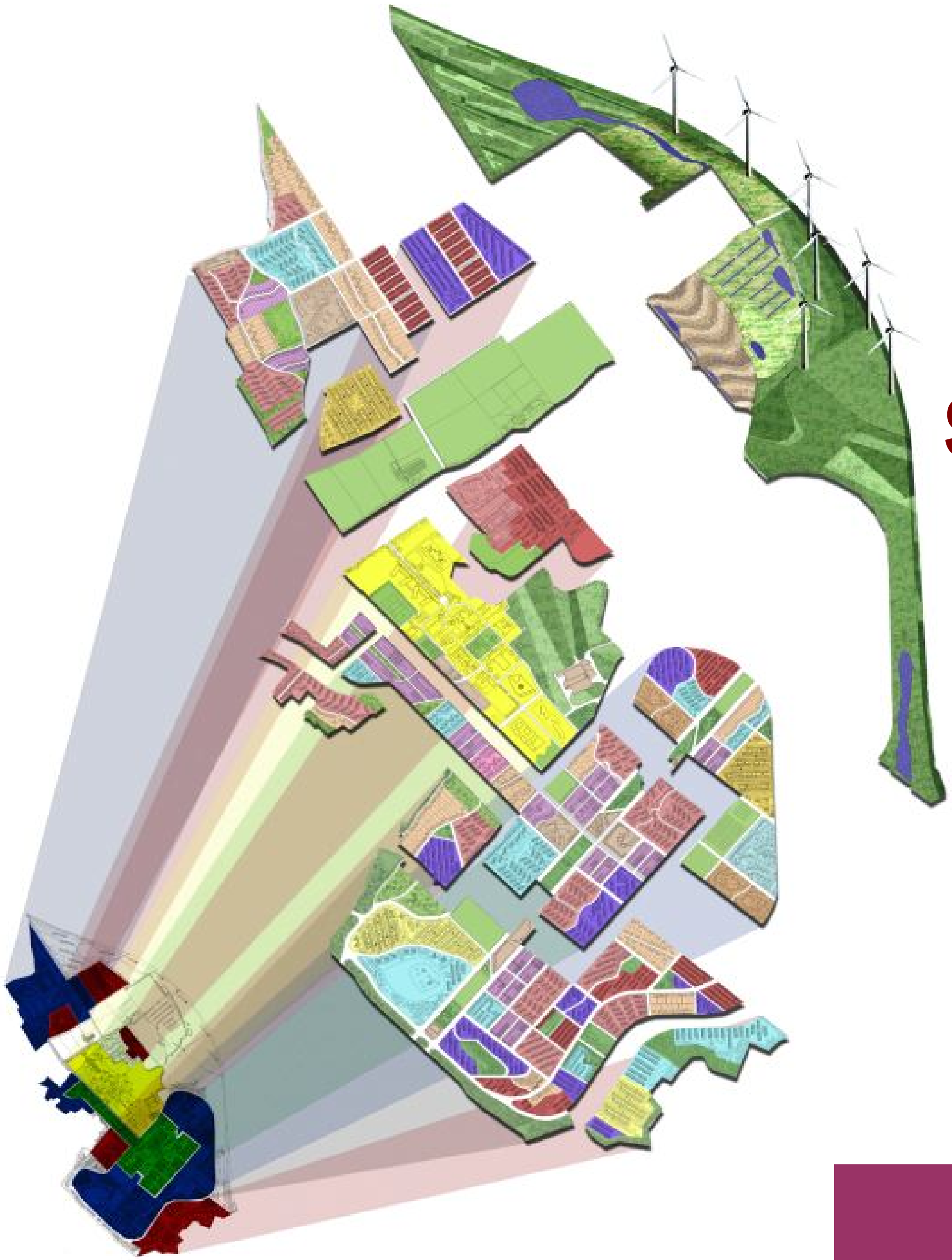

Scenario-based Urban Water Management

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Granada, June 2012

Overview

- Context and approach
- Research:
  - Form
  - Function
- Conclusions

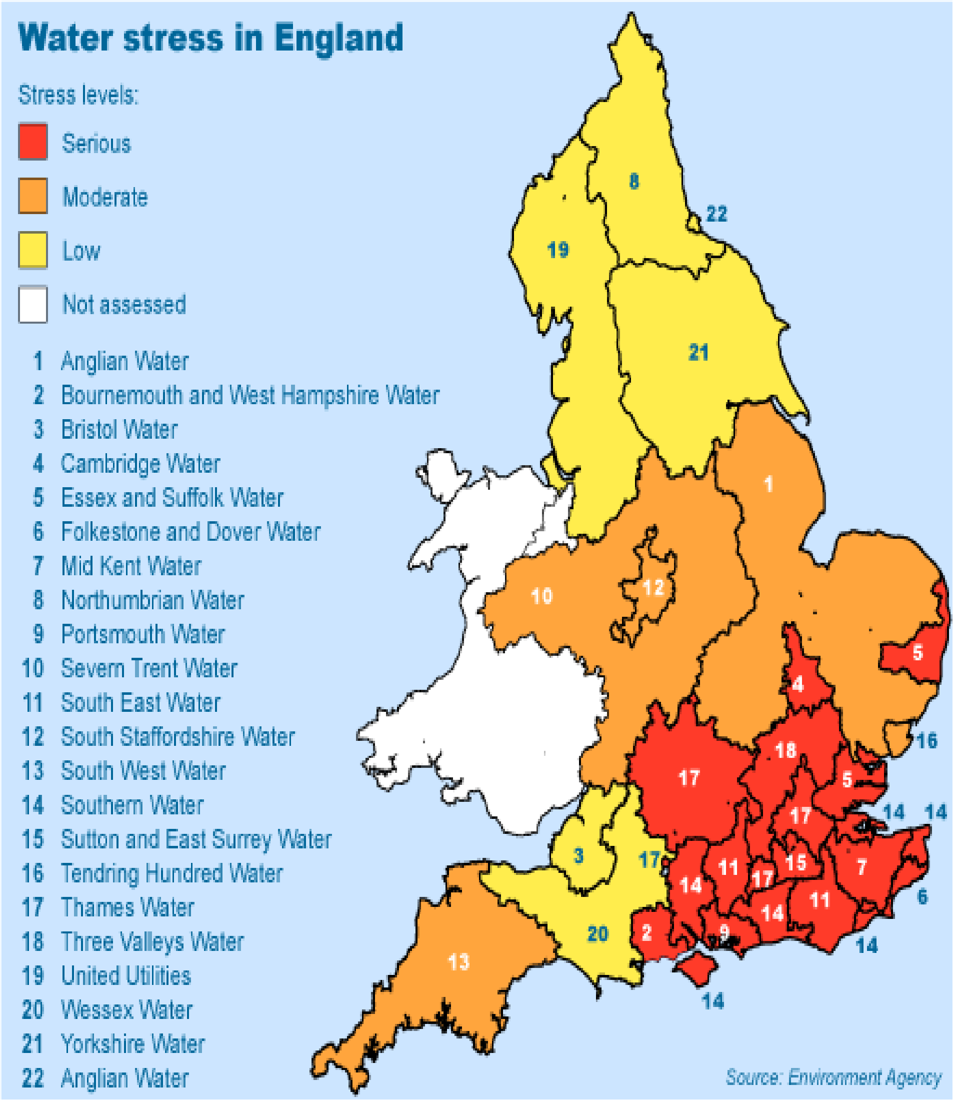
UK Drivers

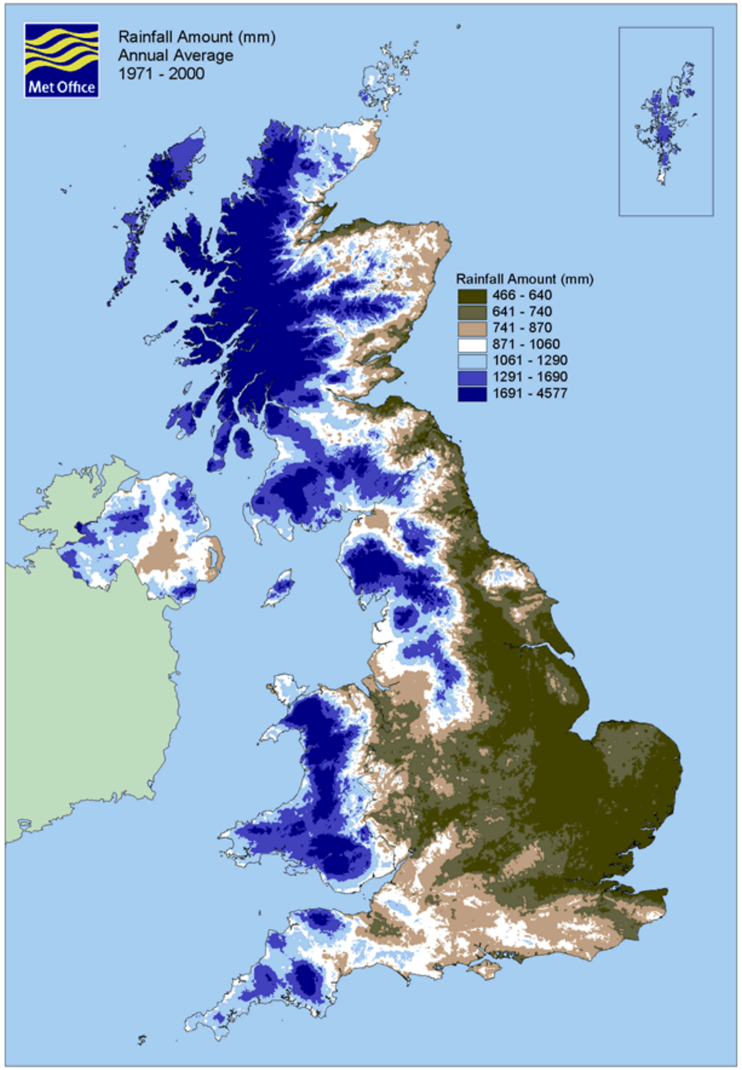
University of Exeter Centre for Water Systems

- Reduce per capita ***potable water demand*** to 130 l/p/d by 2030
- Improve surface water management, especially to ***manage flood risk***
- Continue progress in improving ***environmental water quality*** to Water Framework Directive ‘good’ status
- Reduce ***greenhouse gas emissions*** (80% by 2050)
- Provide 200,000 ***new homes*** by 2016

Water Stress levels in England

Annual UK rainfall





Regional Visions of Sustainable Infrastructure Optimised for Neighbourhoods

ReVISIONS, 2008-2012

Aims to provide the knowledge and evidence base to aid the **planning of regional spatial development** together with **infrastructure** for transport, water, waste and energy in a more coordinated and integrated way so as to:

- **reduce impacts** on the **environment** and resources,
- improve **economic** competitiveness
- allow households to live more **sustainably**, with a socially inclusive and enhanced quality of life.

