Innovation in Urban Water Infrastructure

ANWA's 2013 Annual Meeting

(28, October, 2013)

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Urban Sustainability

@

Patel College of Global Sustainability

USF

Bad News – External Pressures make the Situation Worse

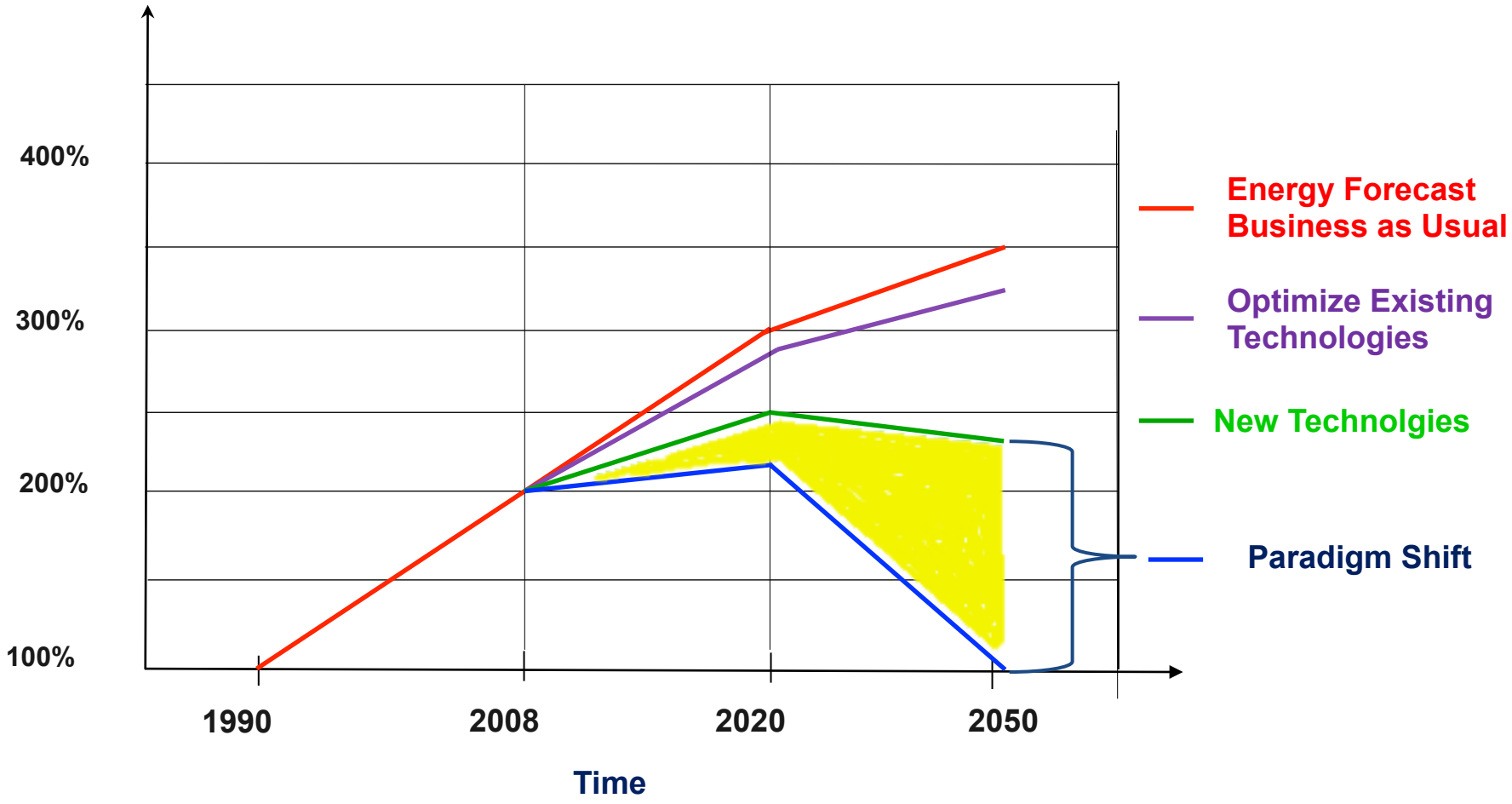
- **Entire earth system is changing!**






Trying harder is not enough
We need a paradigm shift

Forecasted Energy Usage in Water Industry in UK



Source: Council for Science and Technology UK 2009

Move away from 19 c. Principles

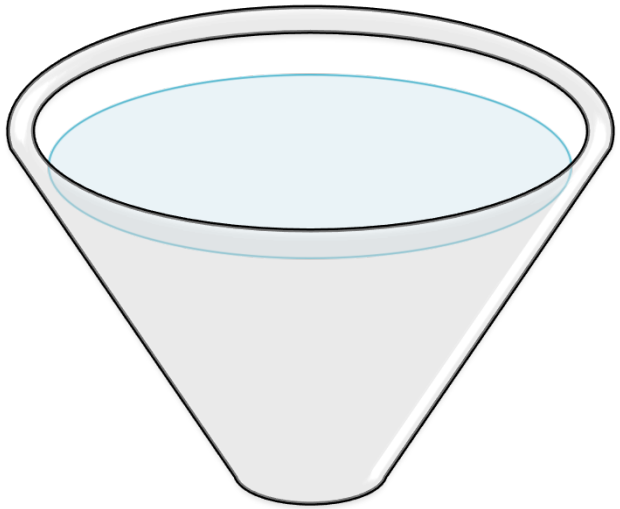
- Linear systems – use once and discharge
- Drinking water used for all purposes
- Institutions not conducive for integrated thinking
- Urban form, no input from water sector

Education reinforces these principles

Need to think differently

IUWM is not a methodology but a mindset - a different way of thinking

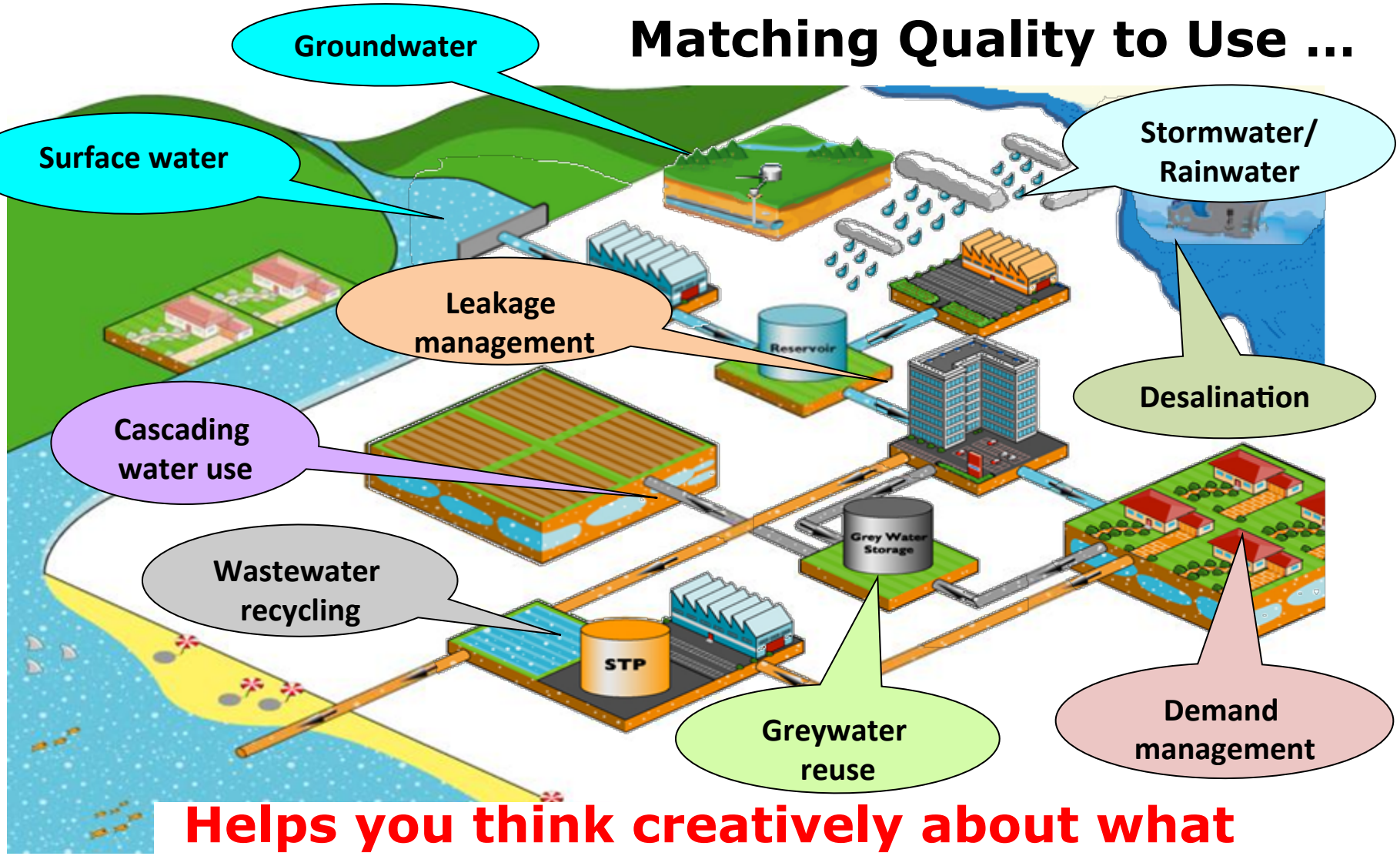
- Stakeholders are a key for effective decision making



Doing more with less
'Integration the key'

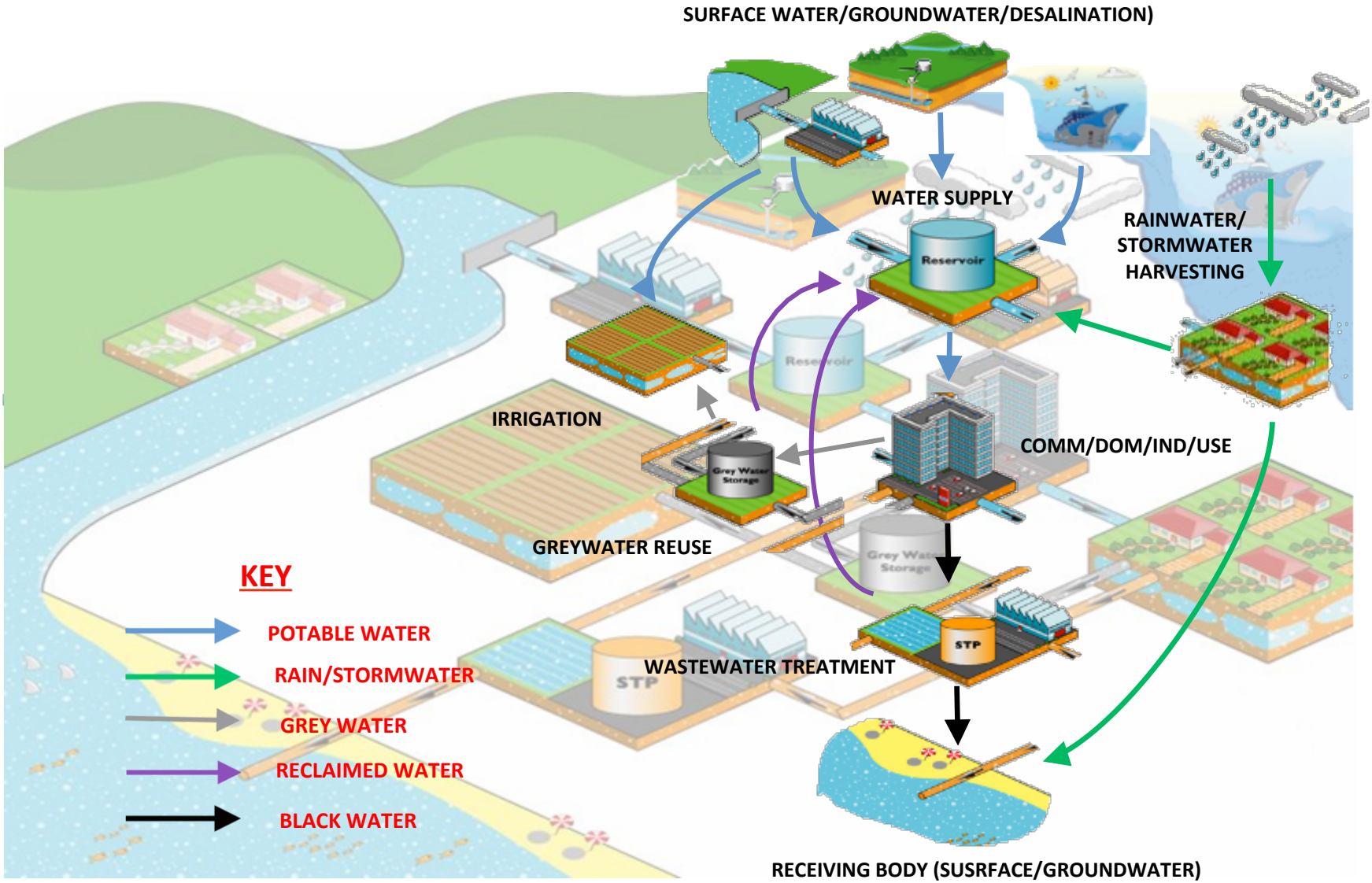
Holistic systems approach
to the urban watershed

Integrated Urban Water Management: provides good framework for analysis

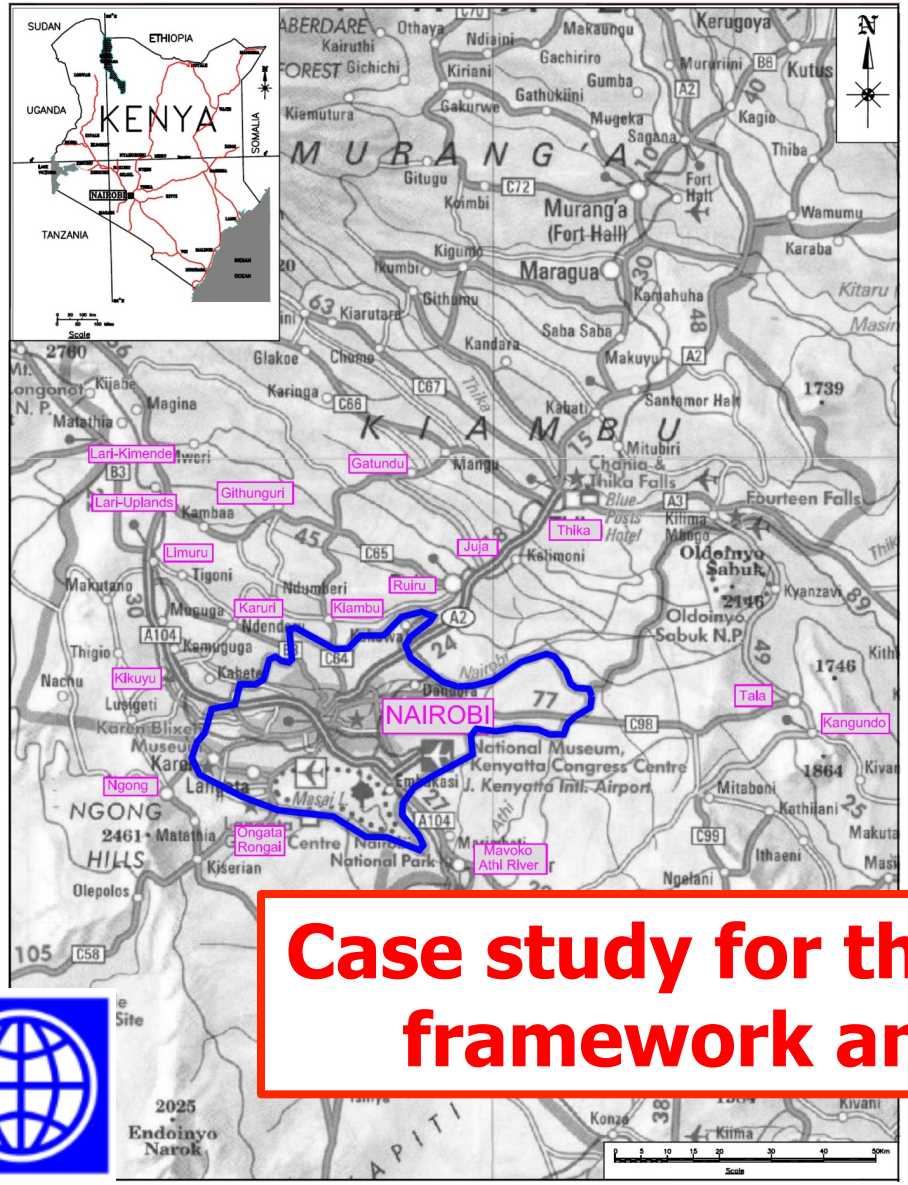


Helps you think creatively about what could be potential water sources

Integrated Urban Water Management: provides good framework for analysis



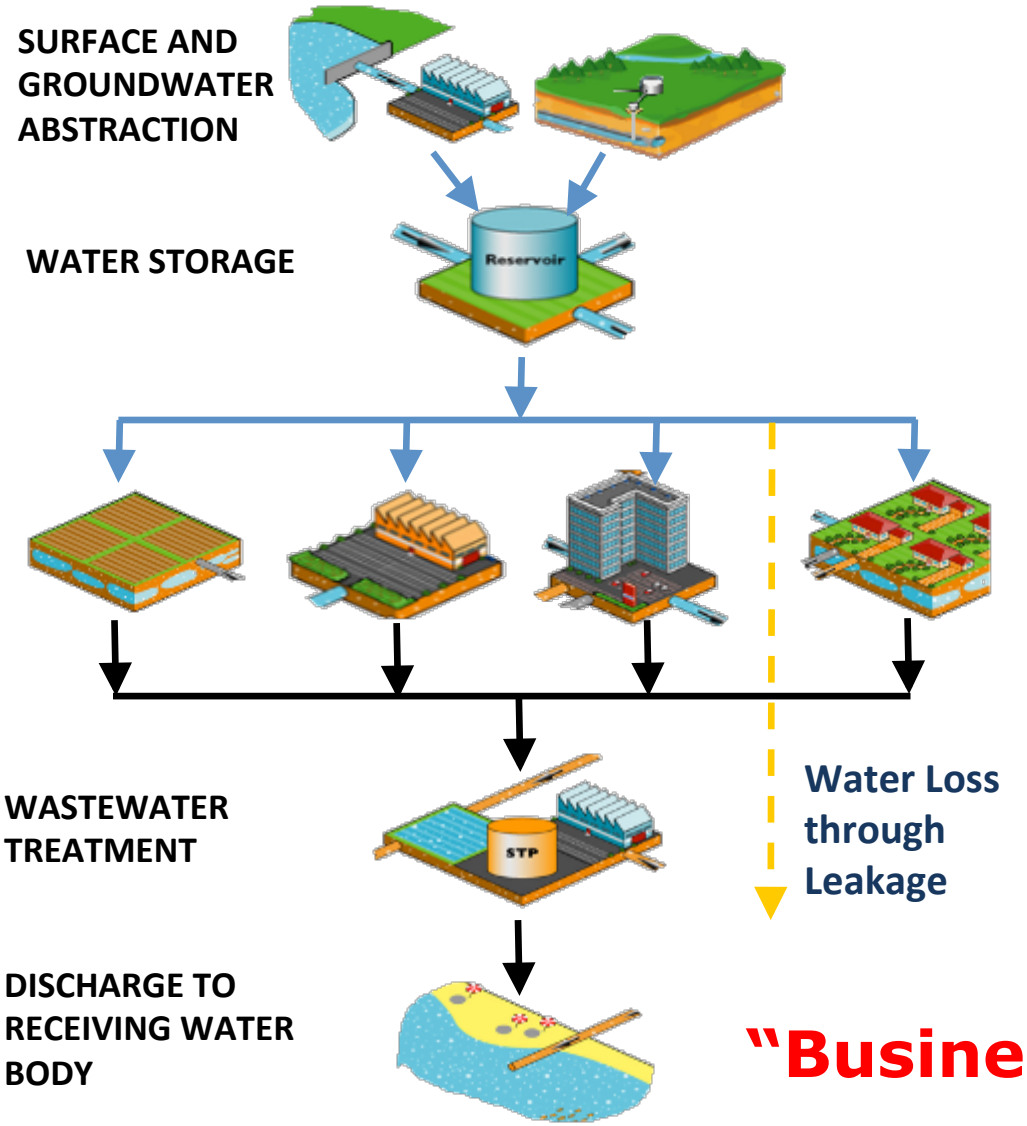
Case Study: Water Resources for Nairobi and Satellite Towns



- Today 3.14M people
- Predicted to increase to between 6.4 and 11.2M by 2035
- Result in major supply-demand deficit

Case study for the application of the framework and the principles.

