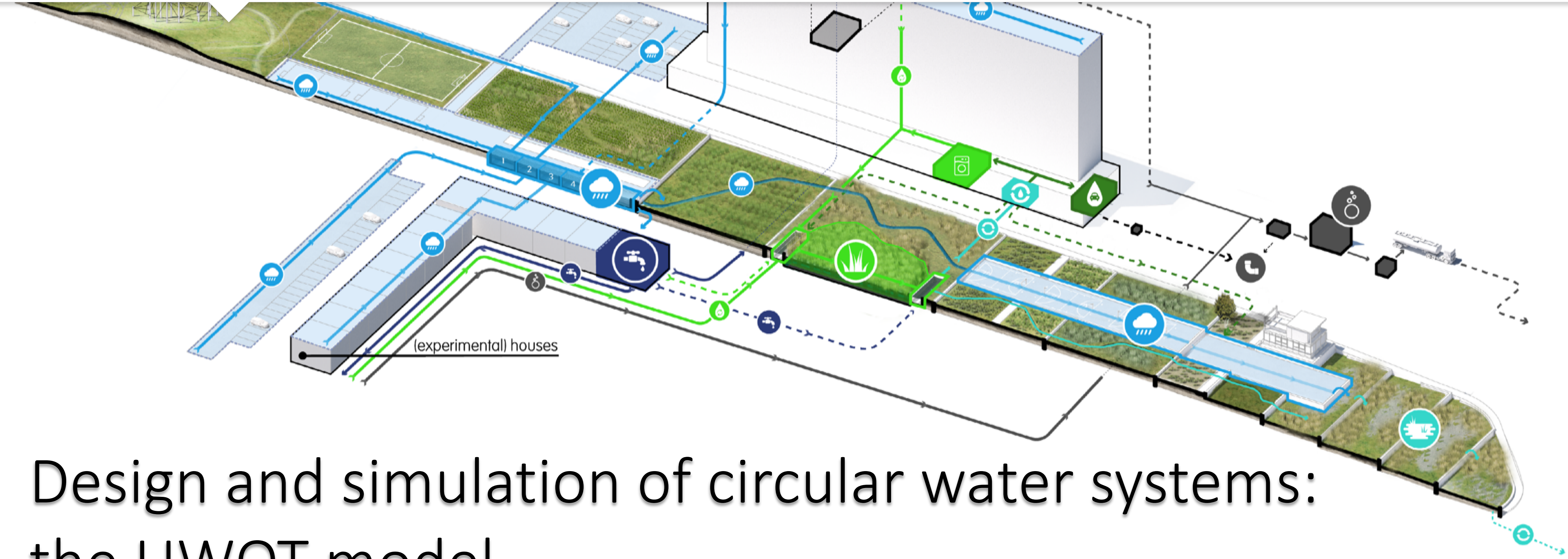


Design and simulation of circular water systems: the UWOT model

RAINWATER

DRINKING WATER

GREY WATER

BLACK WATER & FOOD REMNANTS

PURIFIED GREY WATER

WASH WATER

The context: water in the circular economy and circular water systems

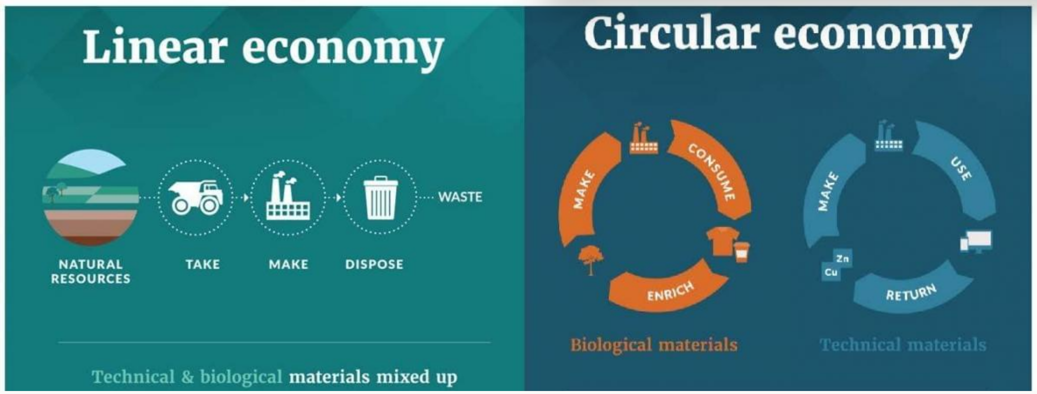
Conventional water management systems are linear: **produce** (potable) water – **use** – **dispose** (as quickly as possible)

Limitations: Intensive source exploitation, high cost of ecological degradation, large infrastructure, capital intensity (Gleick, 2002)

Circular water management is proposed as alternative:

- Emphasis on **enabling loops** (greywater recycling at residential units, water reuse) **reuse/recycle**
- Addition of **local sources** (rainwater harvesting)
- Retention of stormwater (SUDS)
- More proactive **reduction of demands** (water-smarter devices at households) **reduce**

circular water
An analogue of circular economy (using water as a resource)



The means: decision support tools for circular systems are needed

Circular water management is proposed as alternative:

- Emphasis on **enabling loops** (greywater recycling at residential units)
- Addition of **local sources** (rainwater harvesting)
- Retention of stormwater (SUDS)
- More proactive **reduction of demands** (water-smarter devices at households)

Need to have decision support systems (DSS) that:

1. Assist in the **design of circular water systems** at **arbitrary spatial scale** (household -> regional/city).
2. Can model **combined (hybrid) systems** that include an **array of decentralized techs** (RW, GW, SUDS).
3. Include **diverse circular techs** from the household, neighborhood and regional scale (hh appliances, household RW, central RW, central GW, blue-green areas, SUDS), **in combination with central technologies** (central WTP, WWTP, supply nodes).
4. Allow the **exploration of scenarios with different drivers** (climate/society). Applications: resilience, sustainability, climate change

UWOT:
A modular simulation engine for (arbitrary) circular water systems

modular
Bottom-up, component based urban water cycle model

simulation engine
Built in C/Python, expandable, able to simulate daily/hourly flows
Typical scenarios run for 5-30 years (~10^4 values)

circular water system
able to model a range of decentralized, distributed
Interventions: RWH, GWR, blue-green areas, smart appliances

arbitrary systems
from appliance level and up, house/neighborhood/city
Can model water quantity, as well as a single conservative pollutant in water quality (mg/L)

UWOT as part of Watershare: expert tools for global water challenges

- Part of a toolbox that addresses water issues in various thematic areas.
- Accessible to Watershare partners (https://www.watershare.eu/)

