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Water-Energy-Pollutant Nexus Assessment of Water Reuse Strategies in Urban Water Systems using a Metabolism Based Approach

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Water-Energy Nexus in Urban Water Systems

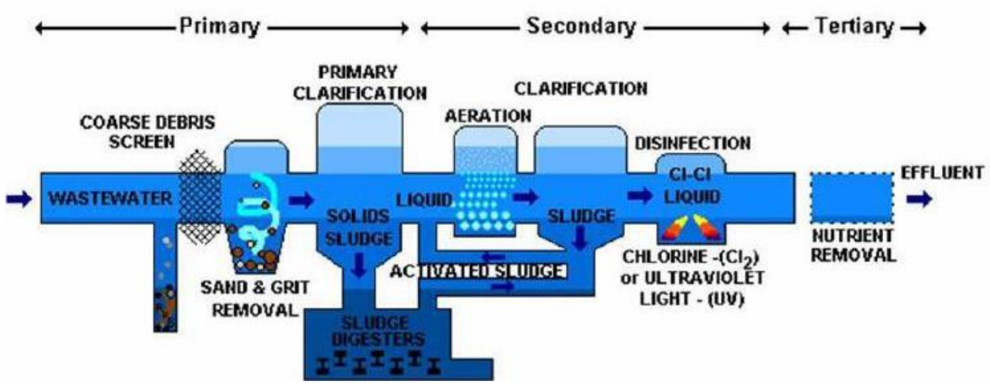
New challenges of water-energy nexus

Reducing water availability for drinking extends water conveyance systems which need more energy.

-In California, two-thirds of population receives water that can travel thousands of miles to supply water.

-Advanced energy intensive treatment processes are increasingly needed to treat source waters

-New water-saving technologies are energy intensive



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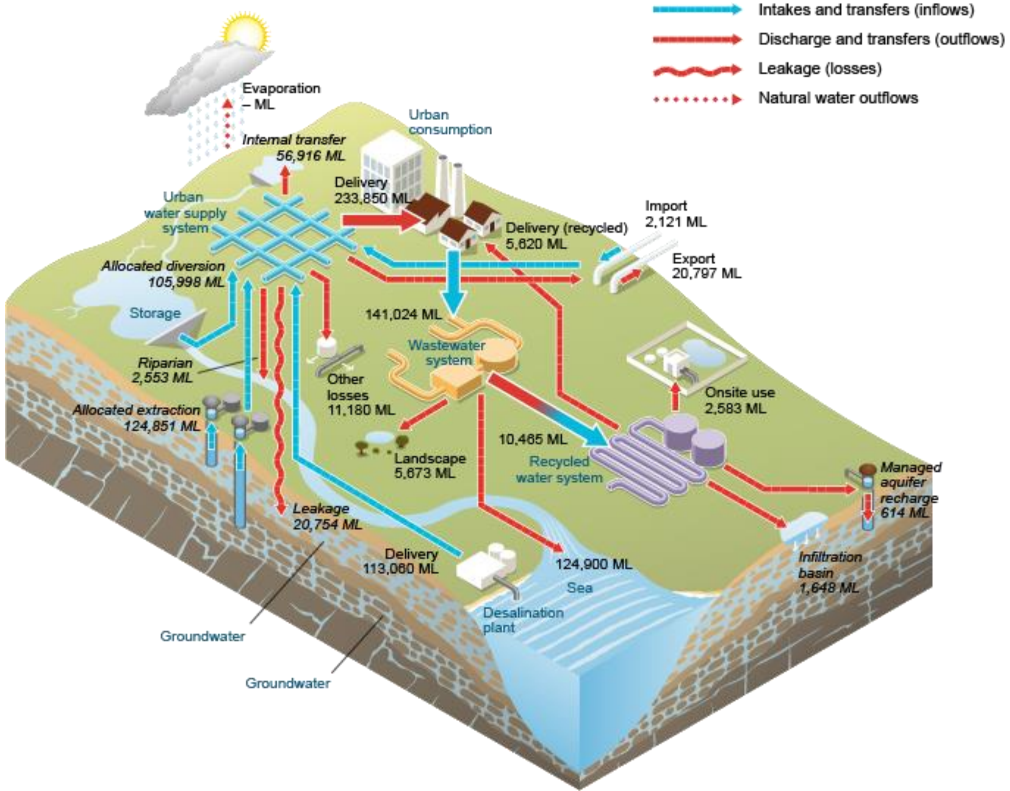
Key questions of water-energy-pollutant nexus in Urban Water Systems