Conventional Solution – Focus only on Surface and Groundwater



DEMAND = 1,207,000 m^3/d

SOURCES:

568,000 (Existing)

\+ 65,000 (New GW)

\+ 518,000 (New SW1)

\+ 56,000 (New SW2)

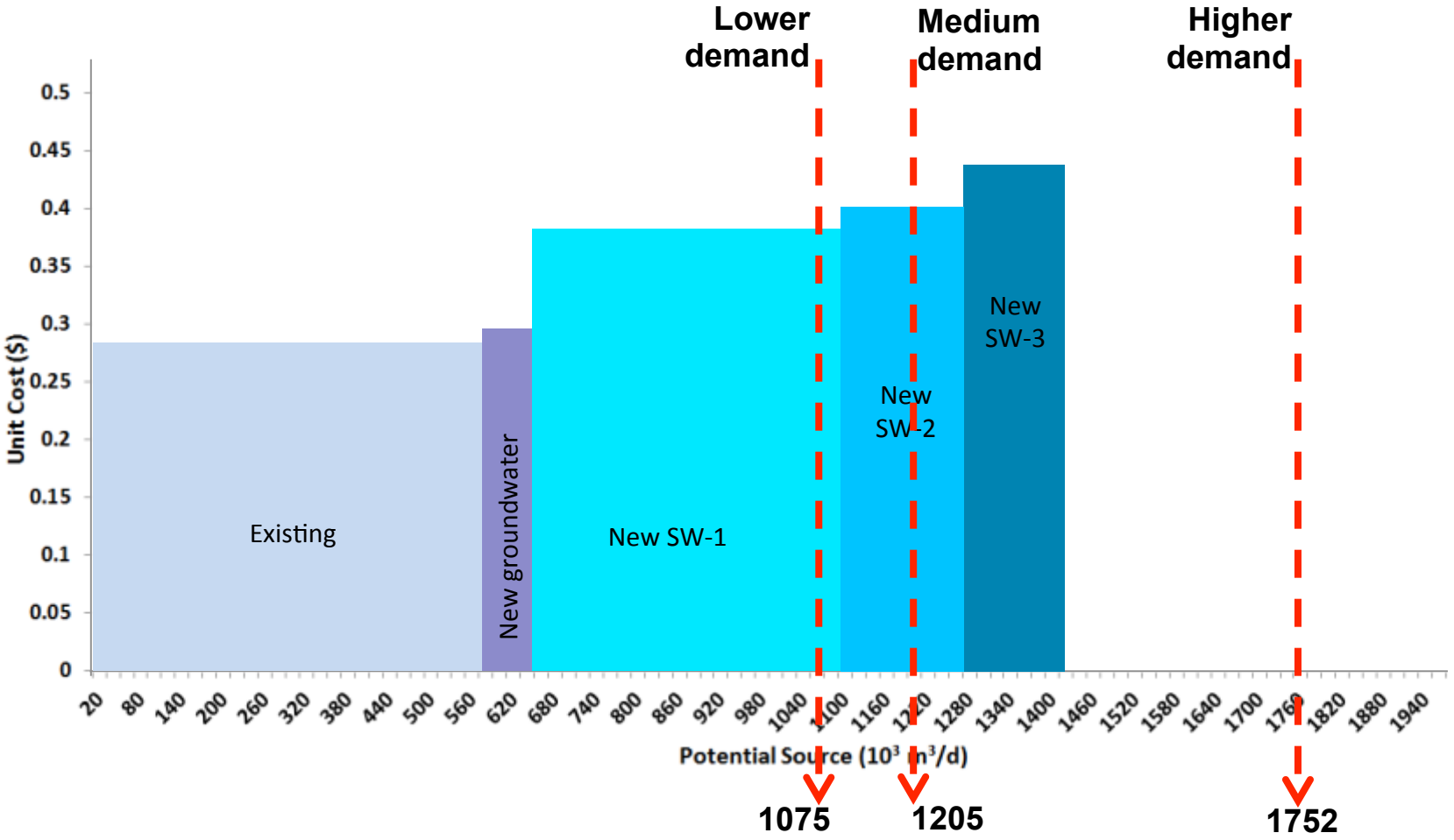
= 1,207,000 m^3/d

UNIT COST = US$ 0.36/m^3

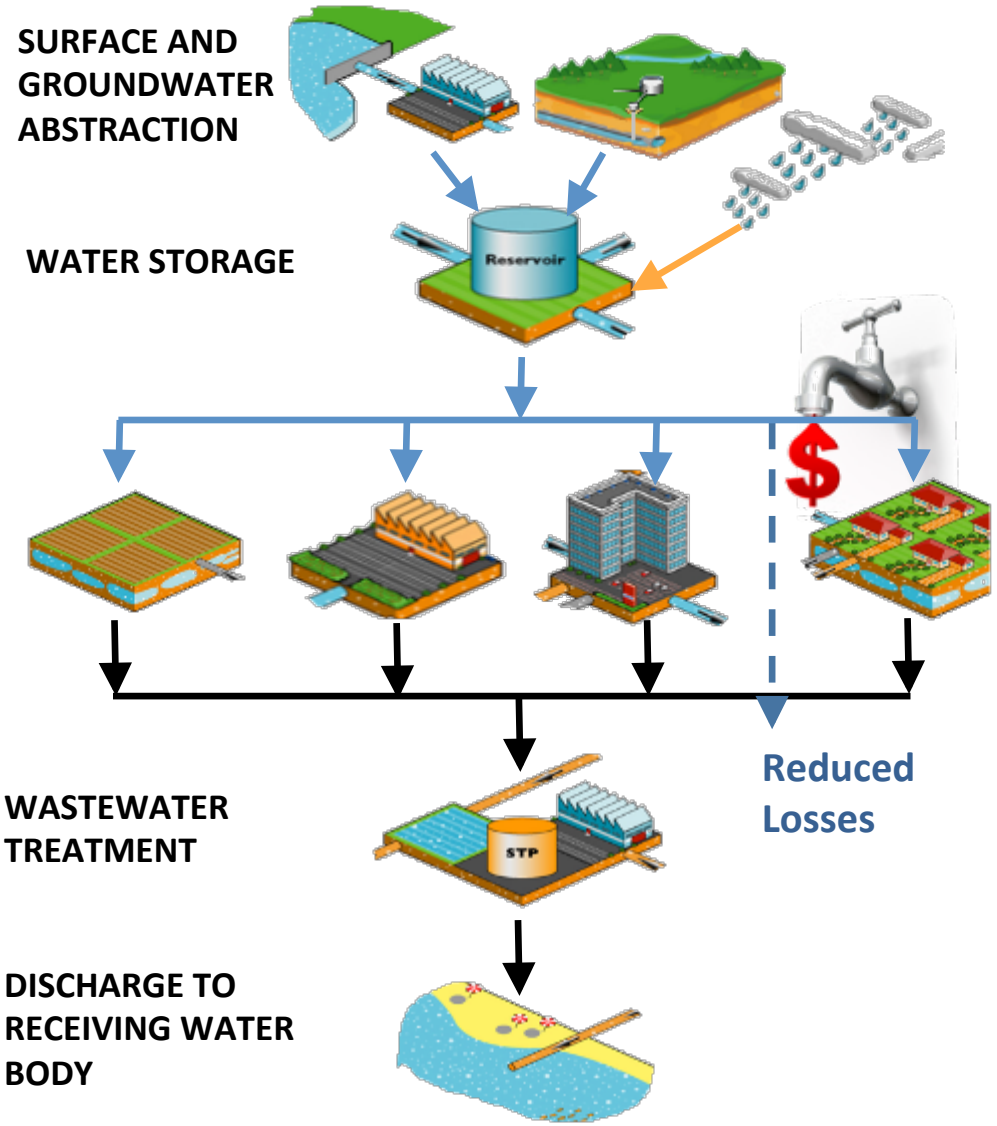
"Business-As-Usual" Trajectory

Conventional Solution cannot meet full range of uncertainties

- Unit costs of **US$ 0.36/m3**
- Can only meet medium demand scenario (not high demand scenario)



IUWM Application 1 (stormwater, leakage, demand management)



DEMAND = 1,207,000 m^3/d

SOURCES:

568,000 (Existing)
\+ 65,000 (New GW)
\+ 219,000 (New SW1)

\+ 193,000 (Leakage Mgt.)

\+ 111,000 (RWH)

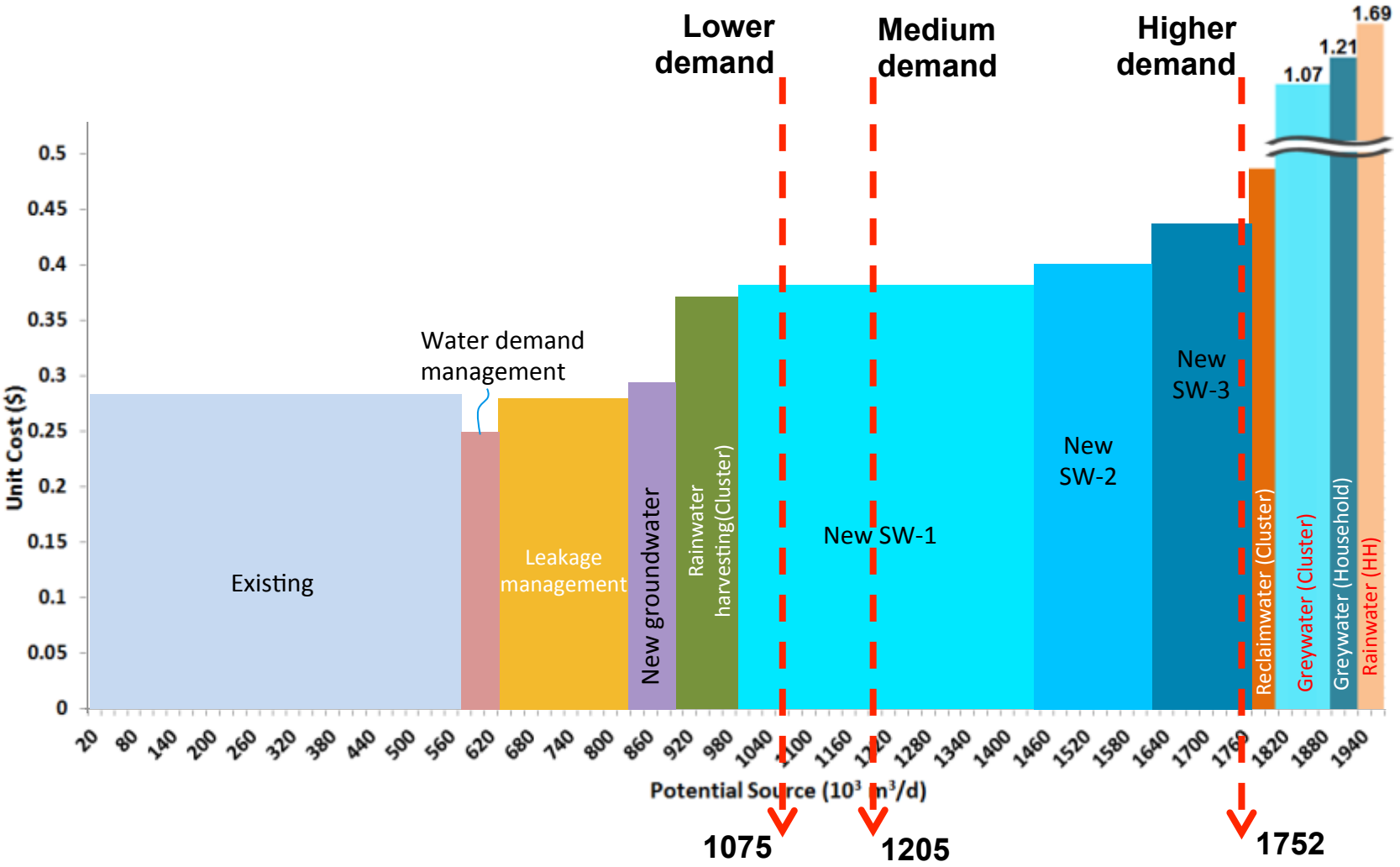
\+ 51,000 (Demand Mgt.)

= 1,207,000 m^3/d

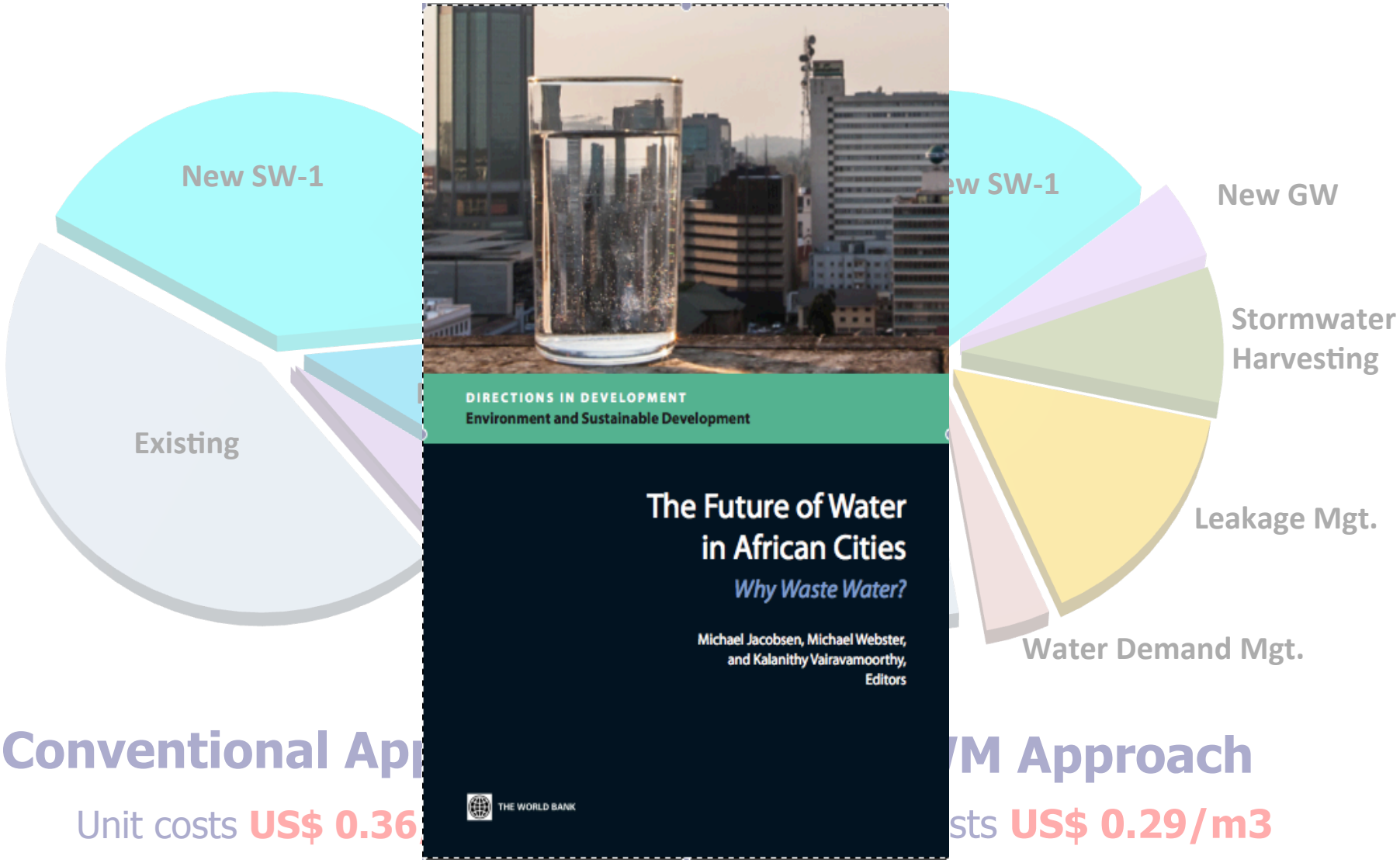
UNIT COST = US$ 0.29/m^3

IUWM Application 1 (stormwater, leakage, demand management)

- Unit costs of **US$ 0.29/m3** (cf. to 0.36)



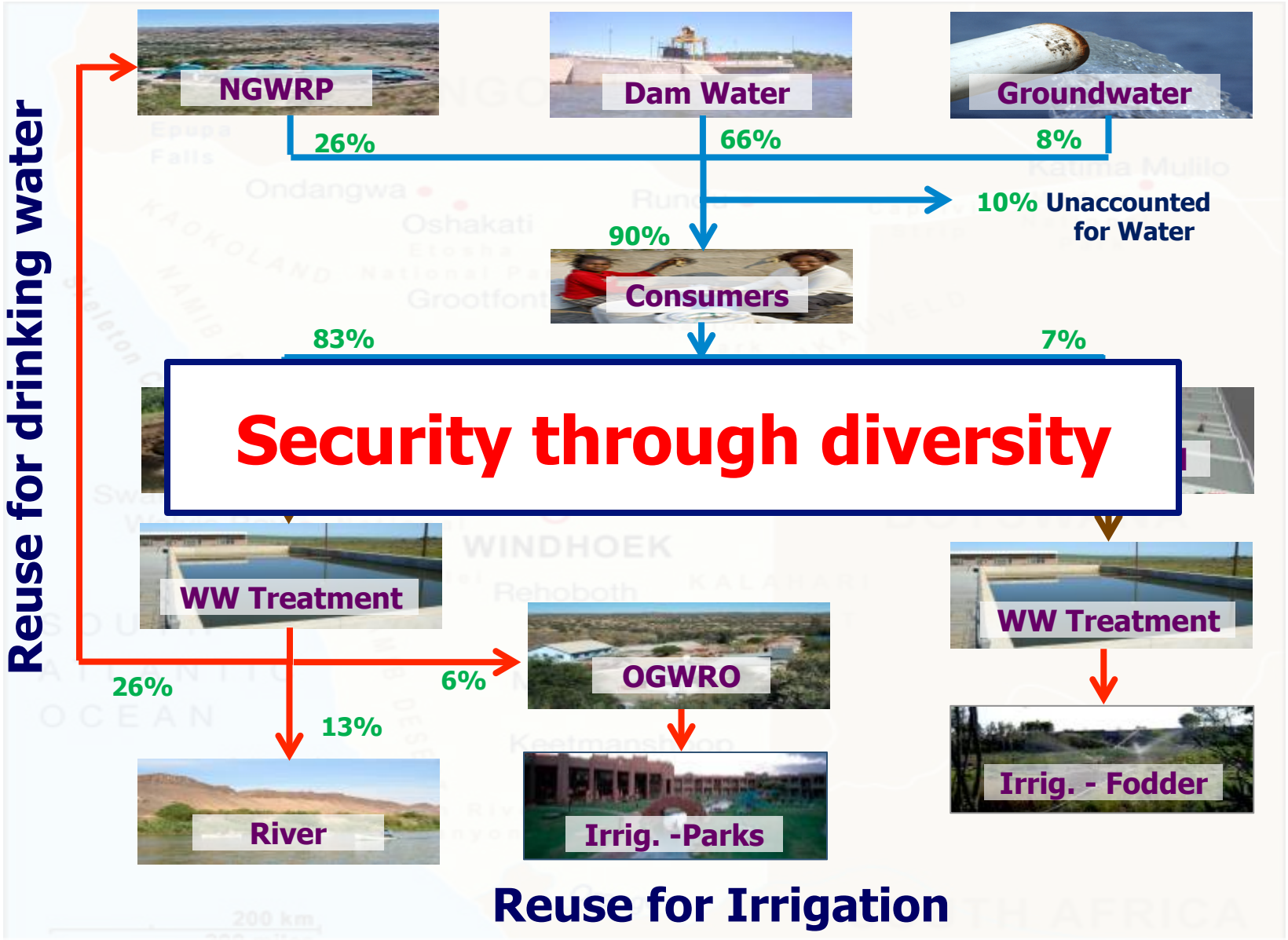
It's about having a Portfolio of viable options – Nairobi



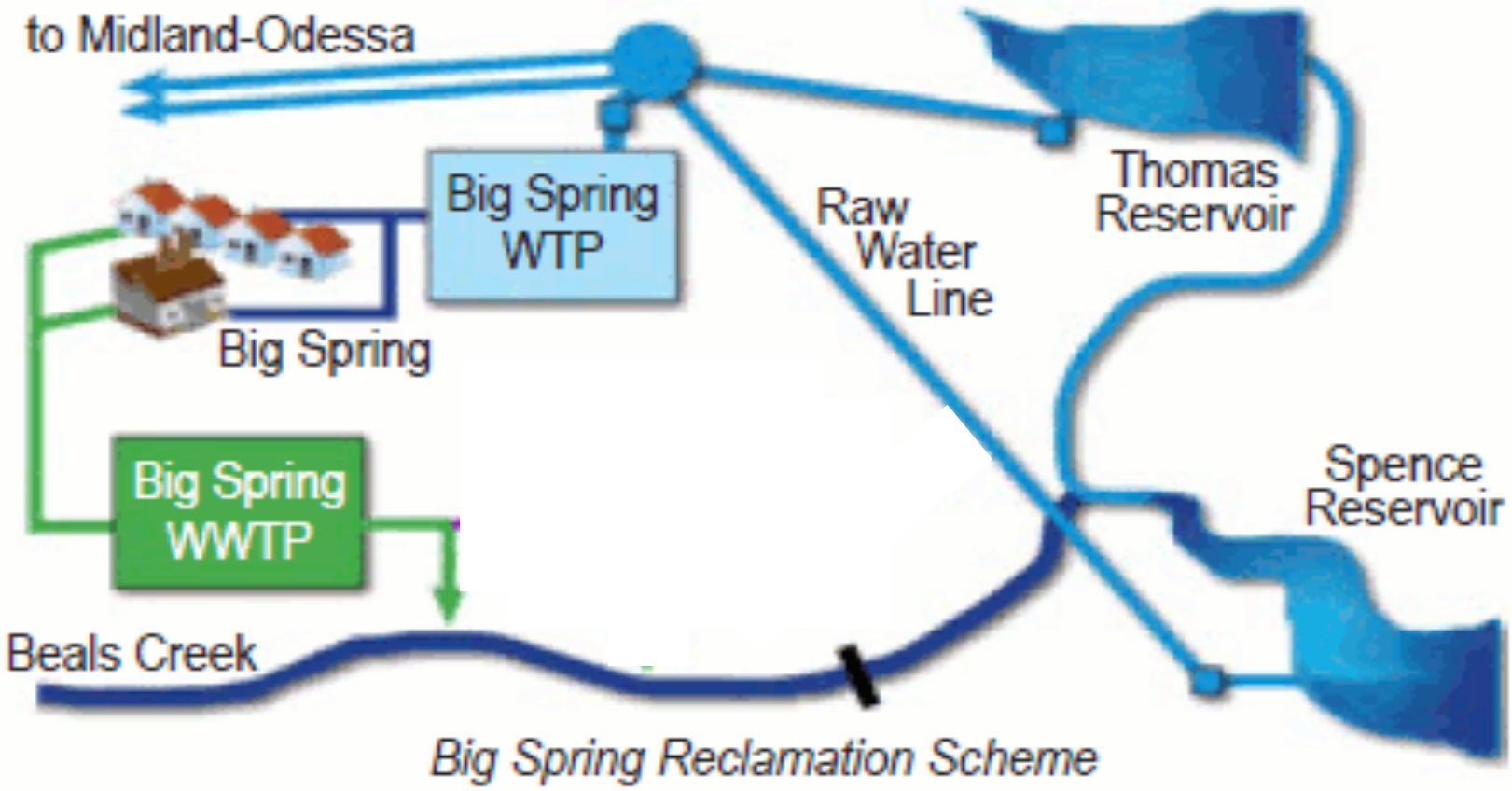
Conventional App **M Approach**

Unit costs **US$ 0.36** sts **US$ 0.29/m3**

It's already happening: Windhoek



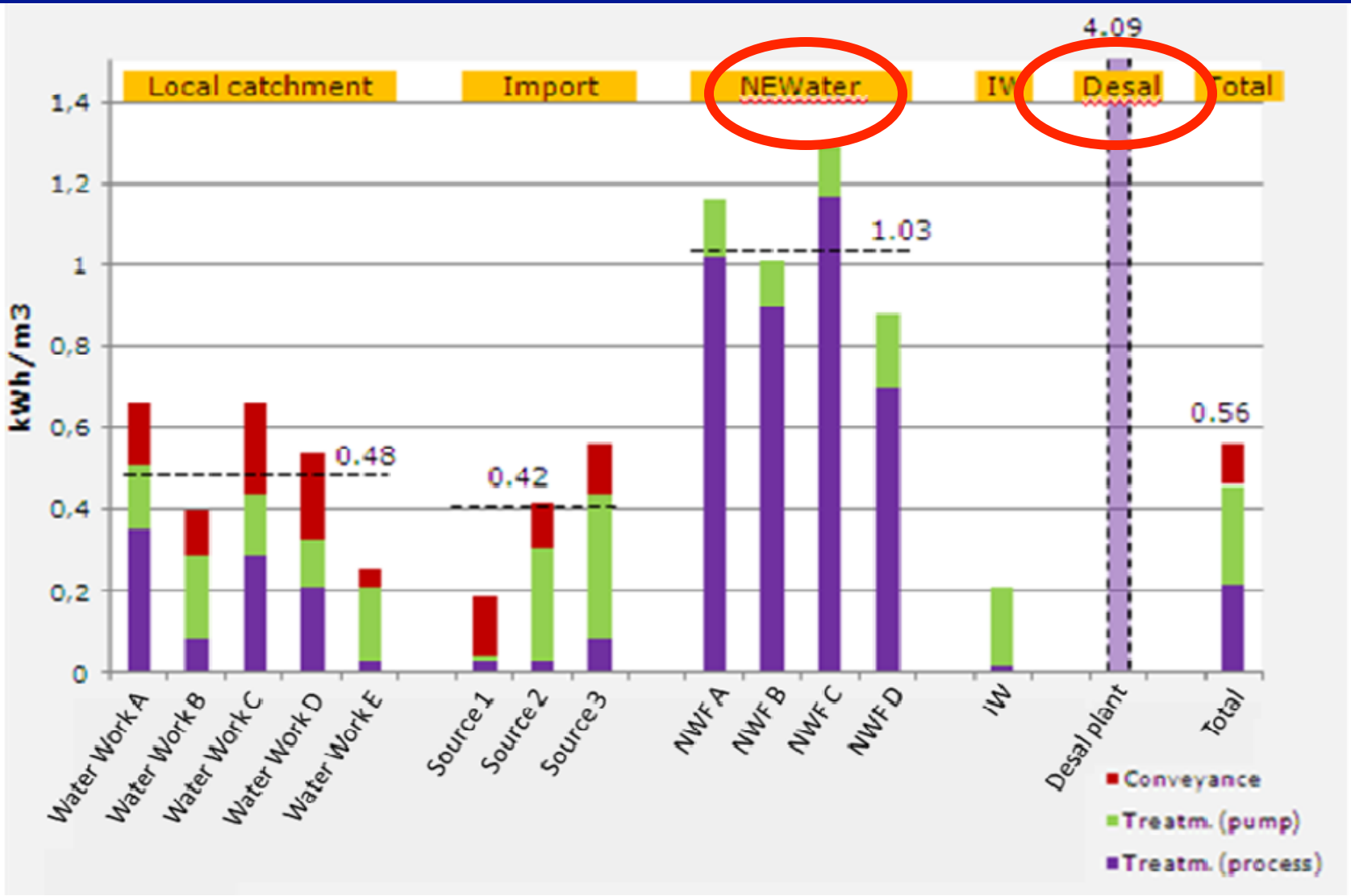
It's already happening –Big Spring, TX



Big Spring Reclamation Scheme

FOUR NATIONAL TAPS

Unconventional water sources: more energy intensive



NEWRI 2010

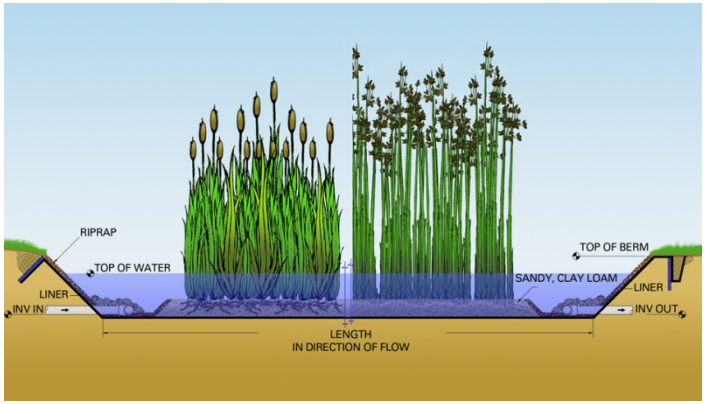
Natural systems can help close the water cycle