The way it works

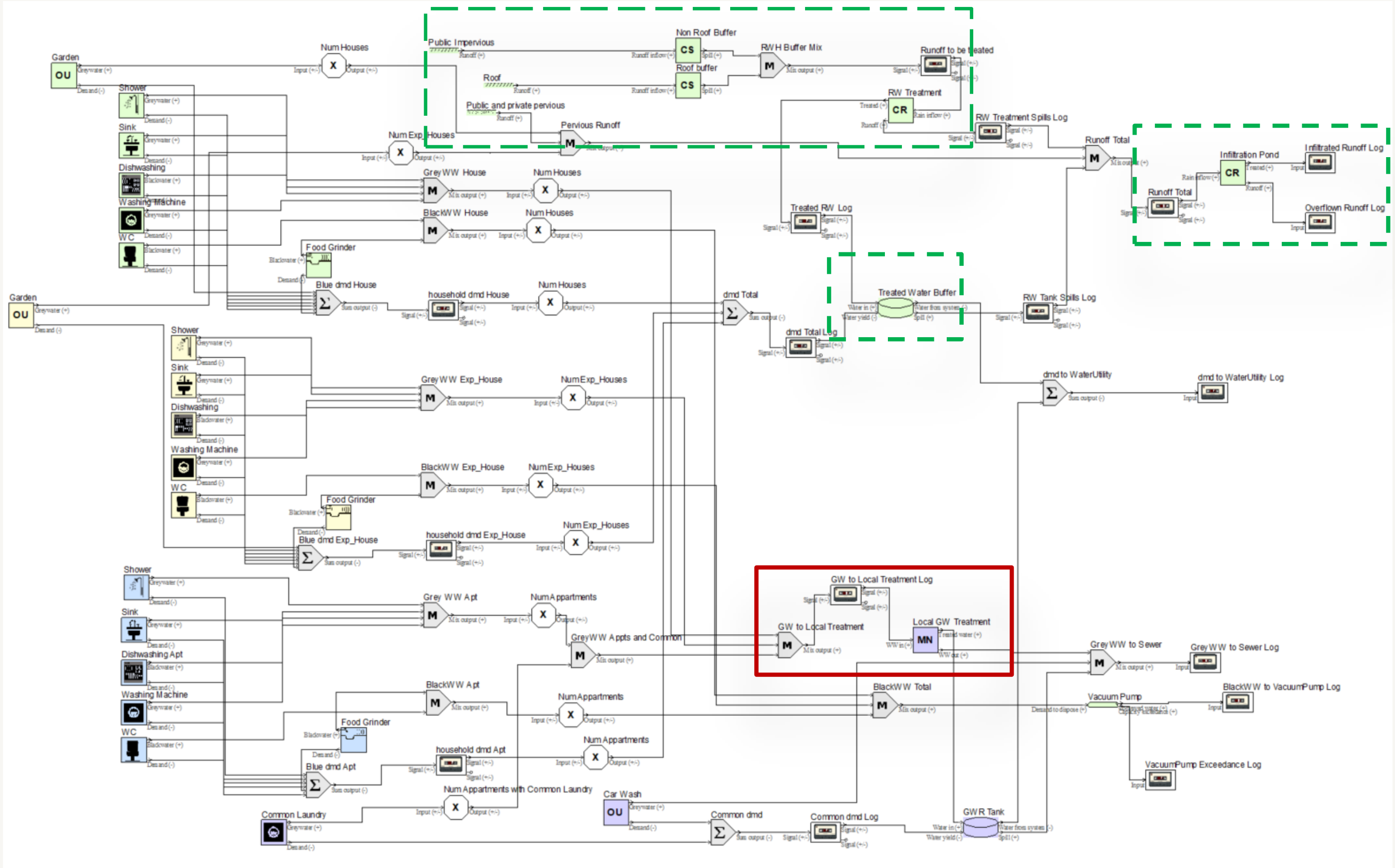
Signal-based, from demand nodes to sources.

Add household appliances, mix them together under different households.

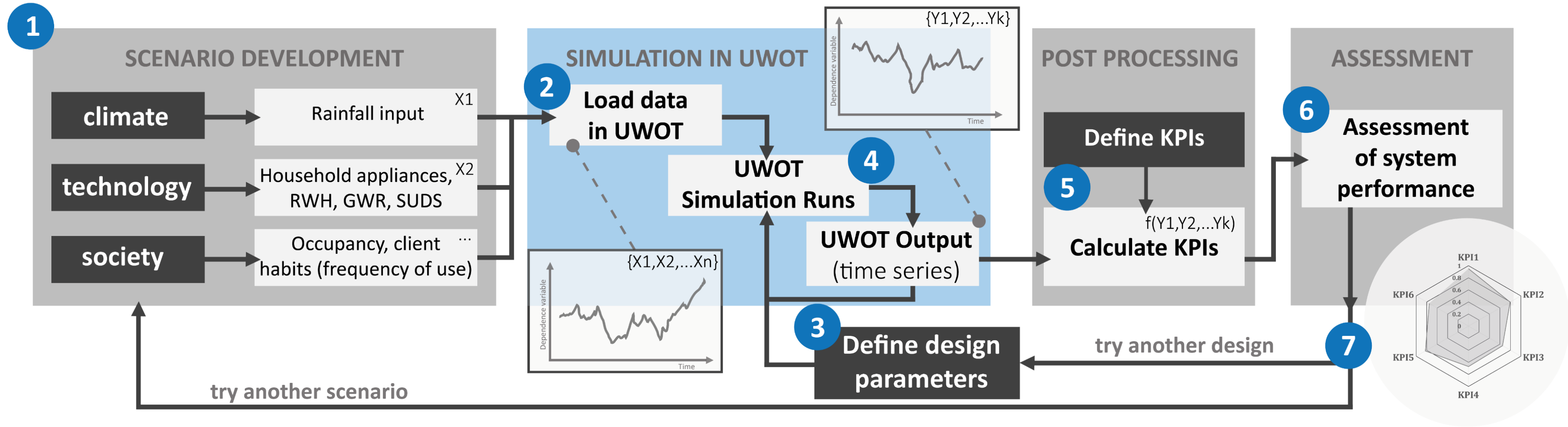
Include rainwater management and (potential) greywater recycling components.

Log stored water, covered demands, required energy at each time step.

View results for a specified topology (set of techs).



Not only simulation…



APPLICATIONS

2012-2018
Early applications (NTUA)
Resilience Framework

2019
Circular water neighborhood design
SUPERLOCAL – WiCE

2020
Athens
Westland circulaire
NextGen demo cases

TBA
Circular water neighborhoods SG (VO)

Smart water systems design (BWaterSmart)

Urban Water Optioneering Tool

MELISSA

INTRODUCTION | METHODOLOGY | RESULTS | CONCLUSIONS

2019 SUPERLOCAL

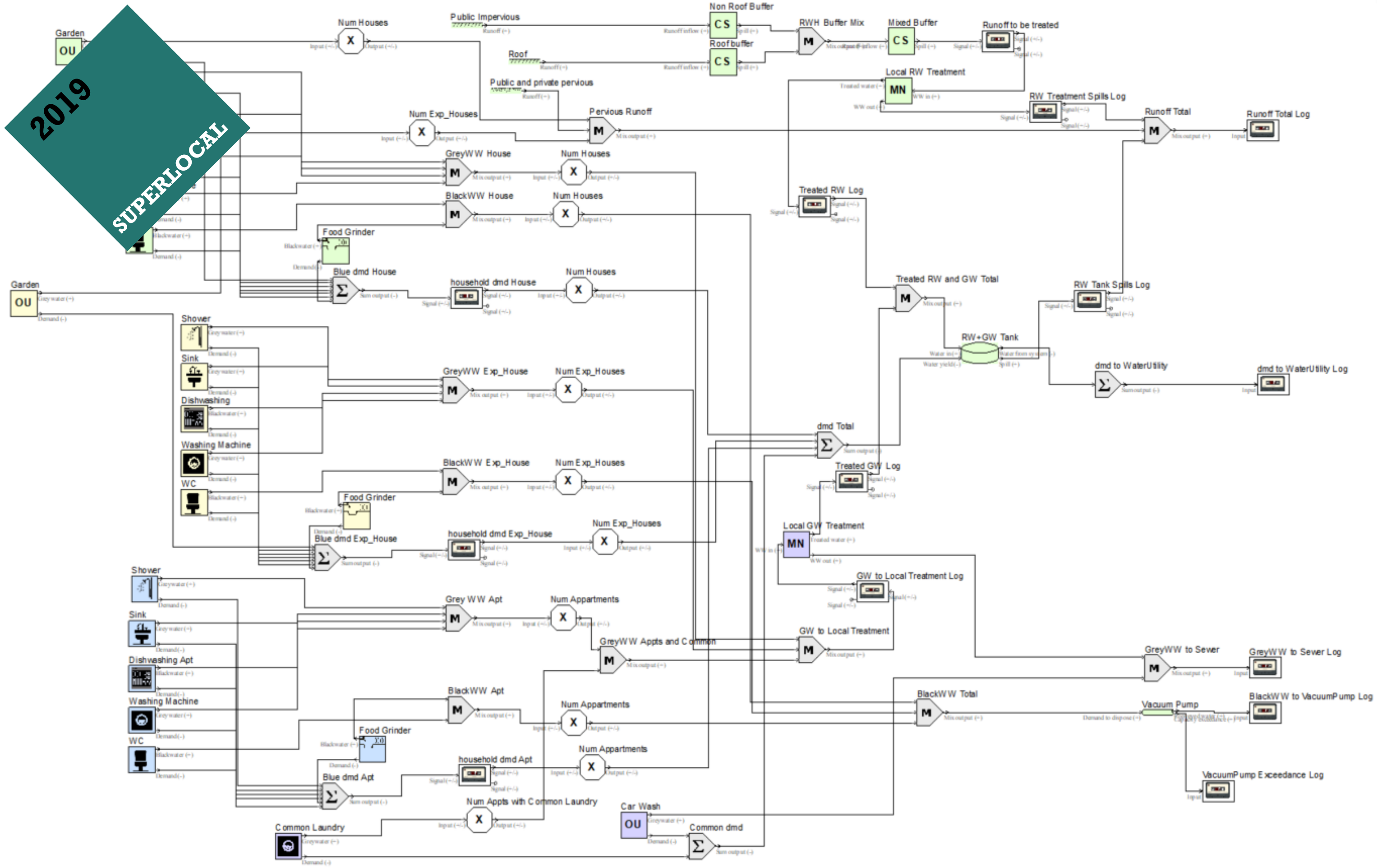
Circular neighborhood design SUPERLOCAL (Limburg, NL)