Research areas

- Environmental modelling and overall assessment
- Water services
- Energy conversion and supply
- Water demand modelling
- Waste management
- The building stock and building energy demand
- Health
- Transport

Case studies

- The South East region
- The East of England region
- The North East of England
- International case studies
  - Beijing, China
  - Sao Paulo, Brazil
  - Southern California, USA

Urban Futures, 2008-2012

- Sustainable urban regeneration
  - envisioning the future to make more sustainable decisions today

Research areas

1: Biodiversity

2: Air Quality

3: Water and Wastewater

4: Sub-Surface Built Environment (infrastructure and utilities)

5: Surface Built Environment and Open Space

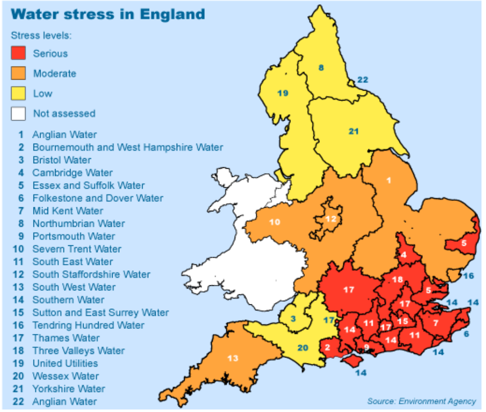
6: Density and Design Decision Making

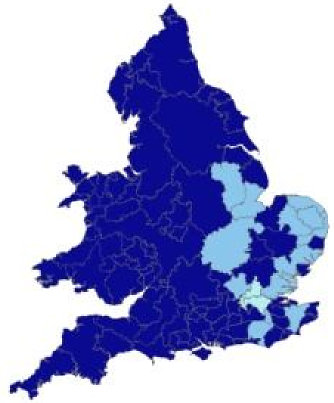
7: Organizational Behavior and Innovation

8: Social Needs, Aspirations and Planning Policy

The 3 main linking elements of this research were ***urban regeneration***, ***sustainability***, *and* ***futures scenarios***

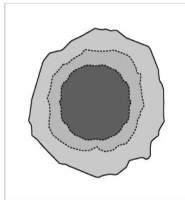
Regional scale



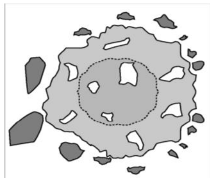


City scale

Policy Reform (compact)

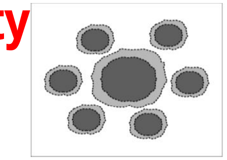


Market Forces (urban sprawl)



Fortress World Monocentric

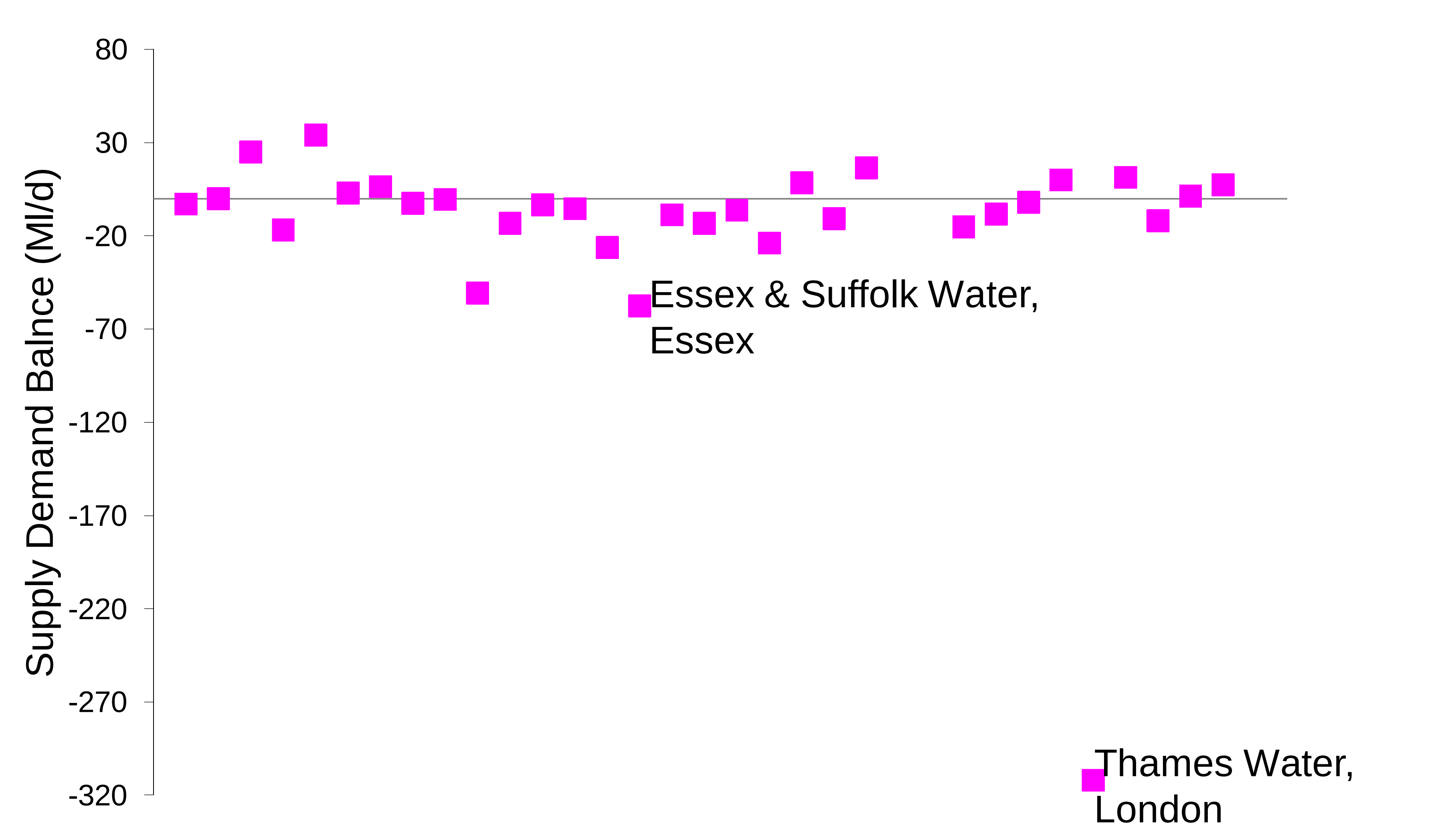
New Sustainability Paradigm Polycentric



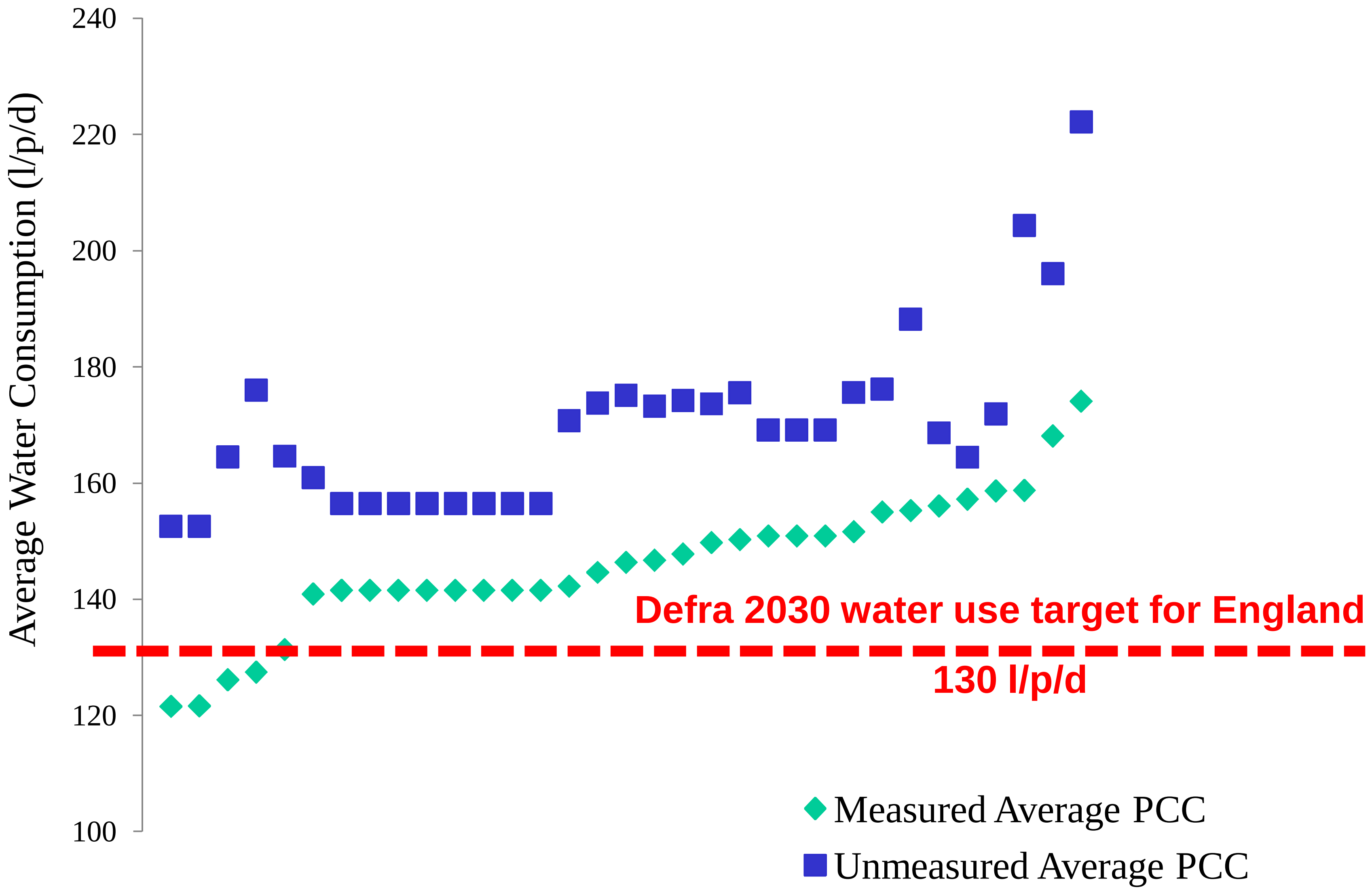
Development/ household scale

RWH – individual / communal
GWR – individual / communal
Swale
Pervious pavements
Pond

