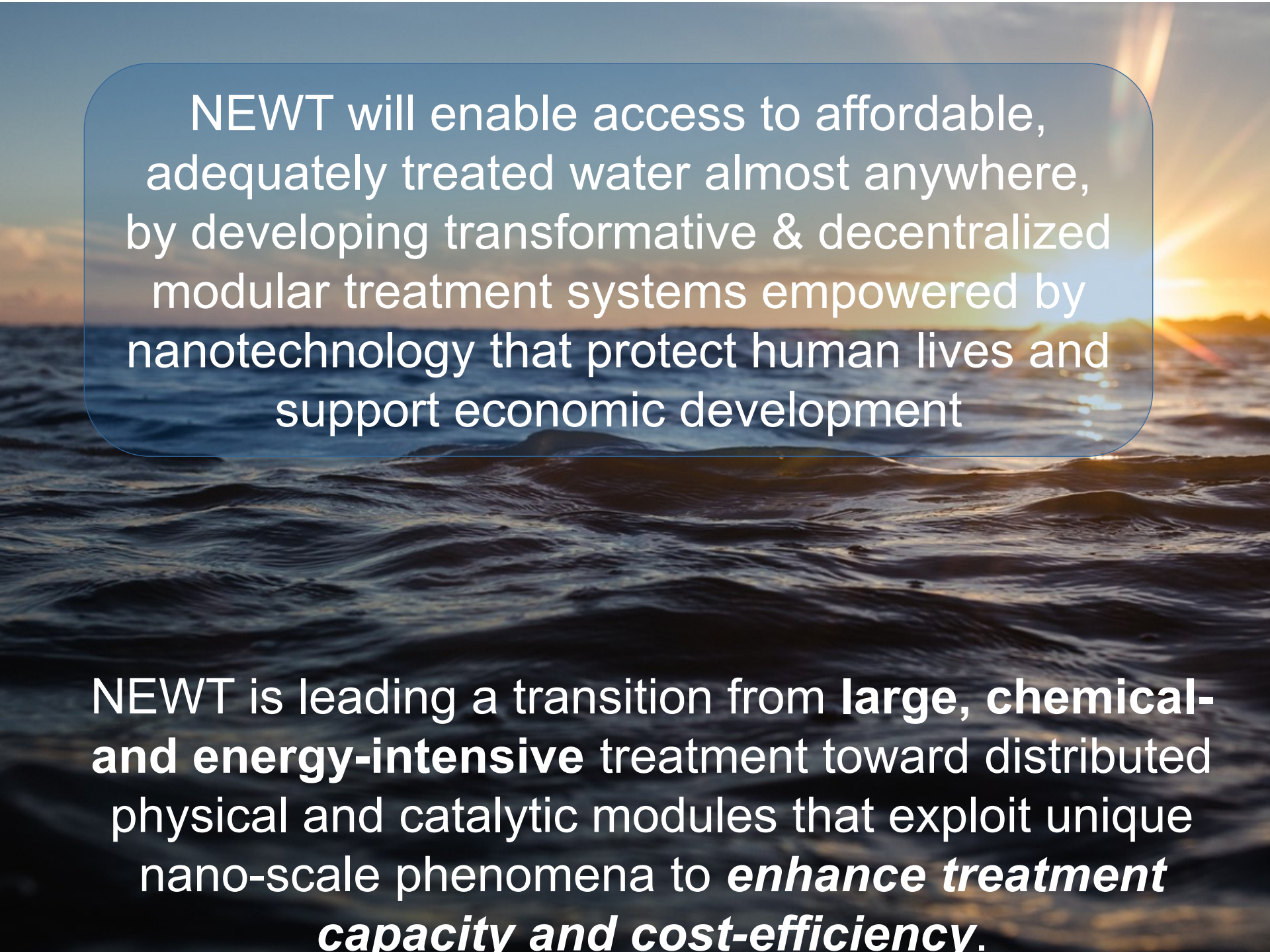
November 8, 2019

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NEWT Center

- The **N**anotechnology-**E**nabled **W**ater **T**reatment Center is the first national center to develop water treatment systems using nanotechnology.

- Innovation ecosystems funded by NSF ($37M, 10 years) & 20+ industrial partners that help accelerate commercialization.