Target		Way
SLOW	Slower runoff response Lower flood peaks Rainwater absorbed locally	RWH Local RW buffer (storage) Infiltration basin (SUDS)
LESS	Less water use per household	Vacuum toilets Water-saving/recirc. showers Common laundry space for some units
LOCAL	Water recycled locally WW treated locally	RWH to DW GWR / treats WW back to specific uses Local treatment units for RW/GW BW stream (toilets, food grinders)

PARTNERS

KWR

wml Limburgs drinkwater



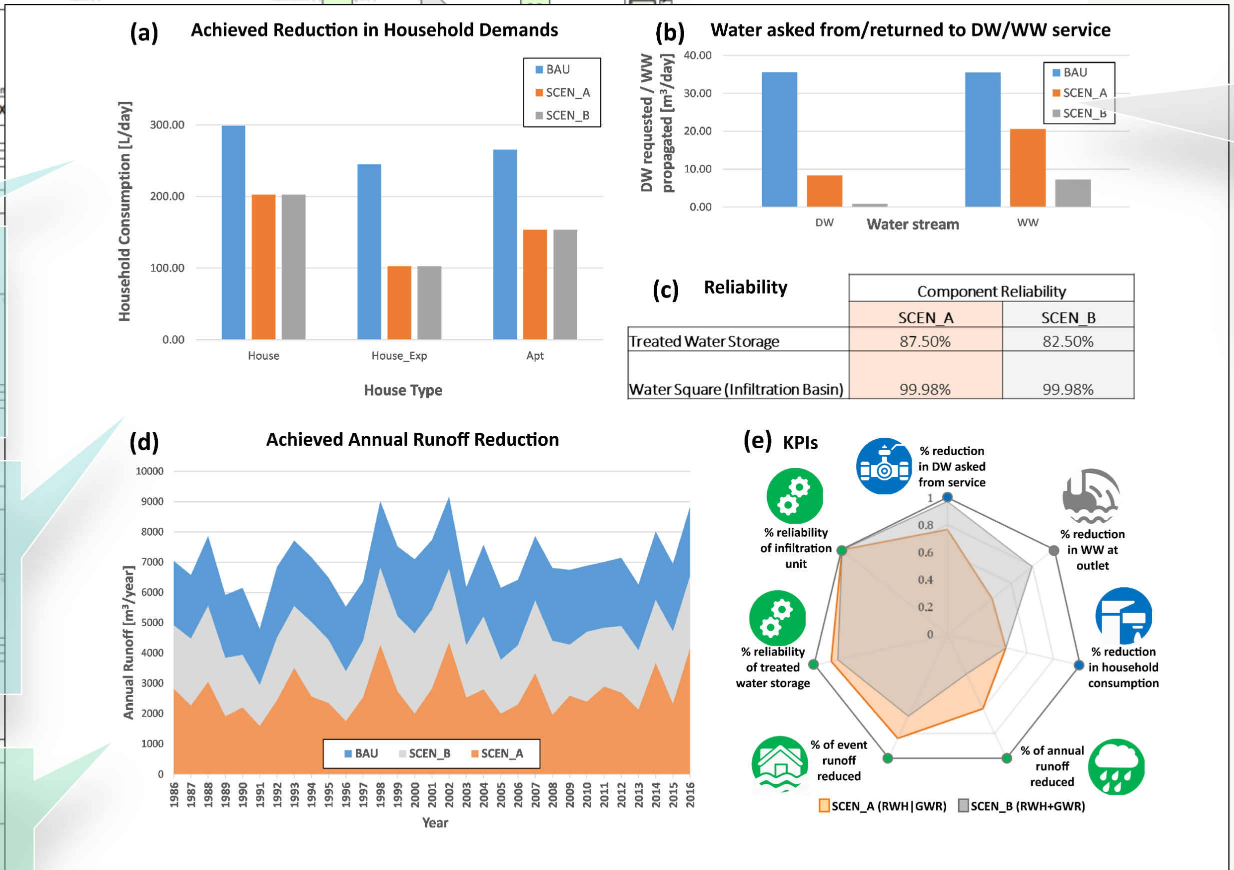
Scen A: Distinct decentralized systems (RWH/GWR)

Scen B: Combined recycling (RWH+GWR)

Reduction of
- 32% (houses)
- 58% (exp. houses)
- 42% (apartments)

Dependence on mix of appliances (household type)

Runoff reduction
- SCEN_A (RWH|GWR) for efficient at retaining flood volumes and peaks



DW asked centrally / WW propagated
- SCEN_B (RWH+GWR) more efficient / relies on a 'steadier' source of treated GW

Scen A: Distinct decentralized systems (RWH/GWR)

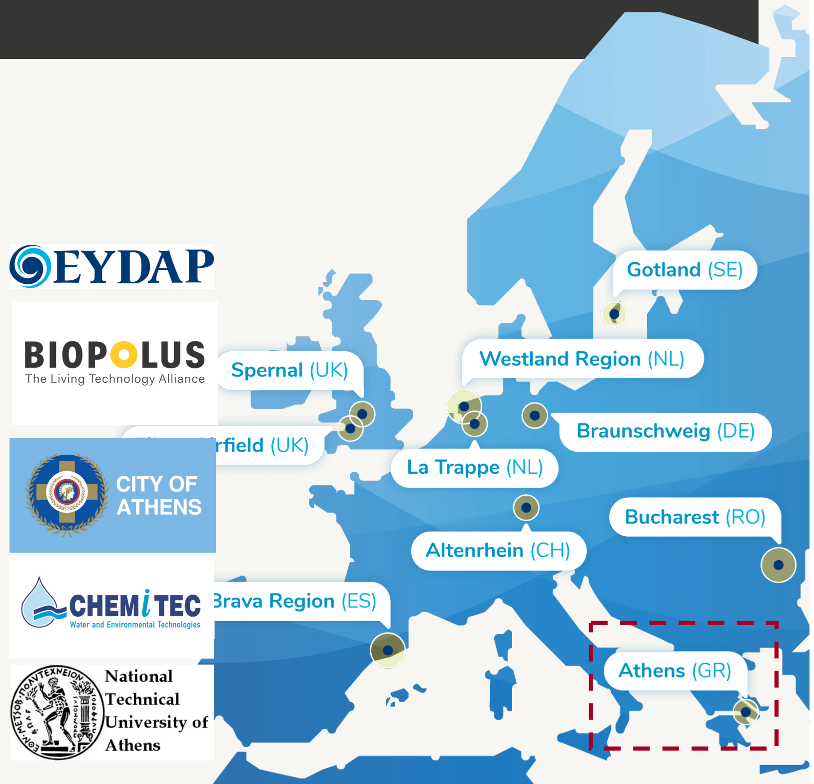
Scen B: Combined recycling (RWH+GWR)