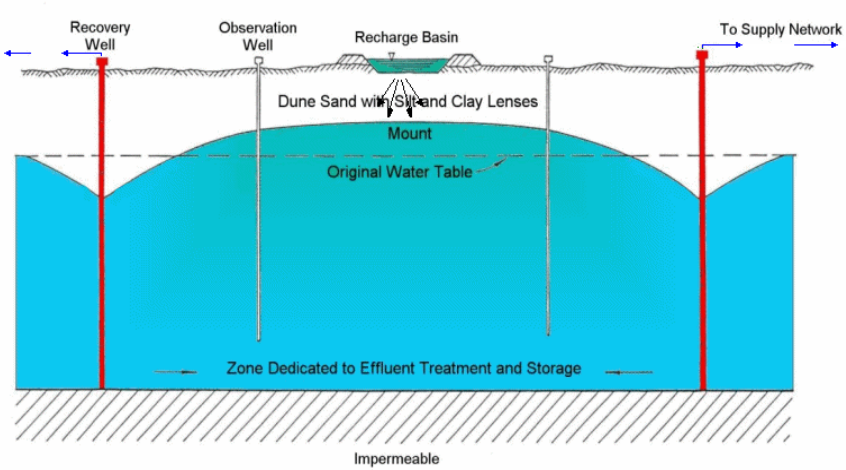
bank filtration,

soil-aquifer treatment,

constructed wetlands,

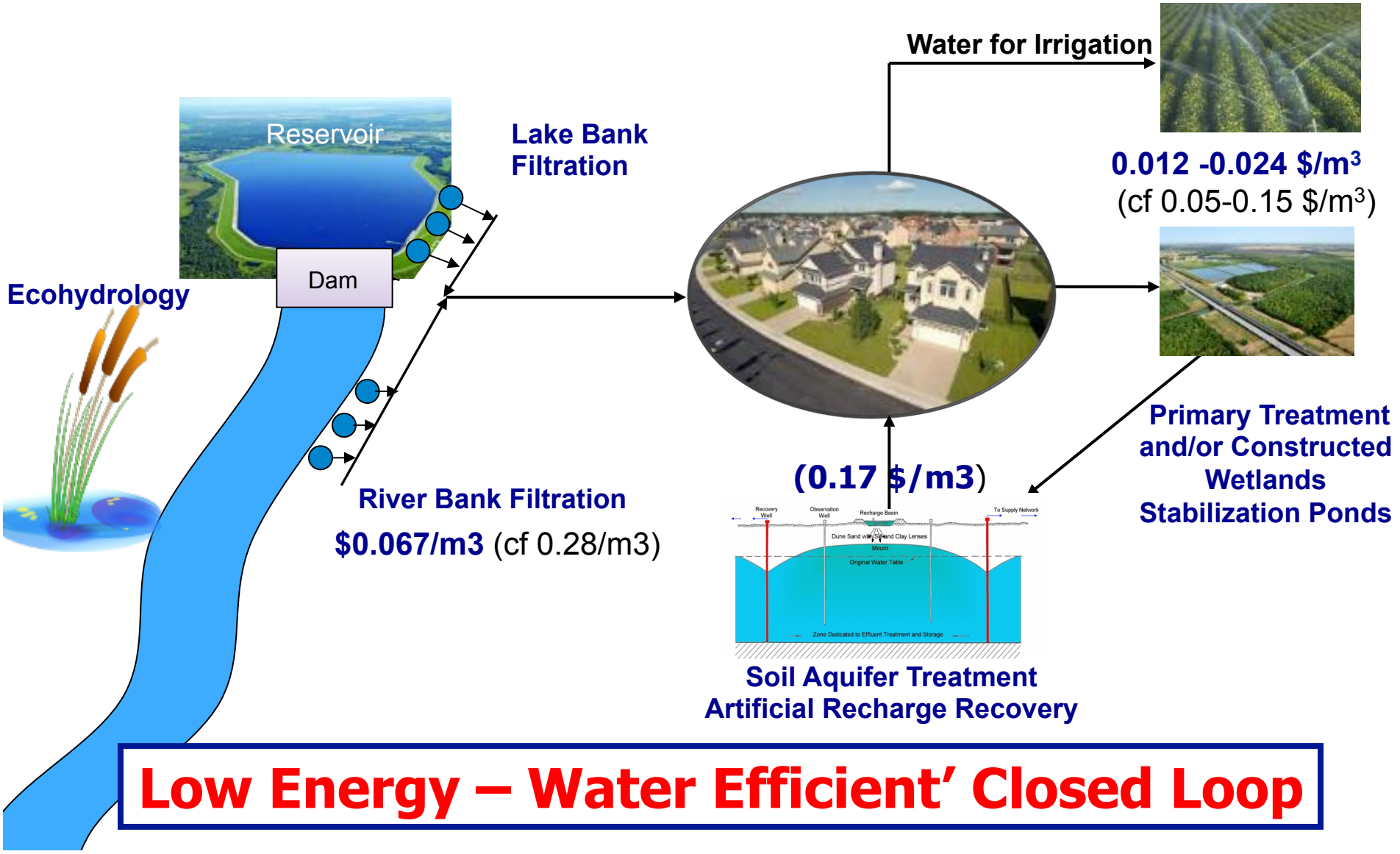
hybrid systems





Recharge - Recovery Scheme

Natural systems can help close the water cycle



Low Energy – Water Efficient' Closed Loop

Take home message

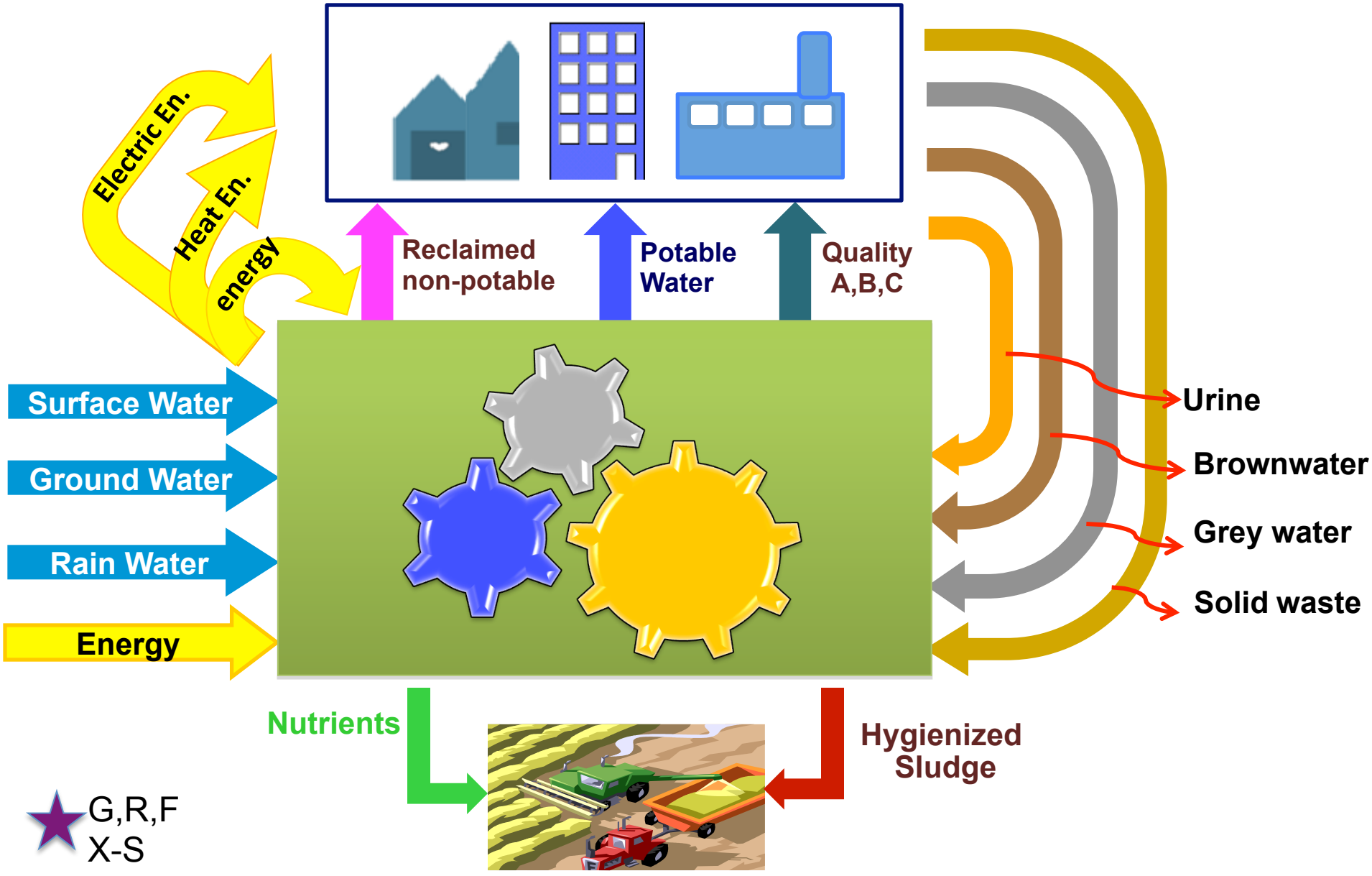
Manage water supply, wastewater & stormwater together (one urban water cycle)……. and think creatively about what could be your water sources (and don't focus on the obvious ones).

(educate future urban leaders on the integrated perspective of the urban water cycle and contextualize each component of the water system within this perspective)

Think about Harvesting

Integrated Treatment

Think about a Water Machine



Water Machine – 'designer waters'

Tertiary: **Irrigation**

RO (Single): **Refinery**

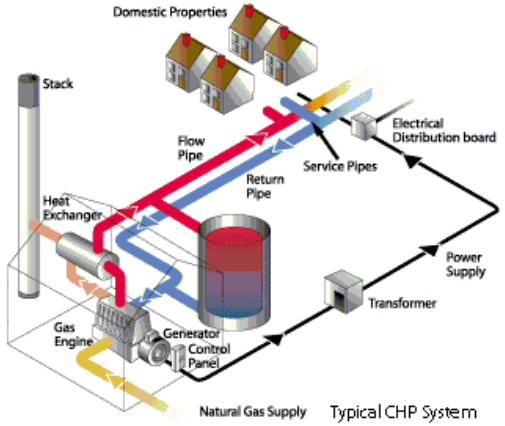
Nitrified: **Cooling**

2nd+RO+MF: **AAR**

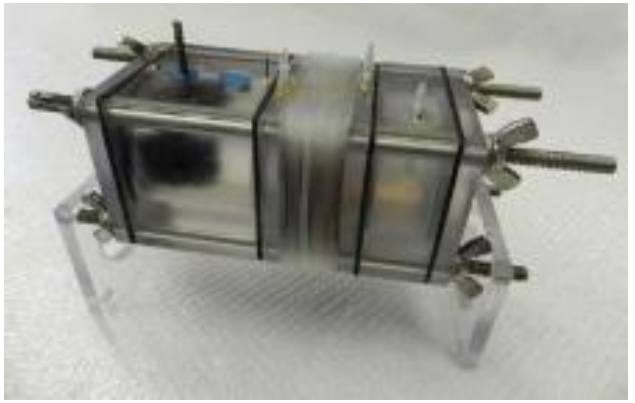
RO(Double): **Refinery**

Innovations taking place in energy harvesting (heat and power)

Combined Heat and Power (CHP)



Microbial Fuel Cells (MFC)

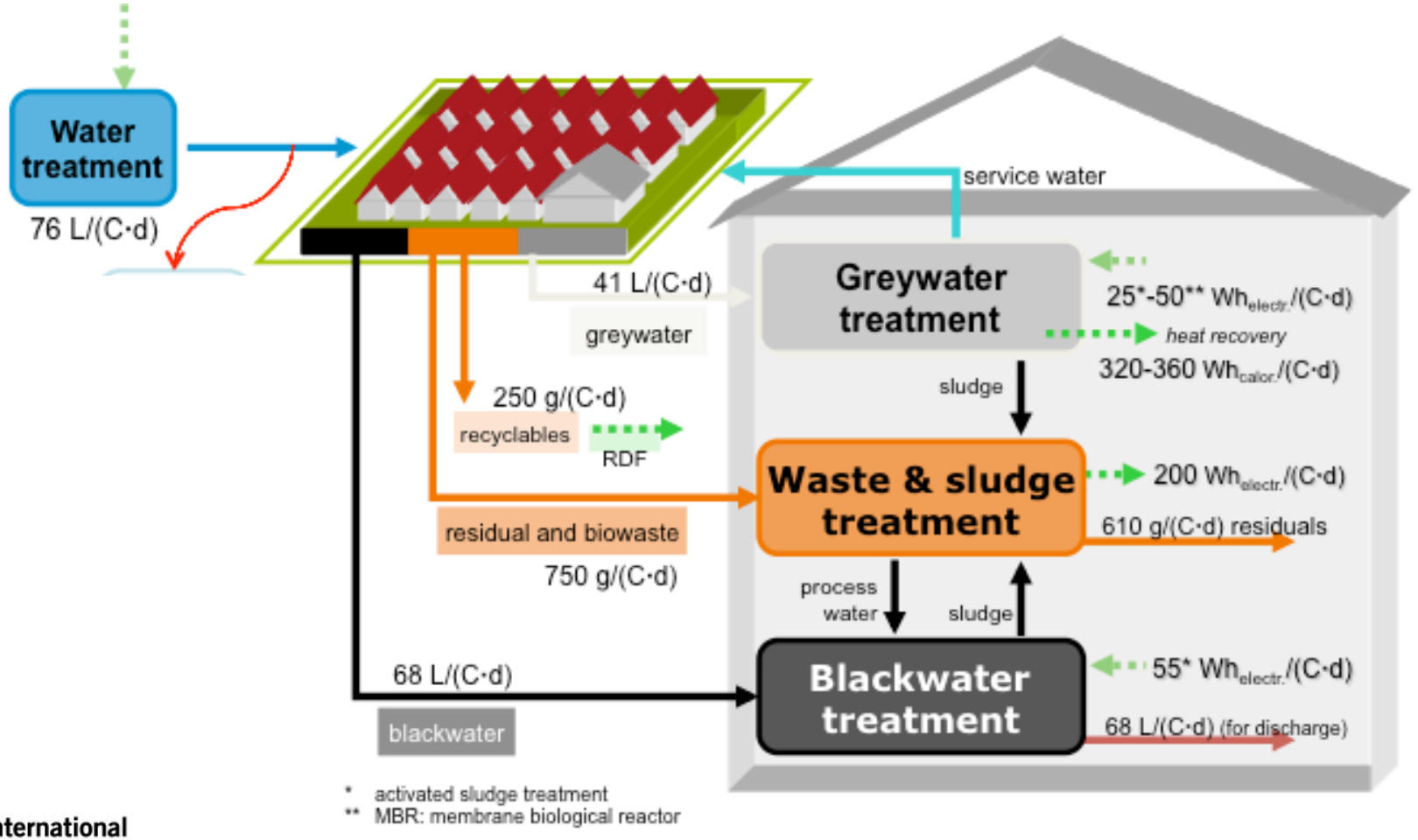


Harvesting heat from sewer

Biogas

Water Machine: Semi - Centralized

Water consumption reduced by 35%
Harvesting of 18% of energy demand (China 3KWh/C*d)



International Water Association

TU Darmstadt | Institute IWAR | Cornel et al.

Xing Dao proposal

TU Darmstadt | Institute IWAR | Cornel et al.

It's already happening – integration of water and energy

Solar-City, Linz

- 4
- C
- D

Battery Park City NY

ng

Water efficient new developments

+ Retrofitting old homes

= WATER NEUTRALITY

(a win for utilities & environment)

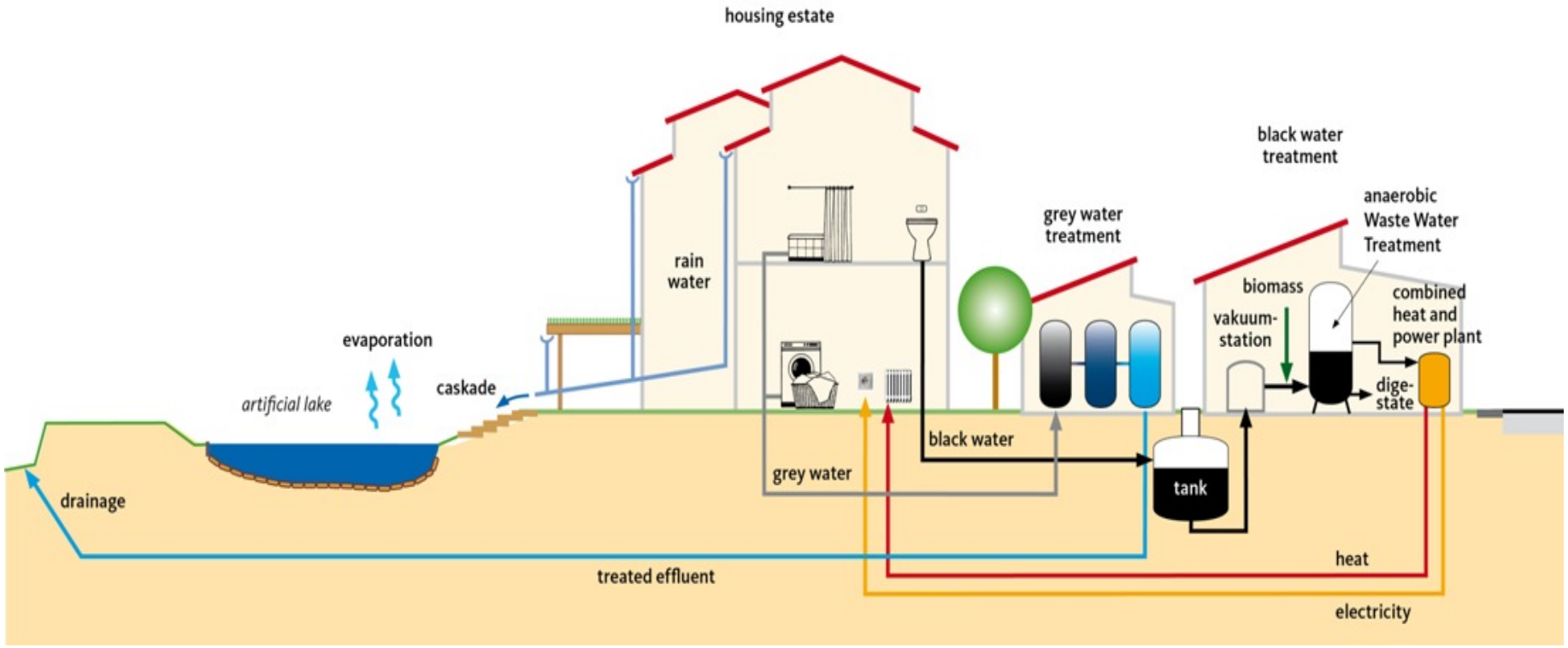
Ha

- 55,000 inhabitants
- Renewable energy, district heating,
- Water recycling

Trff

Traditional utilities are proactively seizing the opportunities – Hamburg

Hamburg Water Cycle™

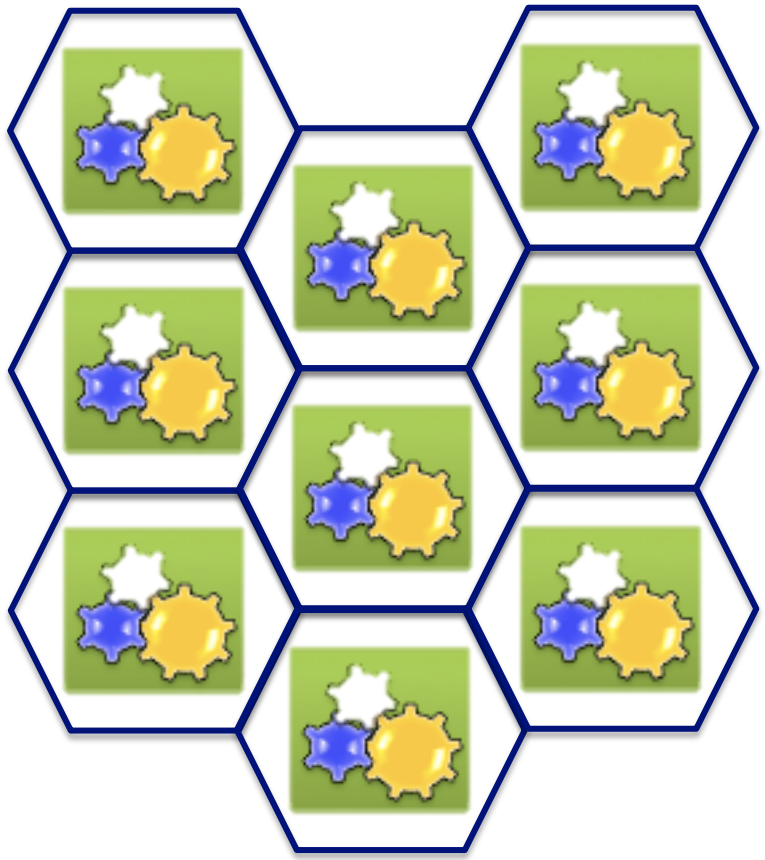


DCentrl; LDC

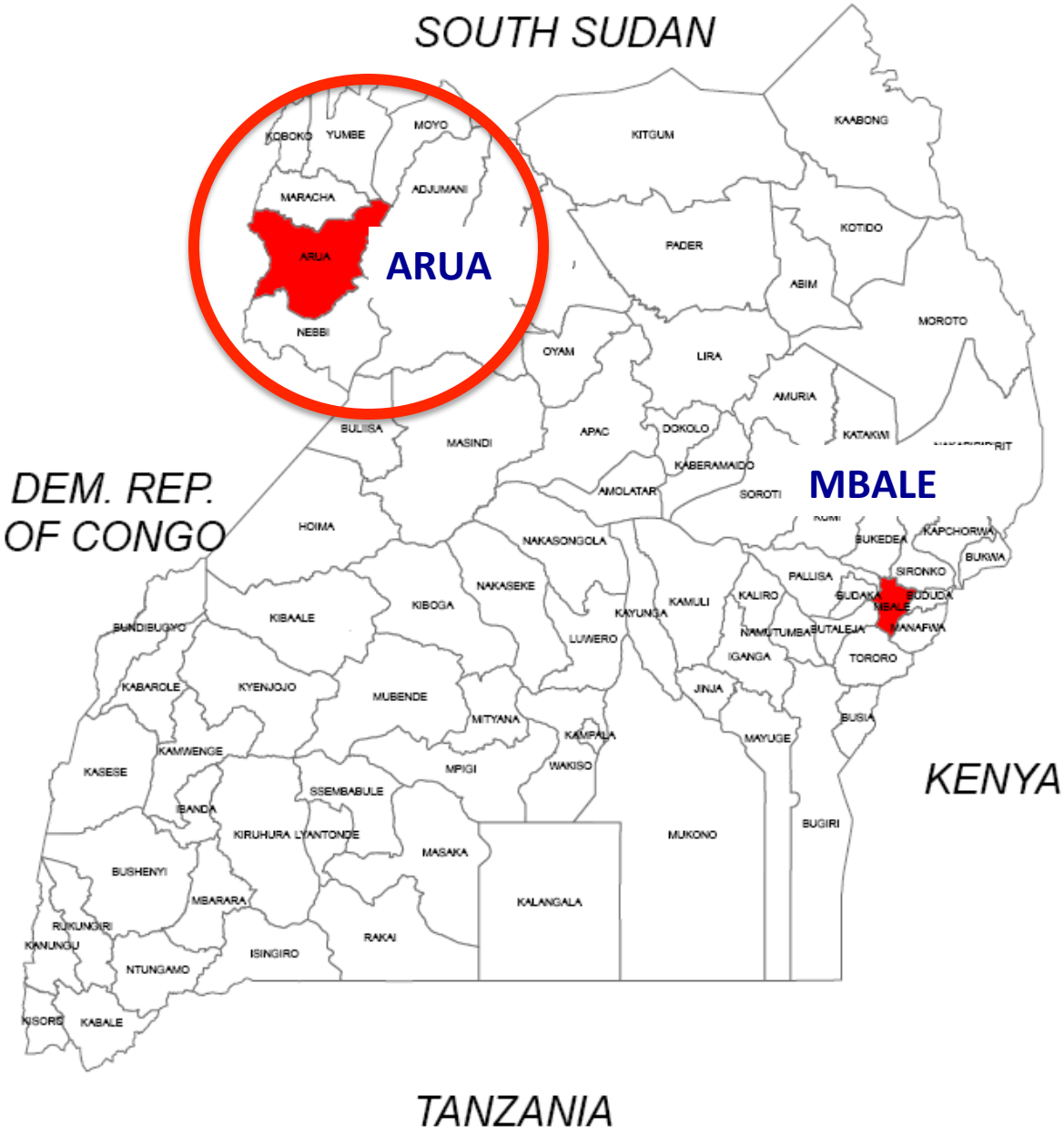
Cluster Structure and Scalable System

A supply and treatment unit (water machine) for each district

- Semi central supply and treatment unit as part of clustered city structure
- Use scalability of treatment technology (membranes)
- Customized supply and treatment for each cluster
- Utilizing synergy effects and re-use potentials