- 27 Faculty, 82 Grad Students, 47 Undergrads, 18 Post-Docs, 8 Staff Members
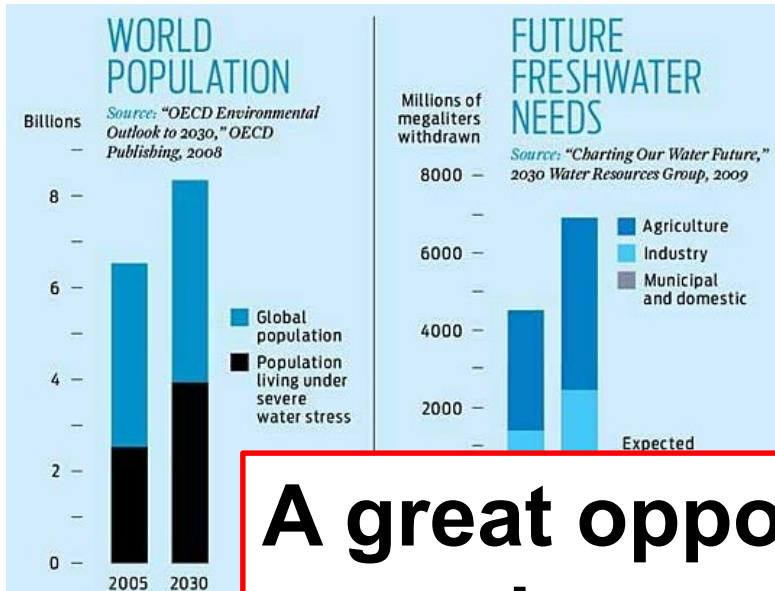
NEWT will enable access to affordable, adequately treated water almost anywhere, by developing transformative & decentralized modular treatment systems empowered by nanotechnology that protect human lives and support economic development

NEWT is leading a transition from **large, chemical- and energy-intensive** treatment toward distributed physical and catalytic modules that exploit unique nano-scale phenomena to *enhance treatment capacity and cost-efficiency.*

WORLD POPULATION
Source: "OECD Environmental Outlook to 2030," OECD Publishing, 2008

Billions
8
6
4
2
0
2005 2030

Global population
Population living under severe water stress

FUTURE FRESHWATER NEEDS
Source: "Charting Our Water Future," 2030 Water Resources Group, 2009

Millions of megaliters withdrawn
8000
6000
4000
2000

Agriculture
Industry
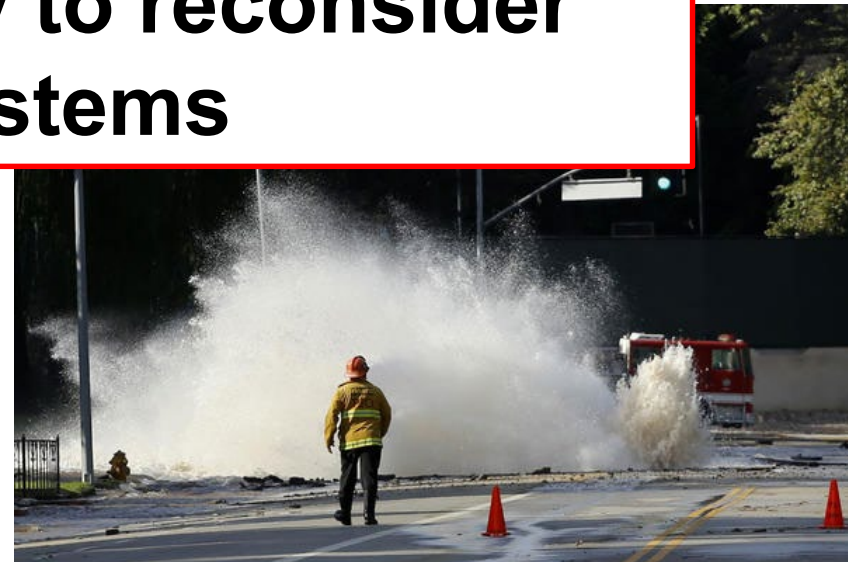Municipal and domestic