2020 NEXTGEN ATHENS

Demonstrating circular economy principles in water: a local pilot for sewer mining

Sewer mining pilot in Athens Nursery area:

- decentralized WW treatment option (MBR treatment)
- Intermediate, localized water reuse option
- modular treatment units that can be placed anywhere on the network
- production of non-potable treated water (25 m^3/day)
- placement at point of demand (urban green spaces)

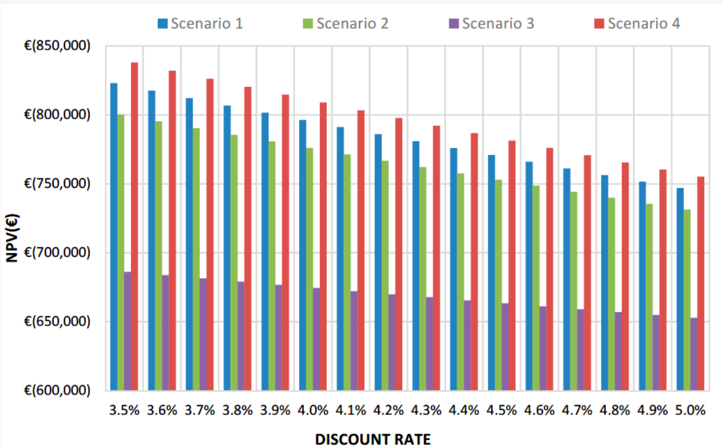


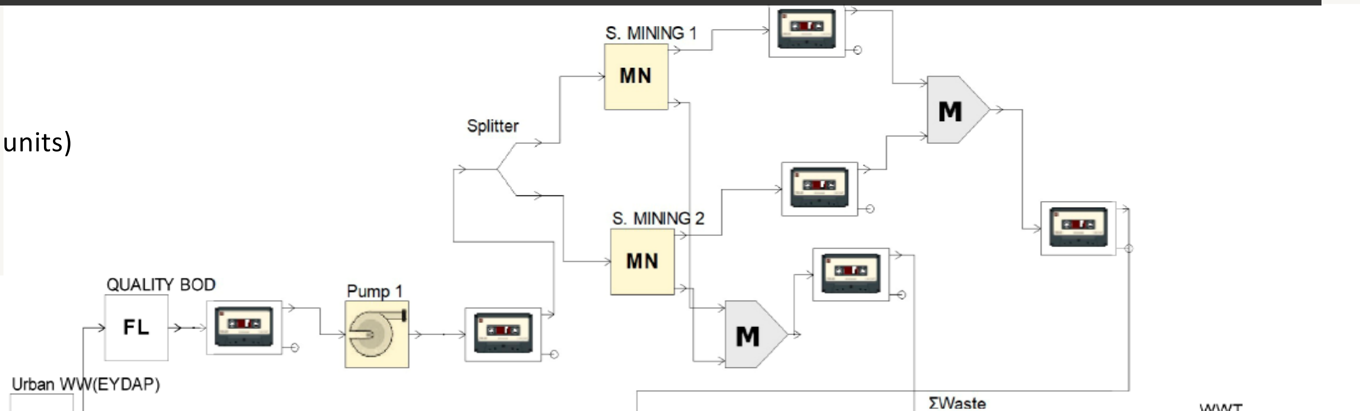
2020 NEXTGEN ATHENS

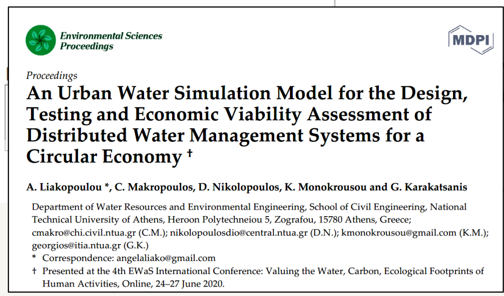
Demonstrating circular economy principles in water: a local pilot for sewer mining

Role of UWOT in Athens:

- Support model for different pilot layouts (multiple modular units)
- Calculation of BOD concentration based on WW influx
- Economic evaluation of technology over 15 years (NPV/IRR)







Environmental Sciences Proceedings

MDPI

Proceedings

An Urban Water Simulation Model for the Design, Testing and Economic Viability Assessment of Distributed Water Management Systems for a Circular Economy †

A. Liakopoulou *, C. Makropoulos, D. Nikolopoulos, K. Monokrousou and G. Karakatsanis

Department of Water Resources and Environmental Engineering, School of Civil Engineering, National Technical University of Athens, Heroon Polytechneiou 5, Zografou, 15780 Athens, Greece; cmakro@chi.civil.ntua.gr (C.M.); nikolopoulosdio@central.ntua.gr (D.N.); kmonokrousou@gmail.com (K.M.); georgios@itia.ntua.gr (G.K.)

* Correspondence: angelaliako@gmail.com

† Presented at the 4th EWaS International Conference: Valuing the Water, Carbon, Ecological Footprints of Human Activities, Online, 24–27 June 2020.

ELSEVIER

Journal of Environmental Management

Volume 216, 15 June 2018, Pages 285-298

Research article

Sewer-mining: A water reuse option supporting circular economy, public service provision and entrepreneurship

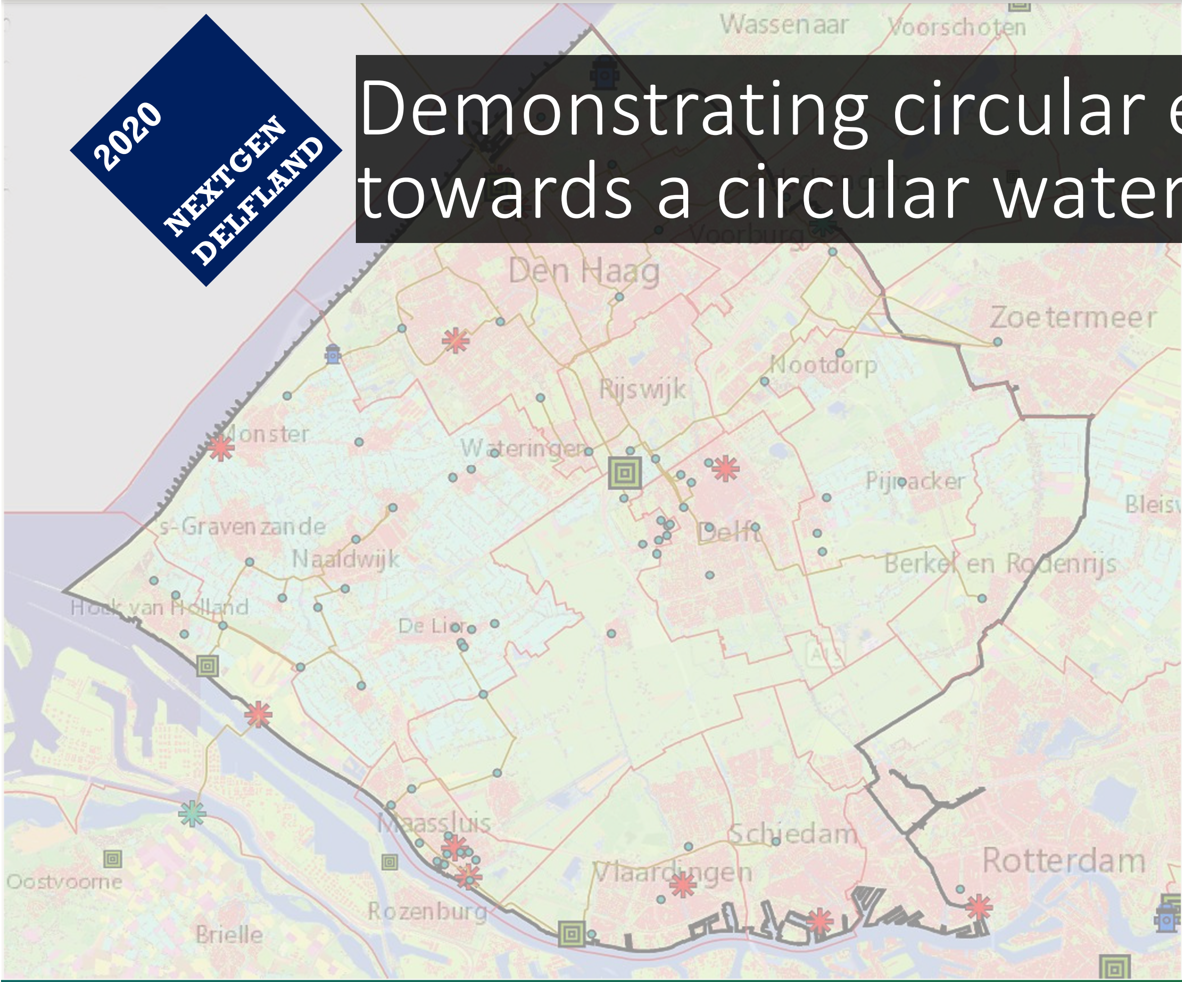
C. Makropoulos [a], E. Rozos [a], I. Tsoukalas [a], A. Plevri [b], G. Karakatsanis [a], L. Karagiannidis [c], E. Makri [d], C. Lioumis [e], C. Noutsopoulos [a], D. Mamais [a], C. Rippis [b], E. Lytras [b]