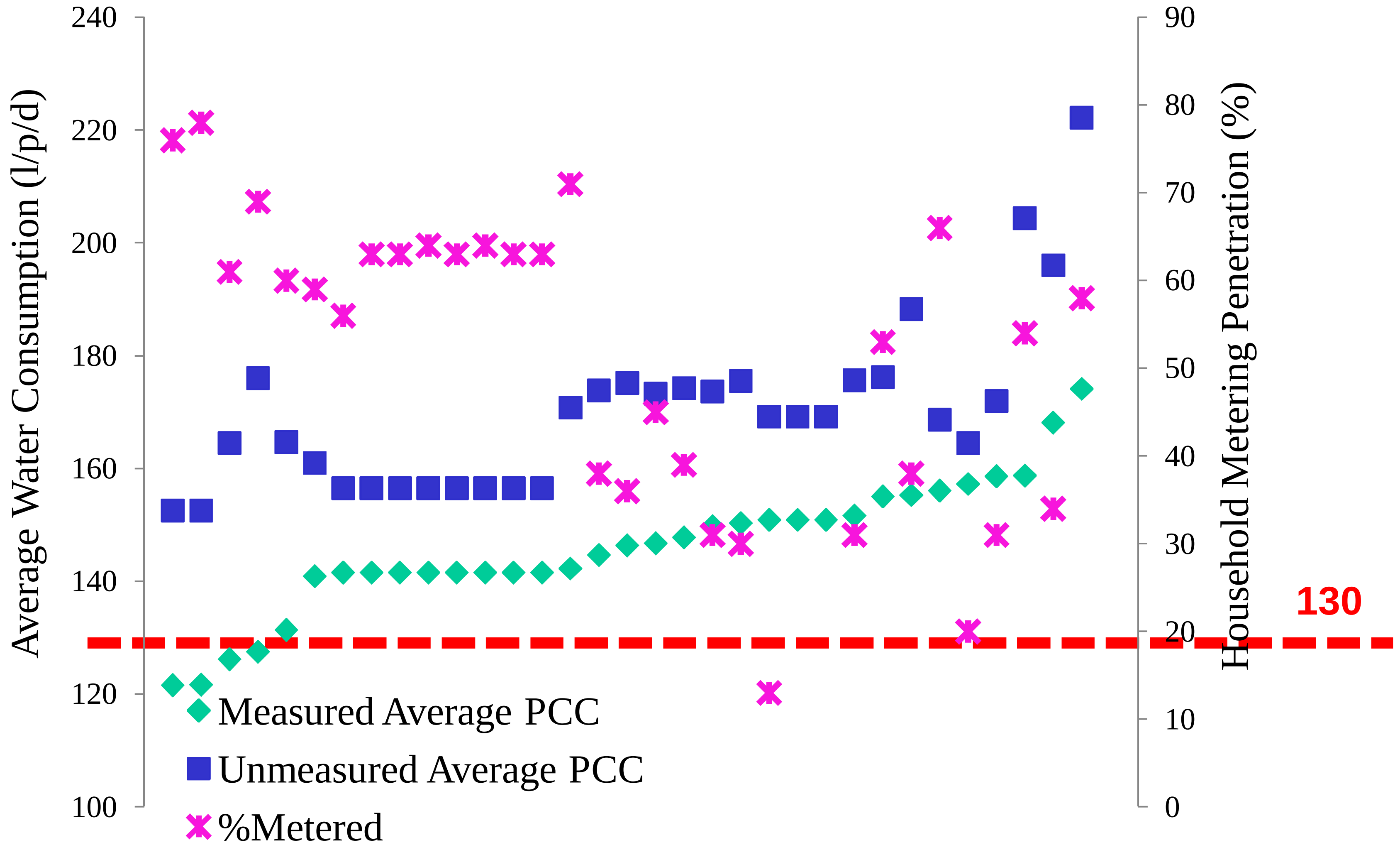
Supply Demand Balance (Wider South East, 2031)



Water consumption – PCC
(Wider South East Water Companies, 2031)



Water consumption and %metered households (Wider South East, 2031)



Future Scenarios

Impact of alternative scenarios on supply-demand balance

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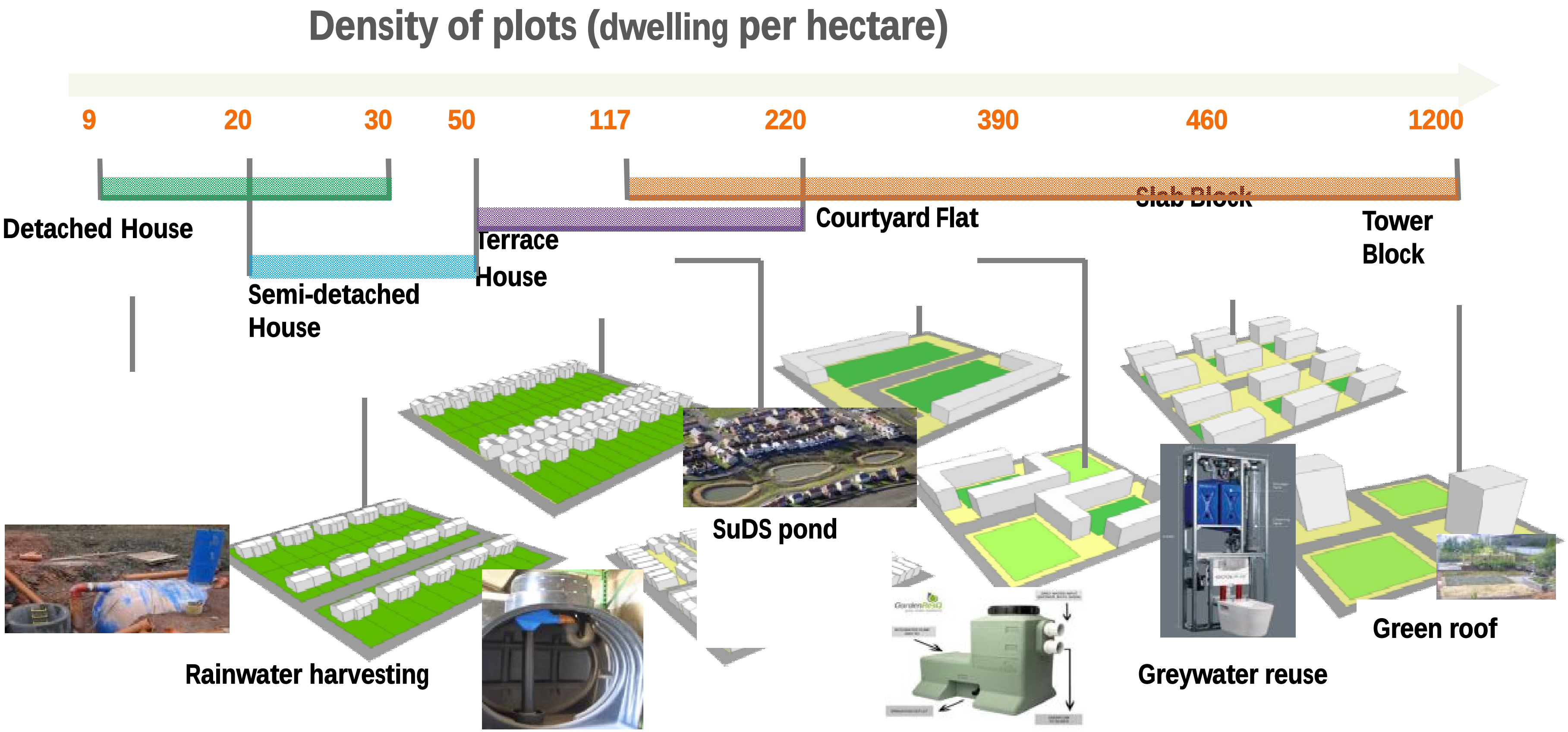
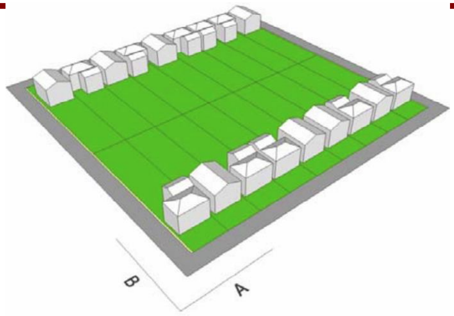
- Land Use Scenarios
  - Trend
  - Compaction
  - Market led
- Water Technology Options
  - Metering and Water Efficient Appliances
  - Rainwater Harvesting (RWH)
  - Greywater Reuse (GWR)
- Sustainable Drainage (SuDS)
  - Pond
  - Swale
  - Permeable Pavement
- Green Roofs