Expected

http://igeogers.wee

Increasing water demand
- ❑ 80% increase in urban water demand by 2050
- ❑ 1,386 – 6,764 Mm^3 surface water deficit
- ❑ Competition for water from different sectors
- ❑ Food, water & energy nexus/conflicts
- ❑ Deteriorating ecosystem health

A great opportunity to reconsider our urban water systems

Aging infrastructure
- ❑ Loss of water
- ❑ Secondary contamination of water quality (e.g., DBPs, pathogens, WW contaminants)
- ❑ Expensive maintenance

http://graphics.latimes.com/la-aging-water-infrastructure/

Flörke et al., Nature Sustainability, 2018;

A Hybrid, Adaptive Urban Water and Wastewater System

What are the **water**, **energy** and **financial** implications of

- *Direct potable reuse (DPR)*
- *Indirect potable reuse*
- *Non-potable reuse*

City of Houston

(Liu et al., Nature Sustainability, *submitted*, 2019)
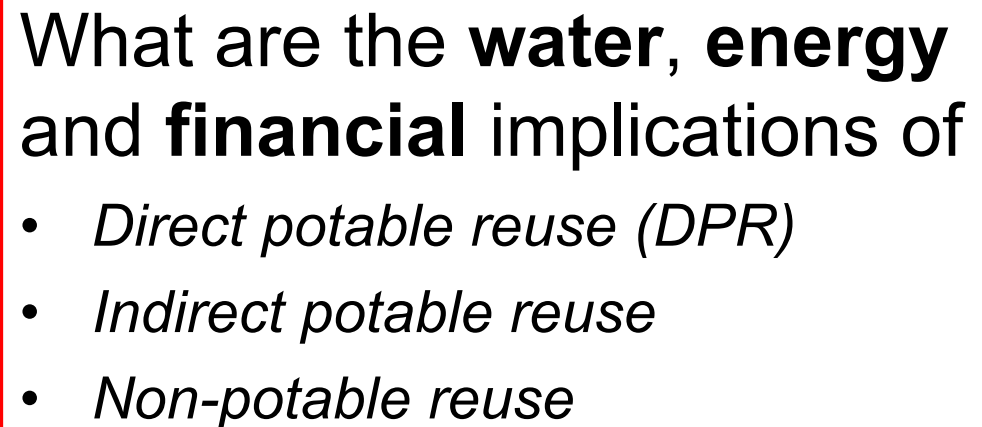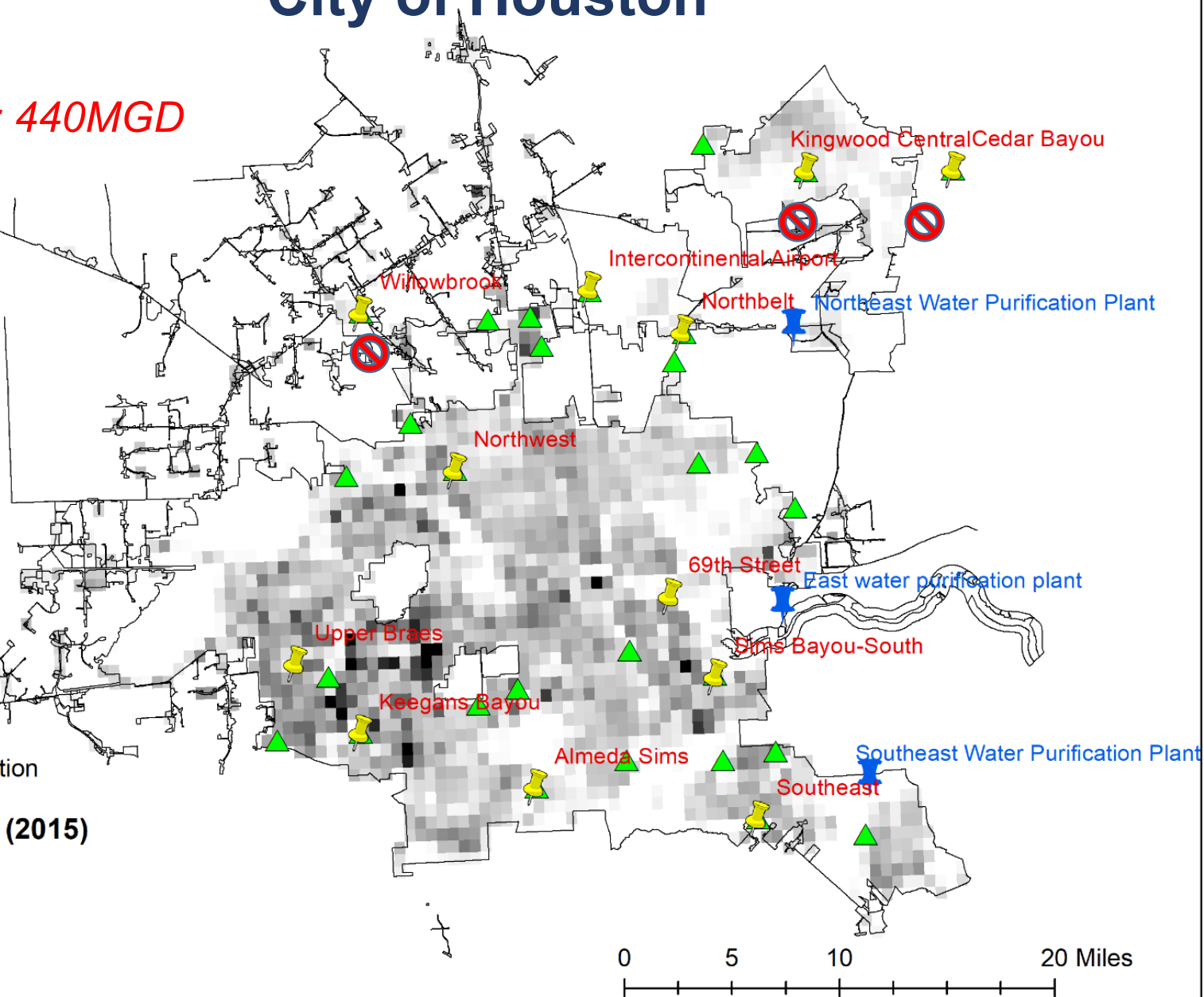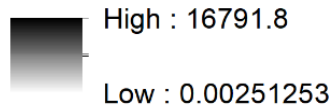
Decentralized Water Supply via DPR