UGANDA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ABIM
MOROTO
OYAM
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AMURIA
BULISA
MASINDI
APAC
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KABERAMAIDO
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SOROTI
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OF CONGO
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NAKASONGOLA
BUKEDEA
KAPCHORWA
BUKWA
PALLISA
SIRONKO
BUDAKA
BUDUDA
MBALE
MANAFWA
NAKASEKE
KIBOGA
KAYUNGA
KAMULI
KALIRO
NAMUTUMBA
BUTALEJA
IGANGA
TORORO
BUNDIBUGYO
KIBAALE
LUWERO
KABAROLE
KYENJOJO
MUBENDE
JINJA
BUSIA
MITYANA
KAMPALA
MAYUGE
KAMWENGE
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MPIGI
WAKISO
KENYA
SSEMBABULE
BANDA
KIRUHURA
LYANTONDE
MUKONO
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KALANGALA
MBARARA
RUKUNGIRI
KANUNGU
RAKAI
ISINGIRO
NTUNGAMO
KISORO
KABALE
TANZANIA

Clustering is a multi-criteria problem: So how do we define boundaries

NUTRIENT POTENTIAL & DEMAND

Adaptive capacity

Minimize management overhead

Security thro' diversity

Heat recovery potential & demand

Potential & demand for reuse water

Demand for different qualities of water

MINIMIZE MOVEMENT OF WATER

Clustering is a multi-criteria problem: So how do we define boundaries

Nutrient potential & demand

Adaptive capacity

Population density

Management overhead

Topography

Security thro' diversity

Heat recovery potential & demand

Distance to water sources

Energy costs

LAND USE

Unit cost of reuse water

Demand for different qualities of water

Minimize energy to move water

Clustering is a multi-criteria problem: So how do we define boundaries

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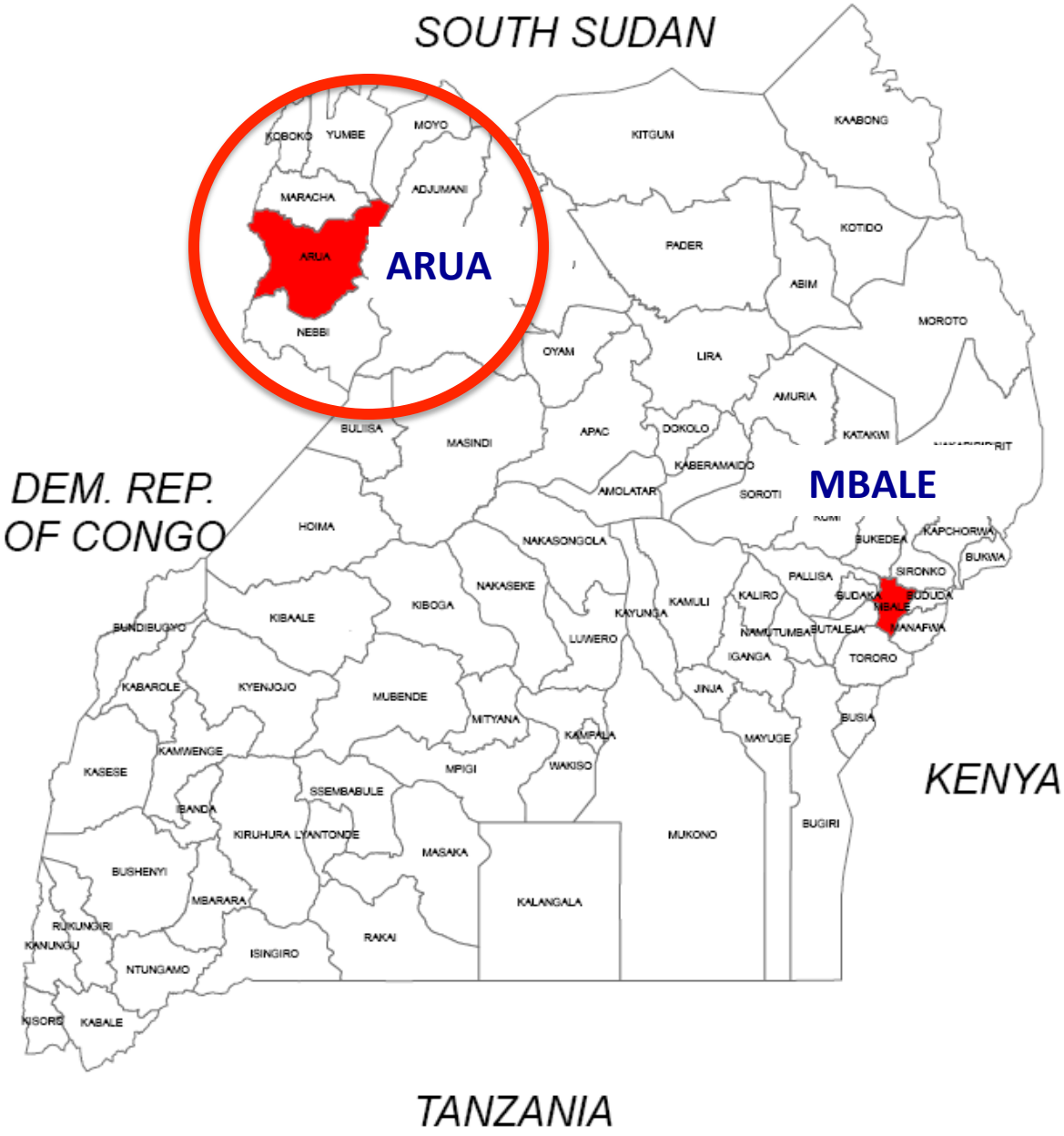
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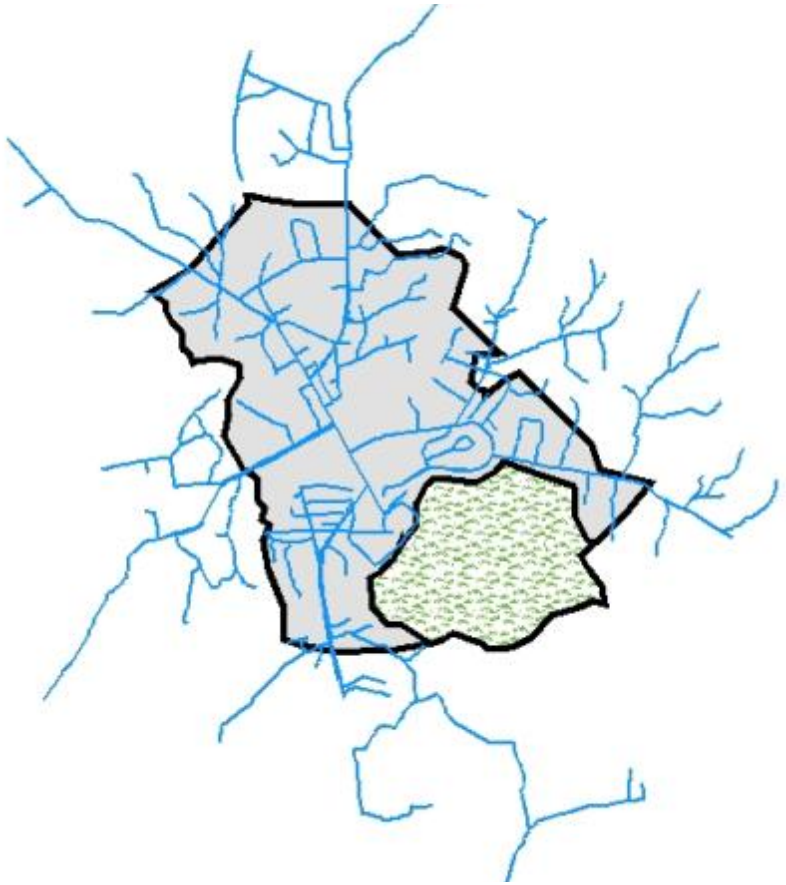
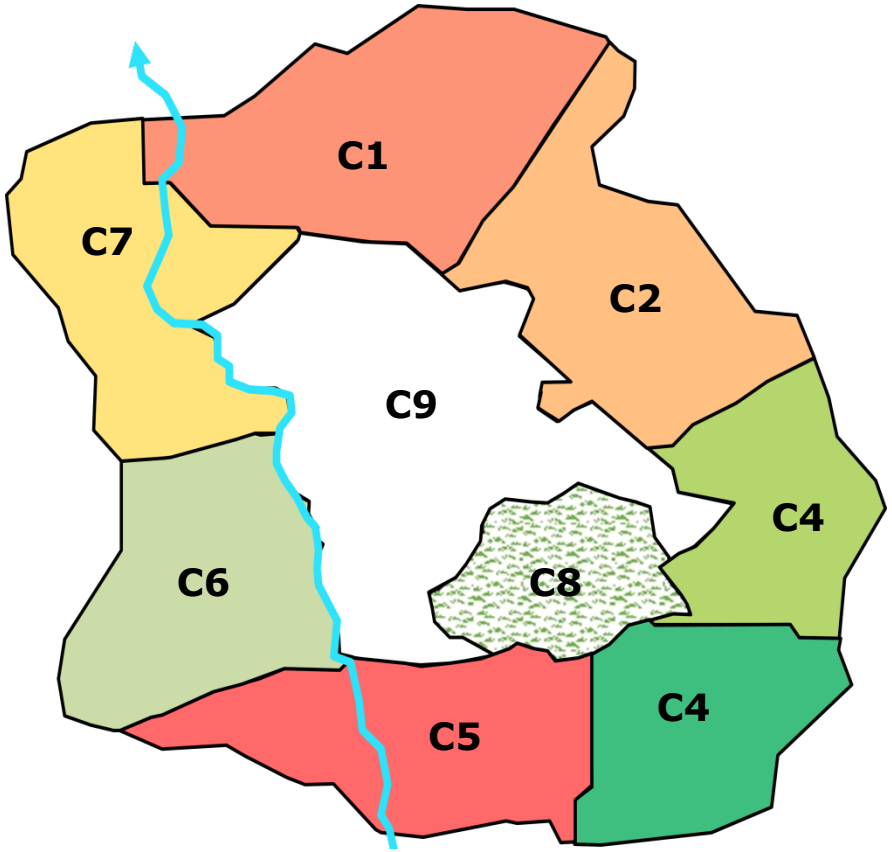
Central infrastructure core expanding



Spatial optimization can help establish cluster boundaries



Tsegaye, S., Vairavamoorthy,K. (2012)

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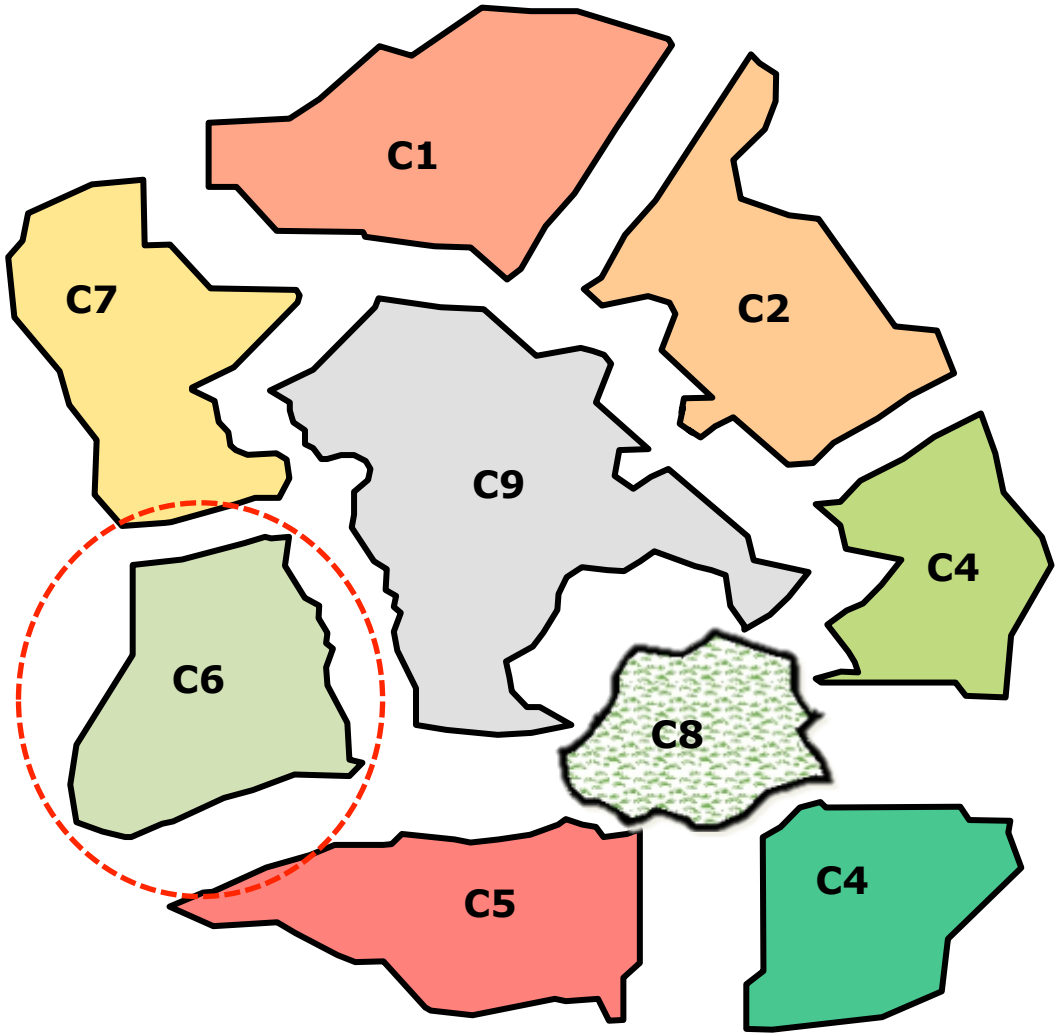
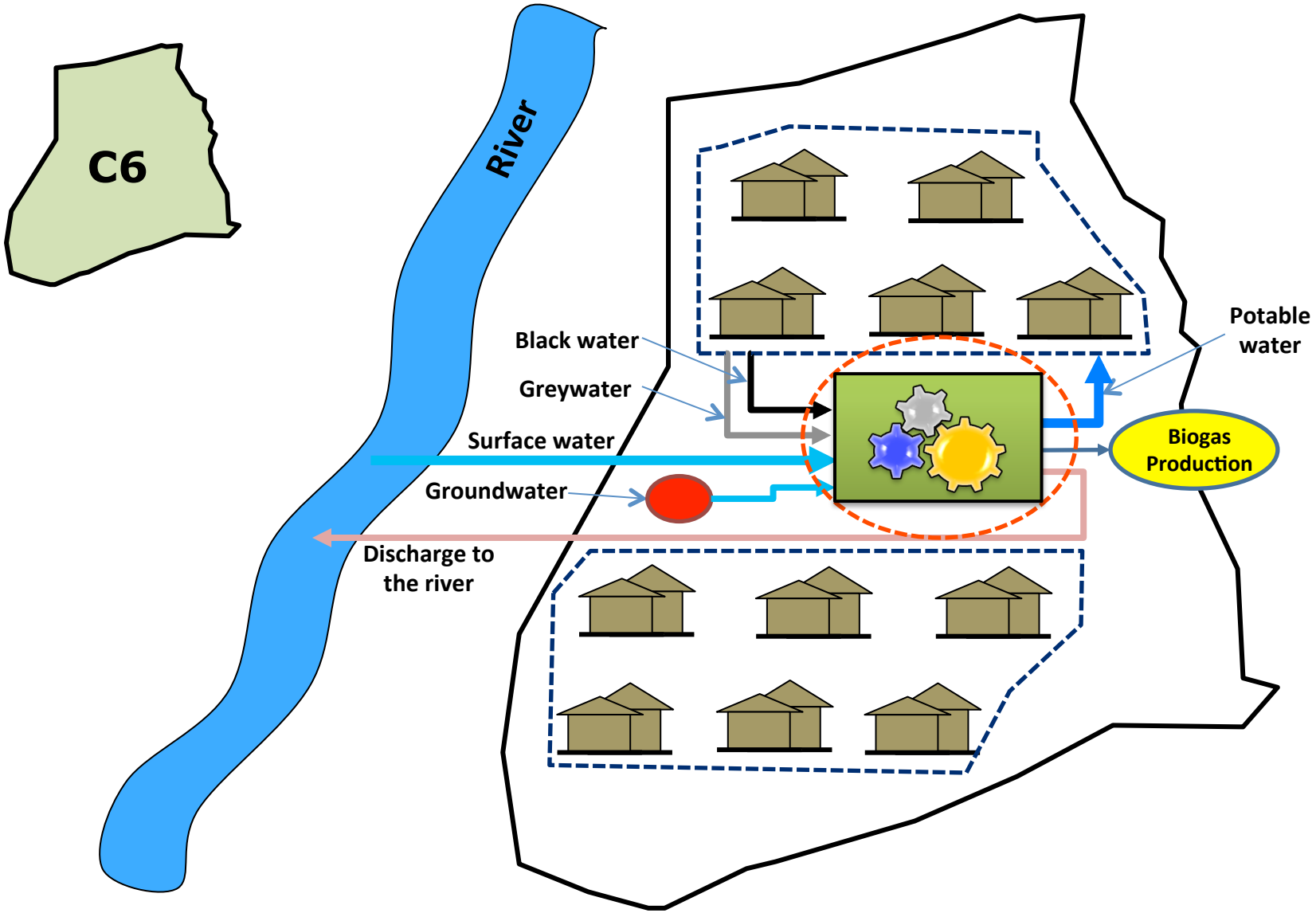


Tailor made solutions for cluster



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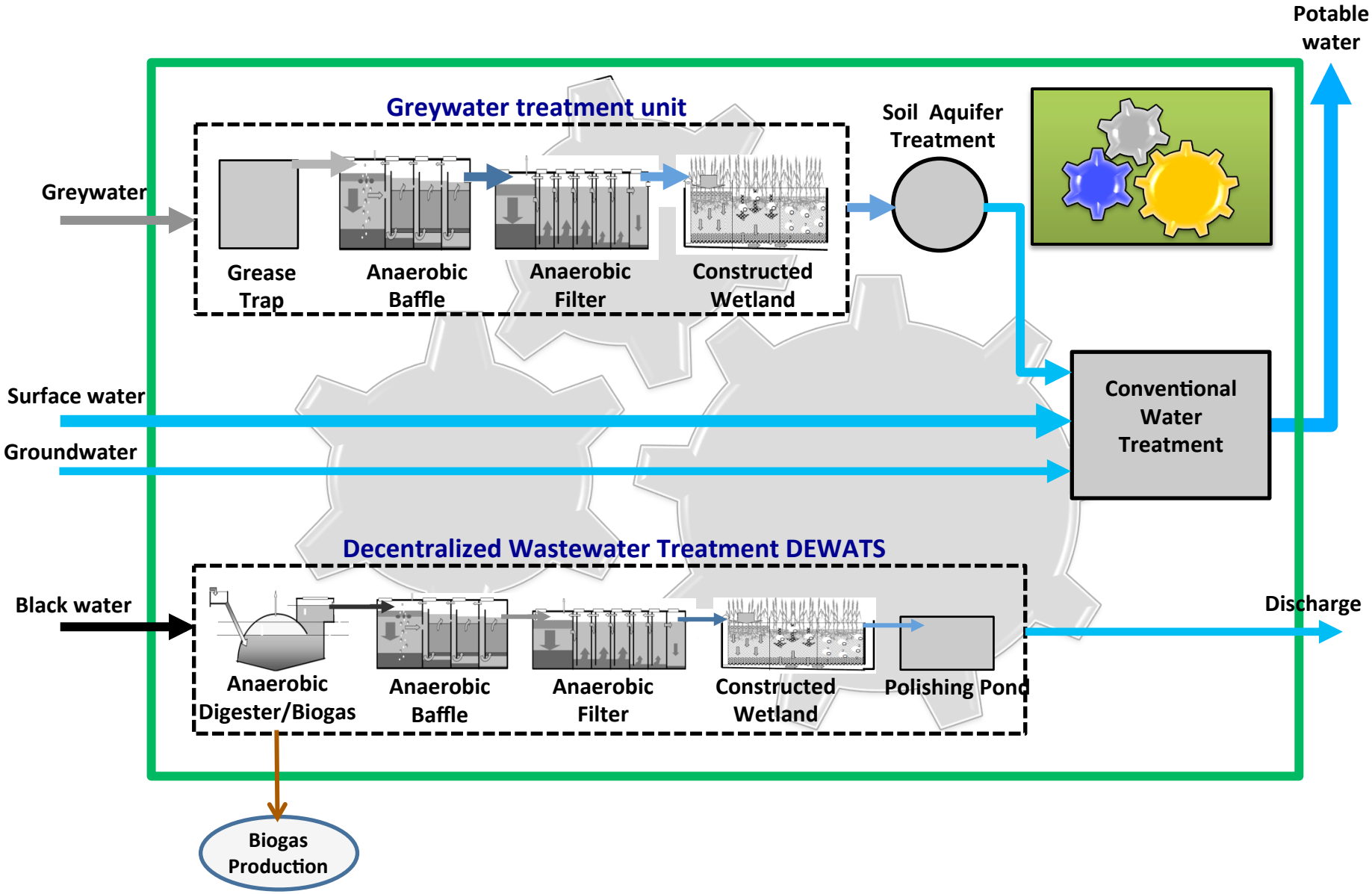
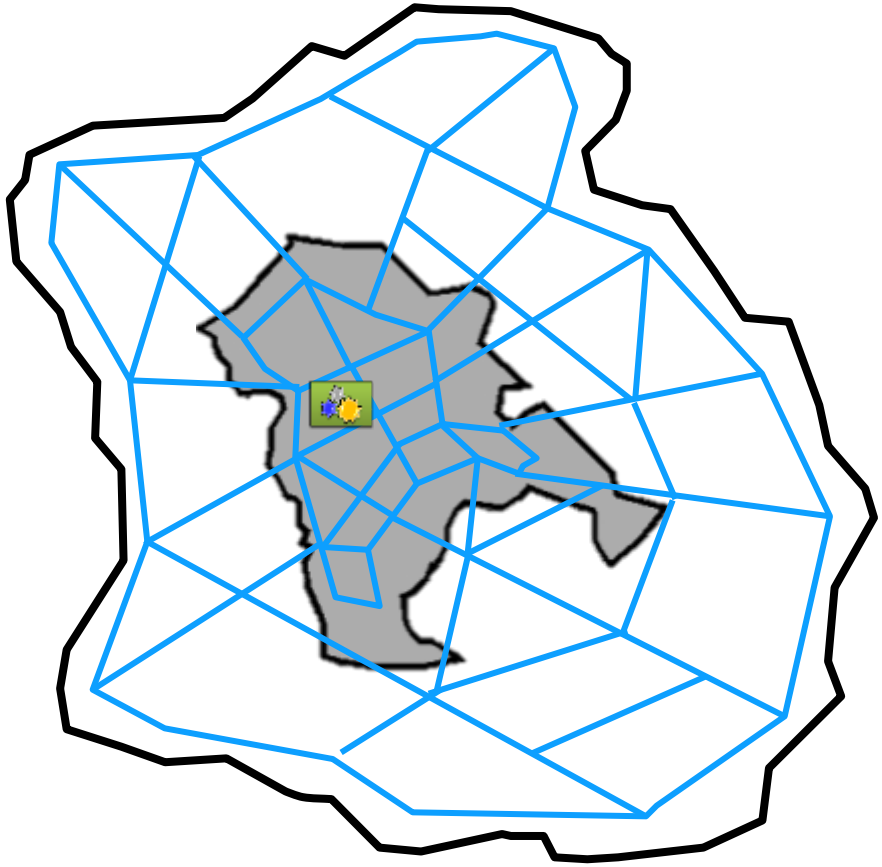


Semi-centralized is cheaper?



