Towards Improved Water and Energy Efficiency in Urban Water Systems

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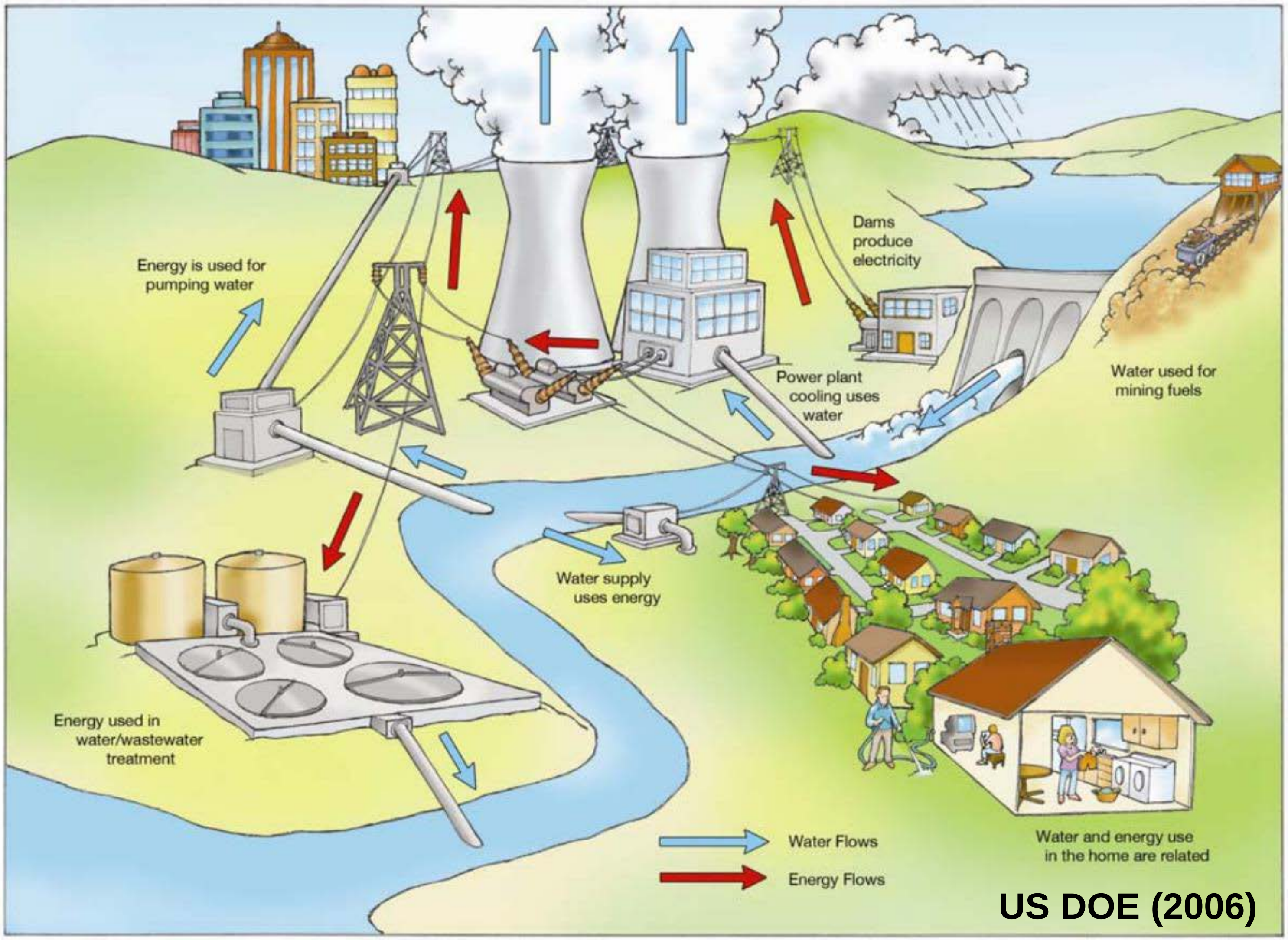
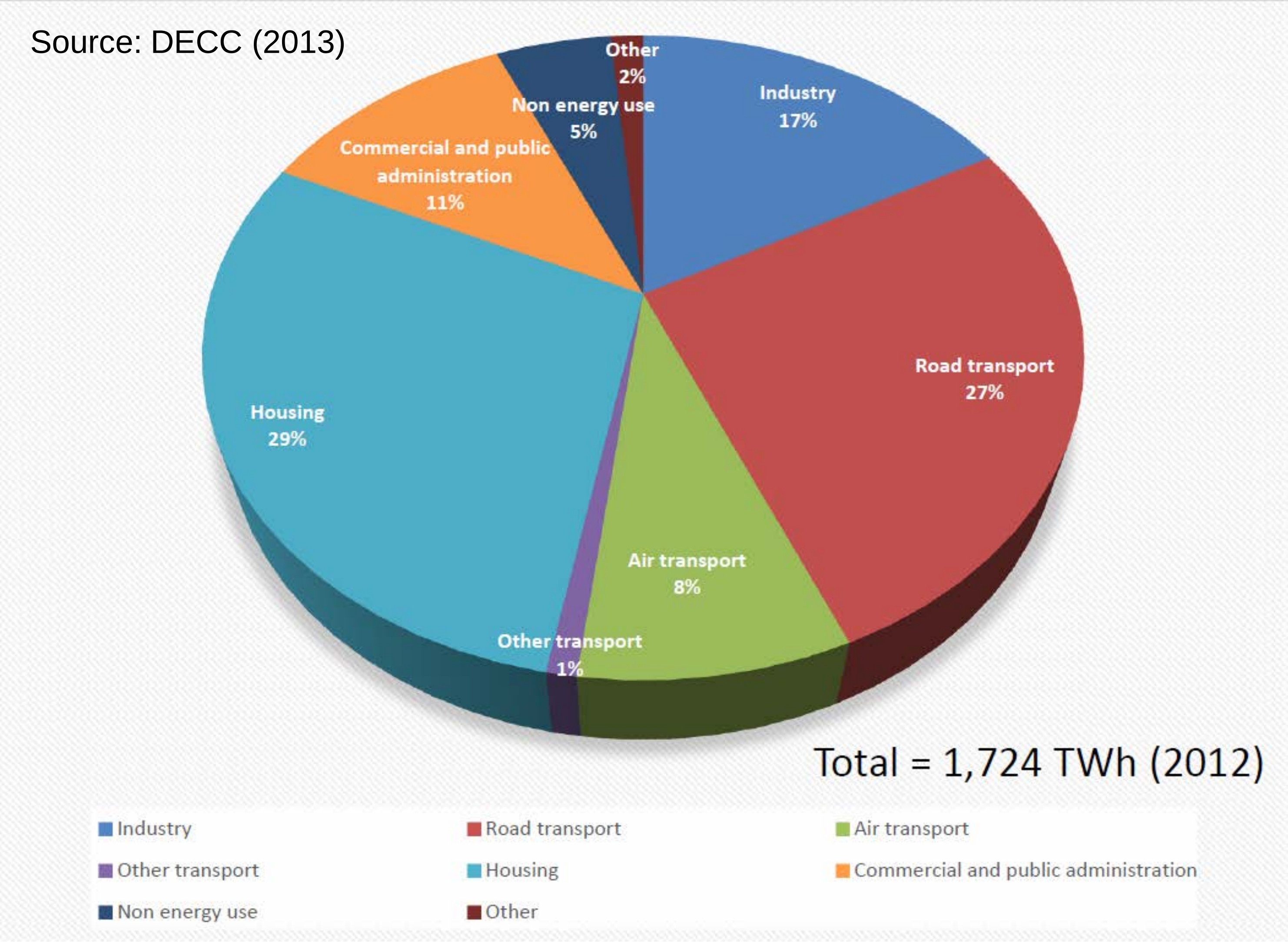
Overview