Minimum 50% return rate

Surface water

Groundwater

Extracted

Treatment at DWTP

Distributed

Decentralized DPR

N

5 km

♻ WW treatment & reuse plant
★ Surface water treatment plant

Energy Implication

(a) Groundwater Treatment Plants

(b) Surface Water Treatment Plants

(c) WWTPs

Energy for distribution
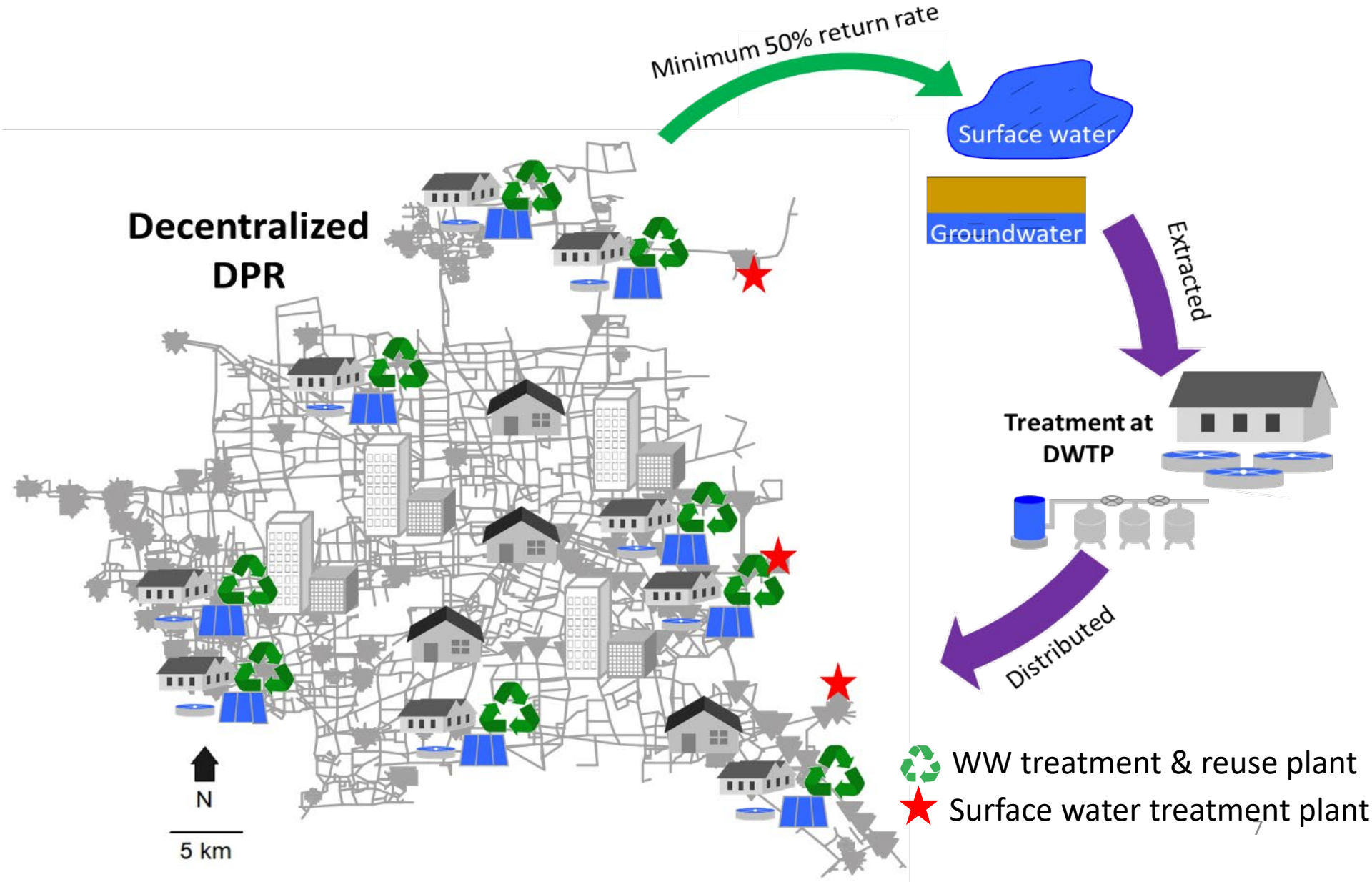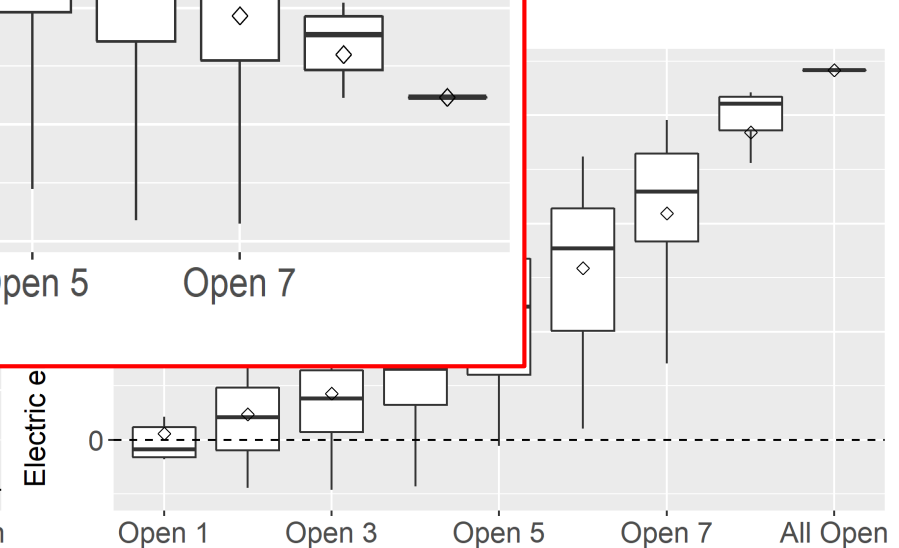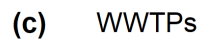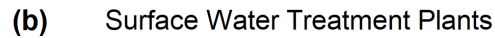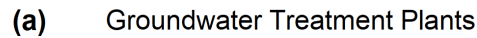
Interplay between freshwater withdraw, energy consumption and cost

512 configurations

Status quo
(no water reuse)

Reclaimed water (%)