Tile-based Water Service Optioneering

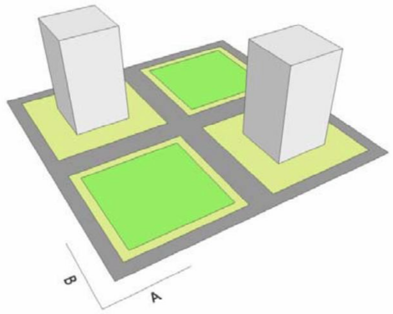


Tile-based Water Service Optioneering

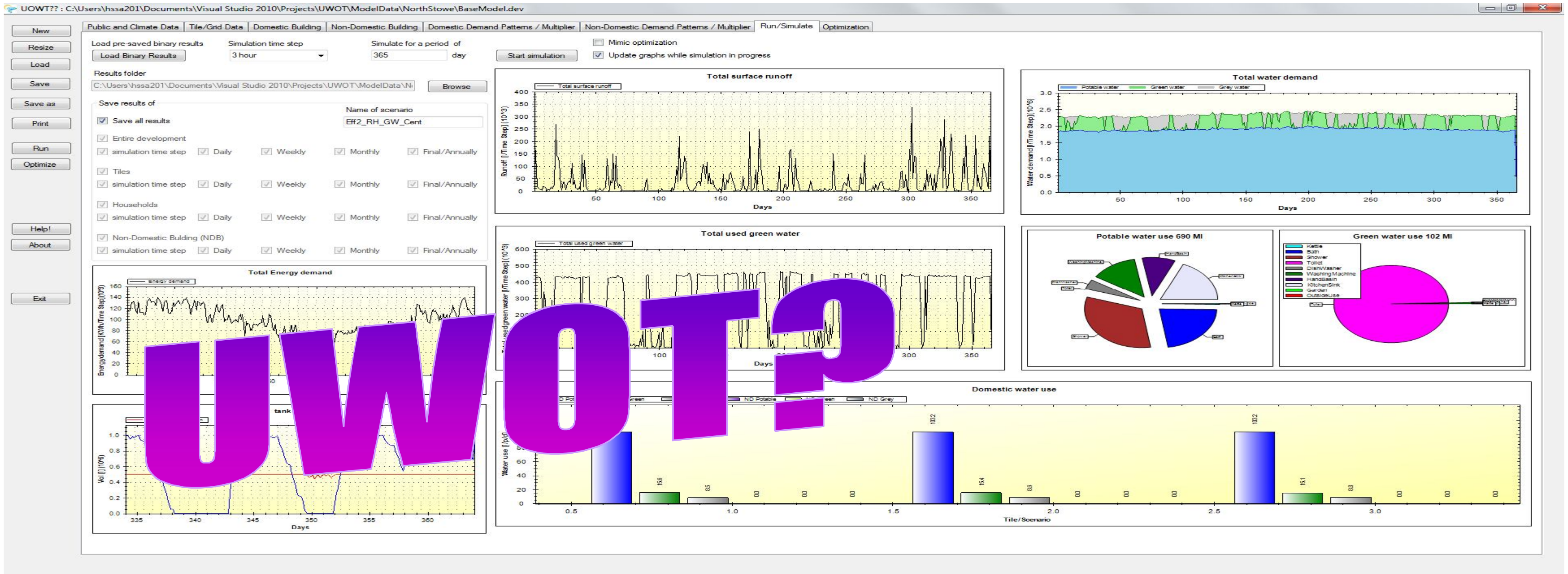
Detached House



Flat



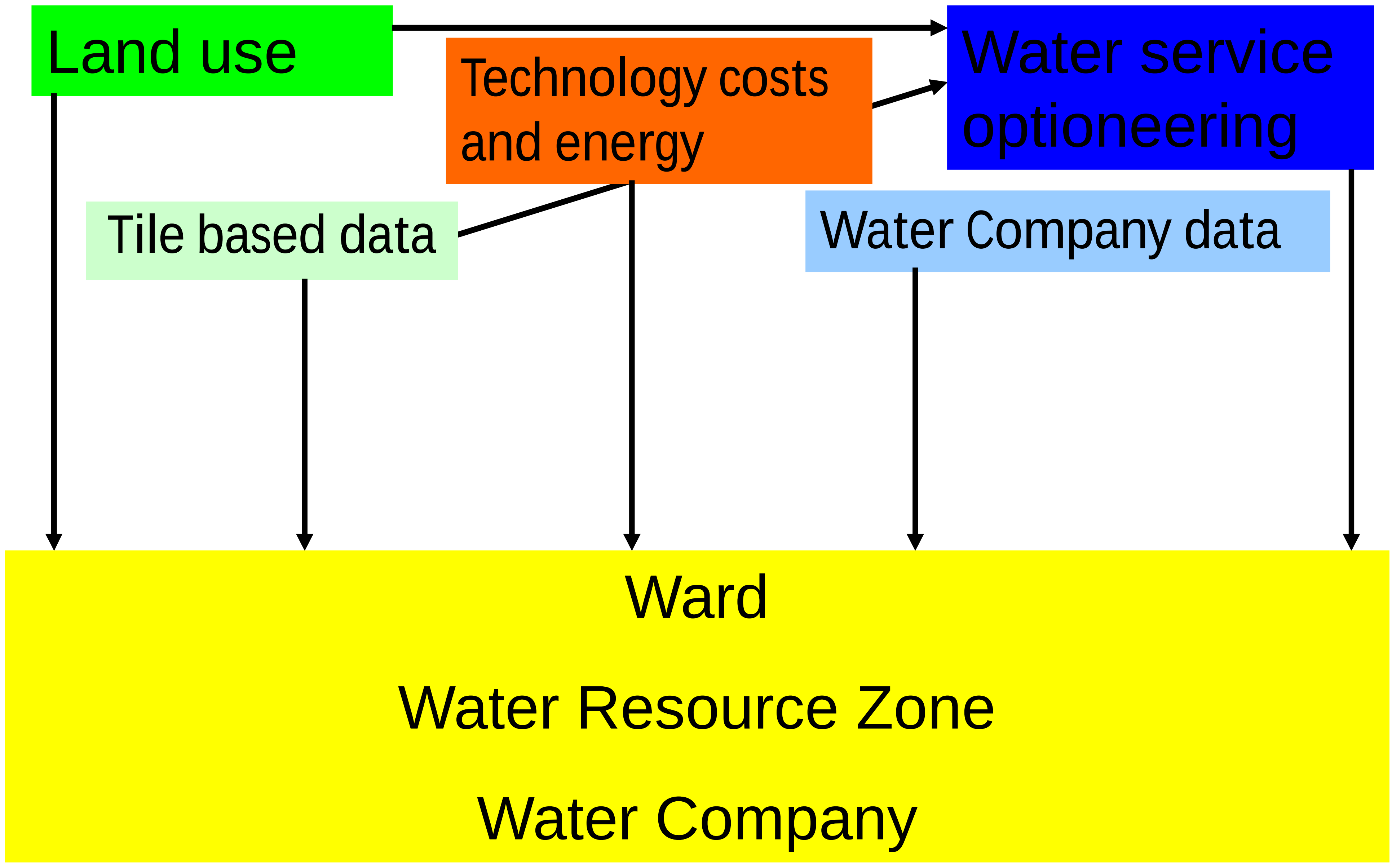
RWH - individual
RWH - communal
GWR - individual
GWR - communal
Swale
Pervious pavements
Pond



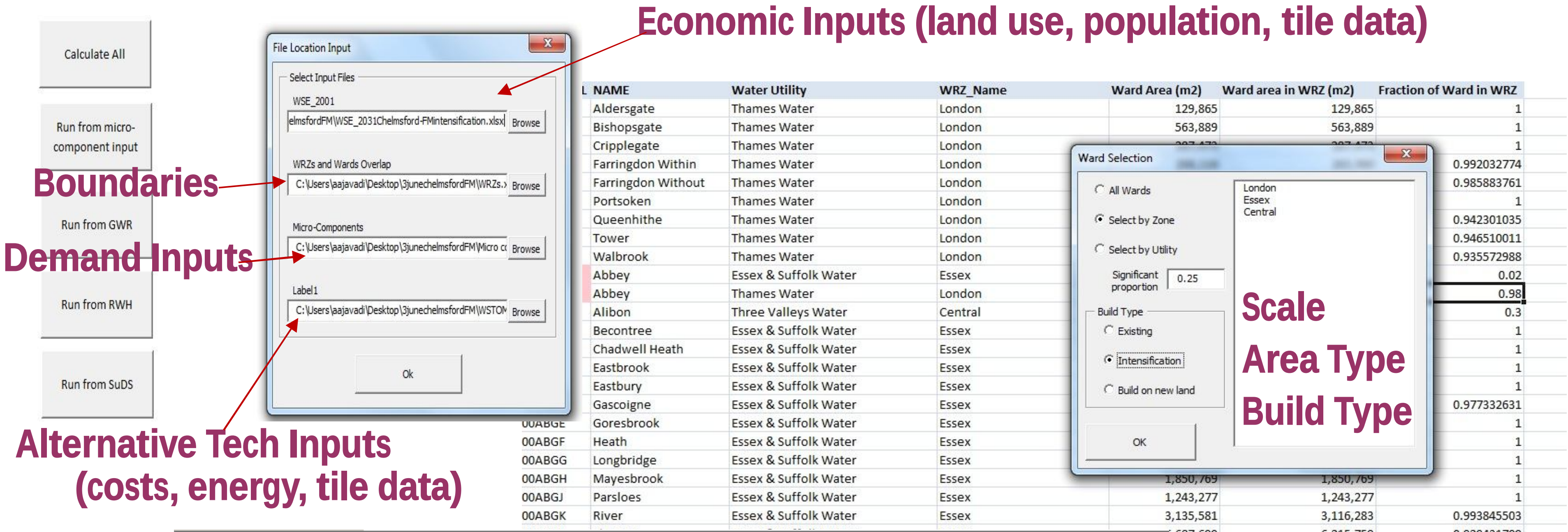
Area Type – Water Service Optioneering

	Area type			
	Central	Urban	Suburban	Rural
New Build	GWR (I), RWH (C), GR, PermPave, Swale	GWR (I), RWH (I/C), GR, PermPave, Swale	GWR (I/C), RWH (I), RWH (C), GR, Pond, PermPave, Swale	All
Retrofit	GWR (I), GR, PermPave, Swale	GWR (I), GR, PermPave, Swale	GWR (I), RWH (I), GR, Pond, PermPave, Swale	All except RWH (C) and GWR (C)

Land Use – Water modelling framework



Water Technology Optioneering Model (WTOM)