Show more

https://doi.org/10.1016/j.jenvman.2017.07.026

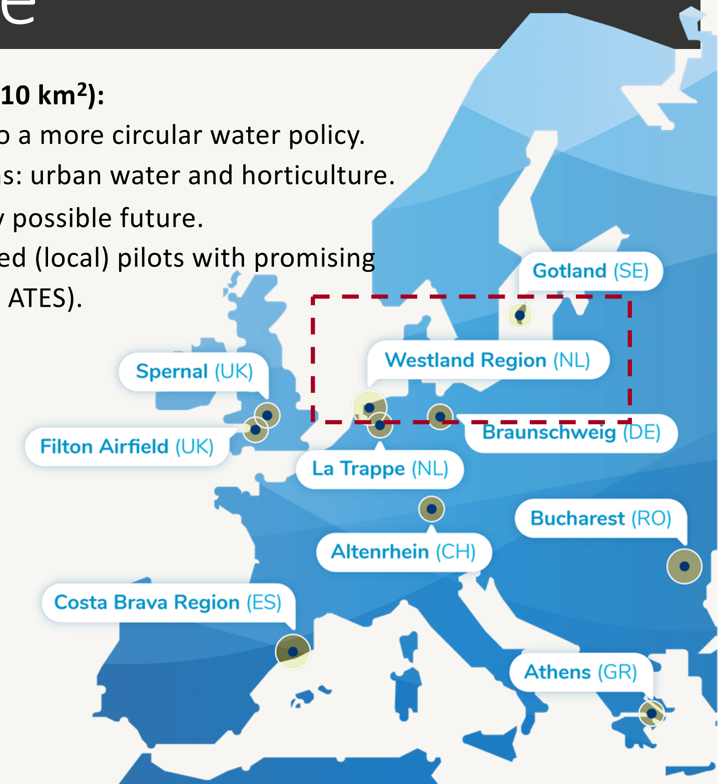
2020 NEXTGEN DELFLAND

Demonstrating circular economy principles in water: towards a circular water province

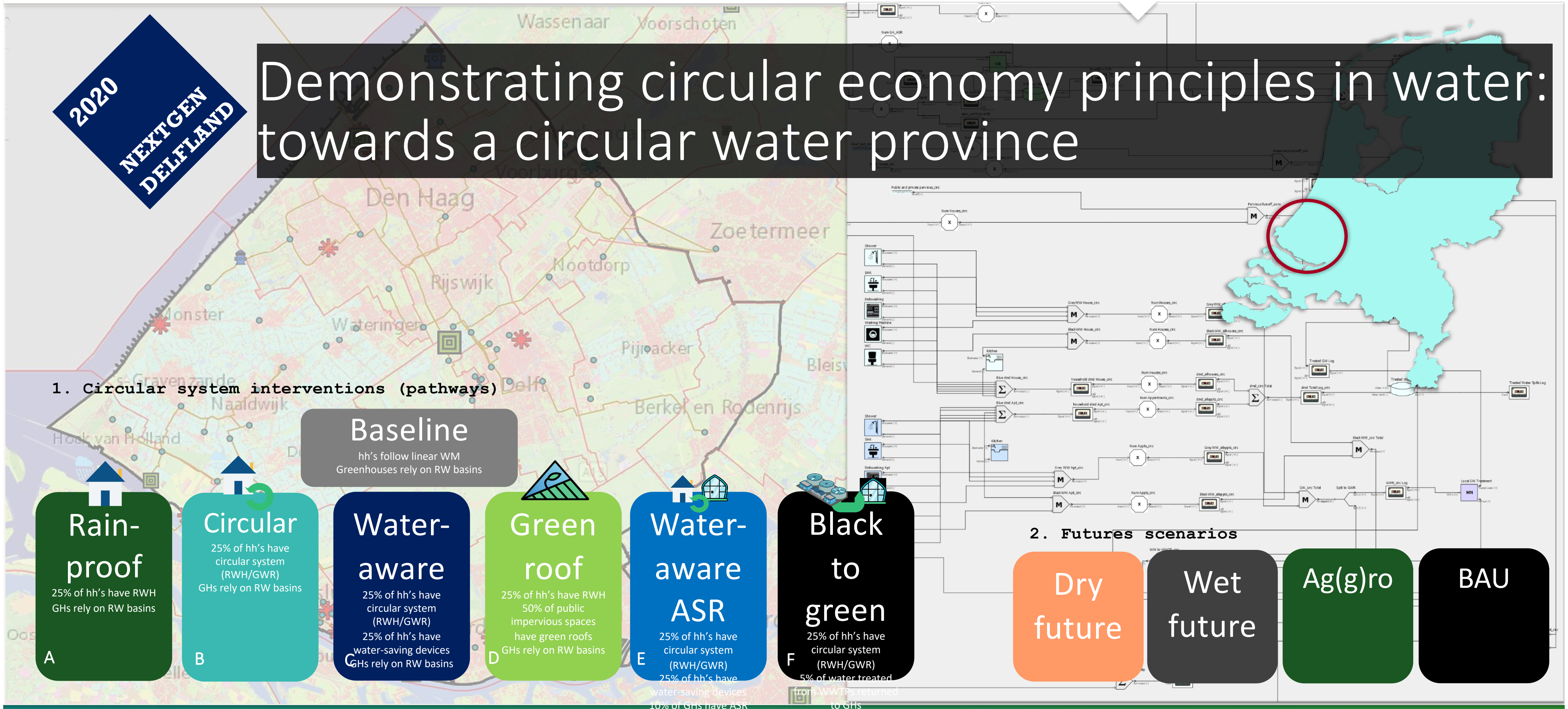


One large province (410 km^2):

- Will to transition to a more circular water policy.
- Two major domains: urban water and horticulture.
- Concern over a dry possible future.
- Multiple fragmented (local) pilots with promising technologies (ASR, ATES).