Million 2018$

Electric energy difference (MWh)
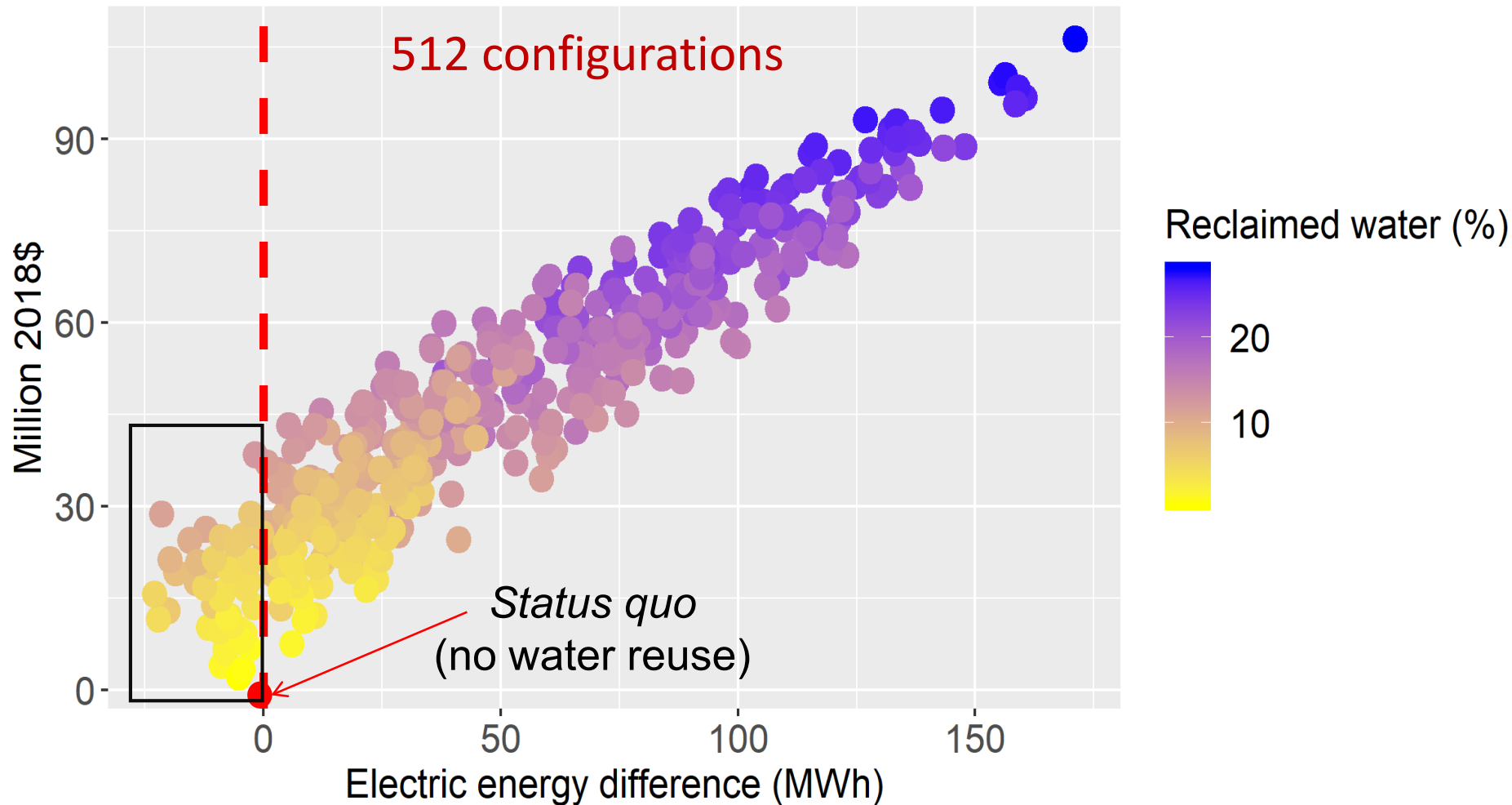
Assumed advanced treatment: 1.5 kWh/m³