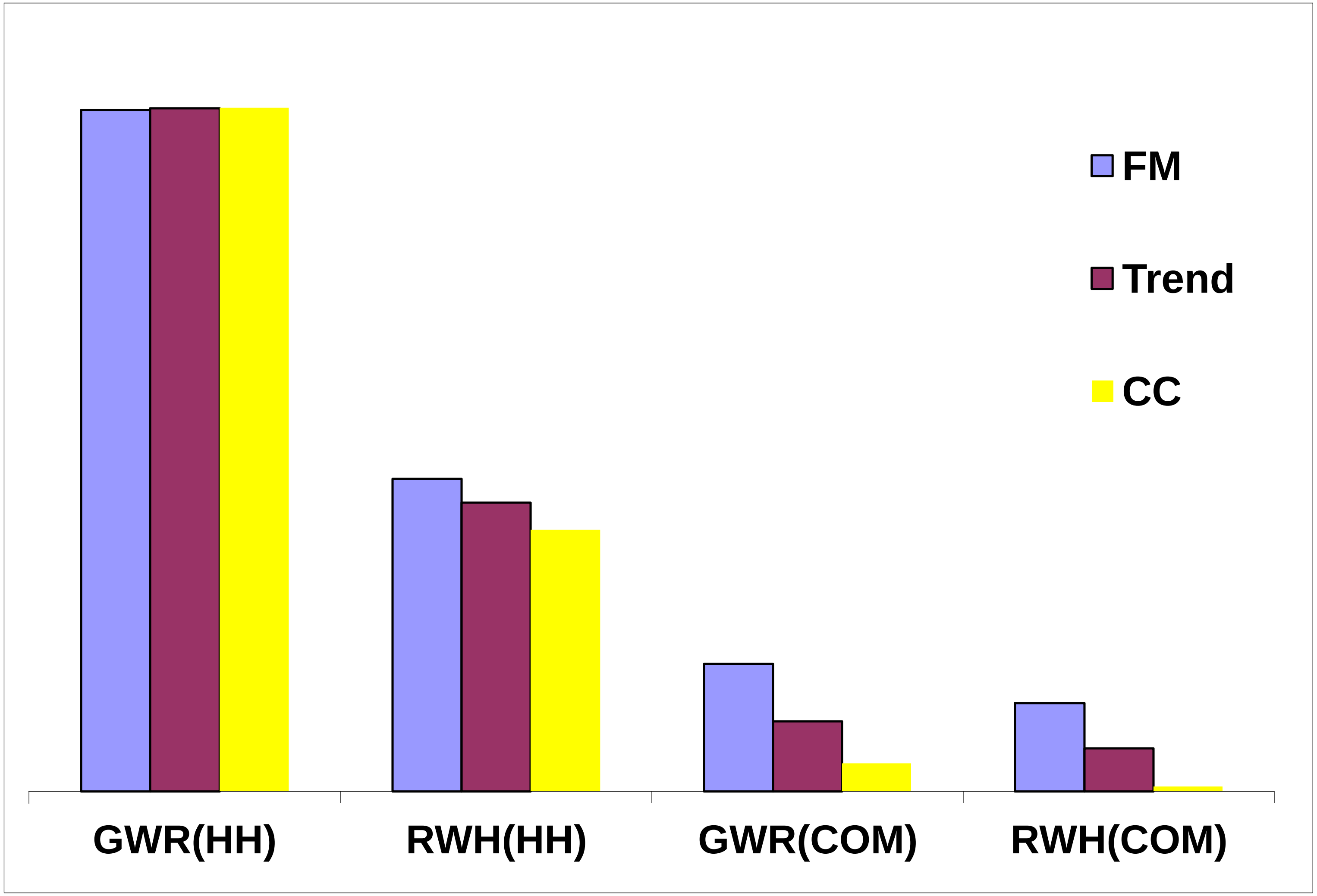


	NAME	Water Utility	WRZ_Name	Ward Area (m2)	Ward area in WRZ (m2)	Fraction of Ward in WRZ
	Aldersgate	Thames Water	London	129,865	129,865	1
	Bishopsgate	Thames Water	London	563,889	563,889	1
	Cripplegate	Thames Water	London			1
	Farringdon Within	Thames Water	London			0.992032774
	Farringdon Without	Thames Water	London			0.985883761
	Portsoken	Thames Water	London			1
	Queenhithe	Thames Water	London			0.942301035
	Tower	Thames Water	London			0.946510011
	Walbrook	Thames Water	London			0.935572988
	Abbey	Essex & Suffolk Water	Essex			0.02
	Abbey	Thames Water	London			0.98
	Alibon	Three Valleys Water	Central			0.3
	Becontree	Essex & Suffolk Water	Essex			1
	Chadwell Heath	Essex & Suffolk Water	Essex			1
	Eastbrook	Essex & Suffolk Water	Essex			1
	Eastbury	Essex & Suffolk Water	Essex			1
	Gascoigne	Essex & Suffolk Water	Essex			0.977332631
00ABGE	Goresbrook	Essex & Suffolk Water	Essex			1
00ABGF	Heath	Essex & Suffolk Water	Essex			1
00ABGG	Longbridge	Essex & Suffolk Water	Essex			1
00ABGH	Mayesbrook	Essex & Suffolk Water	Essex	1,850,769	1,850,769	1
00ABGJ	Parsloes	Essex & Suffolk Water	Essex	1,243,277	1,243,277	1
00ABGK	River	Essex & Suffolk Water	Essex	3,135,581	3,116,283	0.993845503

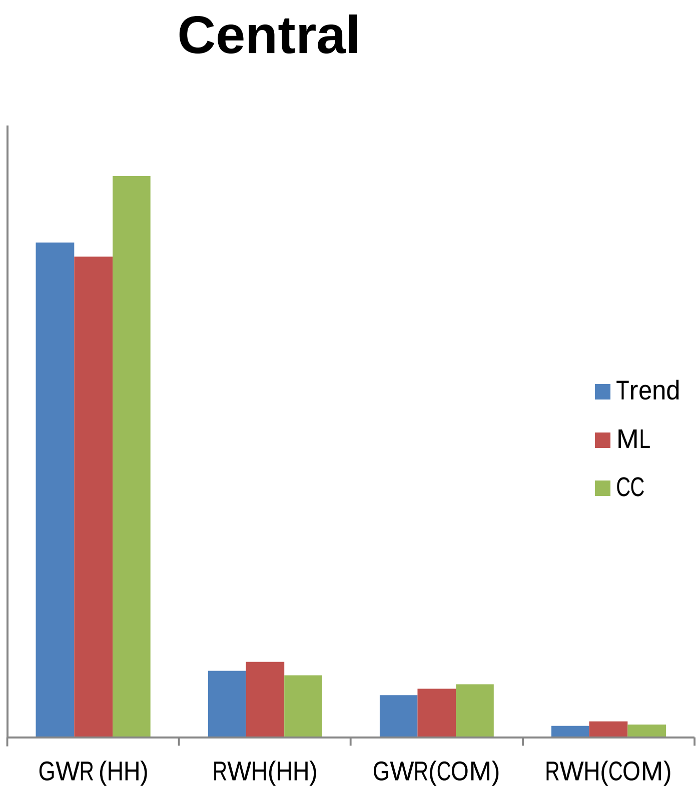
	A	B	C	D	M	N	O	P	Q	R	S	T
1					Standard RWH Technology						Low Carbon RWH	
2		General Ward Information			Water saving from RWH		RWH Costs		RWH CO2		RWH Costs	RWH CO2
3	Ward	WRZ	Total Dwell	Total Pop	HH (m3/day)	Comm (m3/day)	HH Cost (£)	Com Cost (£)	HH CO2	Com CO2	HH Cost (£)	HH CO2
4	Essex & Suffolk Water											
5	00ABFZ	1	4381	10841	64	61	4706400	1621370	374711507	42483	2952400	4407791
6	00ABGA	1	4072	9361	62	60	4523550	1545555	355364493	40488	2827200	4180209
7	00ABGB	1	4043	9921	68	65	4988625	1690333	388217913	44289	3109800	4566669
8	00ABGC	1	4334	10108	56	53	4168450	1381472	322876111	36204	2595200	3798043
9	00ABGD	1	4141	9235	3	0	214650	0	14784039	0	129600	173907
10	00ABGE	1	4124	10271	9	52	556500	1345370	38328990	35259	336000	450870
11	00ABGF	1	4245	9701	11	46	739350	1211188	50922801	31731	446400	599013
12	00ABGG	1	3483	8812	55	52	4141950	1292334	300061236	33852	2533200	3529668
13	00ABGH	1	3920	9412	11	53	707550	1371435	48732573	35973	427200	573249