Average Annual Costs
5,148,000 US$

Average Annual Costs
3,787,000 US$

We need smart networks to be adaptive in an uncertain world

- **Entire earth system is changing!**

Uncertainty in storm events

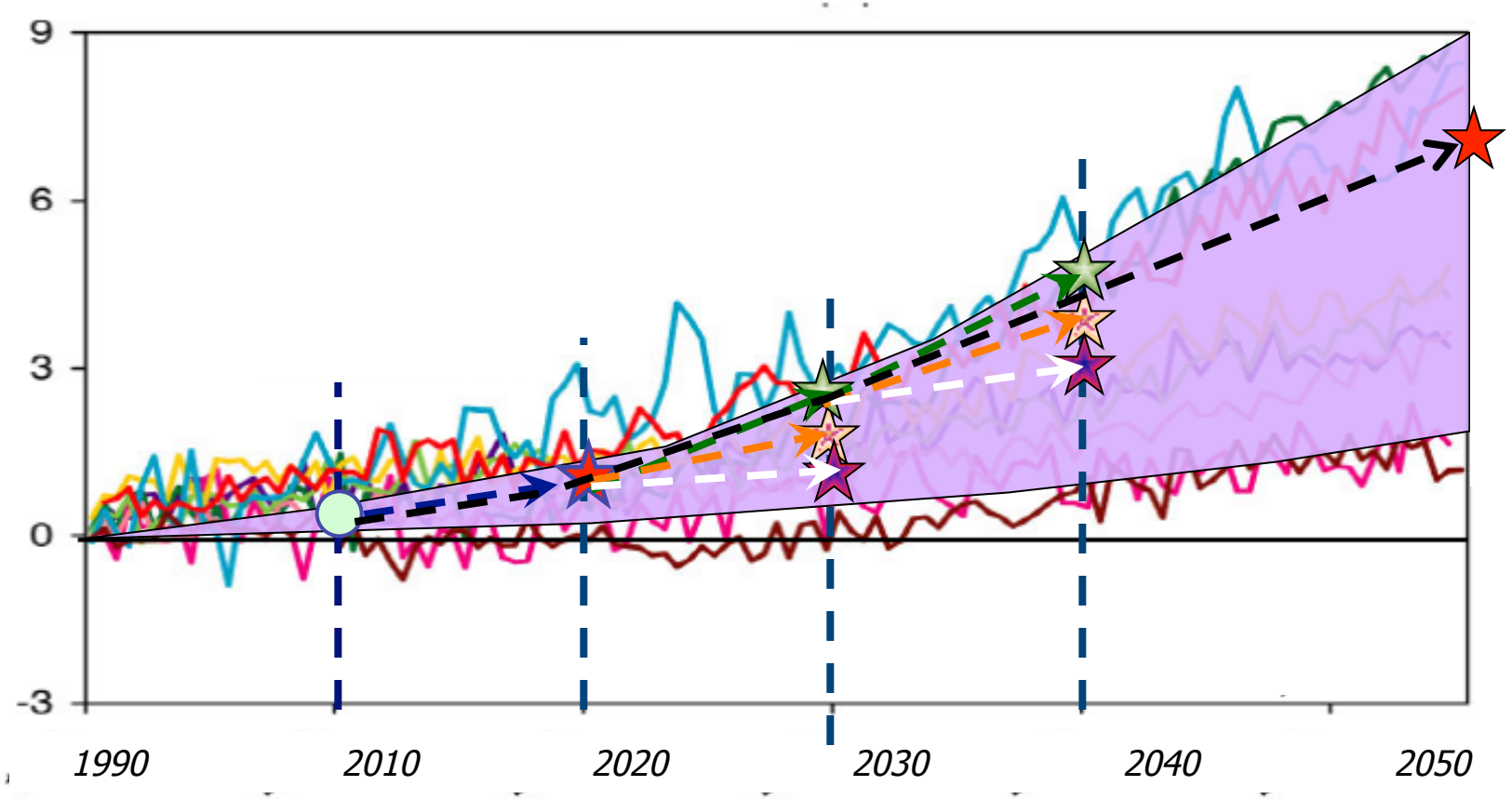
Uncertainty in runoff response

Uncertainty in carrying capacity/breakage rate

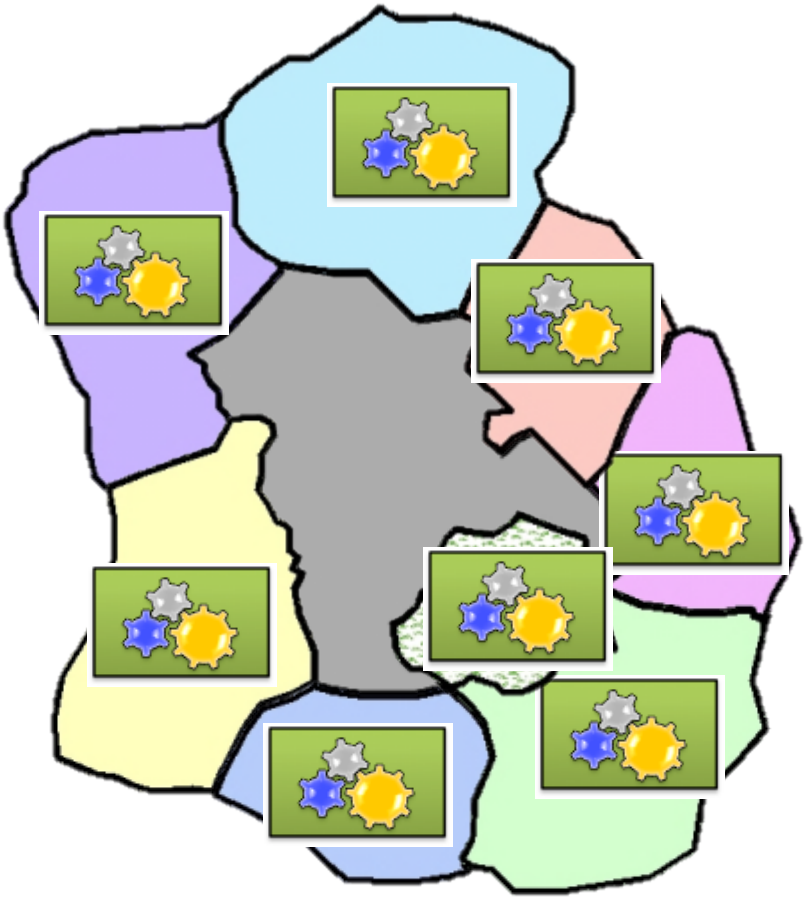
Uncertainty in demand

Uncertainty in quantity & quality

We need smart networks to be adaptive in an uncertain world



Clusters give adaptive` capacity



Take home message

Driver for water management should be beneficiation –maximize value added
(institutions & regulations to support and not hinder)

'All water is good water: fit for purpose'

(educate future urban leaders on all benefits of water – public health, aesthetics, economic development, green economy)

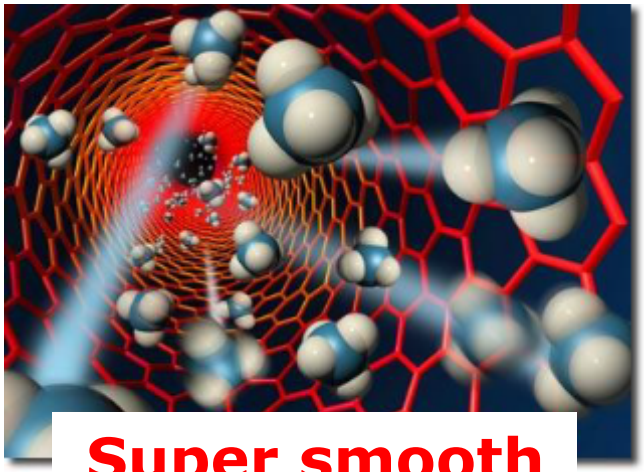
Smart Thinking

Smart Water, Smart Networks, Smart by Design

Scalability & efficiency of membranes makes them attractive across a continuum options

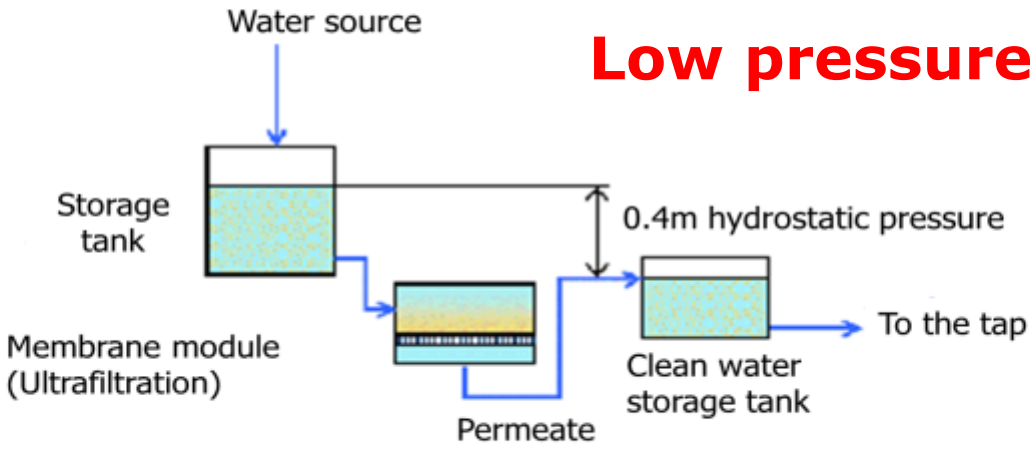
Point-of-Use

City/Town Scale



Super smooth

Carbon nano-tubes



Low pressure

Networks of the future will have lives of their own

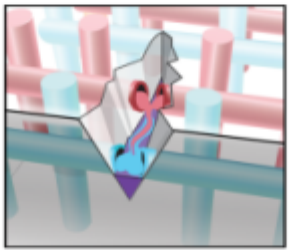
Smart Pipes

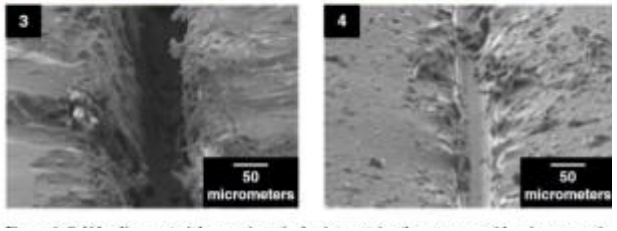
- Nano scale sensors embedded into pipes during manufacturing.
- Sensors monitor data on hydraulic, material, and environmental
- Sensors provide geo-referenced data points

Metje et al. 2011

Self Healing

- Various strategies: *capsule, vascular, intrinsic*
- Pipes store healing agents and polymerizers that solidify when mixed
- Healing efficiencies 100%
- Repair leaking pipes using injected techn. Platelets



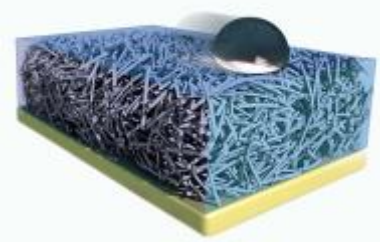


Corrosion formation | Corrosion Repair

White et al. 2011; Brinker 2011

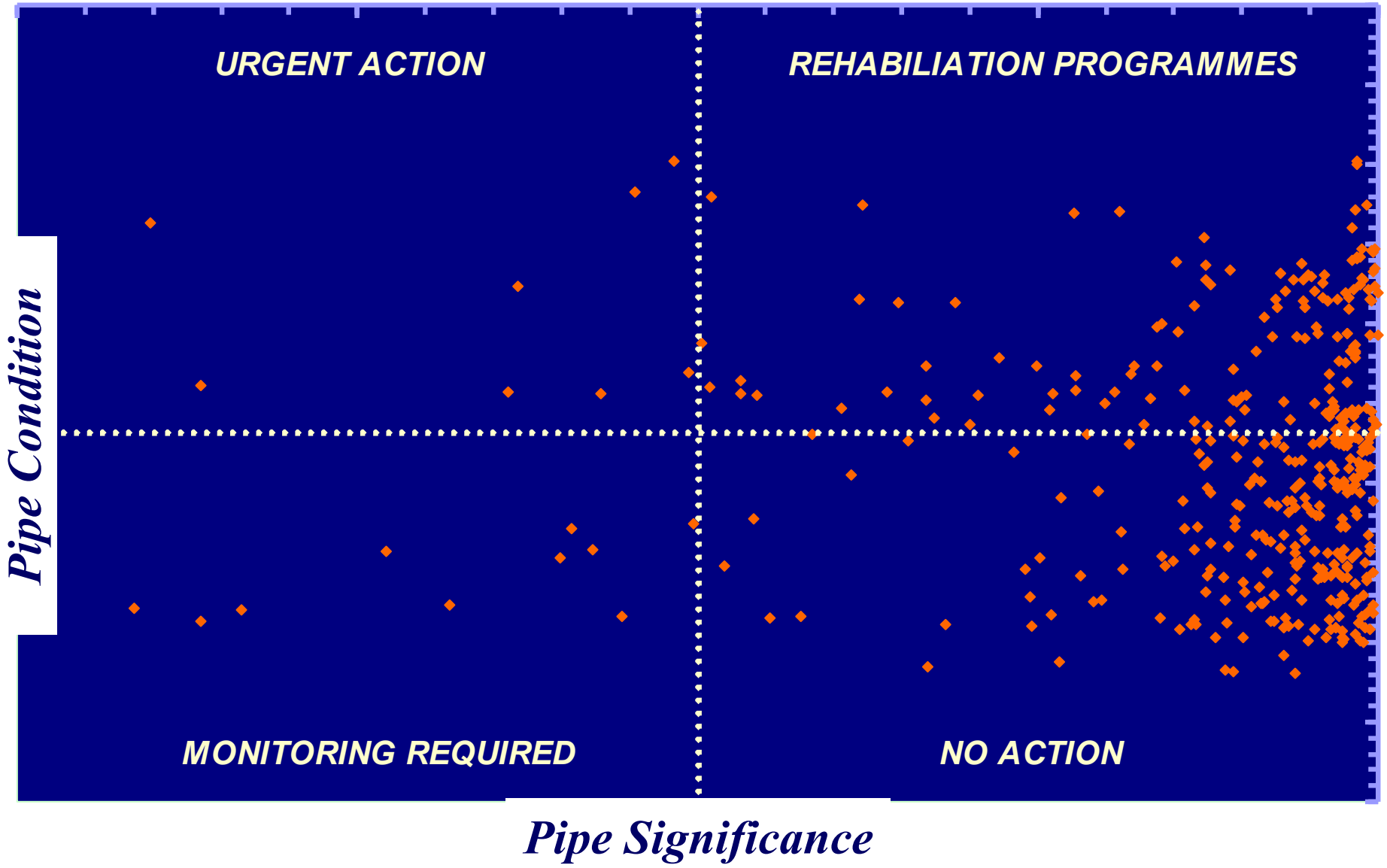
Frictionless

- Slippery Liquid-Infused Porous Surfaces (SLIPS)
- Super-thin Nano-substrates infused with a liquid lubricant creates a smooth surface
- Reduced biofilm formation by 96-99%

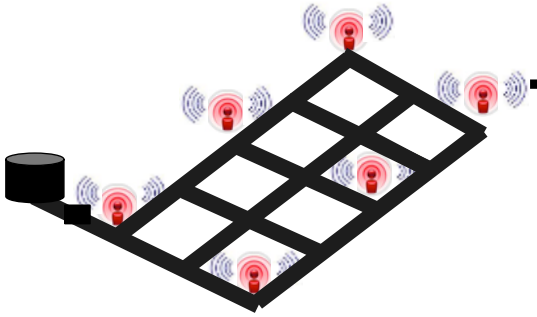


Epstein et al. 2012

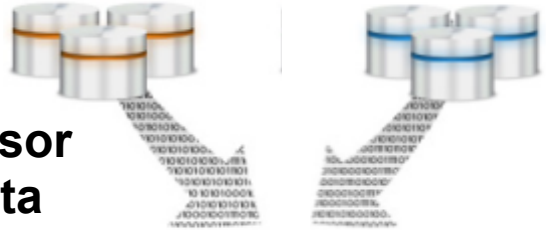
Pipe condition assessment is currently a dark art



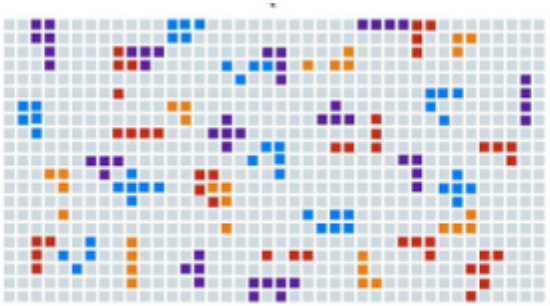
With 'smart sensors' it may become better understood



Sensor Data



Historical Data

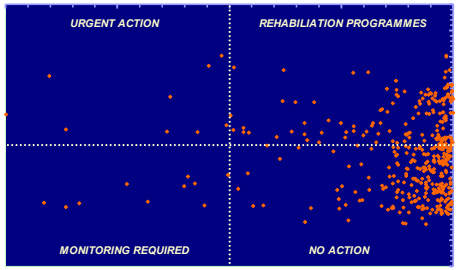


Big Data Analytics

Embedded Sensors Monitor

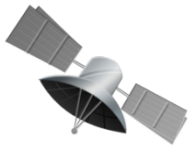
- Pressures
- Velocities
- Temperature
- Water Quality
- Soil Conditions
- Material Strains
- Pipe Stress

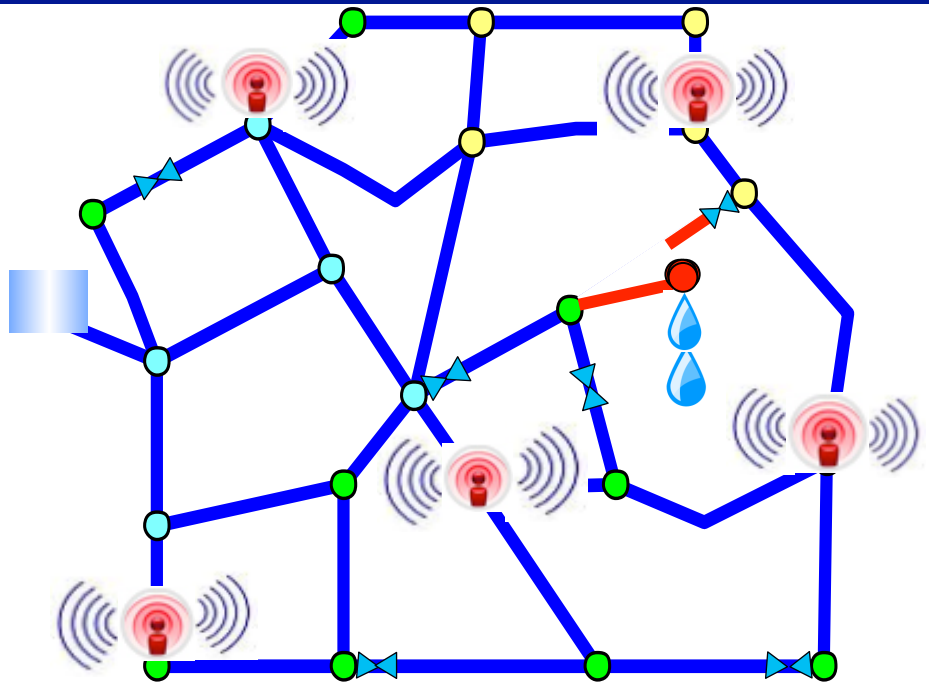
Pipe Condition Assessment



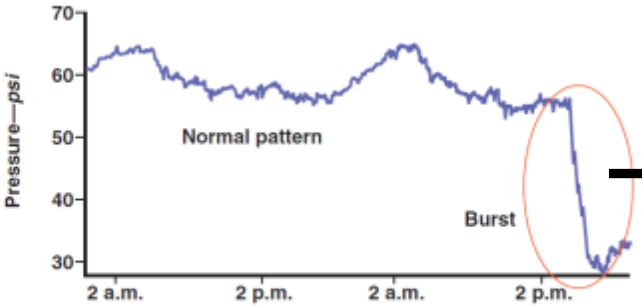
Pipe Replacement Rehabilitation Optimal Plan