- Water-energy nexus
- EU TRUST project
- The metabolism concept
- WaterMet^2 methodology and tool
- Example applications
- Summary
- Ongoing/future work

The Water-Energy Nexus



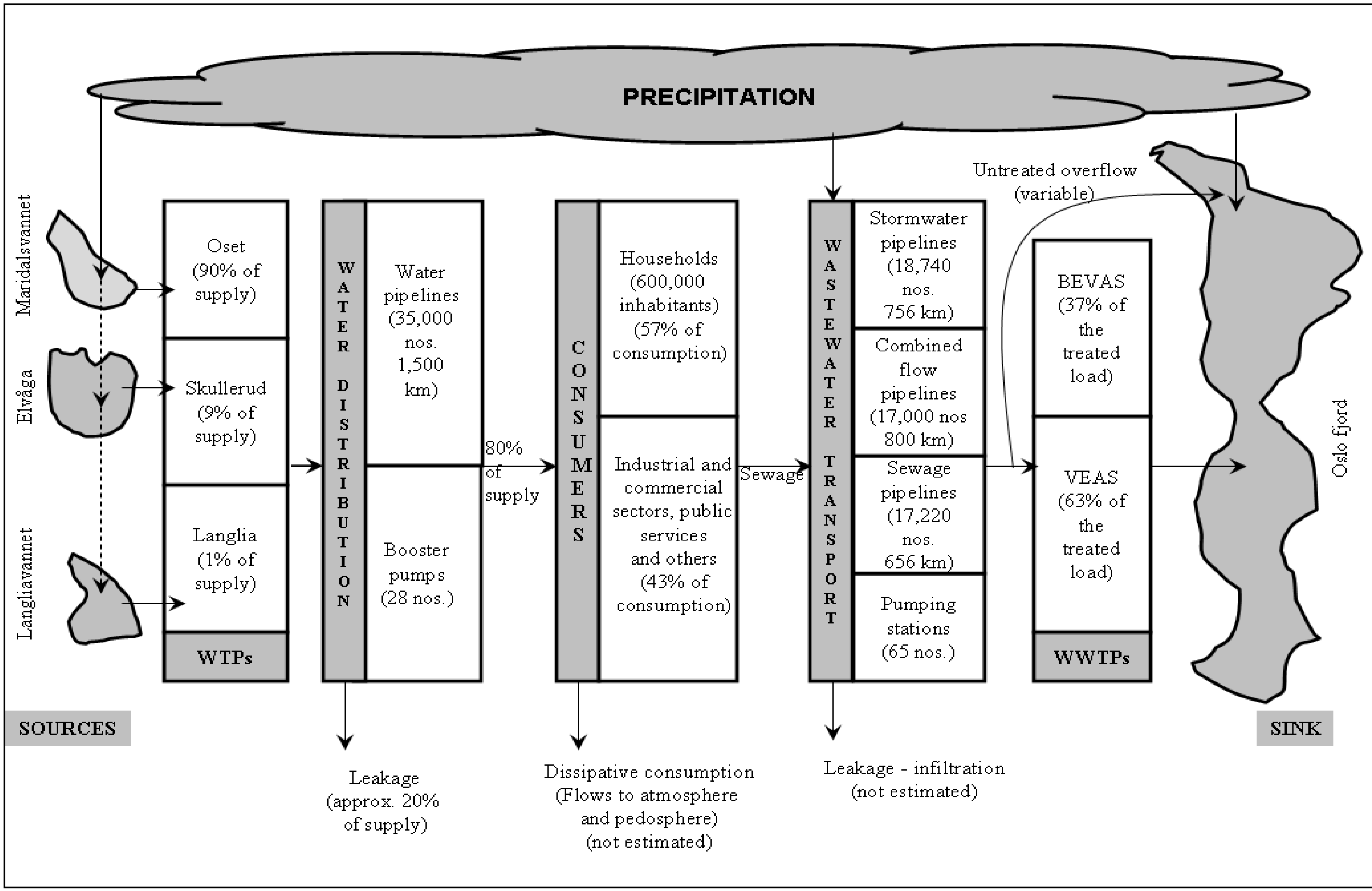
UK Energy Profile



EU TRUST Project

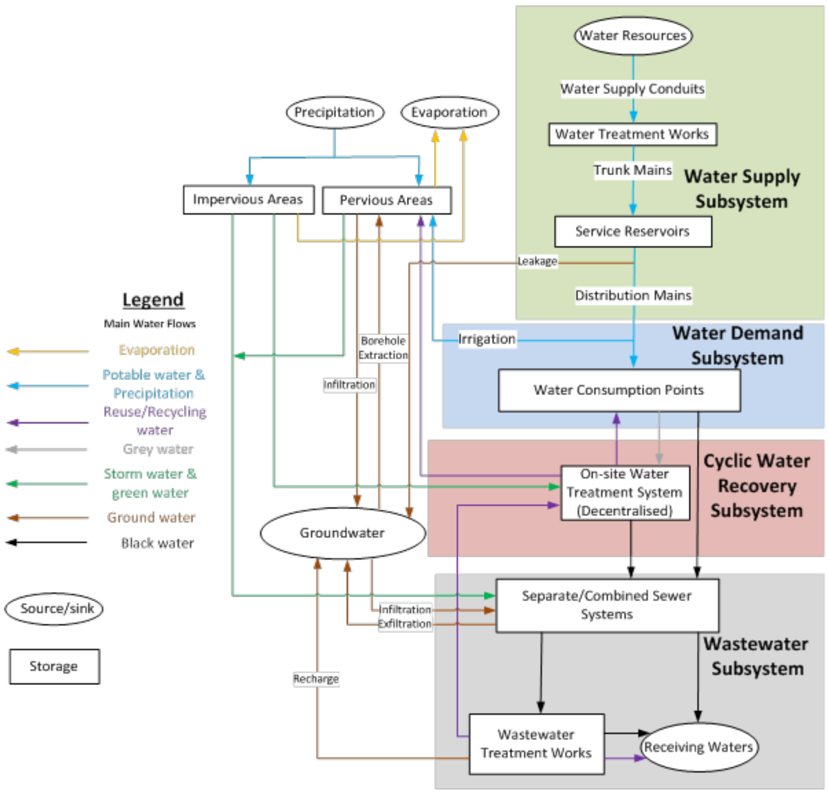
- TRansition to Urban water Services of Tomorrow
- 30 partners led by IWW in Germany
- 2011-2015, 7M Euros
- Wide range of issues
- UoE led 3 WPs
- www.trust-i.net