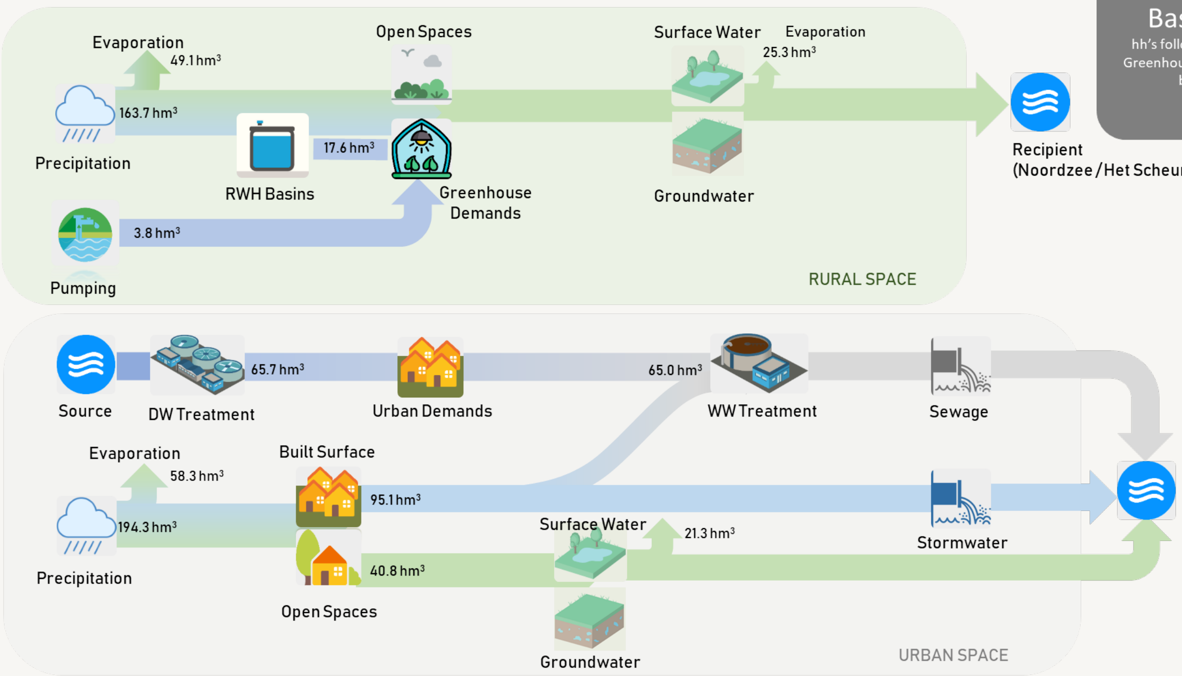


Demonstrating circular economy principles in water: towards a circular water province



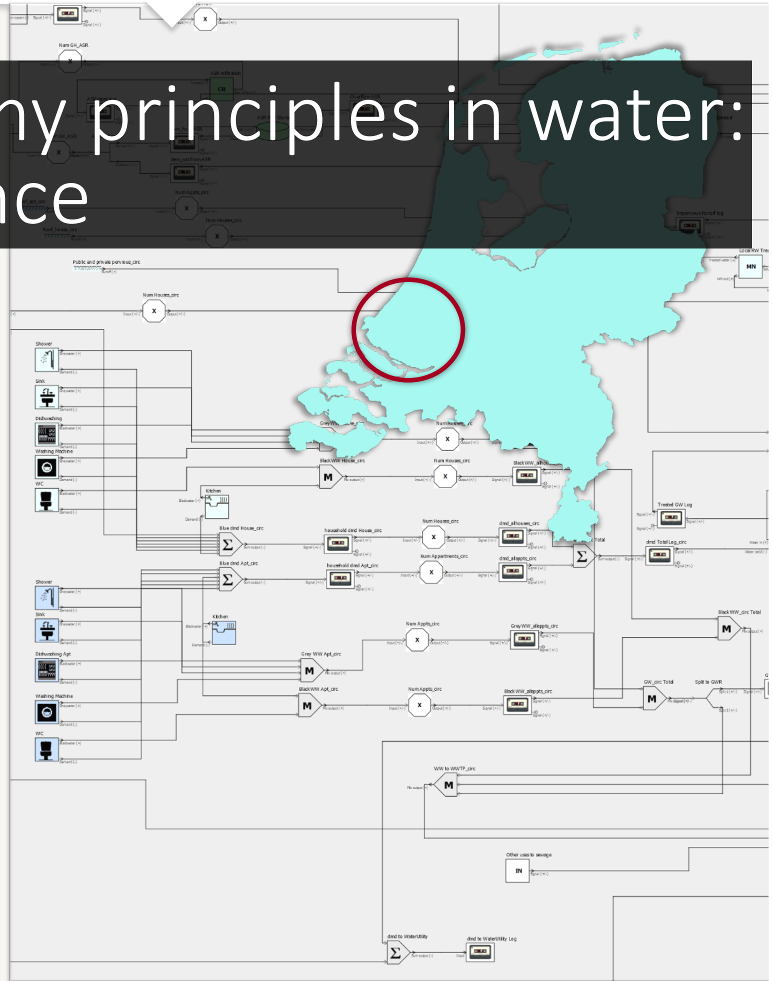
2020 NEXTGEN DELFLAND

Demonstrating circular economy principles in water: towards a circular water province