‘Smart’ helps manage pipe-bursts more effectively





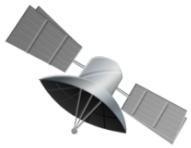
Calculate Location of Burst

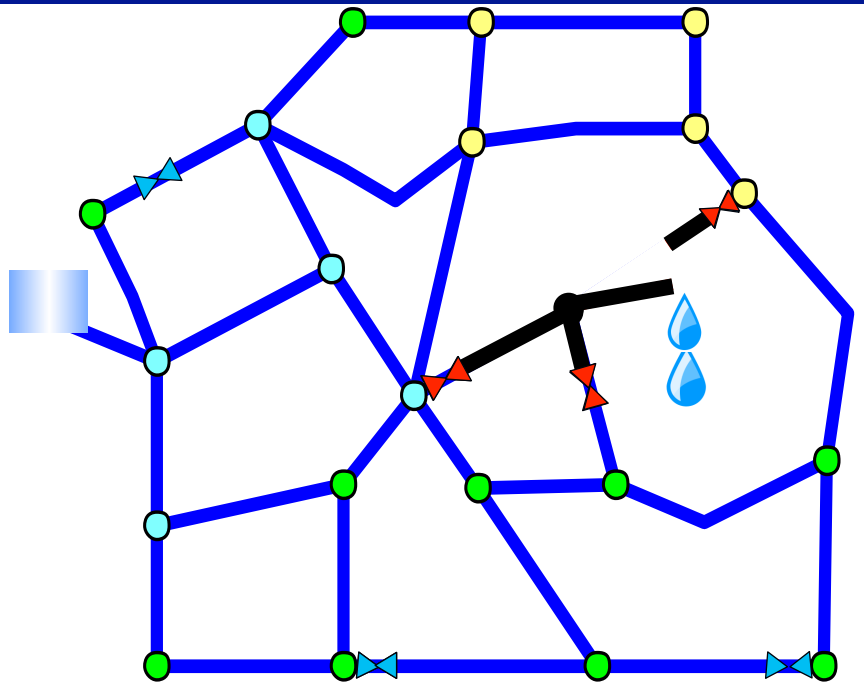


Optimal Valve Isolation

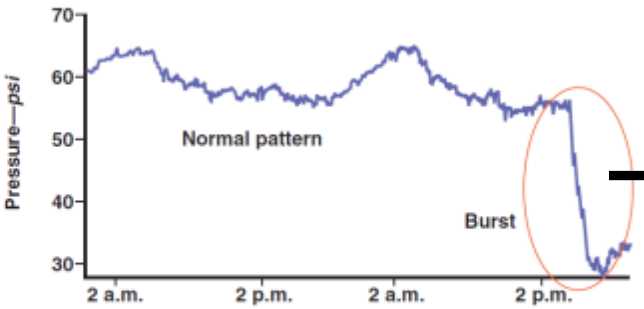
Allen et al. 2011

‘Smart’ helps manage pipe-bursts more effectively





Calculate Location of Burst

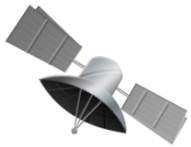


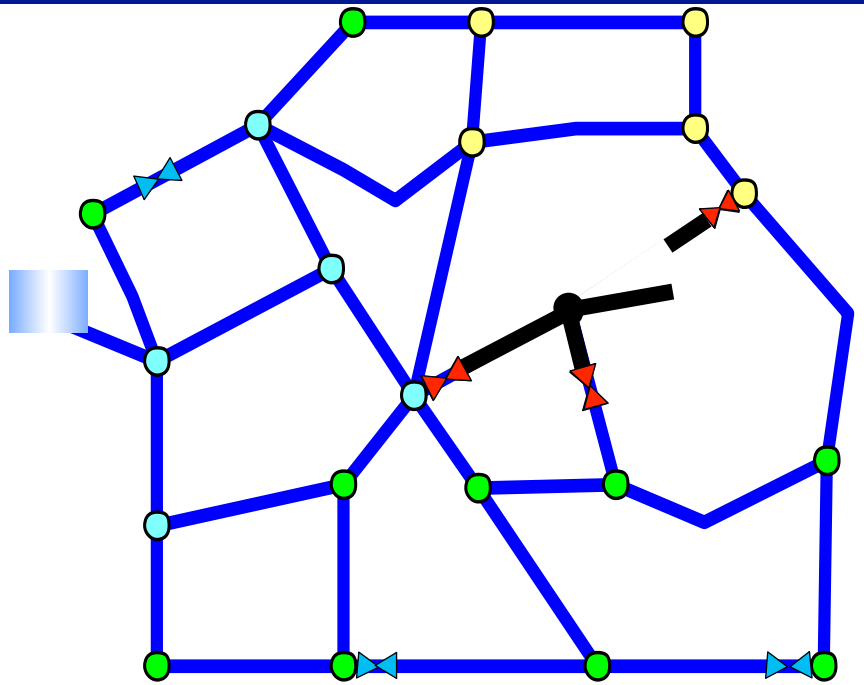
Isolate Leak

Optimal Valve Isolation

Allen et al. 2011

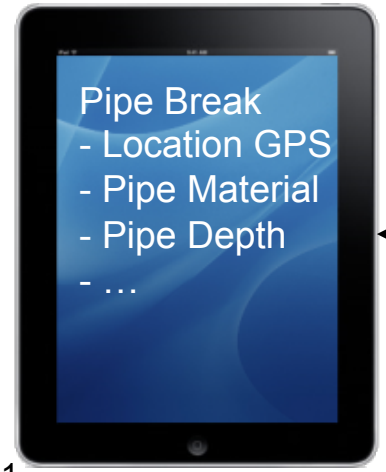
‘Smart’ helps manage pipe-bursts more effectively





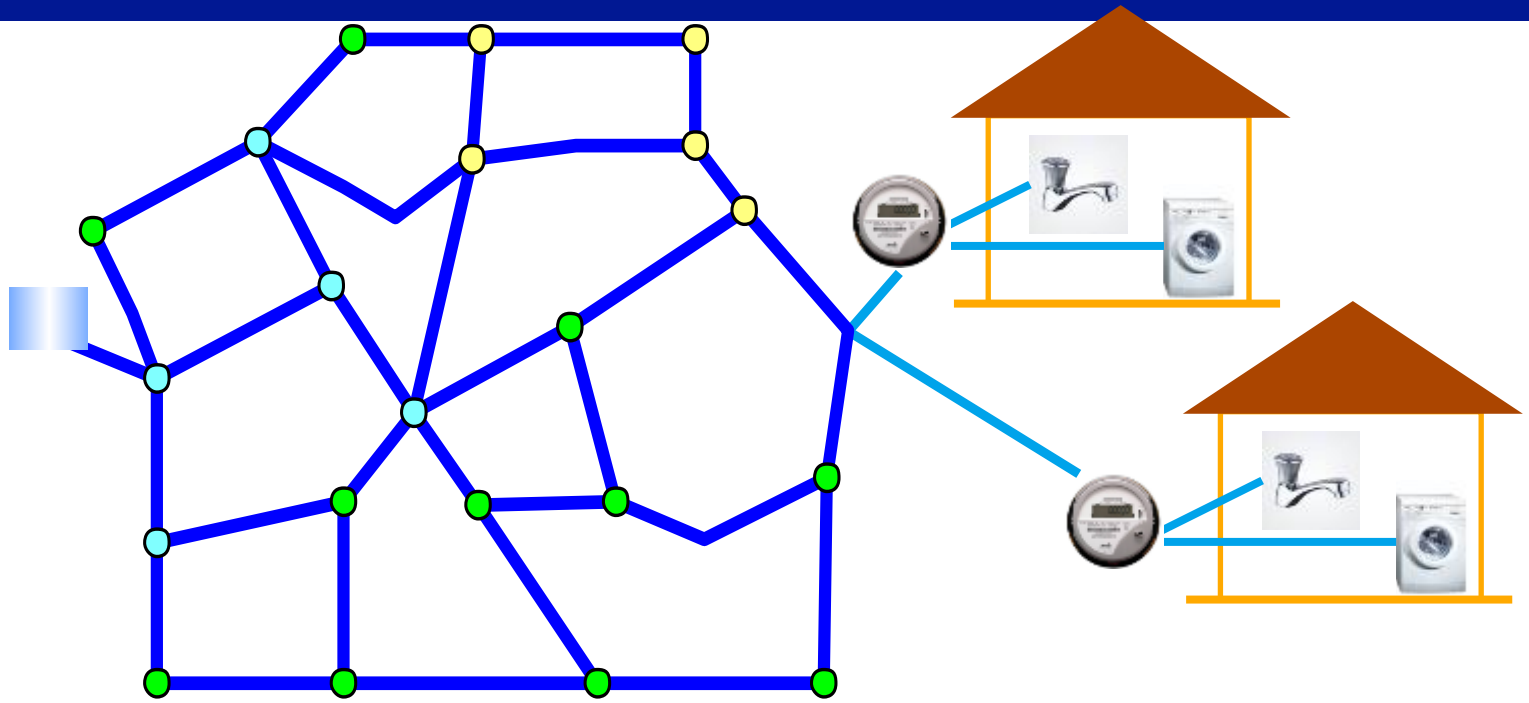
Alert Customer

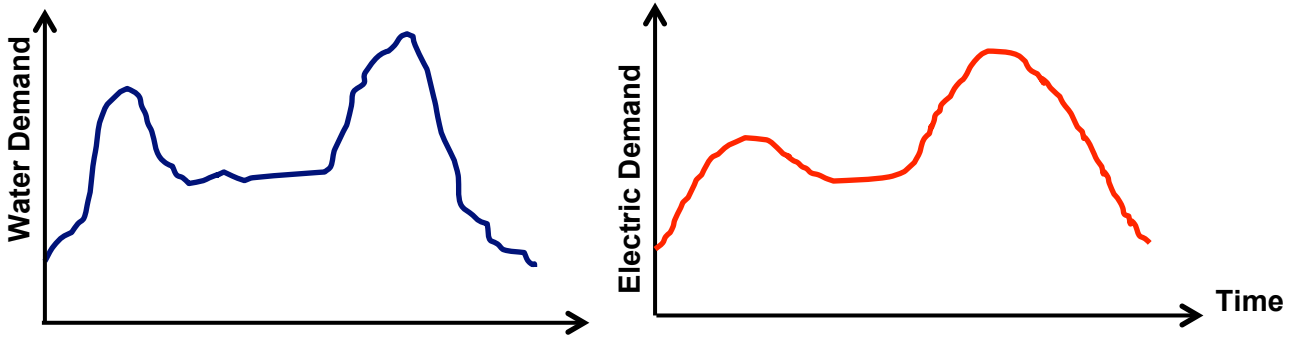
Repair Team



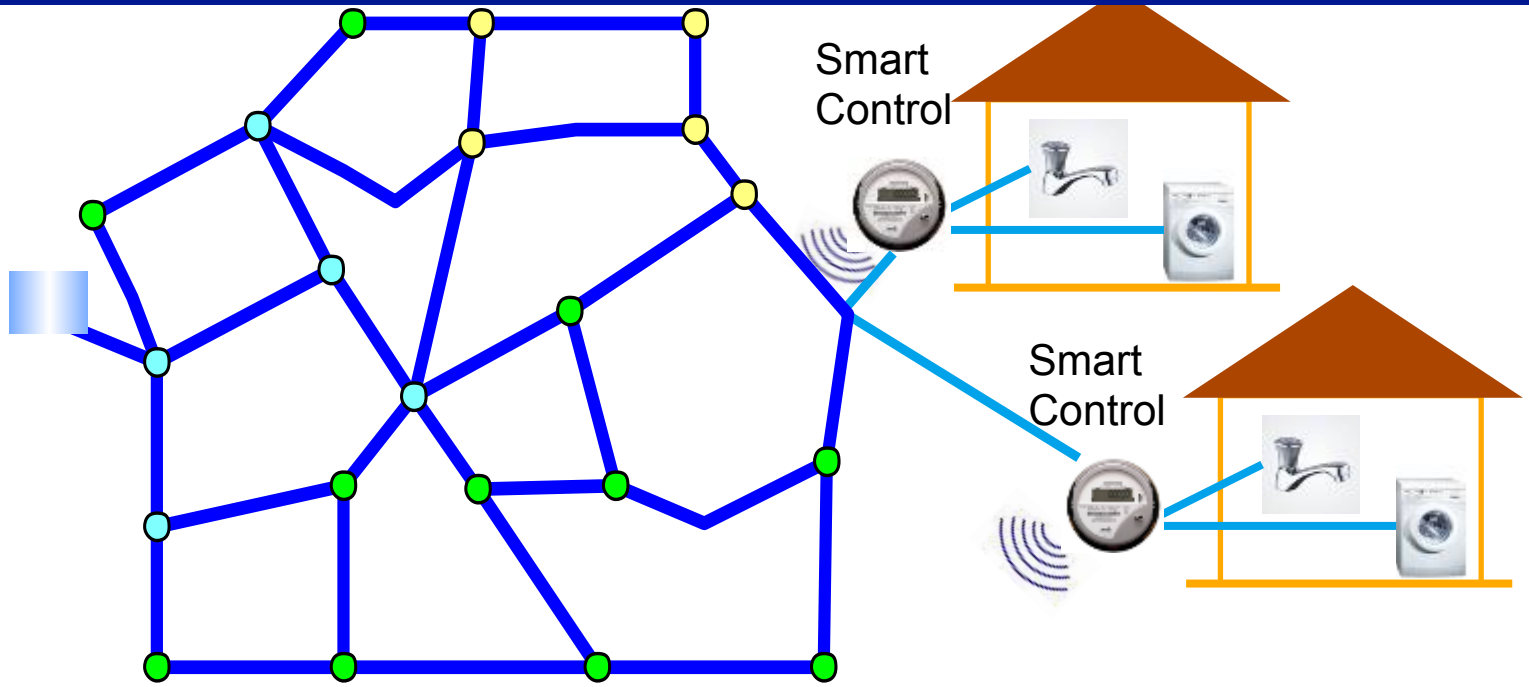
Allen et al. 2011

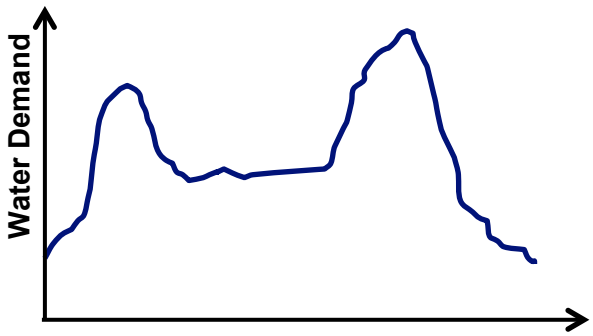
‘Smart’ allows appliances to negotiate with the water market

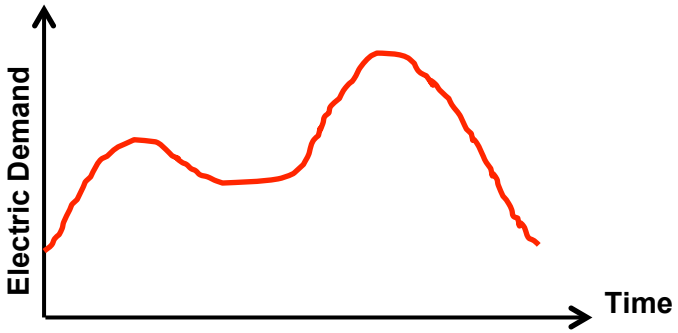




‘Smart’ allows appliances to negotiate with the water market

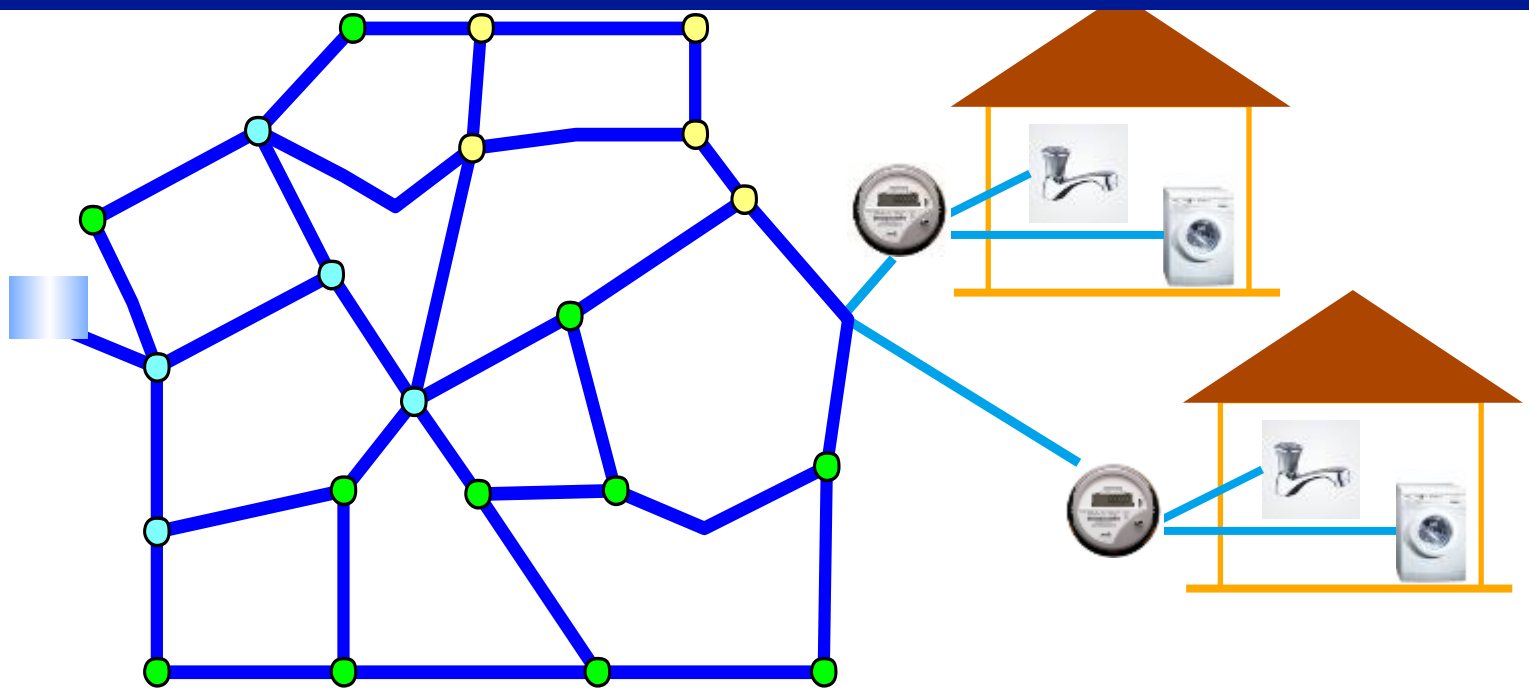


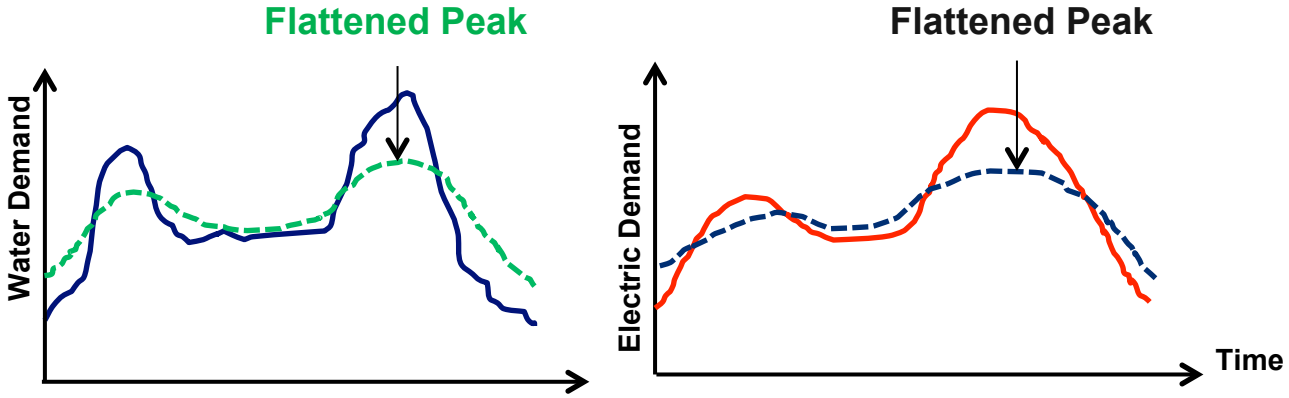




Central Control
Unit

‘Smart’ allows appliances to negotiate with the water market





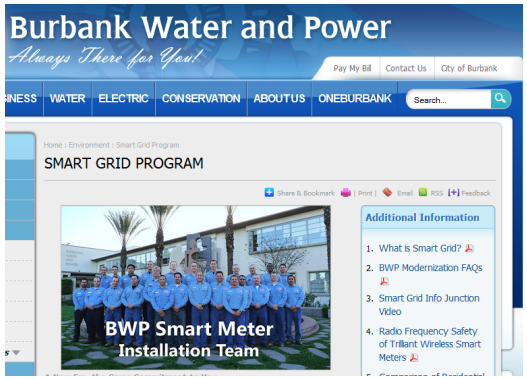
Central Control Unit

It's already happening: smart meters, smart water grid, smarter cities

Dubuque, Iowa

SMARTER SUSTAINABLE DUBUQUE

Burbank California



Rio De Jainero

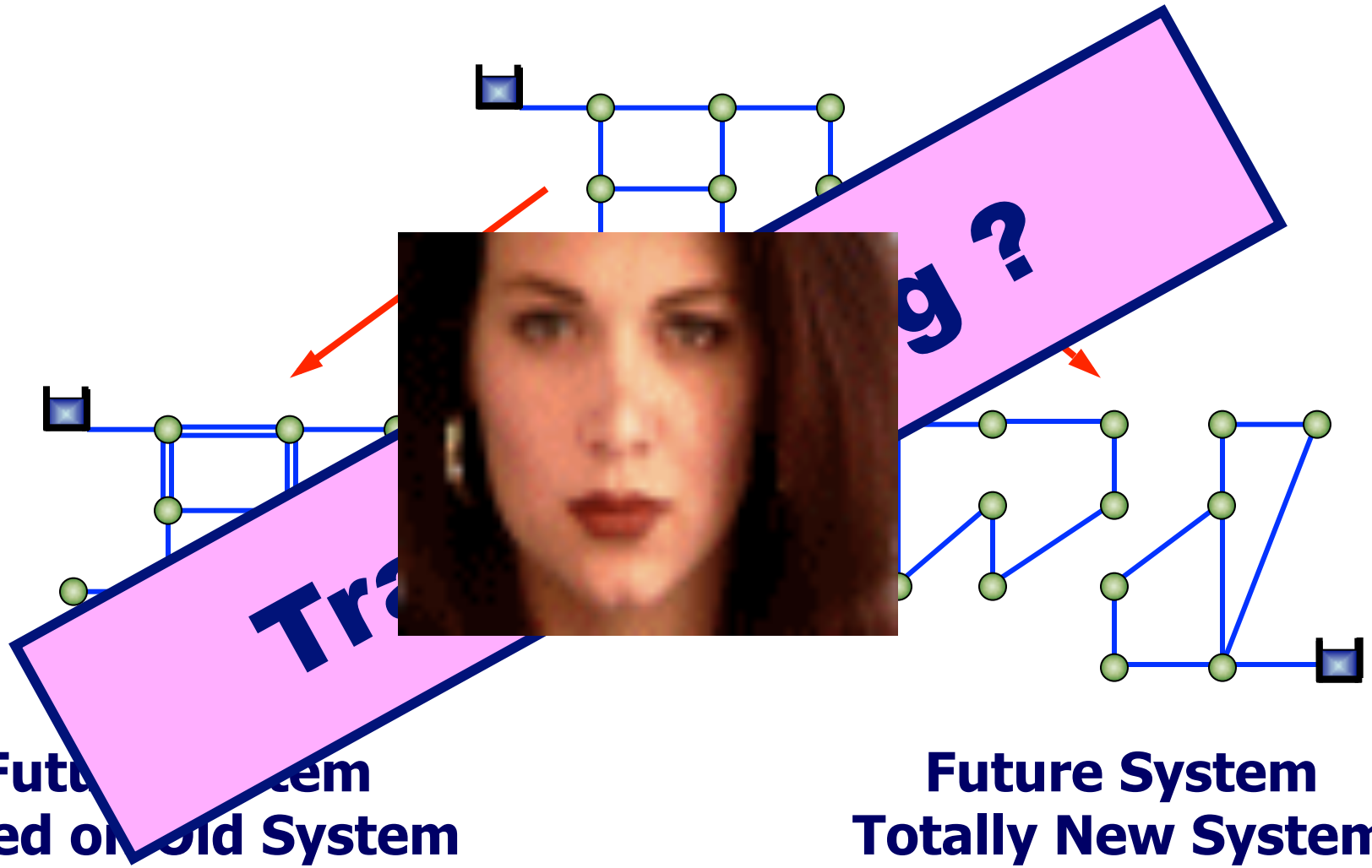
Dunedin/Miami-Dade

Take home message

Think creatively about how new technology from inside & outside our sector can transform water management