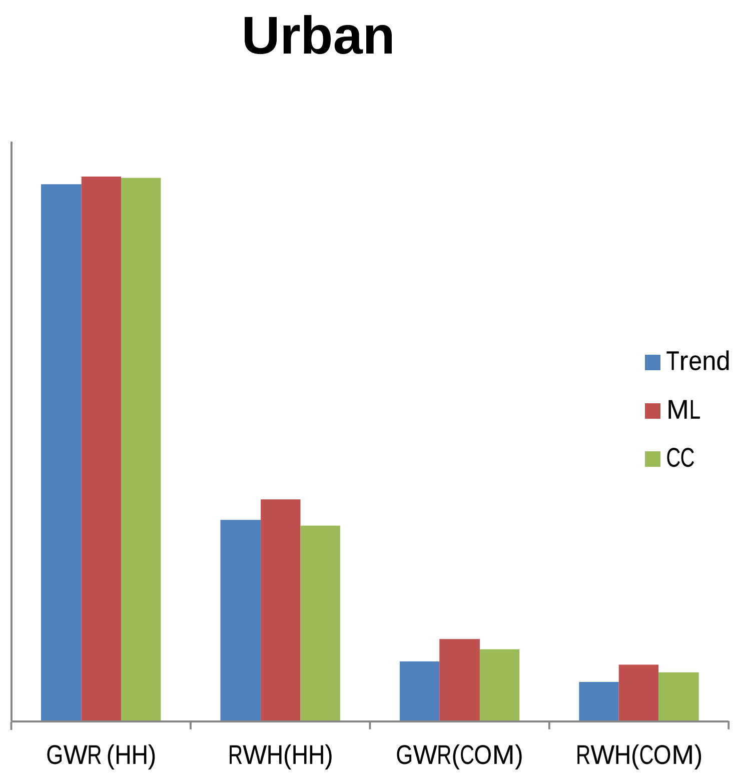
Results

Impact of urban form on supply-demand balance

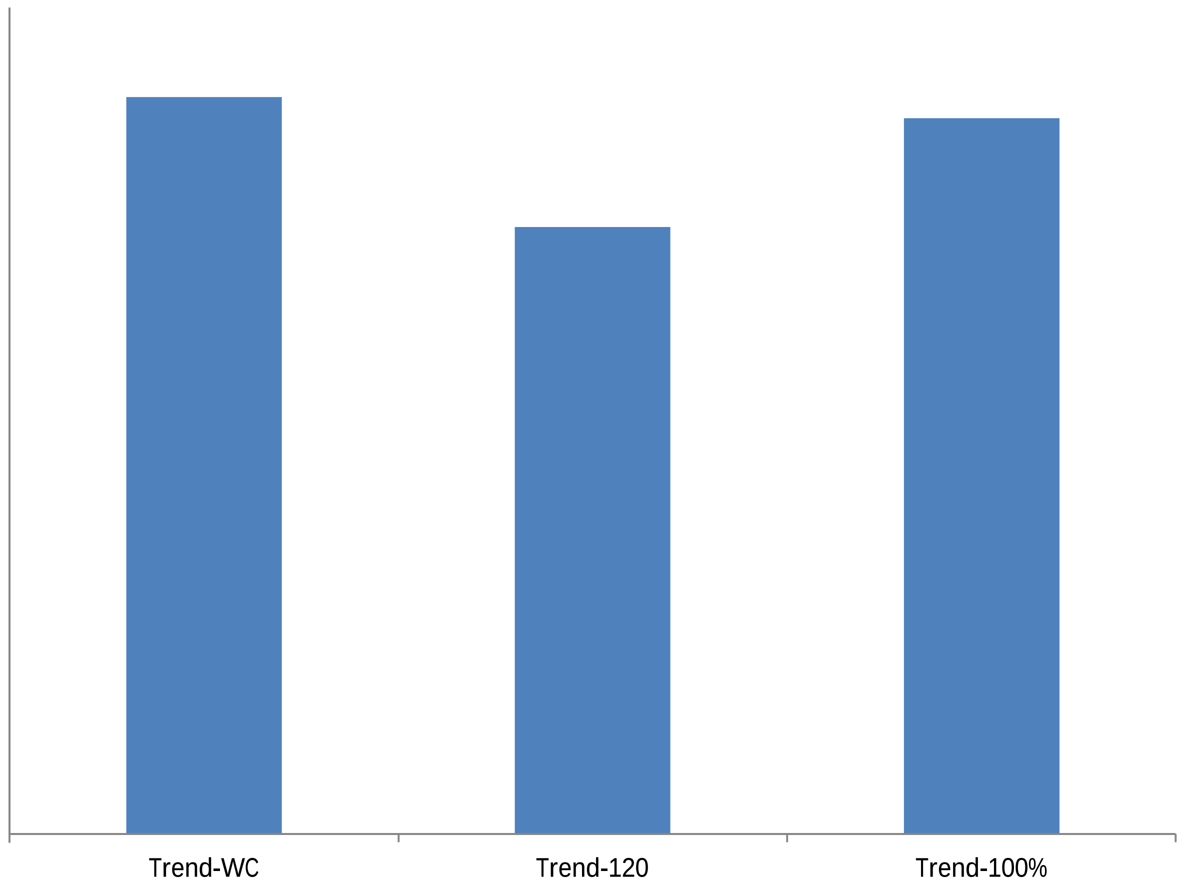


Impact of urban form on supply-demand balance



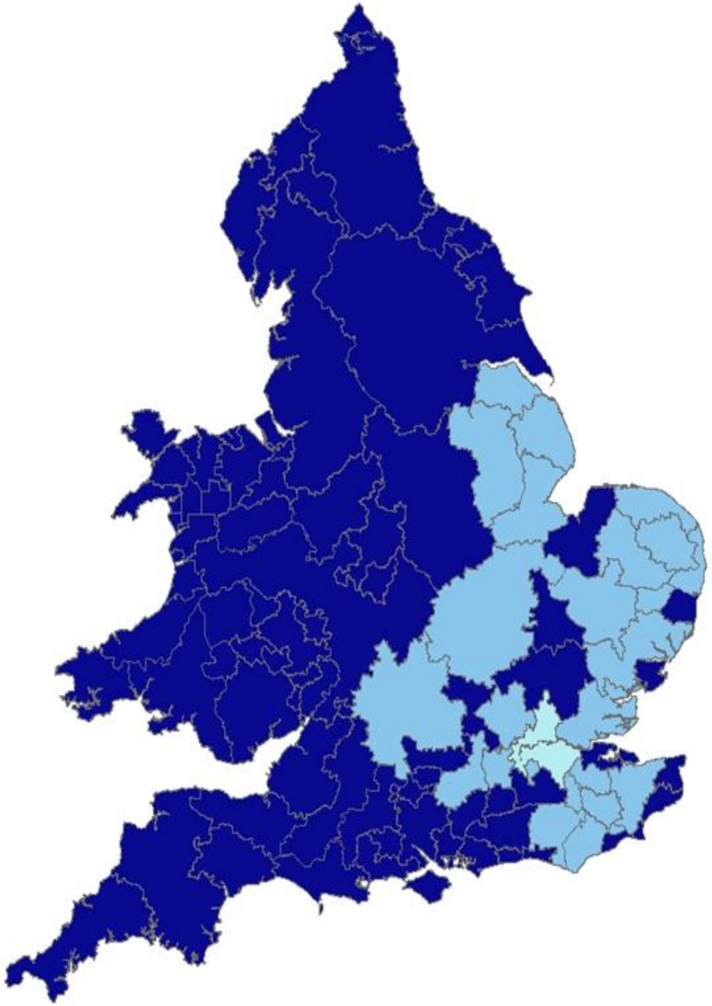


Impact of water management options on supply-demand balance

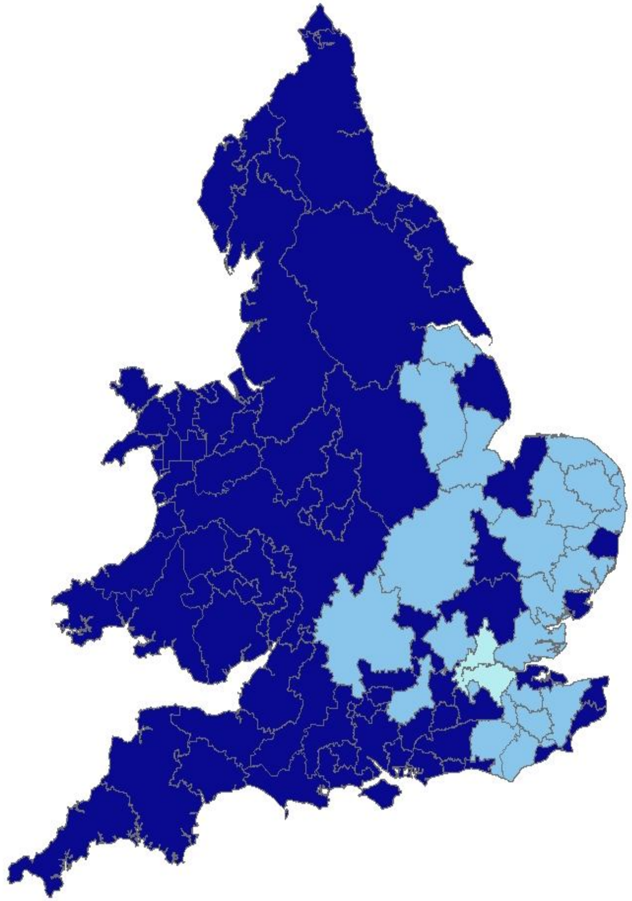


Wider South-East

Supply-demand balance



2031 - Companies projection



2031 – Water efficient appliances

Wider South-East

Supply-demand balance

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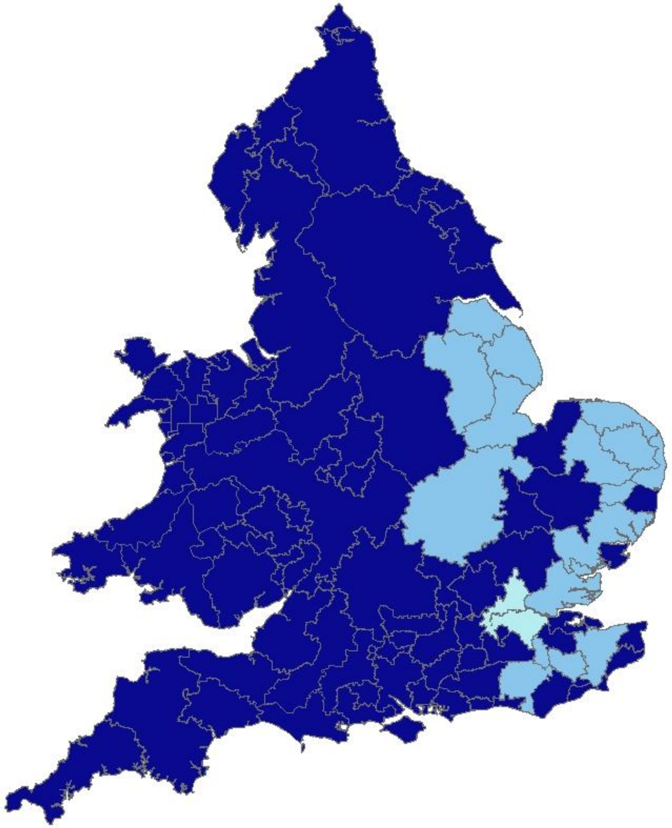
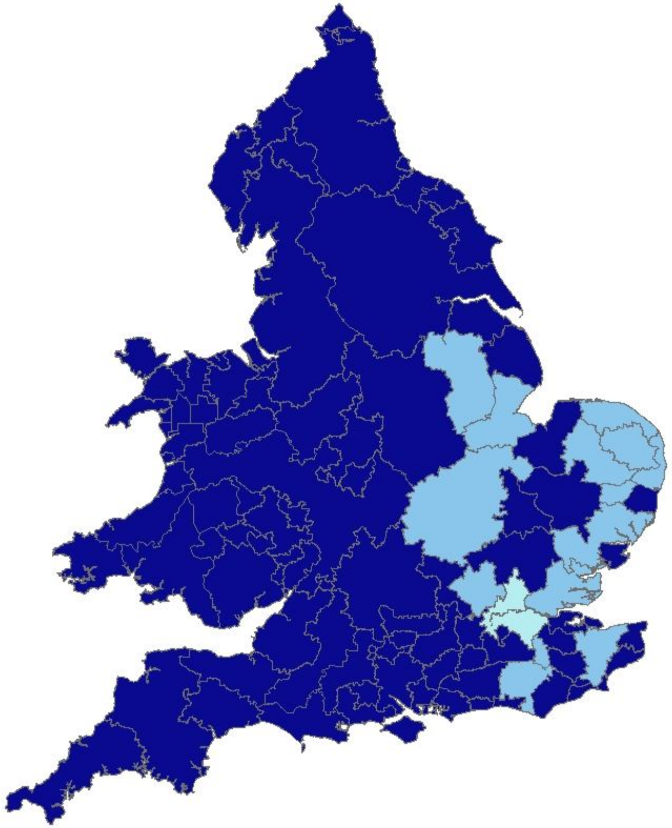


2031
Water efficient appliances + RWH



2031
Water efficient appliances + GWR

Linking Regional Planning/policy to Local Design/management

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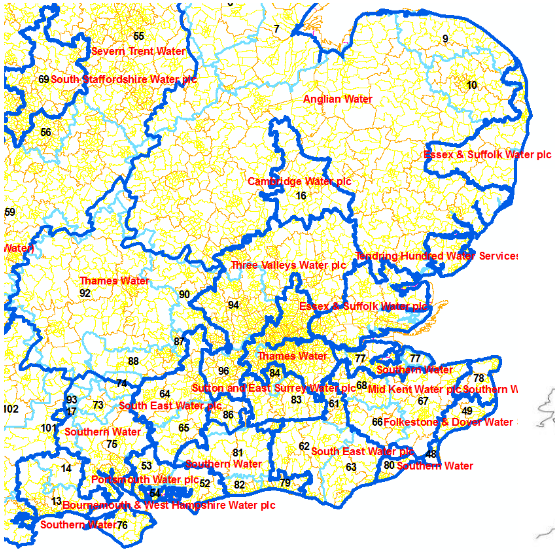
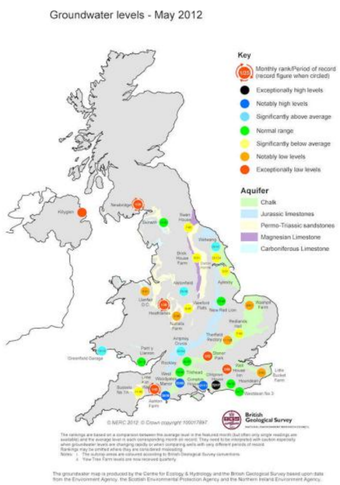
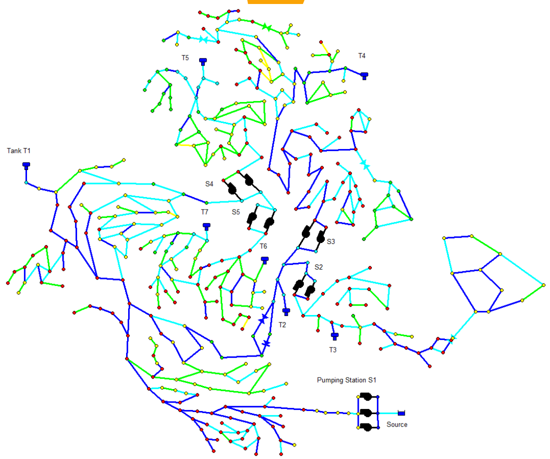




High level Planning:

- Growths (population, demand)
- Spatial availability of water resources

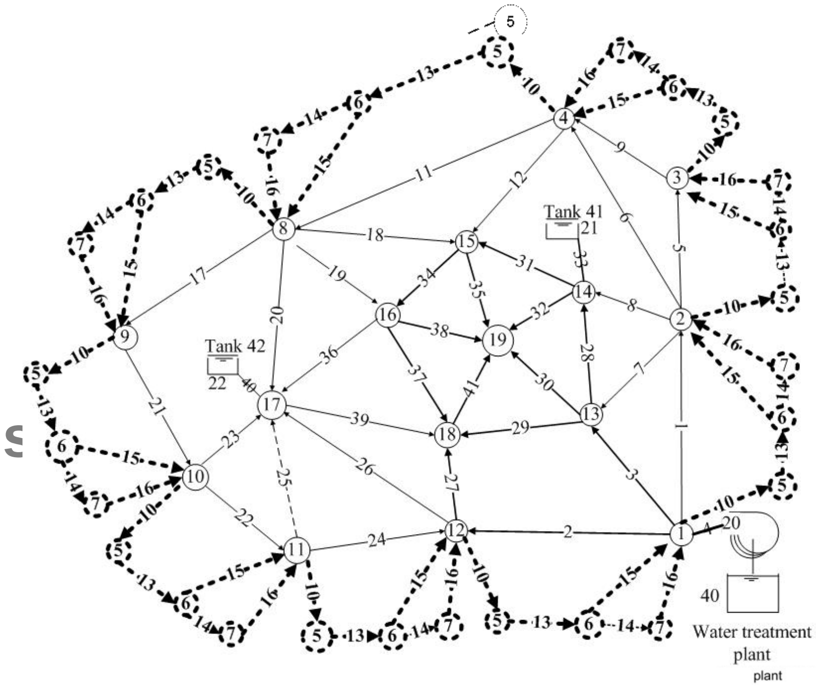


Local Decisions:

- Urban Form
- Infrastructural Design (water, sewer, etc.)

Sensitivity of current water infrastructure performance to different urban forms and water management options

- **Urban form**
  - Compaction/uniform
  - Monocentric
  - Polycentric
  - Edge development
- **Population**
  - Medium
  - High
- **Water demand management options**
  - Water company
  - 100% metering
  - Water efficiency
- **Performance**
  - Cost,
  - Water quality and
  - resilience



Growth and Water efficiency scenarios

Scenario	Existing homes *Per capita (L/head/day)* *Total (m^3/d, gpm)*	New homes *Per capita (L/head/day)* *Total (m^3/d, gpm)*
1. No retrofit		
a. No new growth	150	
	43,608 / 8000	
b. Medium growth	150	120
	43,608 / 8000	16,353 / 3000
c. High growth	150	120
	43,608 / 8000	21,804 / 4000
2. Retrofit		
a. No new growth	120	
	34,886 / 6400	
b. Medium growth	120	120
	34,886 / 6400	16,353 / 3000
c. High growth	120	120
	34,886 / 6400	21,804 / 4000

Urban form and Technology choice influences

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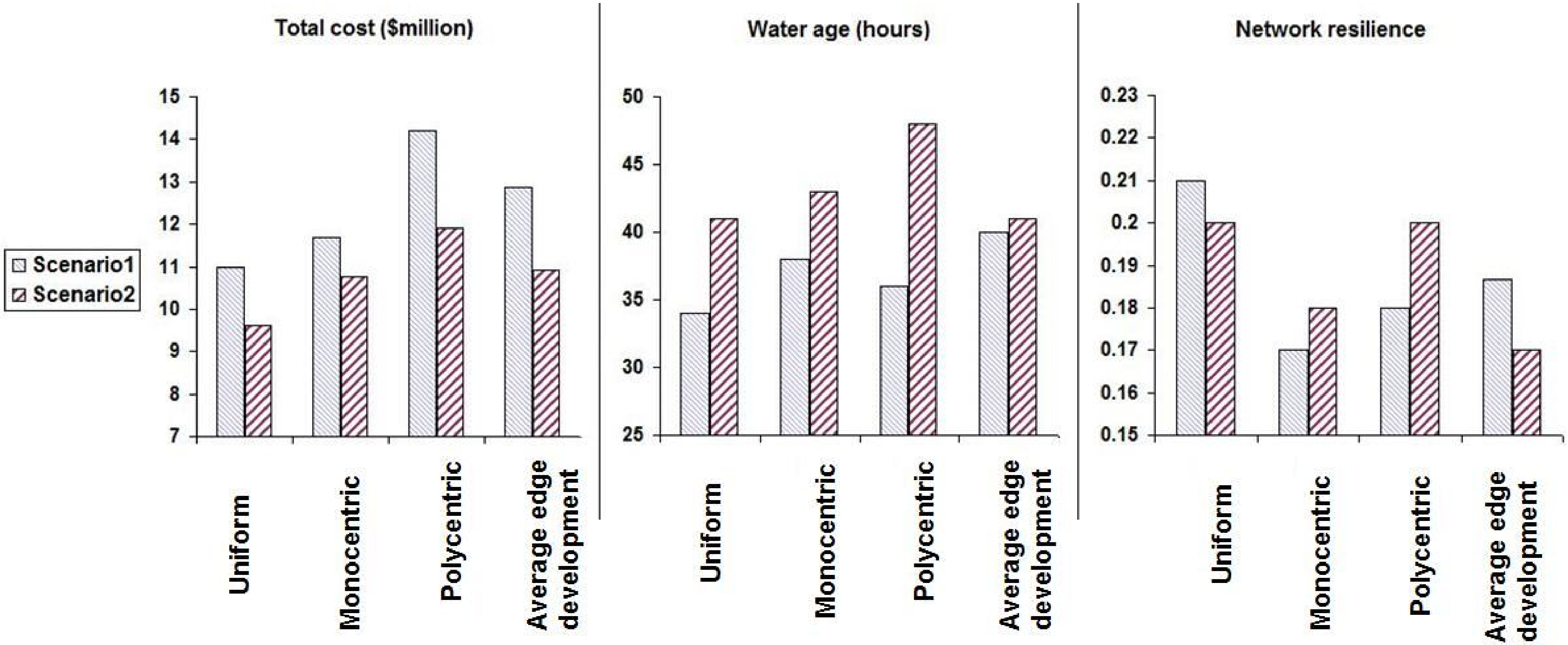


Sensitivity and adaptability of current water infrastructure performance to different futures

Population and demand changes

Future	Population change	PCC change
PR	35%	-20%
MF	45%	5%
FW	20%	-10%
NSP	25%	-30%

EA, 2009

demand changes variation: -50% - +50%

Assess the necessary conditions against the scenario characteristics

Sensitivity of individual scenarios: Designed for	Demand change	CSH level 5/6 (0.5)	NSP (PCC) (0.7)	PR (PCC) (0.8)	NSP (PCC & POP) (0.88)	FW (PCC) (0.9)	Existing demand (1)	MF (PCC) PR and FW (PCC & POP) (1.08)	FW (POP) (1.2)	NSP (POP) (1.25)	PR (POP) (1.35)	MF (POP) (1.45)	MF (PCC & POP) (1.52)	Design scenarios: Costs ($million) Total	Pipe	Tank	Operational	Resilience
CSH level 5/6	0.5		√	x	x	x	x	x	x	x	x	x	x	6.05	3.33	0	2.72	0.24
NSP (PCC)	0.7	√		x	x	x	x	x	x	x	x	x	x	7.48	3.83	0	3.64	0.24
PR (PCC)	0.8	√	√		x	x	x	x	x	x	x	x	x	8.10	3.80	0	4.12	0.24
NSP (PCC & POP)	0.88	√	√	√		√	√	x	x	x	x	x	x	8.40	3.86	0	4.54	0.24
FW (PCC)	0.9	√	√	√	√		x	x	x	x	x	x	x	8.54	3.98	0	4.56	0.24
Existing demand	1	√	√	√	√	√		x	x	x	x	x	x	9.05	4.01	0	5.04	0.24
MF (PCC) PR and FW (PCC & POP)	1.08	√	√	√	√	√	√		x	x	x	x	x	9.31	3.83	0	5.48	0.24
FW (POP)	1.2	√	√	√	√	√	√	√		√	x	x	x	9.60	3.55	0	6.05	0.24
NSP (POP)	1.25	√	√	√	√	√	√	√	√		x	x	x	10.16	3.83	0	6.34	0.24
PR (POP)	1.35	√	√	√	√	√	√	√	√	√		x	x	10.85	4.08	0	6.76	0.24
MF (POP)	1.45	√	√	√	√	√	√	√	√	√	√		x	12.08	4.82	0	7.26	0.24
MF (PCC & POP)	1.52	√	√	√	√	√	√	√	√	√	√	√		12.80	5.23	0	7.57	0.24

There is a reluctance to plan for the long-term impacts of changes due to perceived uncertainty associated with the impacts and the financial risks involved

(Defra, 2010, Adapting Energy, Transport and Water Infrastructure to the Long-term Impacts of Climate Change)

Alternative strategies to introduce resilience

- Operational
- Designed-in operational
- Multistage design and operational

Operational strategy

Sensitivity of individual scenarios

Designed for	Demand change	CSH level 5/6	NSP (PCC)	PR (PCC)	NSP (PCC & POP)	FW (PCC)	Existing demand	MF (PCC) PR and FW (PCC & POP)	FW (POP)	NSP (POP)	PR (POP)	MF (POP)	MF (PCC & POP)	Design scenarios: Costs ($million) Total	Pipe	Tank	Operational	Resilience
		0.5	0.7	0.8	0.88	0.9	1	1.08	1.2	1.25	1.35	1.45	1.52					
CSH level 5/6	0.5		√	√	√	√	√	√	√	x	x	x	x	6.05	3.33	0	2.72	0.24
NSP (PCC)	0.7	√		√	√	√	√	√	√	√	x	x	x	7.48	3.83	0	3.64	0.24
PR (PCC)	0.8	√	√		√	√	√	√	√	x	x	x	x	8.10	3.80	0	4.12	0.24
NSP (PCC & POP)	0.88	√	√	√		√	√	√	√	√	x	x	x	8.40	3.86	0	4.54	0.24
FW (PCC)	0.9	√	√	√	√		√	√	√	√	x	x	x	8.54	3.98	0	4.56	0.24
Existing demand	1	√	√	√	√	√		√	√	√	x	x	x	9.05	4.01	0	5.04	0.24
MF (PCC) PR and FW (PCC & POP)	1.08	√	√	√	√	√	√		√	√	x	x	x	9.31	3.83	0	5.48	0.24
FW (POP)	1.2	√	√	√	√	√	√	√		√	x	x	x	9.60	3.55	0	6.05	0.24
NSP (POP)	1.25	√	√	√	√	√	√	√	√		√	x	x	10.16	3.83	0	6.34	0.24
PR (POP)	1.35	√	√	√	√	√	√	√	√	√		√	x	10.85	4.08	0	6.76	0.24
MF (POP)	1.45	√	√	√	√	√	√	√	√	√	√		x	12.08	4.82	0	7.26	0.24
MF (PCC & POP)	1.52	√	√	√	√	√	√	√	√	√	√	√		12.80	5.23	0	7.57	0.24