- **Is there any nexus between water-energy-pollutant in Urban Water Systems?**
- **How much can this nexus affect indicators in Urban Water Systems?**
- **What is impact of external drivers (climate change, pop. growth) on this nexus?**

- **What is the best Strategies to improve long-term performance of this nexus?**



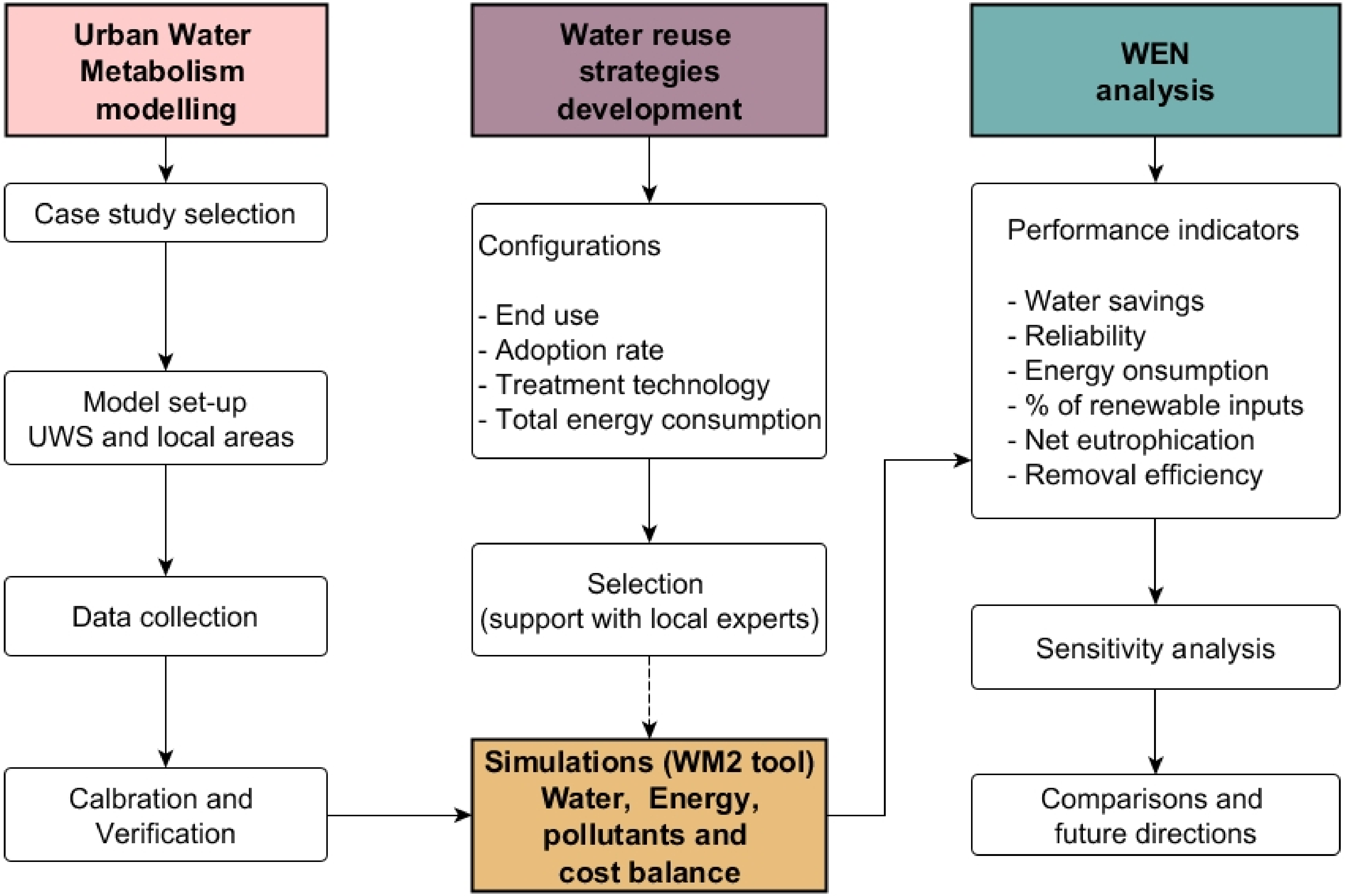
Aim and objectives

- **Develop an integrated assessment framework based on the water-energy-pollutant nexus and the urban water metabolism**

- **Explore the potentials of a water reuse strategies to improve the nexus approach in an integrated UWS.**

- **Evaluate the performance of centralised and decentralised water reuse using this framework.**