Transitioning

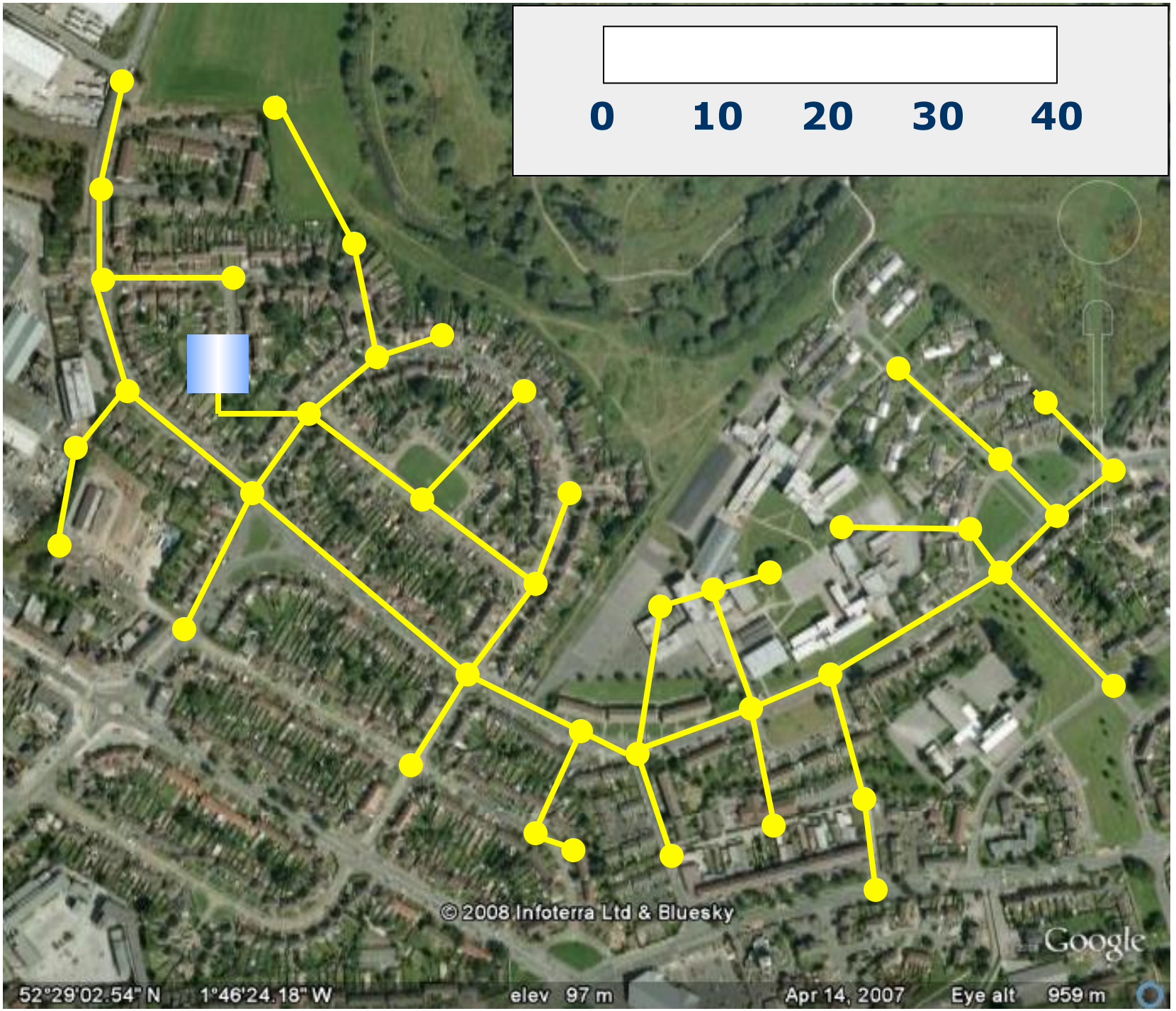
Transitioning



Future System
Based on Old System

Future System
Totally New System

Graph Theory Transition Systems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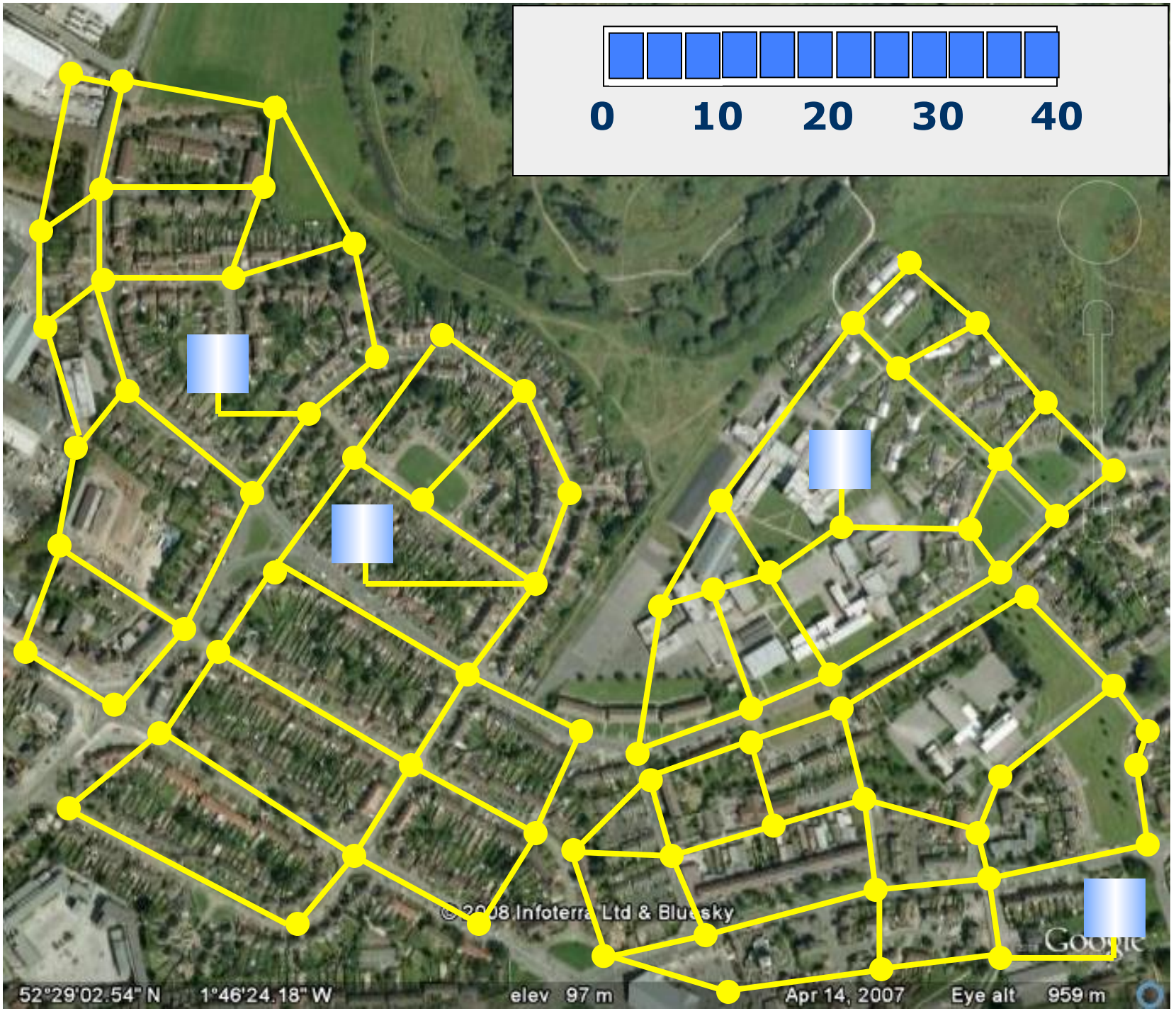
Apr 14, 2007
Eye alt 959 m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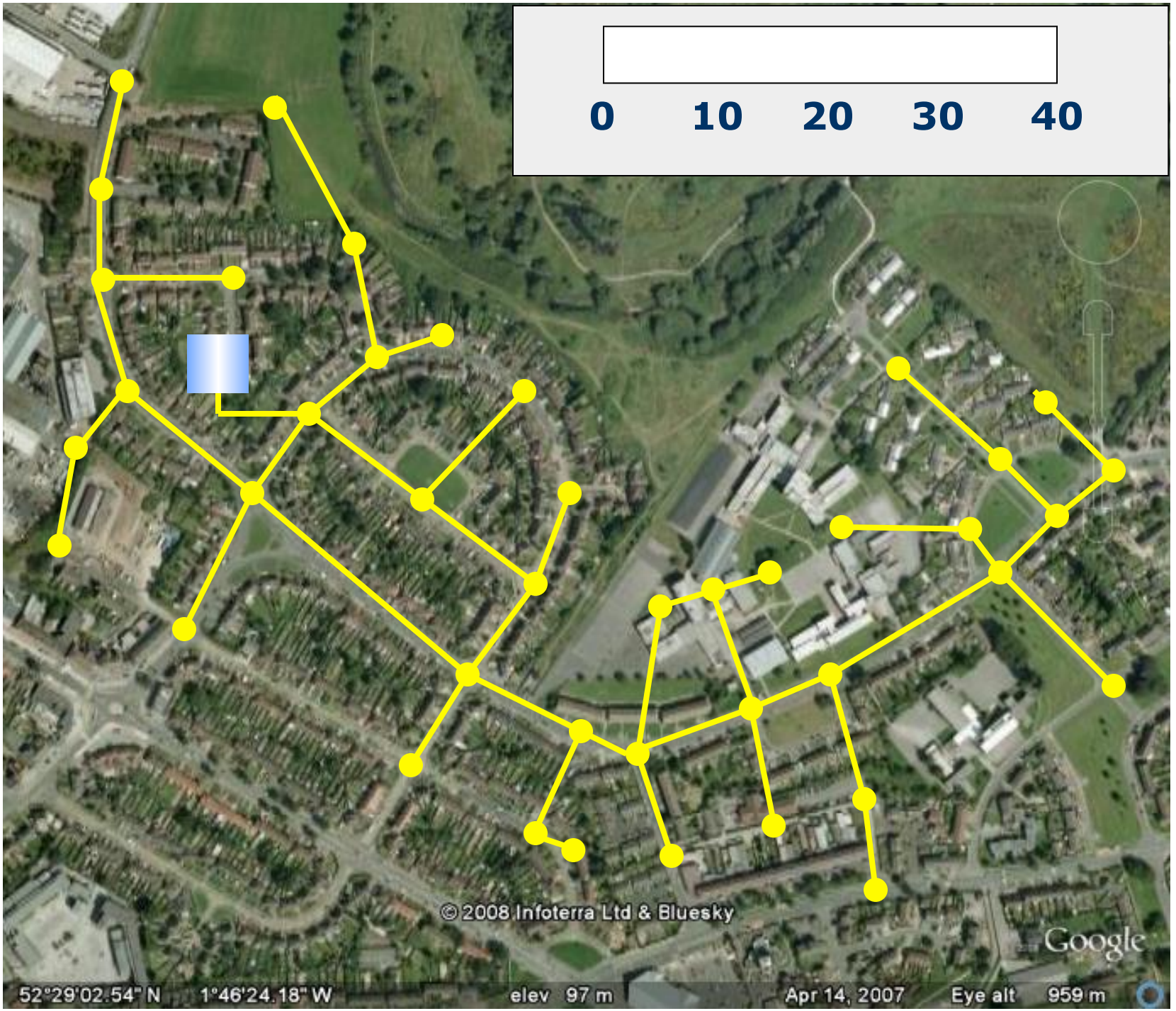
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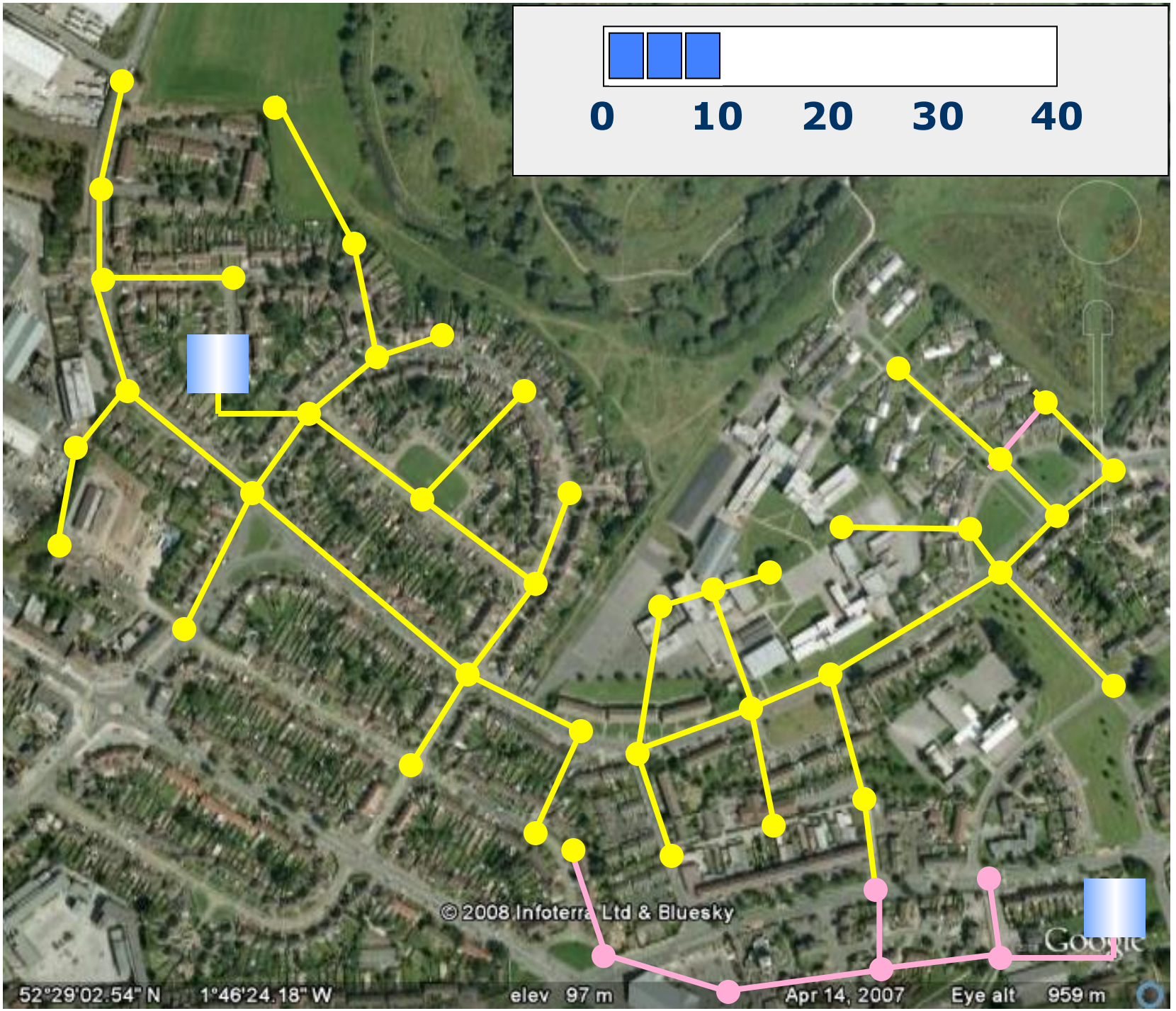
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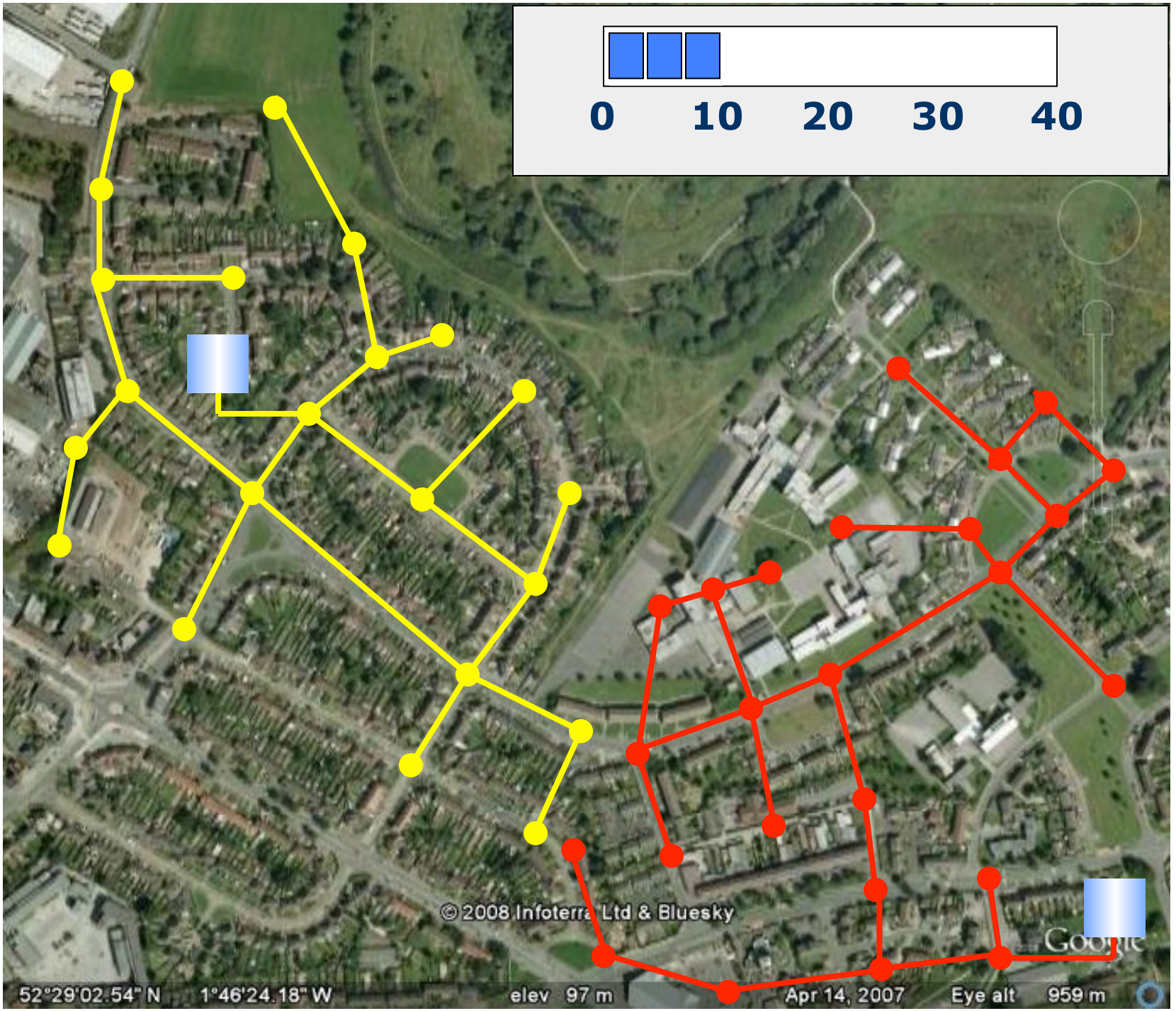
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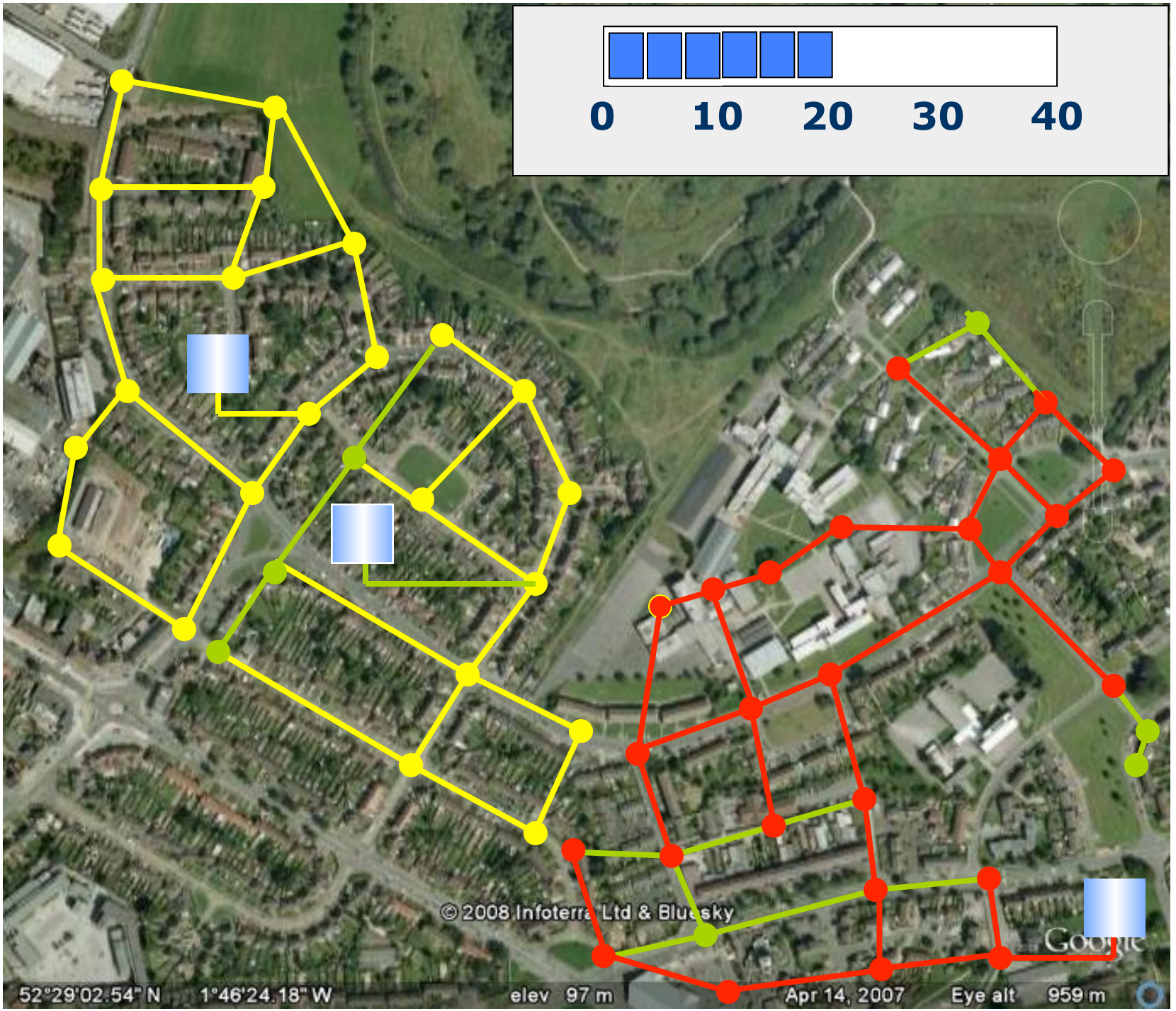
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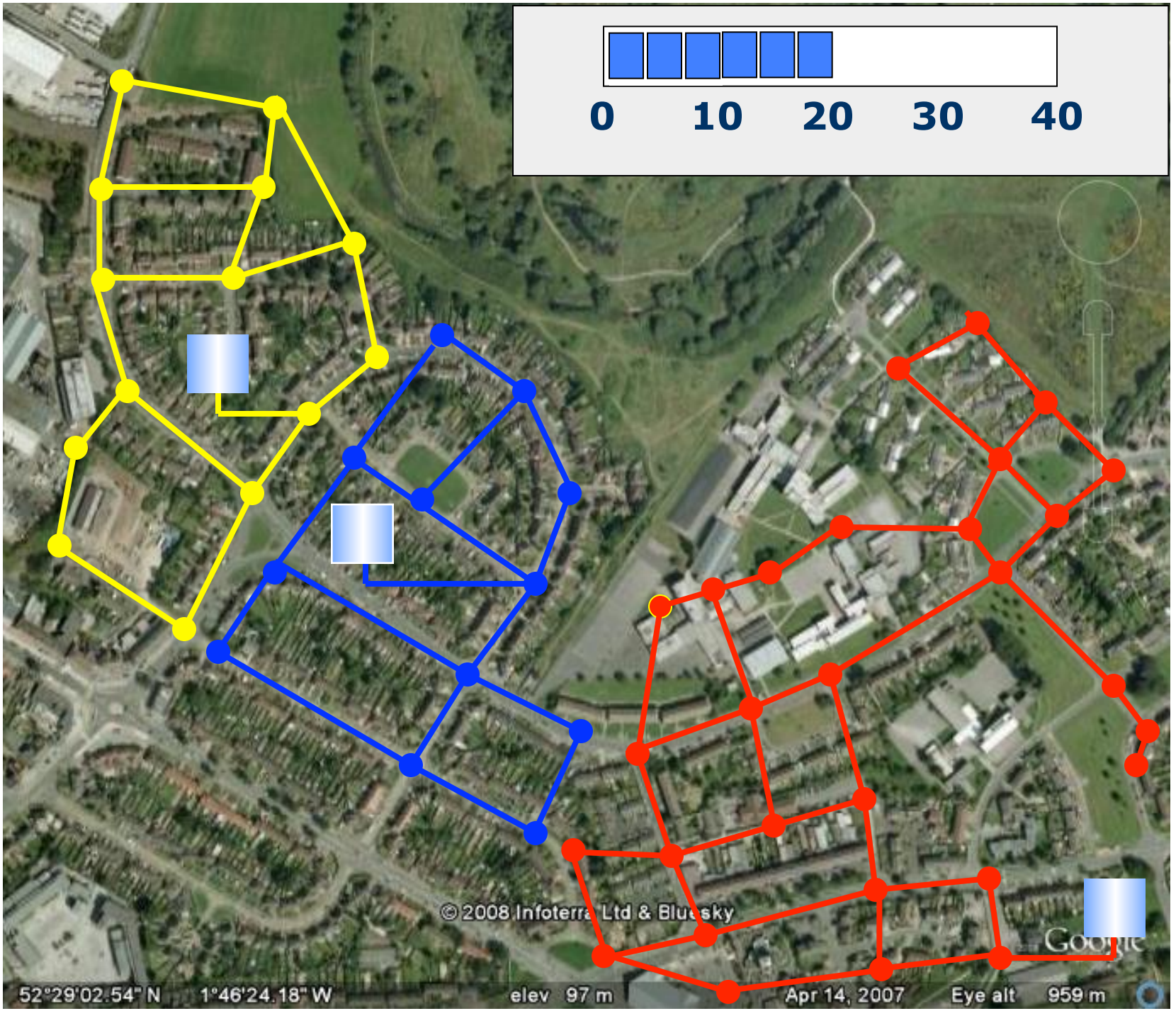
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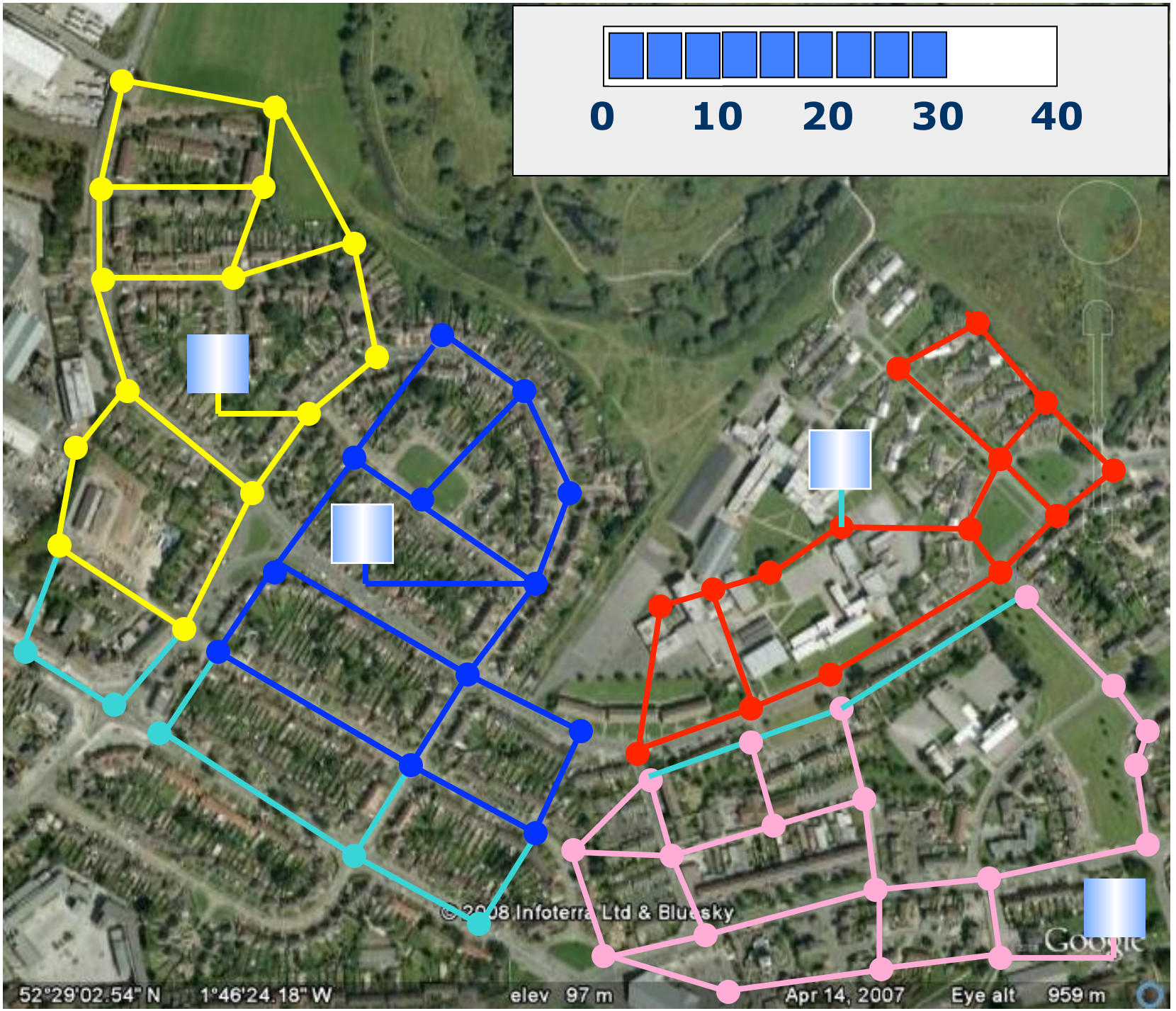