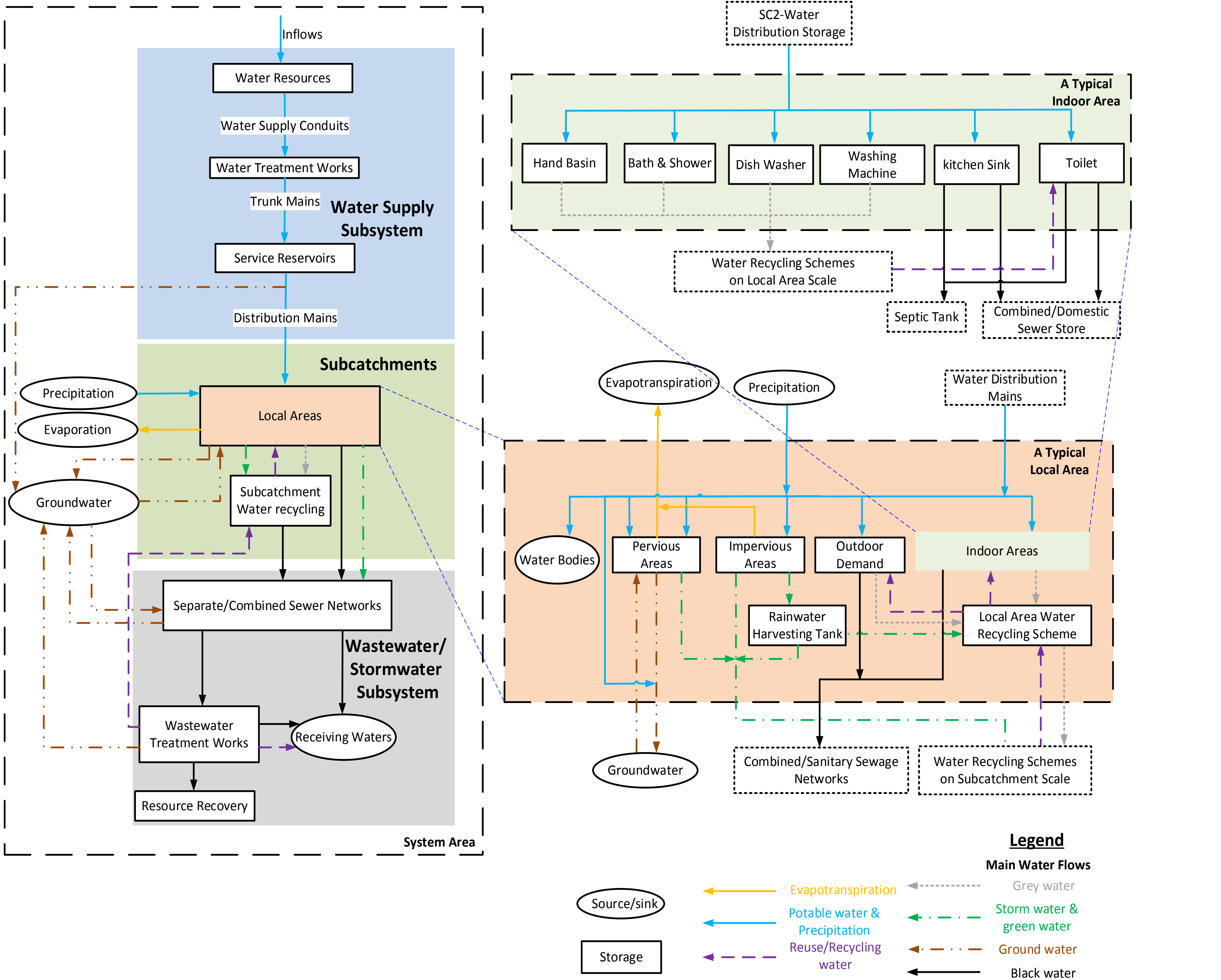
UWS Metabolism



WaterMet^2

- Conceptual model based on <u>water mass conservation</u>
- Evaluates UWS <u>metabolism</u> by quantifying water, energy/GHG emissions, materials, chemicals, pollution and other fluxes
- Covers the <u>full urban water cycle</u> in a generic UWS
- Simulates <u>both</u> water quantity and quality UWS performance
- Focus on <u>sustainability</u> issues
- Daily time step used in a multi-year simulation
- Key UWS elements and processes represented using 4 different <u>spatial scales</u>





Inflows
Water Resources
Water Supply Conduits
Water Treatment Works
Trunk Mains
Water Supply Subsystem
Service Reservoirs
Distribution Mains
Subcatchments
Precipitation
Evaporation
Local Areas
Groundwater
Subcatchment Water recycling
Separate/Combined Sewer Networks
Wastewater/ Stormwater Subsystem
Wastewater Treatment Works
Receiving Waters
Resource Recovery
System Area
SC2-Water Distribution Storage
A Typical Indoor Area
Hand Basin
Bath & Shower
Dish Washer
Washing Machine
kitchen Sink
Toilet
Water Recycling Schemes on Local Area Scale
Septic Tank
Combined/Domestic Sewer Store
Evapotranspiration
Precipitation
Water Distribution Mains
A Typical Local Area
Water Bodies
Pervious Areas
Impervious Areas
Outdoor Demand
Indoor Areas
Rainwater Harvesting Tank
Local Area Water Recycling Scheme
Groundwater
Combined/Sanitary Sewage Networks
Water Recycling Schemes on Subcatchment Scale
Legend
Main Water Flows
Source/sink
Storage
Evapotranspiration
Potable water & Precipitation
Reuse/Recycling water
Grey water
Storm water & green water
Ground water
Black water