Designed-in operational strategy

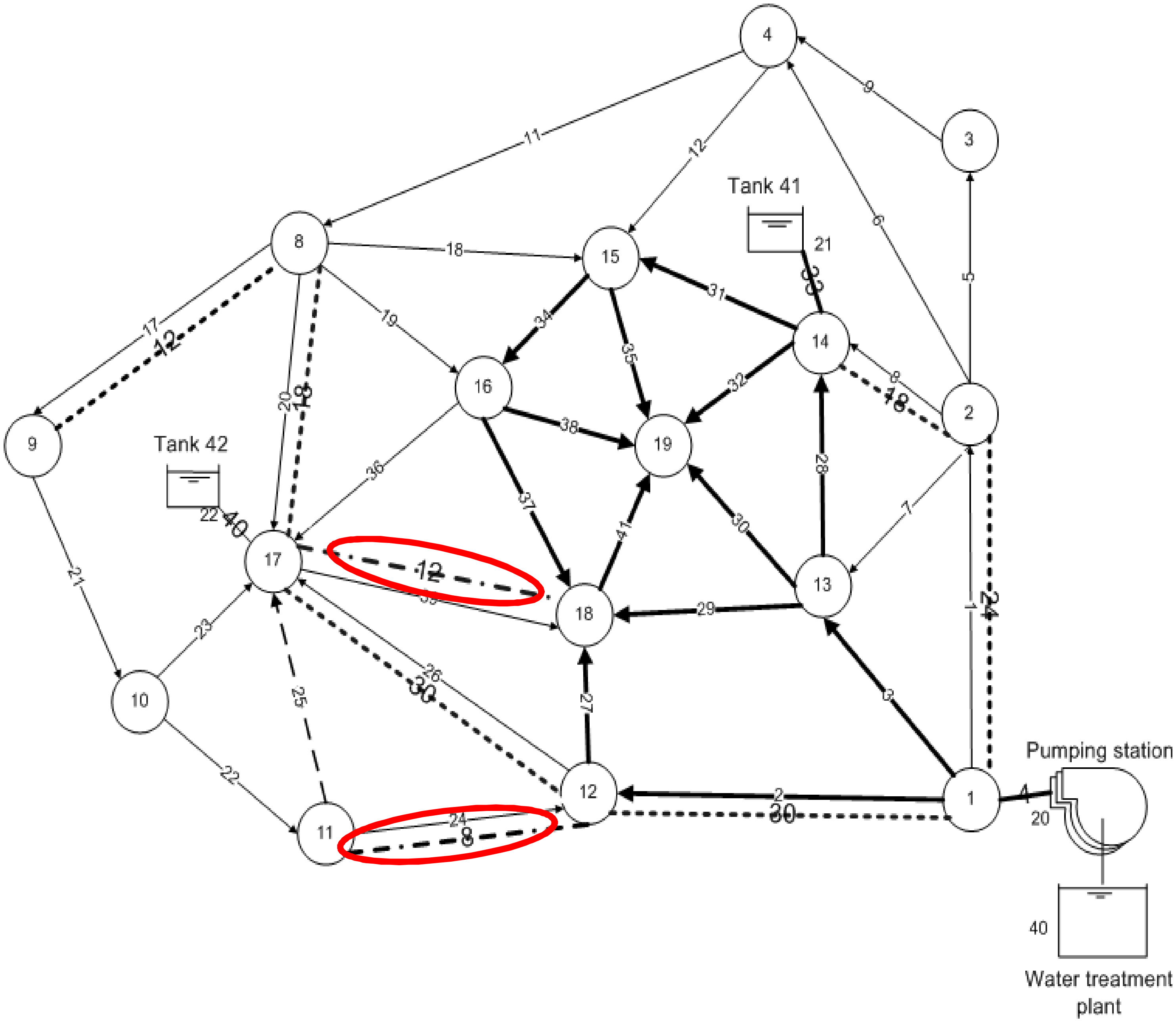
Single design and multiple scheduling based on alternative scenarios

Designed for	Demand change	Design scenarios				
		Costs ($million)				Resilience
		Pipe	Tank	Operational	Total	
CSH level 5/6	0.5	4.81	0	3.94	8.75	0.17
NSP (PCC)	0.7	4.81	0	4.40	9.21	0.24
PR (PCC)	0.8	4.81	0	4.65	9.46	0.28
NSP (PCC & POP)	0.88	4.81	0	4.69	9.5	0.29
FW (PCC)	0.9	4.81	0	4.95	9.76	0.28
Existing demand	1	4.81	0	5.31	10.12	0.27
MF (PCC) PR and FW (PCC & POP)	1.08	4.81	0	5.52	10.33	0.26
FW (POP)	1.2	4.81	0	6.06	10.87	0.20
NSP (POP)	1.25	4.81	0	6.28	11.1	0.26
PR (POP)	1.35	4.81	0	6.74	11.55	0.19
MF (POP)	1.45	4.81	0	7.19	12.00	0.2
MF (PCC & POP)	1.52	4.81	0	7.52	12.33	0.22

Multistage design and operational strategy

Multistage design and multiple scheduling based on alternative scenarios

		Design scenarios				
		Costs ($million)				Resilience
Designed for	Demand change	Pipe	Tank	Operational	Total	
CSH level 5/6	0.5	4.77	0	3.66	8.43	0.17
NSP (PCC)	0.7	4.77	0	4.17	8.94	0.26
PR (PCC)	0.8	4.77	0	4.42	9.19	0.28
NSP (PCC & POP)	0.88	4.77	0	4.69	9.46	0.29
FW (PCC)	0.9	4.77	0	4.76	9.53	0.29
Existing demand	1	4.77	0	5.28	10.05	0.23
MF (PCC) PR and FW (PCC & POP)	1.08	4.77	0	5.52	10.29	0.20
FW (POP)	1.2	4.77	0	6.06	10.83	0.20
NSP (POP)	1.25	4.77	0	6.28	11.05	0.25
PR (POP)	1.35	4.77	0	6.74	11.51	0.21
MF (POP)	1.45	4.77	0	7.19	11.96	0.20
MF (PCC & POP)	1.52	5.09	0	7.53	12.62	0.23


Tank 41
Tank 42
Pumping station
Water treatment plant
1
2
3
4
8
9
10
11
12
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14
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17
18
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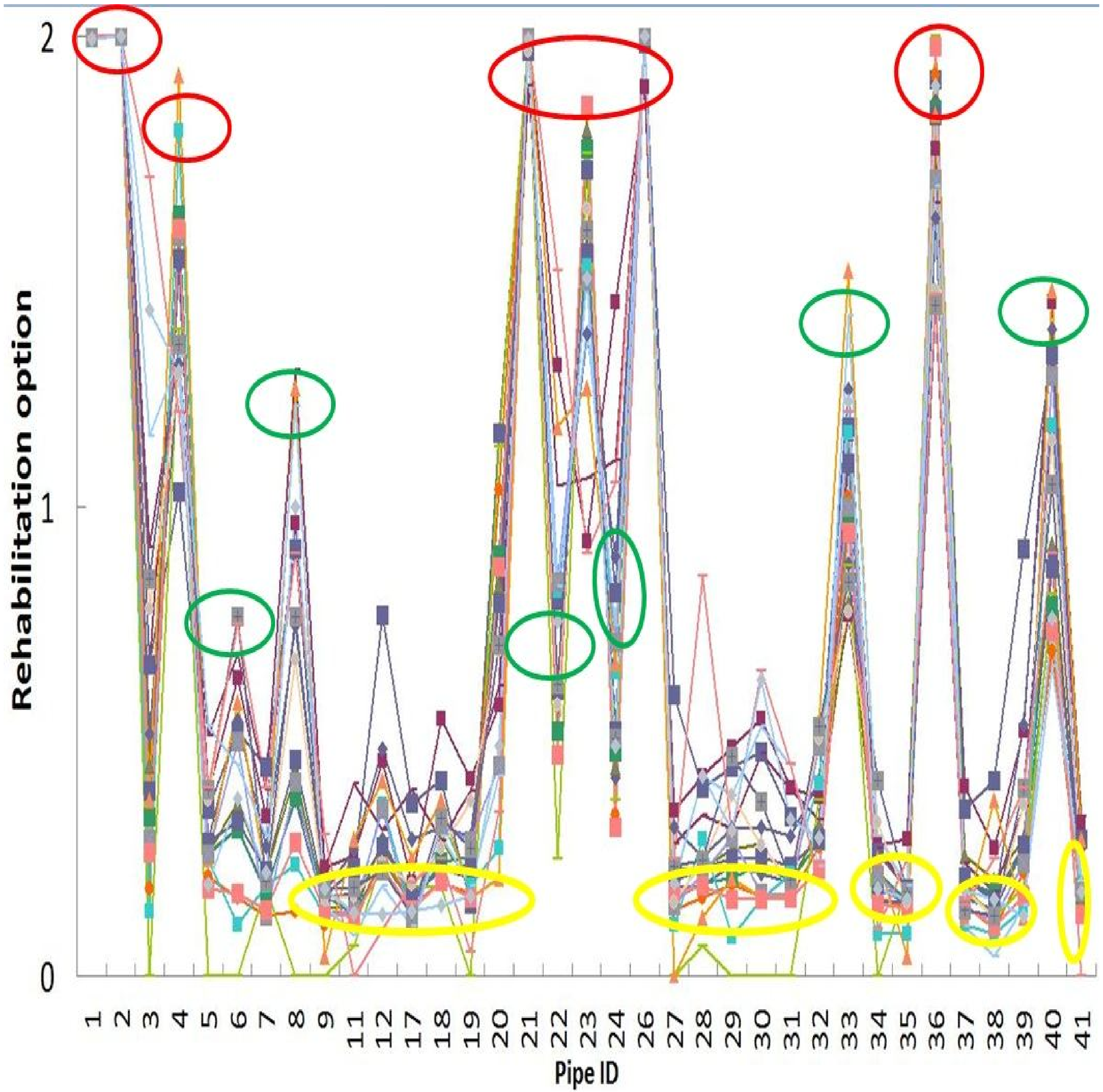
21
22
40



Rehabilitation option
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41
Pipe ID

Conclusions

- Some elements of the system are particularly vulnerable and critical to the long-term performance of the system
- Resilience index values improved for small decrease in demand
- Water quality showed improvement for major reduction in demand.
- Increasing productive capacity is feasible up to about 35%
- Multistage capacity increase created flexibility which
    - allows for diversity in the short term
    - while trying to achieve long-term goals

- **Safe & SuRe**: towards a new paradigm for urban water management (EPSRC, 2013-2018)

- **iWIDGET**, Improved Water efficiency through ICT technologies for integrated supply-Demand side manaGEmenT, (FP7, 2012-2015)

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