Methodology: Proposed framework



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Methodology: WaterMet^2

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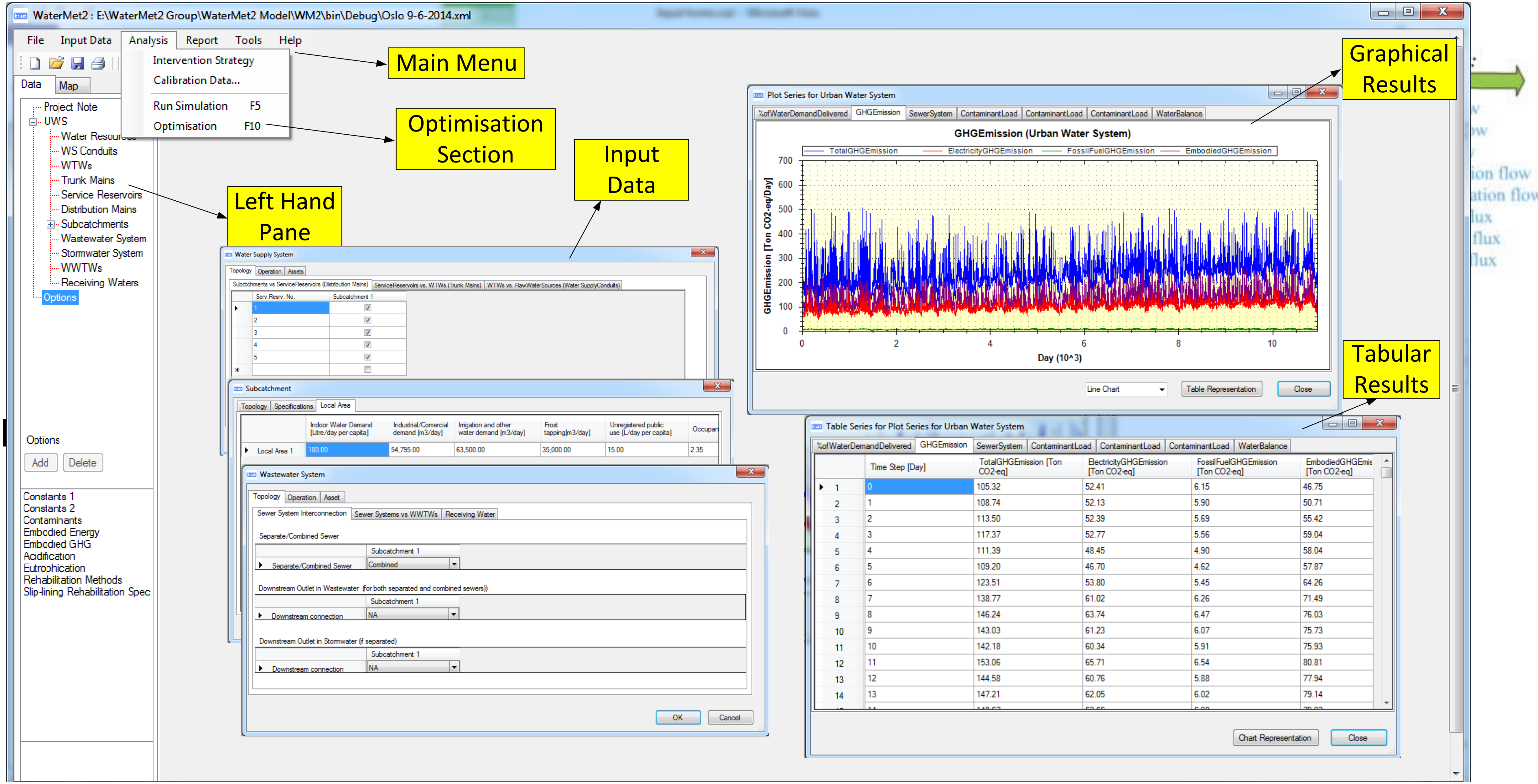
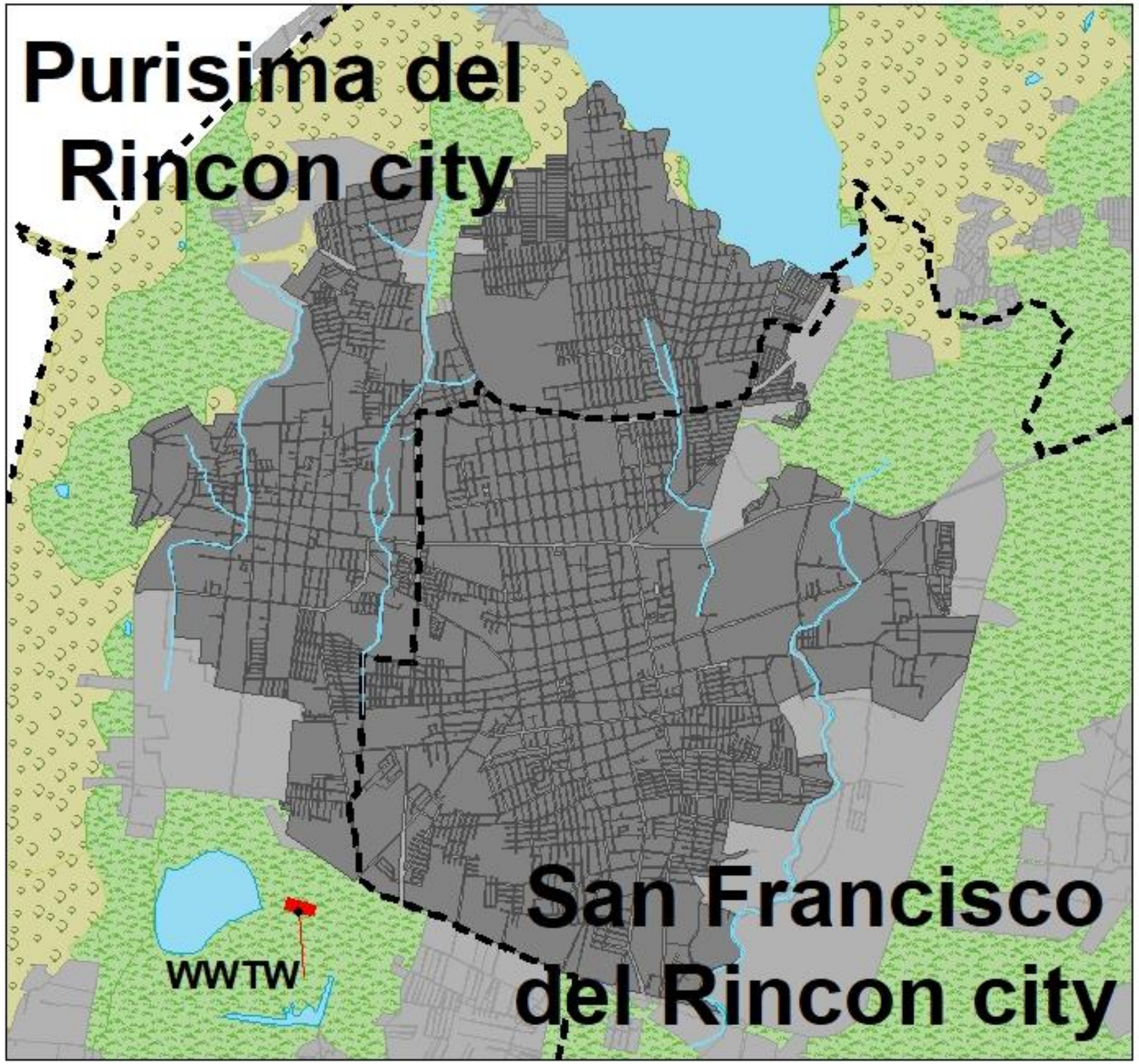