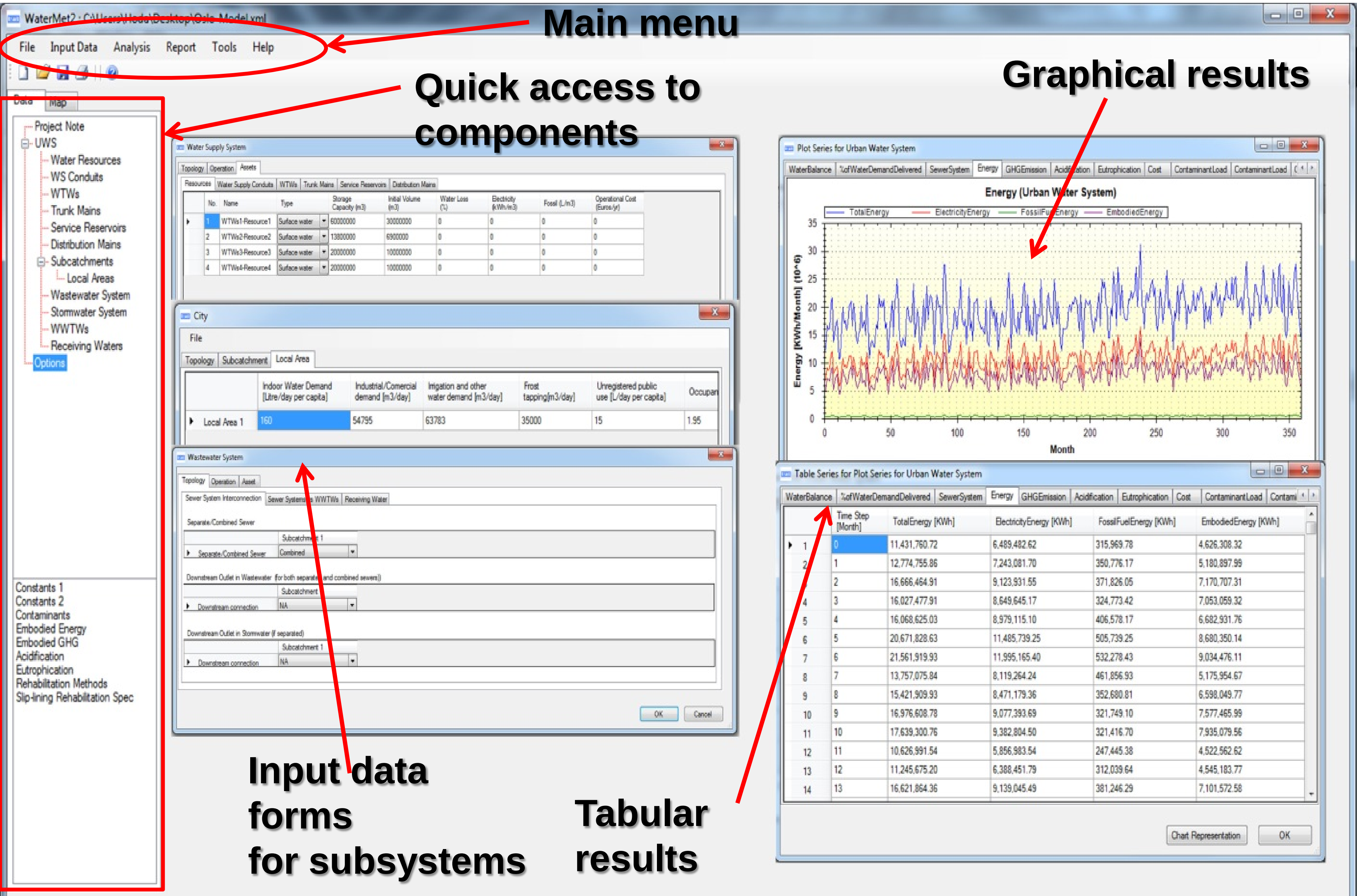
UWS Components and Processes

UWS Component	Description	Spatial Scale in WaterMet[2]			
		System Area	Subcatchment area	Local area	Indoor area
Water supply conduits (SC)	Conveyance of raw water from water resources to WTWs	X			
Trunk mains (TM)	Conveyance of potable water from WTWs to service reservoirs	X			
Distribution mains (DM)	Distribution of potable water from service reservoirs among water consumption points	X			
Combined/separate sewer networks (SN)	Collection of sanitary sewage/ stormwater runoff and conveyance to WWTWs/receiving waters	X			
WTWs, WWTWs	Treatment of raw water and wastewater	X			
Service reservoirs (SR)	Potable water storage prior to distributing among the costumers	X			
Water resources (WR)	Raw water storage				
Grey water recycling tank	Collection and treatment of grey water from water consumption points for water reuse		X	X	
Rainwater harvesting tank	Collection and treatment of rainwater from impervious areas for water reuse		X	X	
Rainfall-runoff modelling	Conversion of precipitation to surface runoff based on hydrologic specifications			X	
Water consumption points	Indoor and outdoor water usages			X	X

WaterMet^2 Data Requirements

- Application dependant
- Data hungry:
  - UWS definition (principal layout, key components, etc.)
  - Energy related
  - Quality related
  - Many other
- Raises substantially with increased spatial resolution

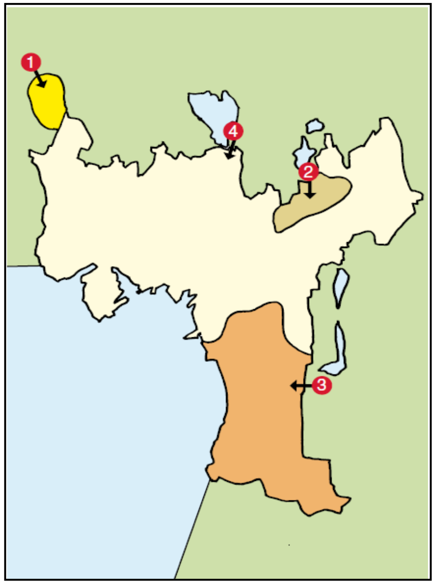
WaterMet^2 Software



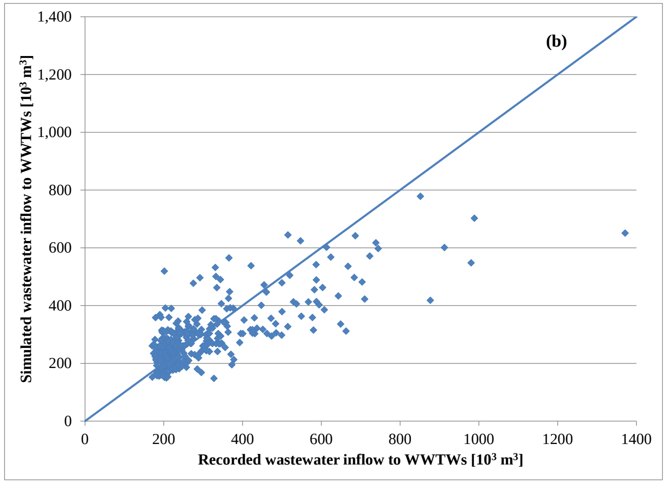
Application #1:
Oslo, Norway

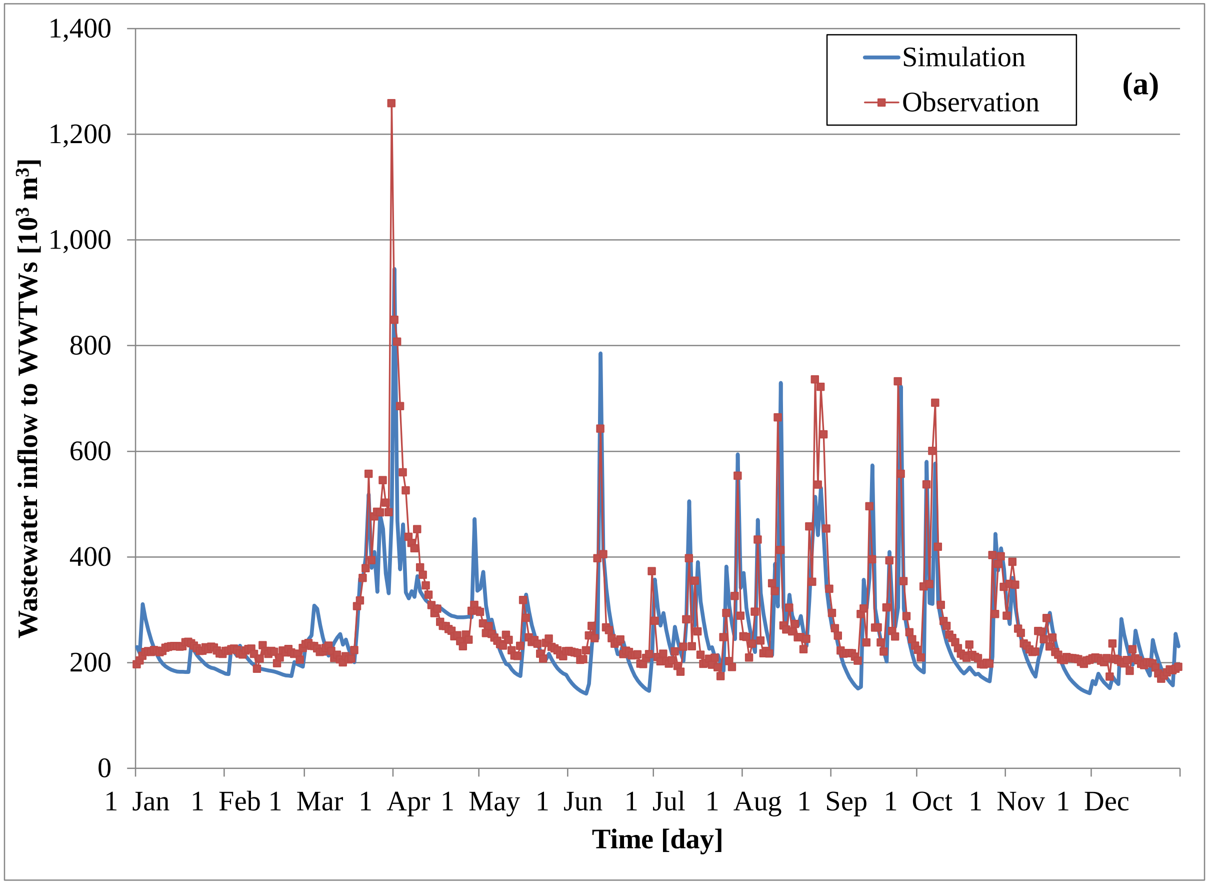
Description

- Two main existing sources / WTWs (90% and 10%)
- Two existing WWTWs (63% and 27%)
- Population of 607K in 2011, expected to increase to 1.15M in 2041
- Ageing system with leakage and other issues
- ‘Lumped’ WaterMet^2 model created and used to evaluate different intervention strategies over 30 years (2011-2040) assuming high population growth scenario
- WaterMet^2 model calibrated manually using historical data