Technology Needs
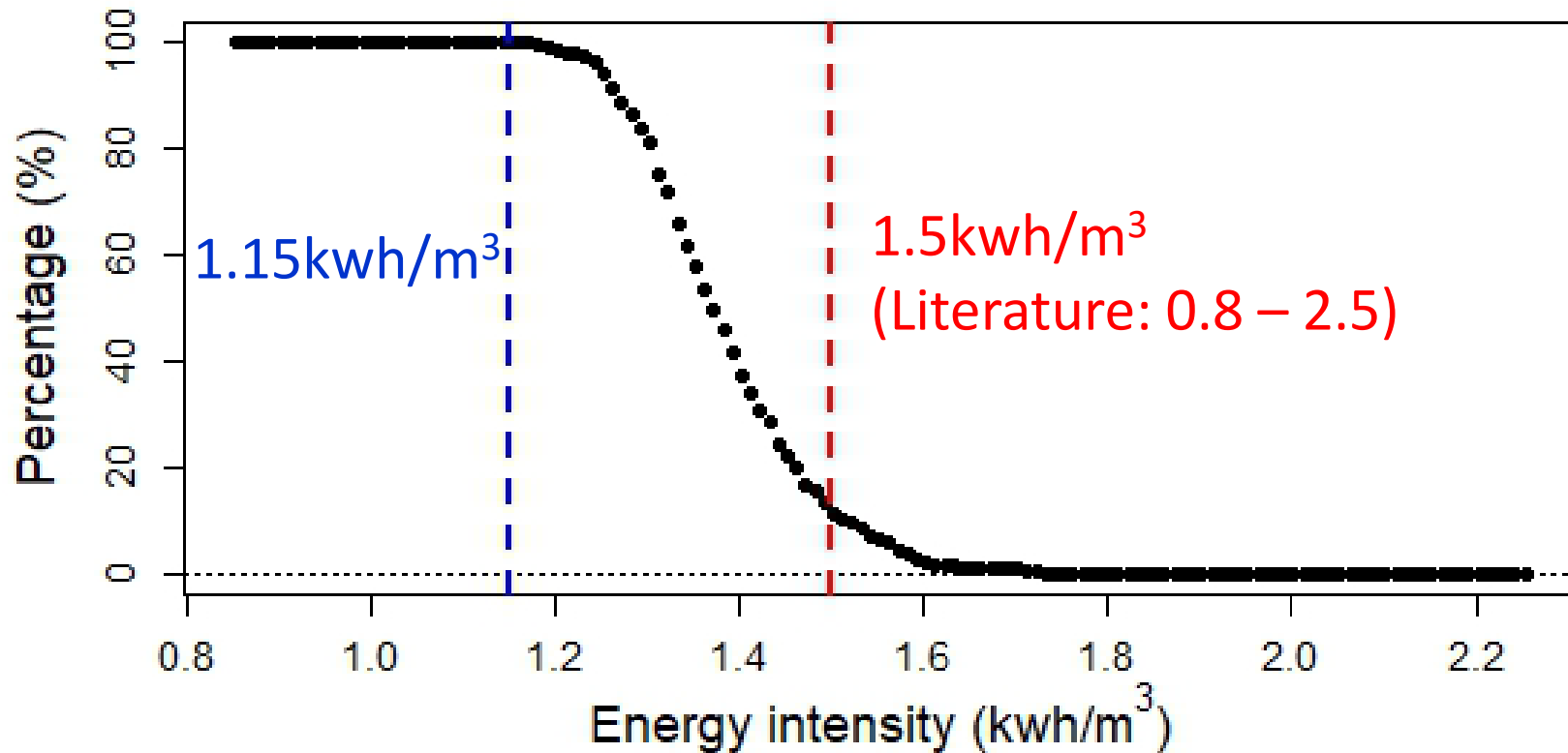
- *< 1.15kwh/m³, all configurations attain net energy saving*
- *> 1.73 kwh/m³, no configuration attain net energy saving*

Study domain

Precipitation

Spatial datasets

Elevation
(1m - LIDAR)

Landuse
(30m - NLCD)

Soils
(30m - NRCS)

in/hr

8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0

00:00   04:00   08:00   12:00   16:00   20:00   00:00
Feb-25   Feb-25   Feb-25   Feb-25   Feb-25   Feb-25