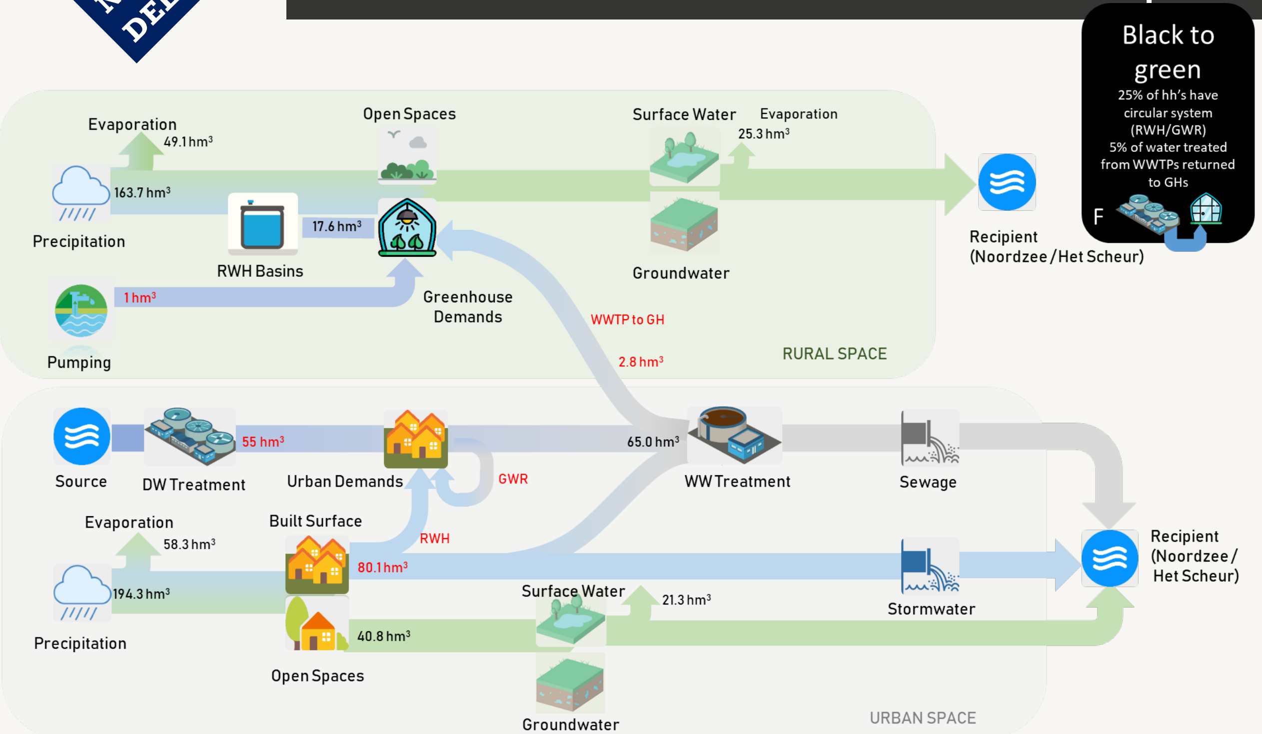
Baseline

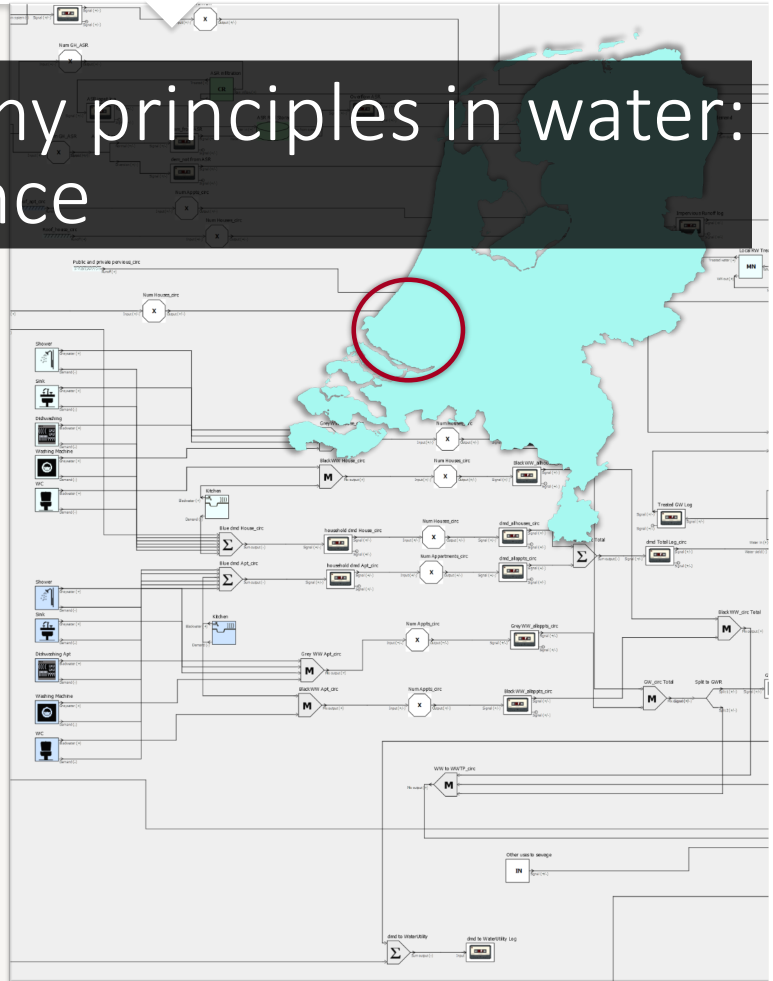
hh's follow linear WM
Greenhouses rely on RW basins



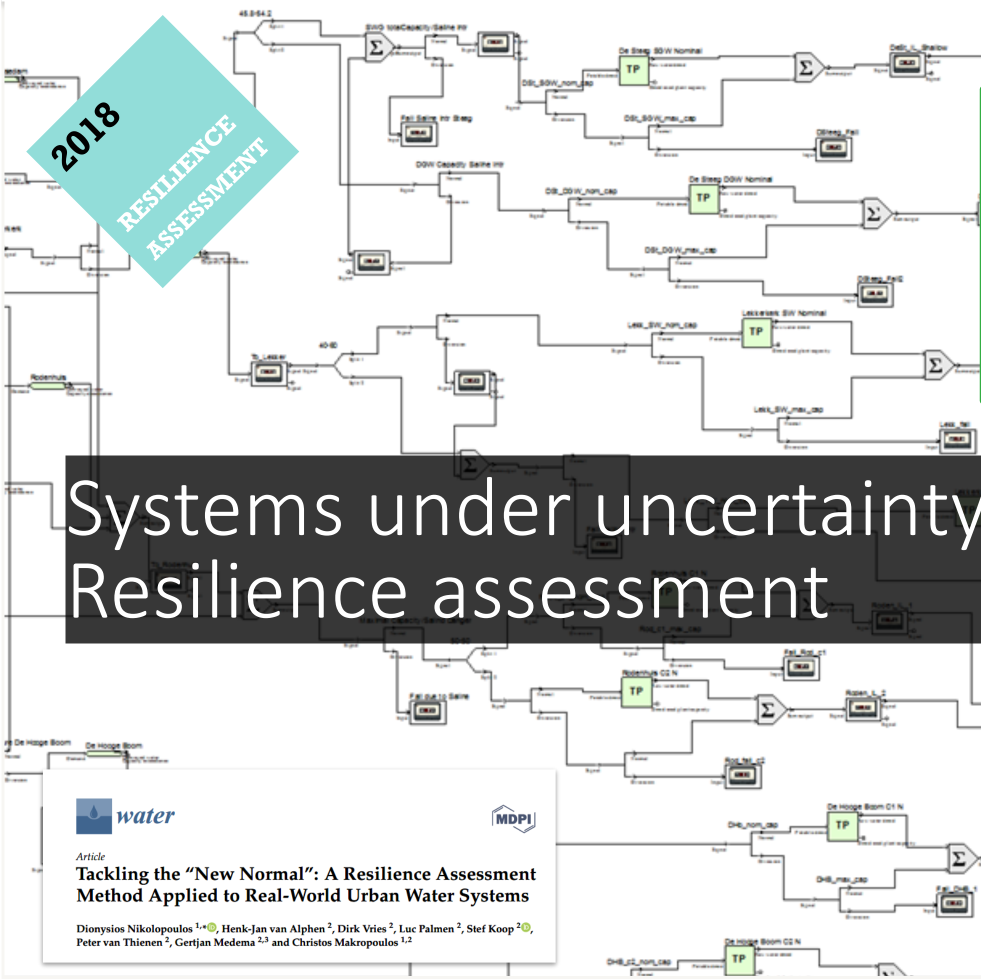
2020 NEXTGEN DELFLAND

Demonstrating circular economy principles in water: towards a circular water province



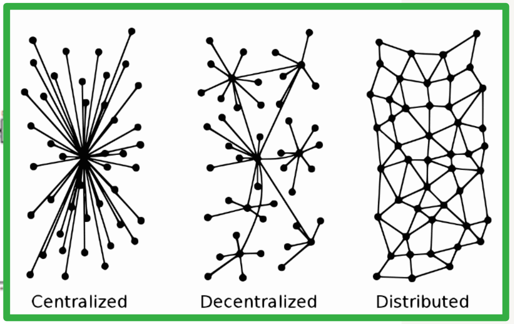


INTRODUCTION METHODOLOGY RESULTS CONCLUSIONS

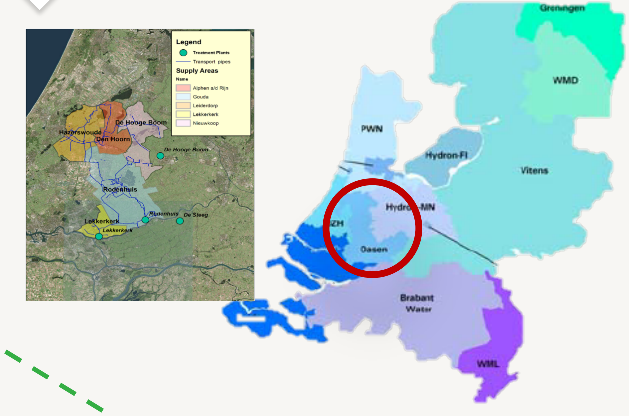


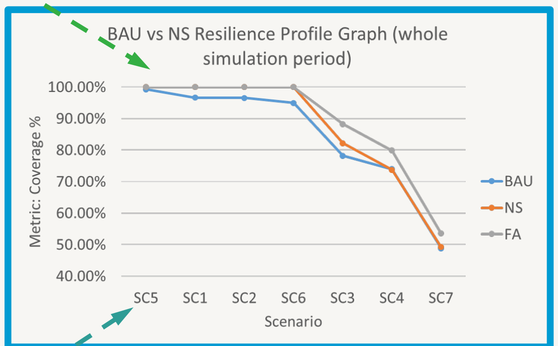
2018
RESILIENCE ASSESSMENT

Systems under uncertainty: Resilience assessment



1. System interventions (pathways)





3. Resilience Profiles

SCENARIOS

Baseline
- Current situation

SC 1&2: Easy does it
- Least change in parameters
- Population ages but remains constant

SC 7: Maximum Overdrive
- Huge increase in demand
- Population doubles
- Climate change worse than expected
- Complete privatization of water sector

SC 3&4: The young Ones
- Inflow of young immigrants
- Privatization
- Increase in demand
- Pollution
- Economic activities expand, quality standards loosened