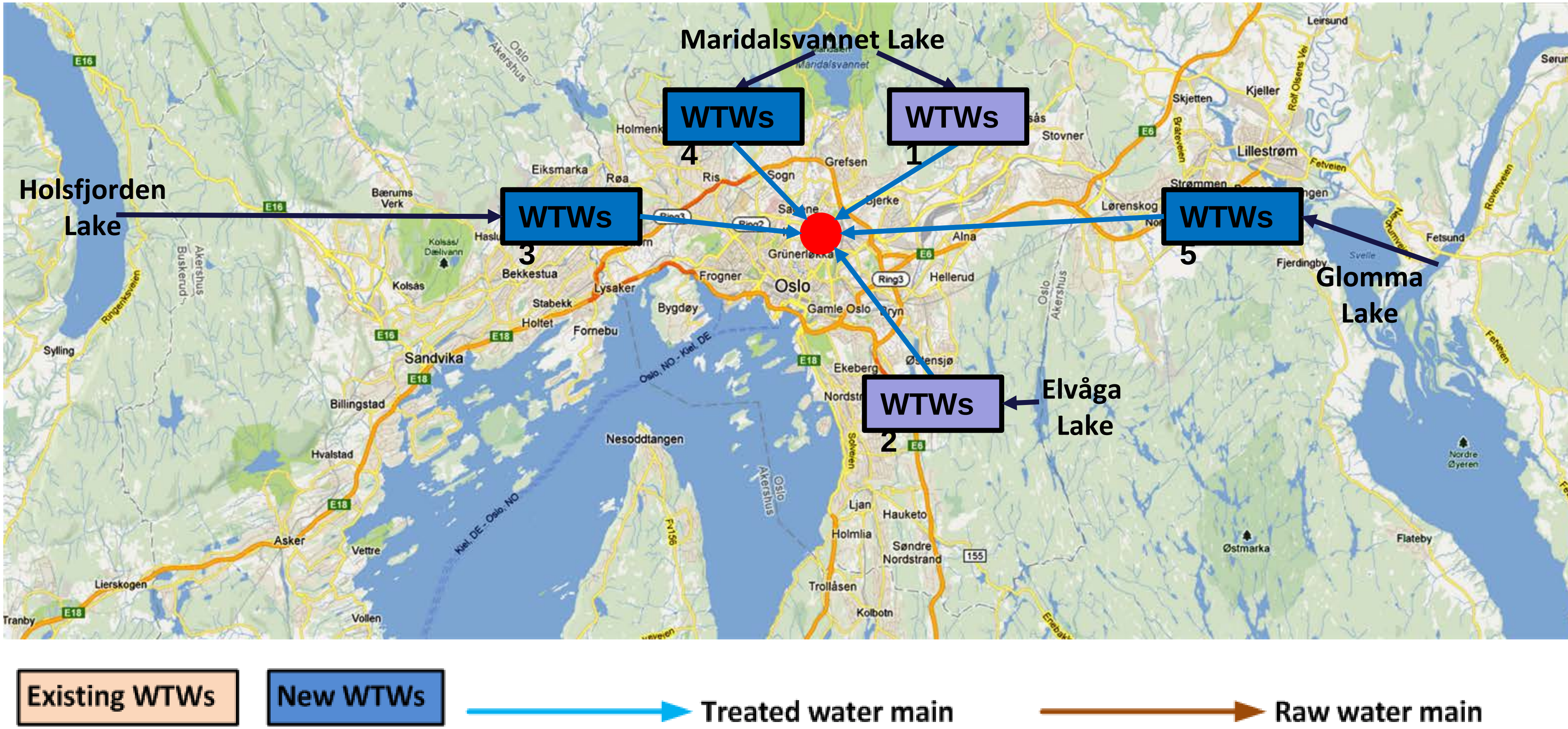


WaterMet² Model Calibration





Water Sources



existing [illegible]