Vflo 6

South

File   View

South
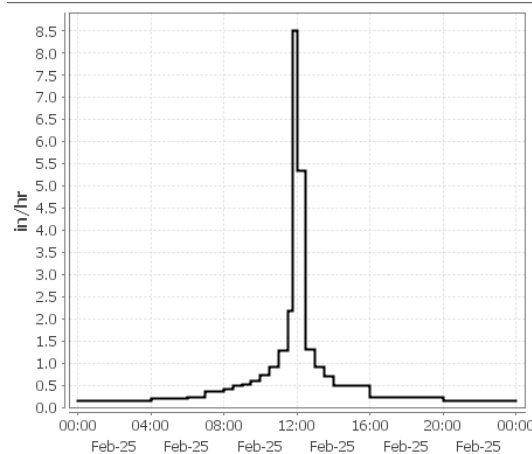
Temporal & spatial distr. of storm water

Reclaimed storm water

Advanced treatment

Potable or nonpotable reuse

End of Rain
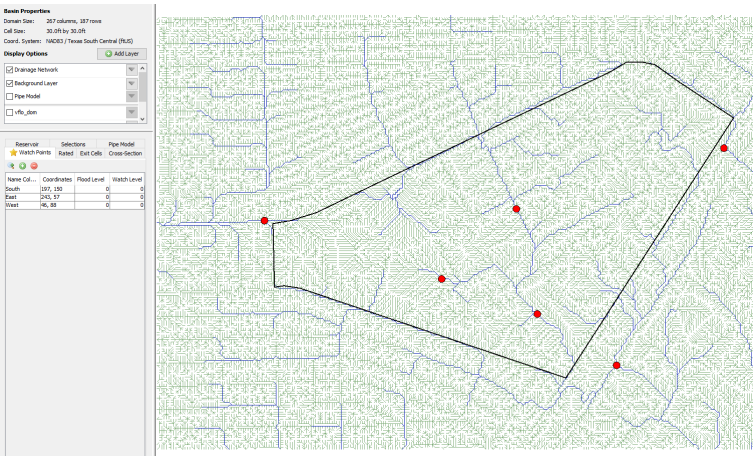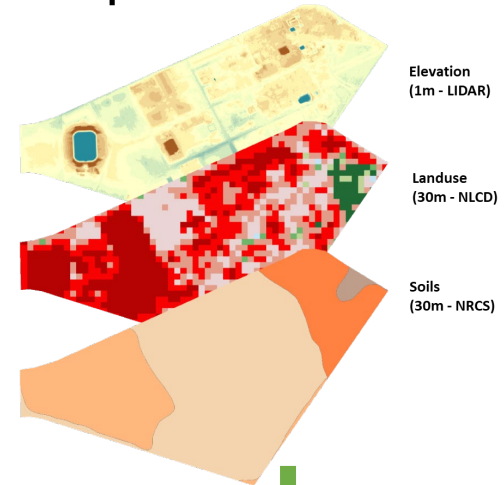
Simulated discharge at South outlet

Discharge (cfs)
2,000
1,750
1,500
1,250
1,000
750
500
250
0

Rainfall (in./hr)
0
1
2
3
4
5
6
7
8

00:00   06:00   12:00   18:00   00:00   06:00   12:00   18:00   00:00
Feb-25   Feb-25   Feb-25   Feb-25   Feb-26   Feb-26   Feb-26   Feb-26   Feb-27

Time (UTC)

Discharge   Upstream Rainfall

Hydrograph Type   ○ Stage   ● Discharge

Notes

Property	Value
Runoff Avg. De...	11.97
Precip. Avg. De...	13.20
Infiltrated Avg...	1.18
Evap. Avg. Dep...	0.00
Peak Discharge ...	2073.90

Upstream Rainfall
● Same Chart
○ Separate Chart
○ Hidden

Resiliency Study

Input

Output

Length   121.72

Age   18

Material   PVC

Diameter   8"

NPB   0

Logistic regression model

Linear model   **Sigmoid function**

$\sum$

Probability

0.052   **1 (Break)**

or

0.948   **0 (No break)**

❏ Test accuracy: 96.8%

❏ 3 times higher pipe breakage frequency during draught (2011)

❏ Length, age and pipe material are dominant factors

Concluding Remarks

❑ Data from different institutions need to be coordinated

❑ There is a great need for analytical tools in order to extract actionable information

❑ Decision making needs to be at the systems level