Key Performance Indicators

Nexus	Key performance indicator	Definition	Formula
Water	Reliability (0-1)	Capacity to supply demand	$R = {Ws}/{\sum d}$
	Water savings (%)	Reduction of water extracted in reference to the BAU	$\%WS = \frac{Ws_{BAU} - Ws_{si}}{Ws_{BAU}} x100$
Energy	Consumption (kWh/m^3)	Energy inputs per m3	Net energy balance
Pollutants	Eutrophication, ($kgPO_4/m^3$)	Caused by C, N and P loads in the systems	Net eutrophication balance
	Removal efficiency (%)	Removal of BOD mass flow	$Re = \frac{Inflow\ P_i mass - [Outflow\ P_i mass\ (effluent + by - pass)]}{Inflow\ P_i mass} x100$ Pi=Pollutant i

Methodology: Case study



Purisima and San Francisco del Rincon cities in Mexico

- Semi-arid region
- Water reuse in practice for urban irrigation and construction

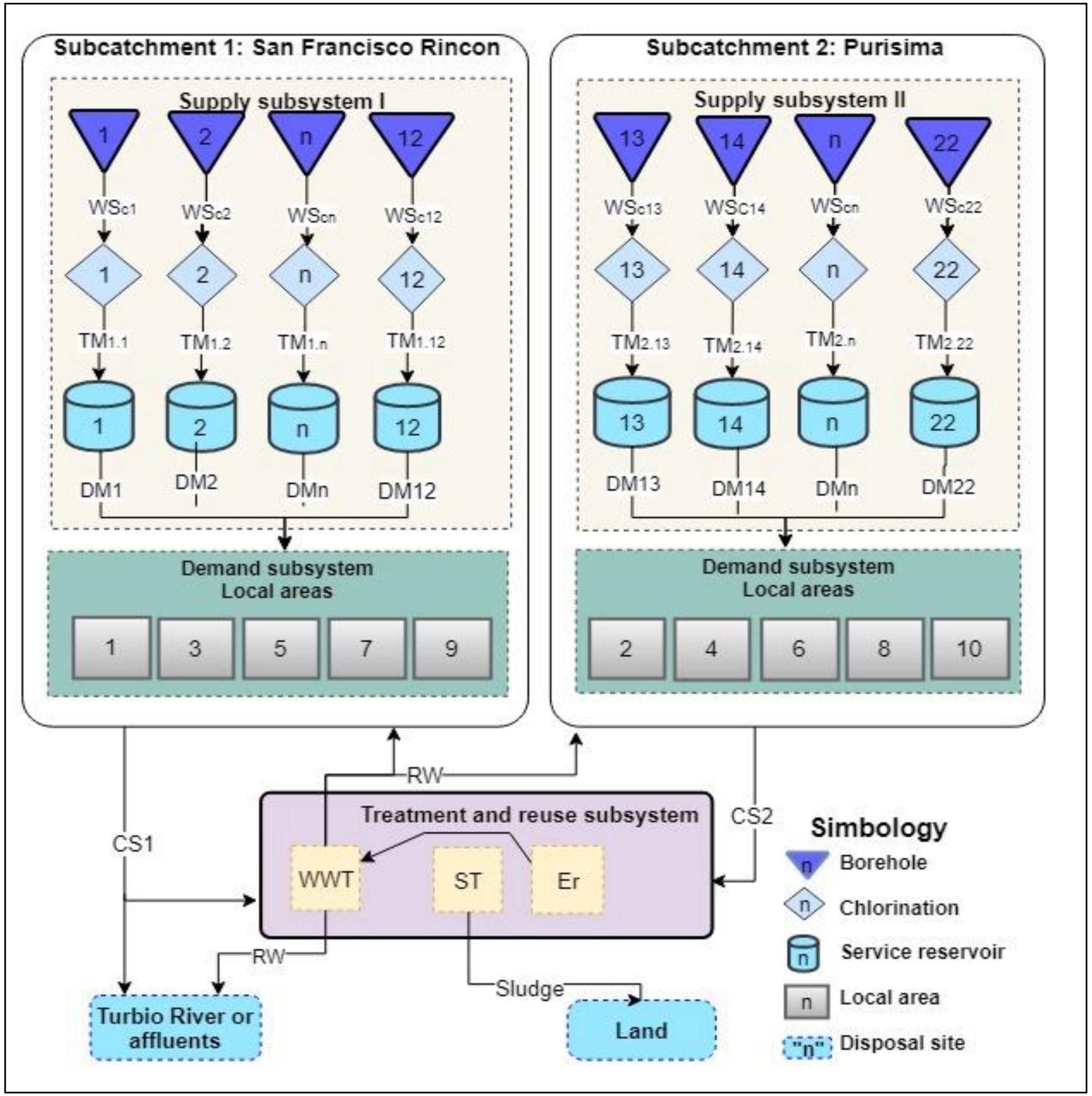
Urban Water system in Rincon Cities

Sub-system	Main parameters	San Francisco	Purisima
Water supply	Total groundwater wells	12	10
	Water supply (Mm^3/y)	6.1	3.4
	Chlorination	Cl_2	NaOCl
	Leakages (%)	40	53
Demands	Inhabitants	71,139	43,512
	Households	15,523	9,228
Sewer	Sewer capacity (m^3/y)	41,900	31,600
Wastewater Treatment	Activated sludge plant capacity (m^3/d)	21,600	
Reuse	Reuse rate Energy recovery (kWh/m^3)	1% 0.3	
Discharge	Receiving water body	Turbio River	

conceptual model

Business As Usual (BAU)

- **Scale specifications**
  - Sub-catchment areas (2): One per city
  - Local areas (10): Five per city
- **Daily step simulation 30 years planning horizon**
- Implementation of interventions at
  - Year 10
  - Year 20
- Equal population, industrial and urbanisation growth (3%)
- **Functional unit**
  - 1m^3 of water supplied, used, treated and reused



Water Reuse Intervention Strategies

Water source	End use	Adoption rate 10 %	Adoption rate 50 %	Technology
Grey water	Urban Irrigation	S1	S2	Sand filter
	Toilet flushing Irrigation	S3	S4	RBC
		S5	S6	MBR
		S7	S8	Constructed wetland
Reclaimed water		S9	S10	Activated sludge from BAU
	Industrial Irrigation	S11	S12	