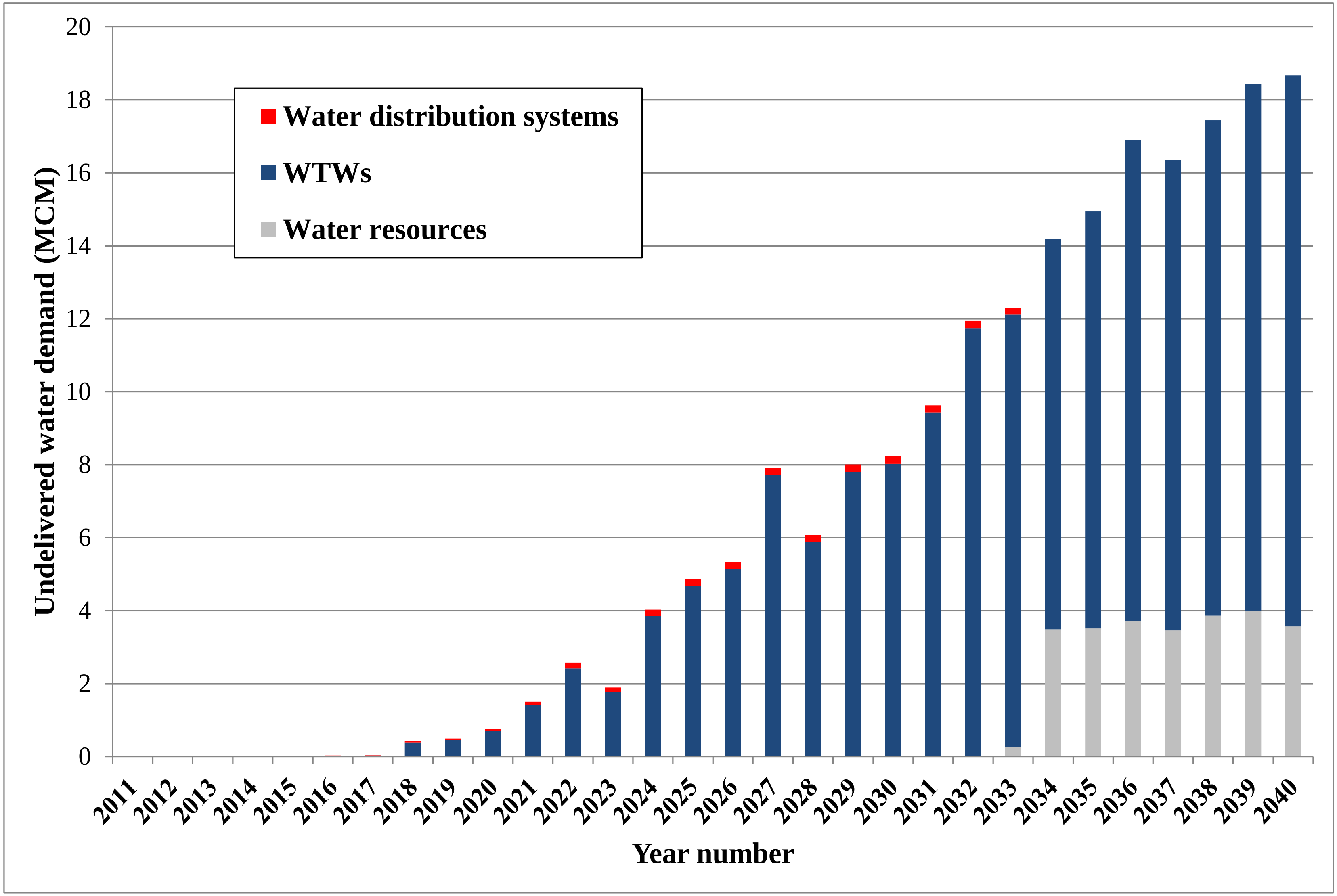
Intervention Strategies

Strategy#1	• Business as usual (BAU) strategy
Strategy#2	Addition of Holsfjorden Lake water source plus WTW3 and WTW4, all from 2020
Strategy#3	1% increase in the rate of annual pipeline rehabilitation starting from 2015
Strategy#4	0.5% increase in the rate of annual pipeline rehabilitation plus 10% additional annual water meter installation starting from 2015
Strategy#5	Large scale addition of RWH and GWR systems

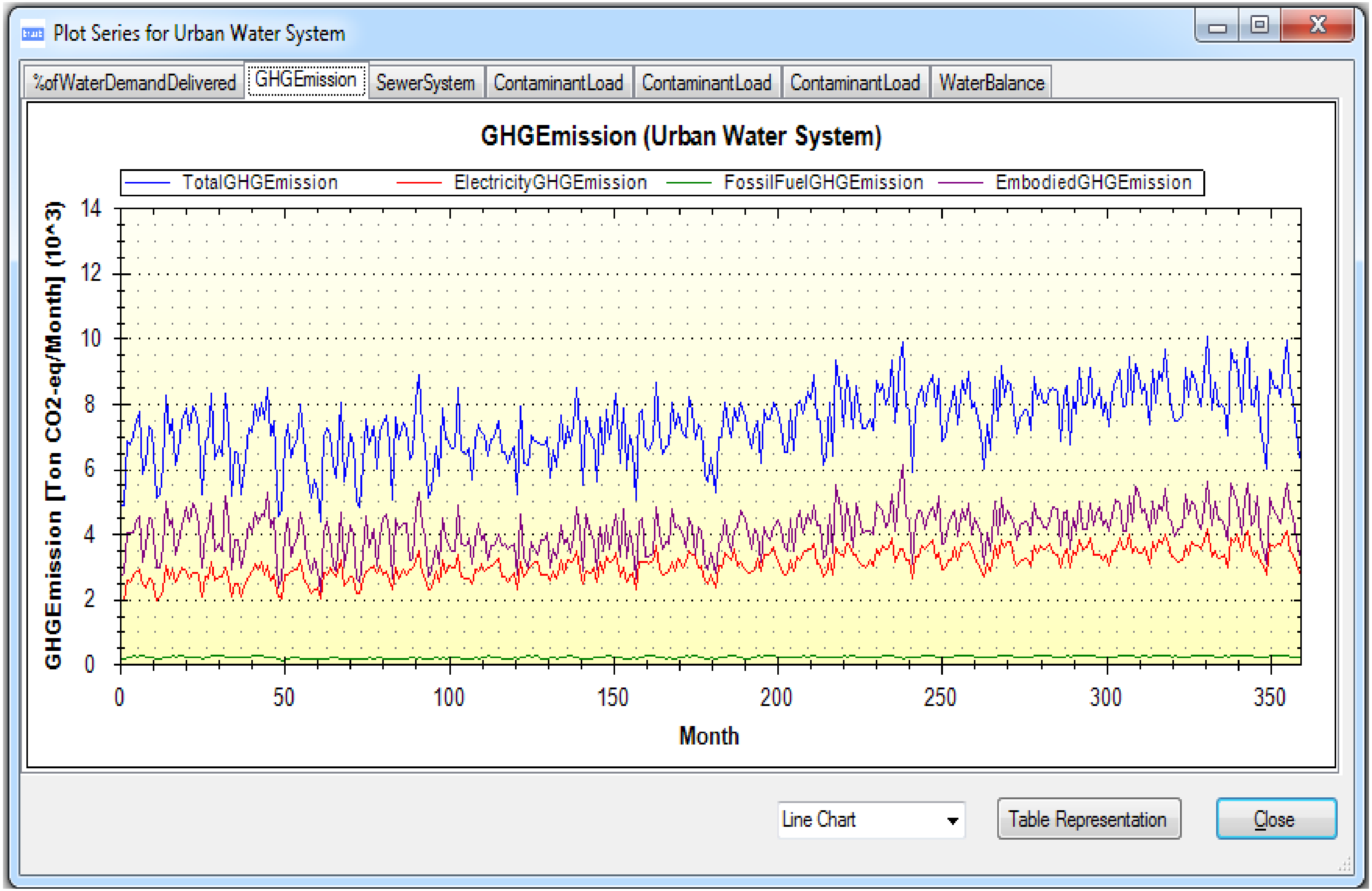
Evaluation Criteria

- Present value of total capital costs (WaterMet^2)
- Present value of total O&M costs (WaterMet^2)
- Reliability of water supply (WaterMet^2)
- Total water leakage (WaterMet^2)
- Total GHG emissions (energy) (WaterMet^2)
- Total volume of annual CSOs (WaterMet^2)
- Social acceptance of demand management schemes (quantified by expert judgement)