SC 5&6: Of old people and things passed
- Economic crisis, low trust in government
- Population ages and declines
- Heavy pollution
- Extreme droughts and floods

+ Wildcards:
- Levee breach
- Hacking of Cls
- Chloride increase
- Immigration influx

2. Scenarios

water MDPI

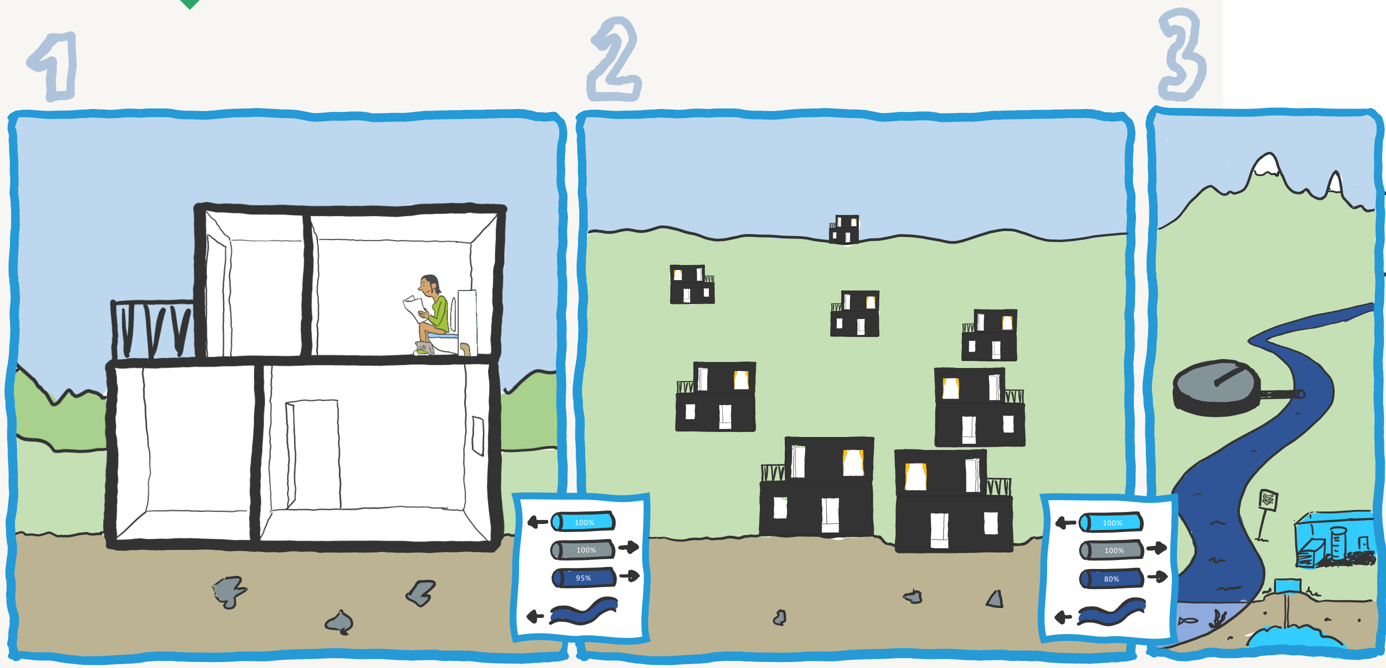
Article

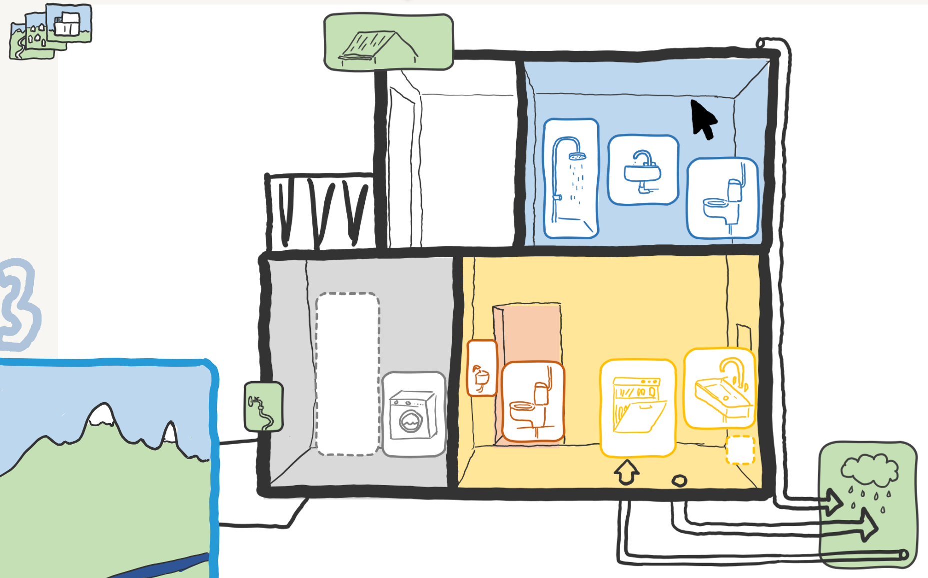
Tackling the "New Normal": A Resilience Assessment Method Applied to Real-World Urban Water Systems

Dionysios Nikolopoulos [1,*], Henk-Jan van Alphen [2], Dirk Vries [2], Luc Palmen [2], Stef Koop [2], Peter van Thienen [2], Gertjan Medema [2,3] and Christos Makropoulos [1,2]

2020 (TBA)

VO SG
UWOT





PARTNERS

wml Limburgs drinkwater
Maastricht University
KWR
University of Exeter

Conclusions

- UWOT is a bottom-up (component-based), spatially agnostic water balance (watercycle) model.
- Suitable for generic **circular water system** studies.
- Tested against **multiple cases**, developed over diverse projects
(household smart water applications, city-scale modeling, green-blue area design, innovative pilots, circular neighborhood design)

Potential links with Melissa – from earth to space

- UWOT is flexible to suit future projects (custom, new components/GUI & API).
- As an agnostic model, can be applied to autonomous, close-loop (space) systems of water reuse (studies on reliability, resilience, upscaling, ex-ante evaluation of different layouts).
- Pairing with data from closed-loop pilots.

Thank you for your attention!

References:

1. Gleick, P.H. Water management: Soft water paths. Nature 2002, 418, 373.
2. D. Bouziotas, D. van Duuren, H. J. van Alphen, J. Frijns, D. Nikolopoulos, and C. Makropoulos, Towards circular water neighborhoods: Simulation-based decision support for integrated decentralized urban water systems, Water, 11 (6), 2019.
3. A. Liakopoulou, C. Makropoulos, D. Nikolopoulos, K. Monokrousou, and G. Karakatsanis, An urban water simulation model for the design, testing and economic viability assessment of distributed water management systems for a circular economy, *Environmental Sciences Proceedings*, 21 (1), 14, 2020.
4. C. Makropoulos, E. Rozos, I. Tsoukalas, A. Plevri, G. Karakatsanis, L. Karagiannidis, E. Makri, C. Lioumis, K. Noutsopoulos, D. Mamais, K. Ripis, and T. Lytras, Sewer-mining: A water reuse option supporting circular economy, public service provision and entrepreneurship, Journal of Environmental Management, 216, 2018.
5. D. Nikolopoulos, H. J. van Alphen, D. Vries, L. Palmen, S. Koop, P. van Thienen, G. Medema, and C. Makropoulos, Tackling the "new normal": A resilience assessment method applied to real-world urban water systems, *Water*, 11 (2), 330, 2019.

@KWR_Water KWR KWR_Water

National Technical University of Athens

Dimitrios Bouziotas
dimitrios.bouziotas@kwrwater.nl

Dionysios Nikolopoulos
nikolopoulosdio@central.ntua.gr

Klio Monokrousou
kmonokrousou@gmail.com

Jos Frijns
jos.frijns@kwrwater.nl

Christos Makropoulos
christos.makropoulos@kwrwater.nl