Strategies
Decentralised: S1-S8
Centralised: S9-S12

Adoption rate:
Proportion of demand users applying reuse strategies

Energy inputs:
Greywater treatment
Distribution
Chemicals

Results: Reliability

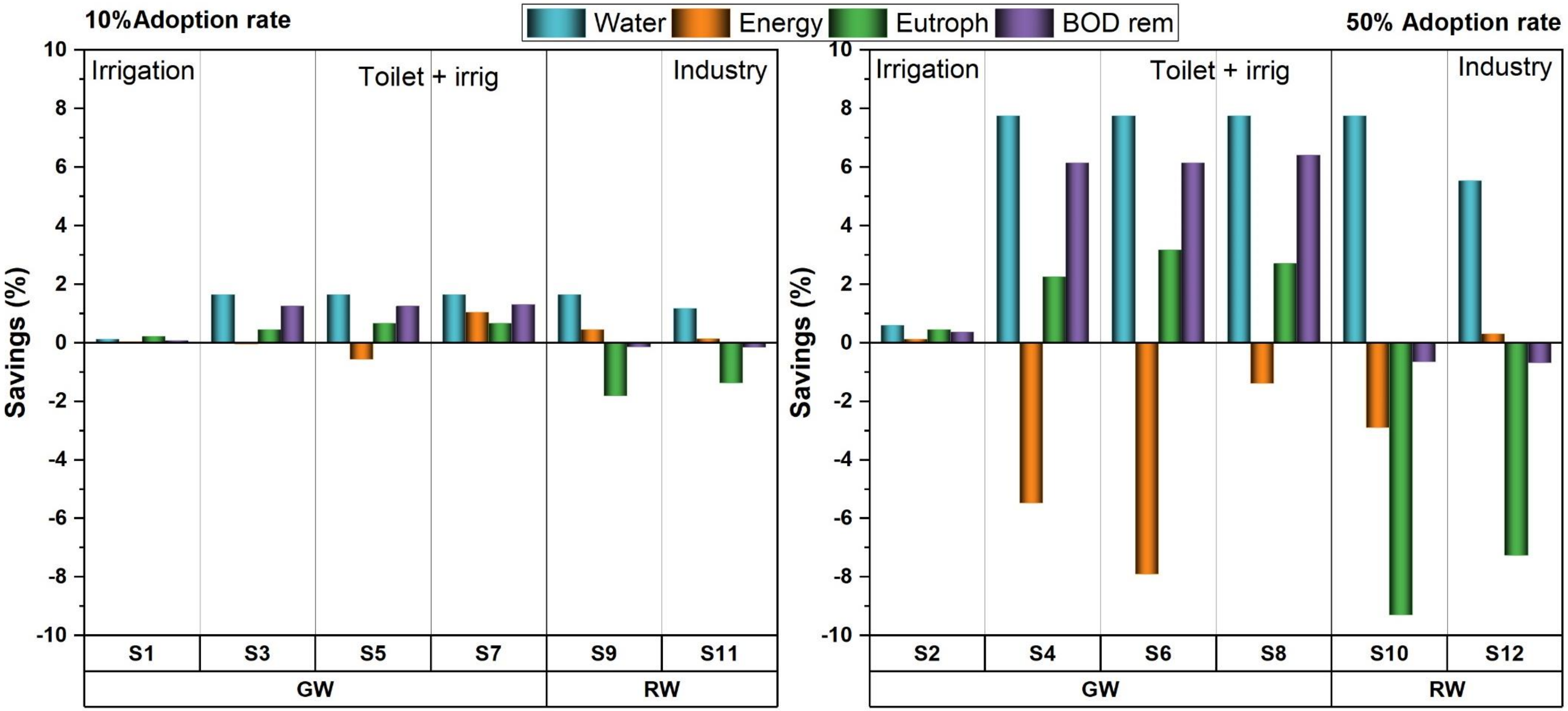
Strategy	Reliability
BAU	0.997
S1	0.997
S2	0.997
S3, S5, S7	0.998
S4, S6, S8	1.000
S9	0.998
S10	1.000
S11	0.997
S12	0.999

- The system can supply the demand in 30 years under current stressed conditions:
- 120-145 Liters per capita

(250 Lpc recommended; CONAGUA, 2007)
Irrigation <5L/m^{2}d

- Motivations for water reuse are related to other benefits (groundwater preservation, costs, etc).