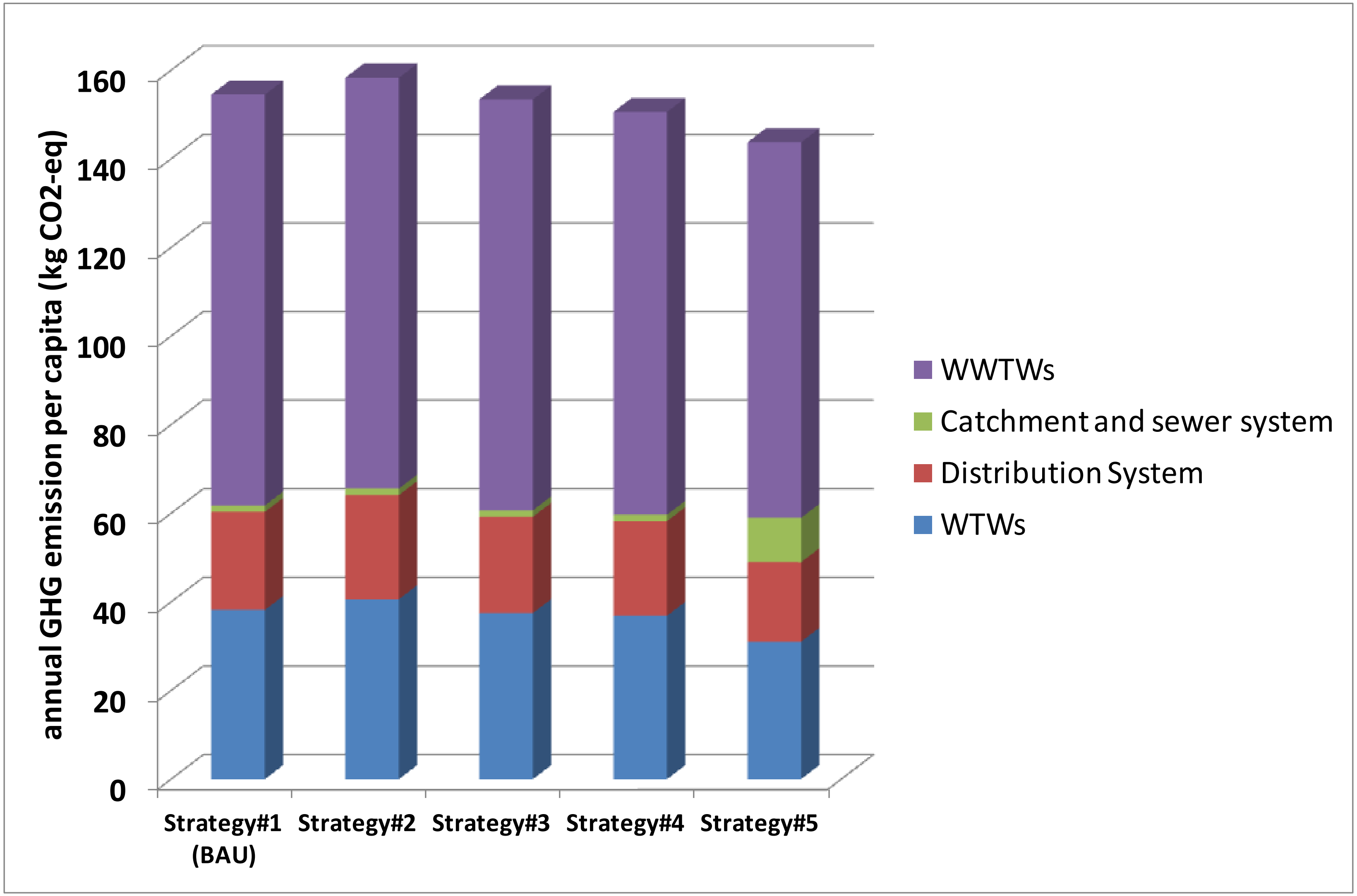
Results: Undelivered Water (BAU)



Total GHG Emissions (Energy)



Total GHG Emissions (Energy)

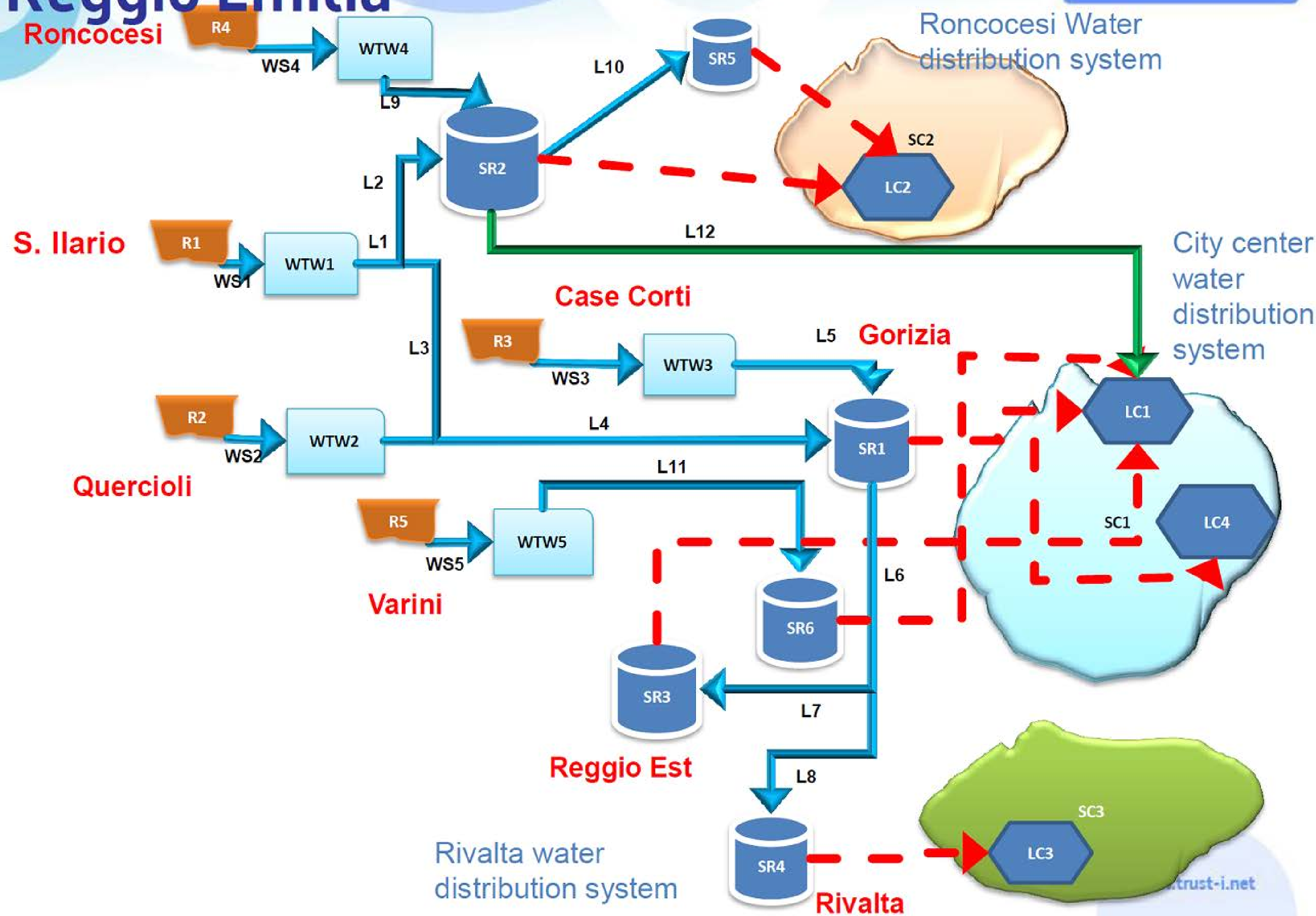


Trade-offs

	Capital cost	*O&M Cost*	*Reliability*	*Leakage*	*GHG emissions*	*CSO volume*	*Public acceptance*
	Million Euro	Million Euro/year	%	MCM/ year	kTons/ year	MCM/ year	-
Strategy #1 (business as usual)	0	55	94	24	95	35	7
Strategy #2 (additional WTW)	401	87	100	25	99	35	5
Strategy #3 (1% additional annual rehabilitation)	265	58	97	19	95	35	6
Strategy #4 (0.5% additional annual rehabilitation & 10% additional annual water meter installation)	264	58	98	21	93	33	4
Strategy #5 (RWH and GWR systems)	278	67	99	19	89	24	2