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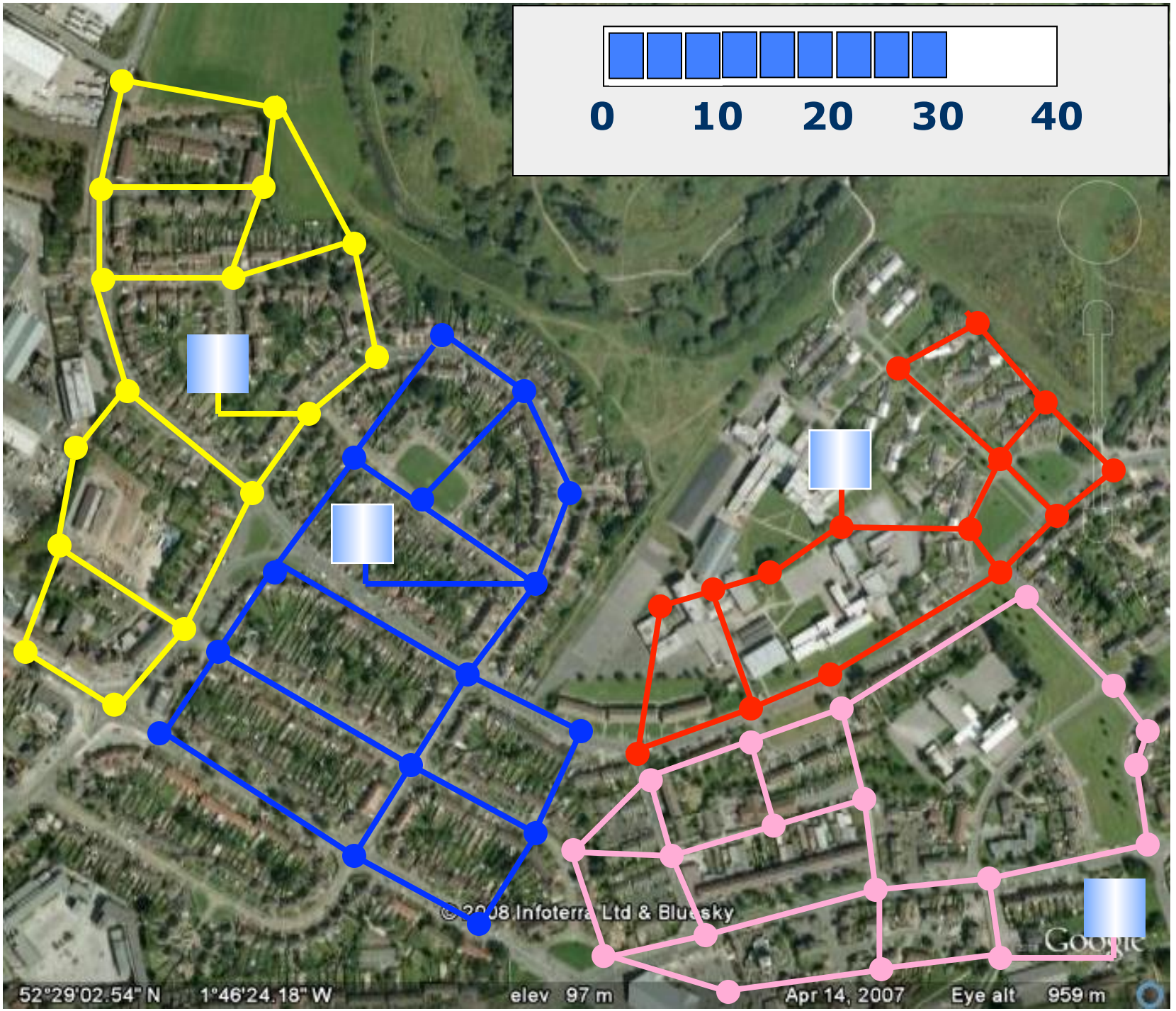
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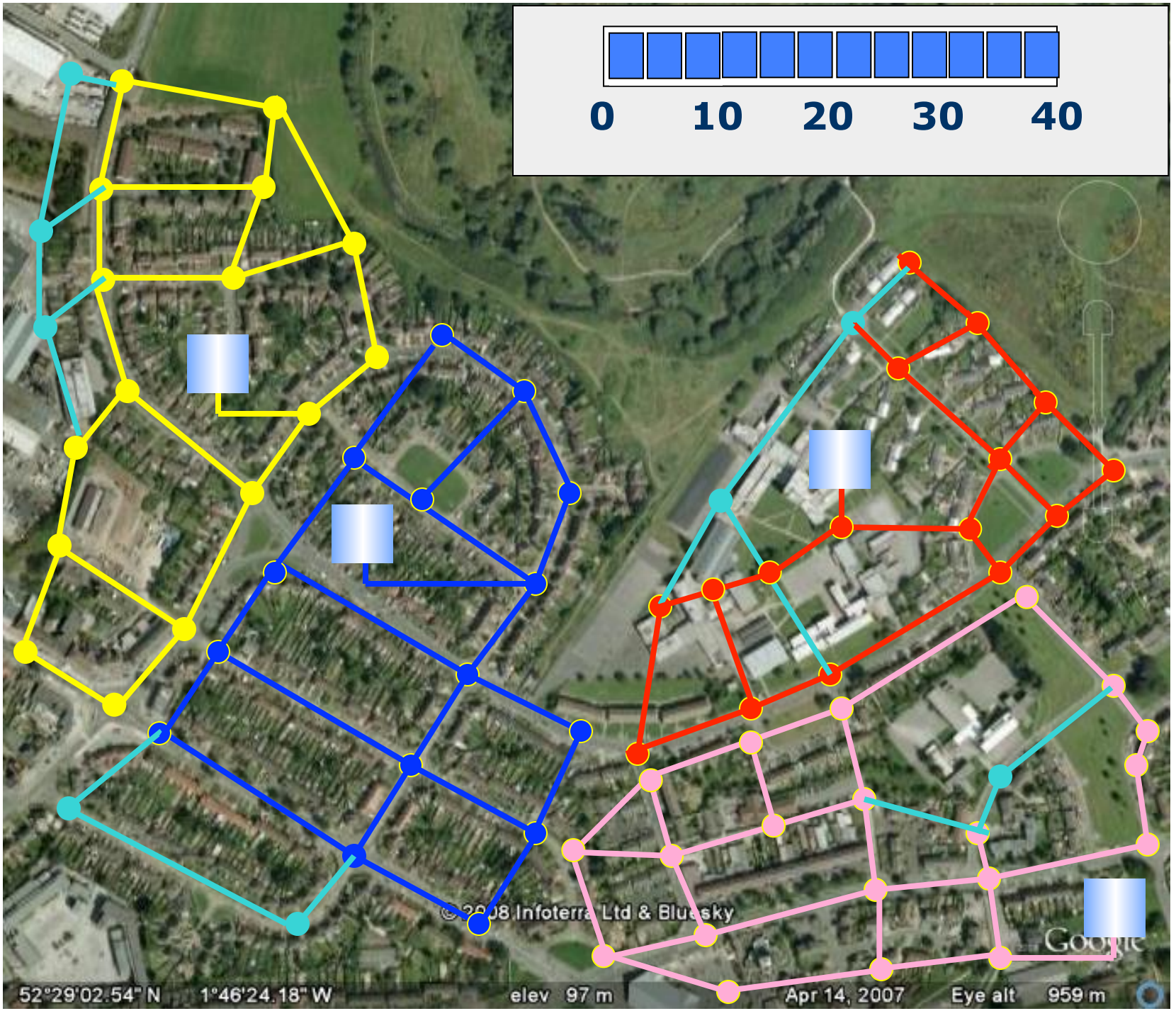
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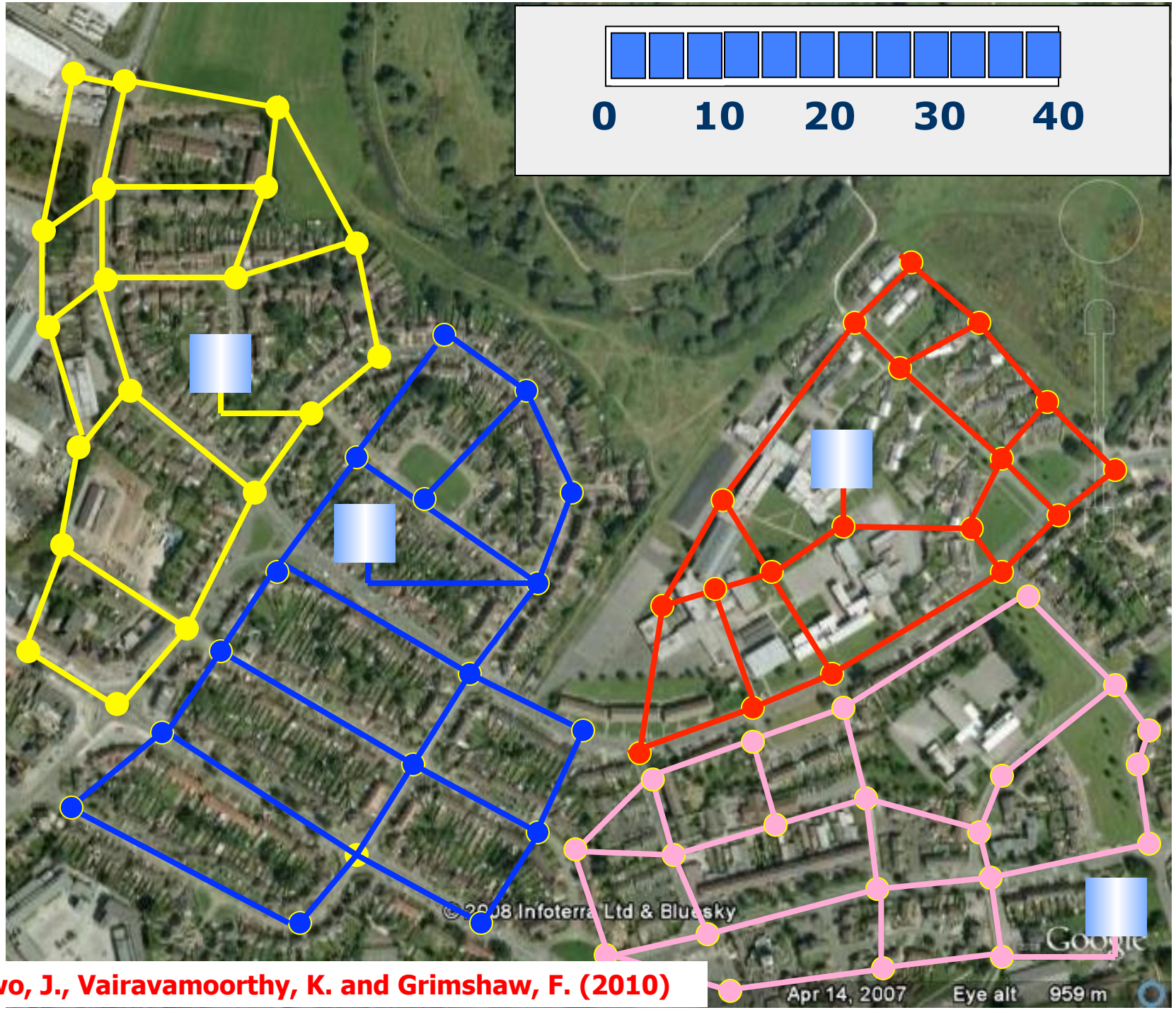


Sempewo, J., Vairavamoorthy, K. and Grimshaw, F. (2010)

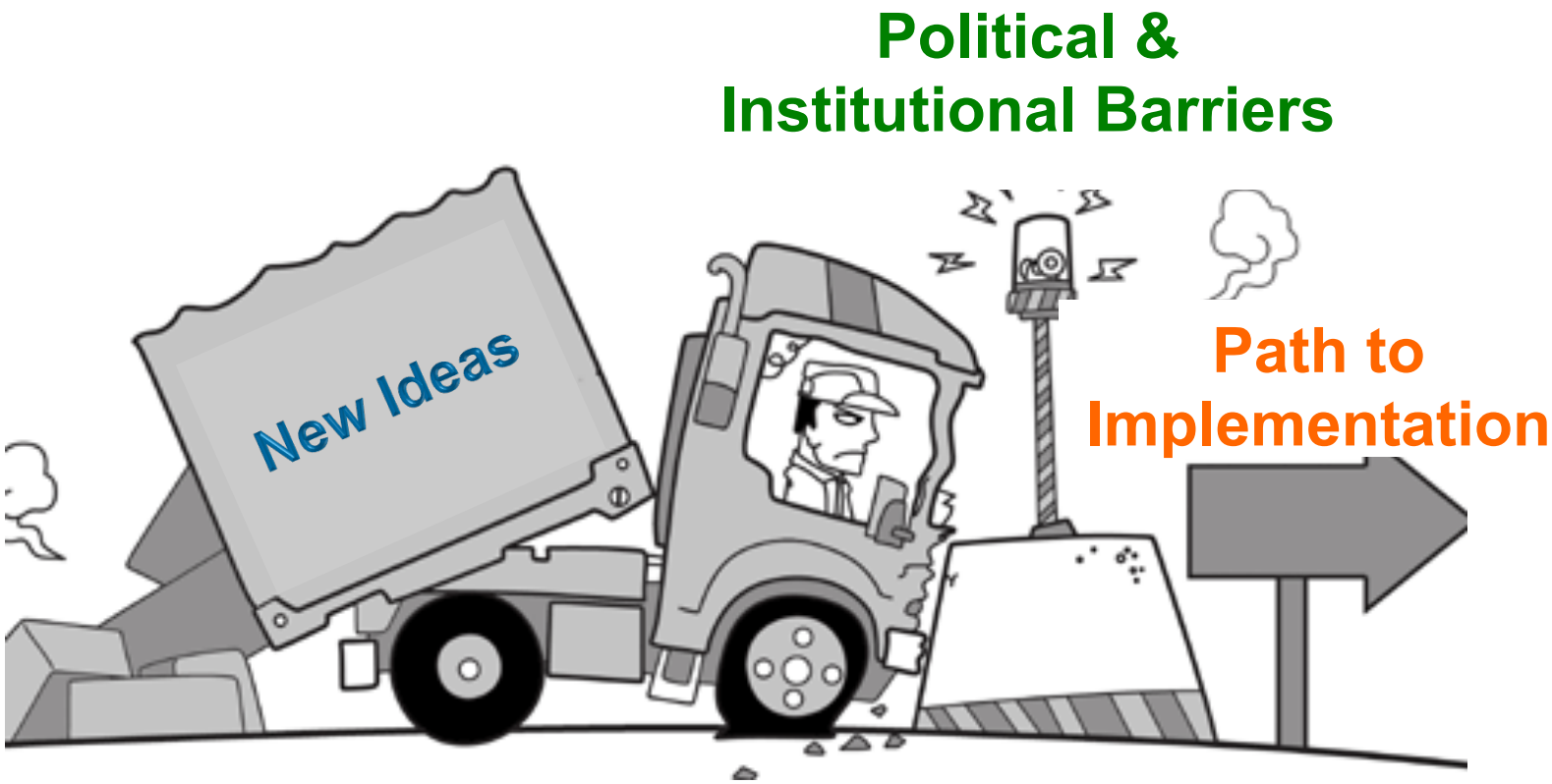
Take home message

Move away from tinkering and think about how you might have designed from scratch - then look at transitional pathways & don't be scared to decommission

Institutions are the origin of change and the medium for legitimizing change

MMM

Need to recognize that main challenges are political and institutional in nature



Need **collaboration, cooperation, and coordination** between institutions

Choices Before Us

Patel School of Global Sustainability

Thank You

Kalanithy Vairavamoorthy

vairavk@usf.edu