Application #2: Reggio Emilia, Italy

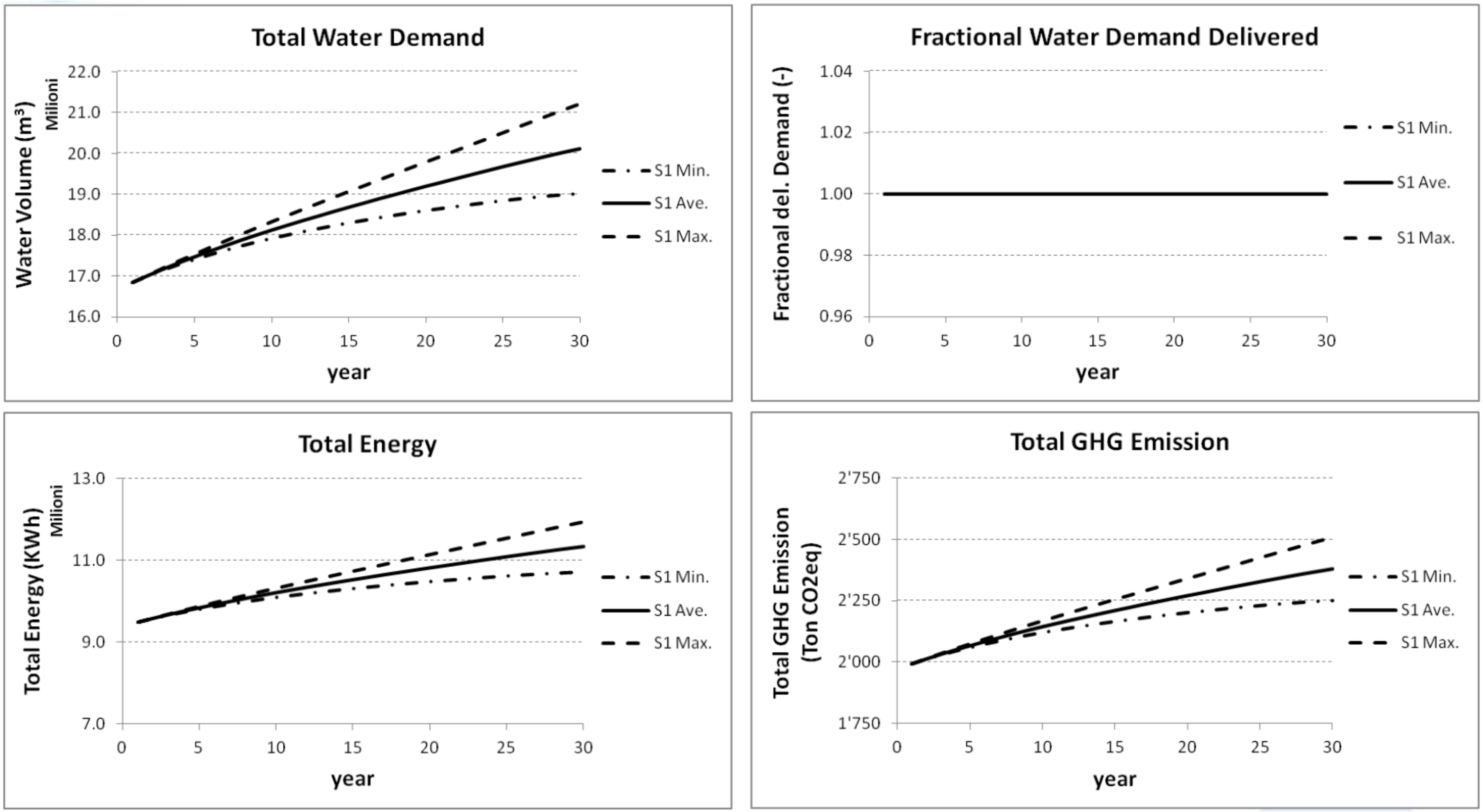
Water supply system of the City of Reggio Emilia



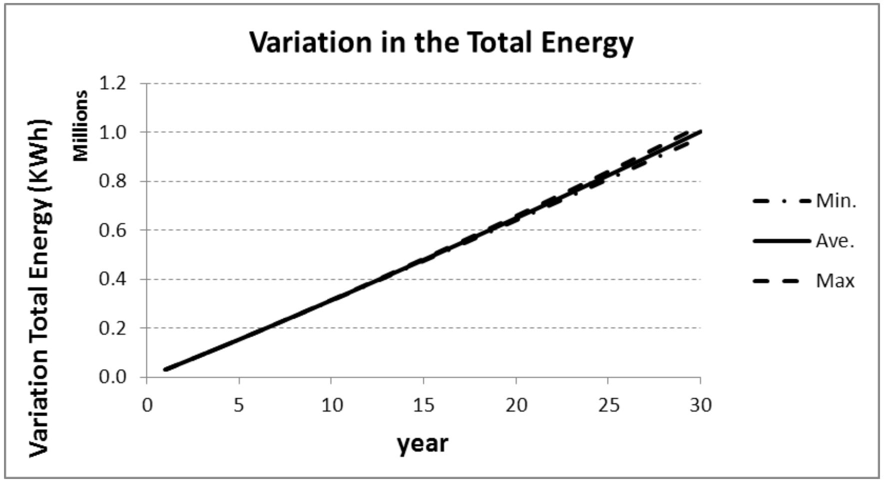
Reggio Emilia

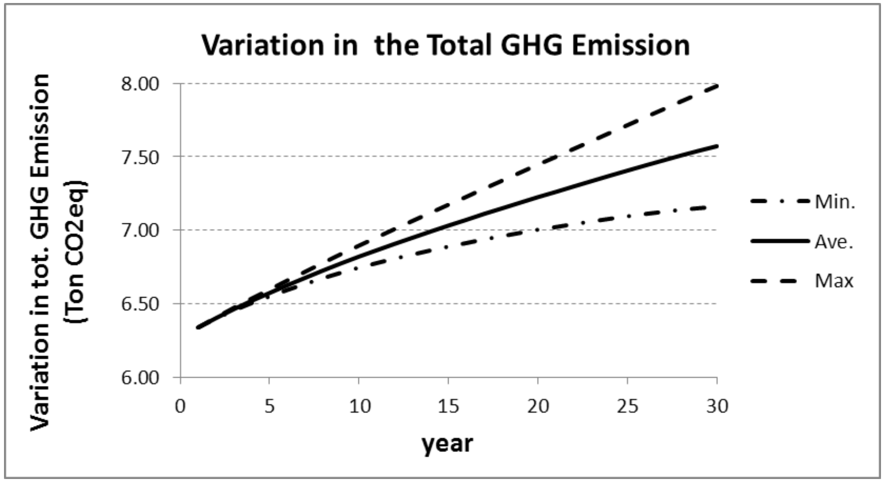
- Two intervention strategies considered:
  - Business as usual
  - New pipeline, located in the northern part of the system which connects an existing water source (R4, via SR2) to the city centre
- Under the following scenarios:
  - Low population increase
  - Medium population increase
  - High population increase

Results: Strategy 1



Difference in Strategies 1 and 2





Year	Total Energy Used (KWh)	GHG emissions (Ton CO2-eq)	Total operational cost (€)
1	30,180	6.3	1,512
10	346,598	72.8	17,369
20	649,582	136.4	32,552
30	1,002,976	210.6	50,261

Summary

- WaterMet^2 model/tool developed based on the UWS metabolism principles

- The applications demonstrate how the metabolism-based concept combined with integrated modelling can be used to assist planning future UWS at the strategic level by identifying complex trade-off under different scenarios

Ongoing/Future Work

- Further validation and demonstration:
  - Two towns in the Galapagos Islands
  - Kerman City, Iran
  - Girona, Spain
- Further development:
  - Additional energy fluxes
  - Expansion to W-E-Food nexus
  - Other

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  - NTNU, Norway
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  - NTUA, Greece

Thank you!

Questions?

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