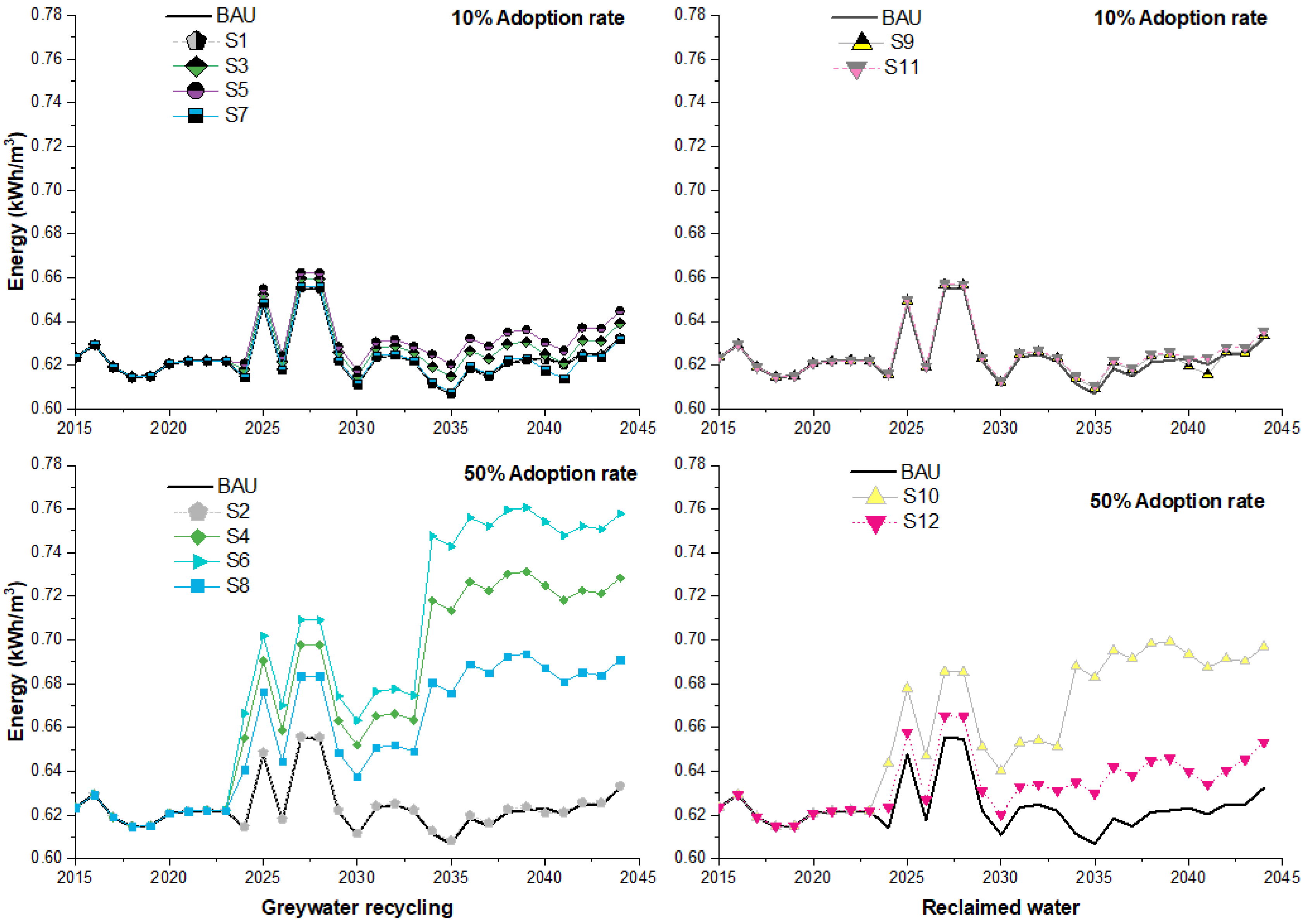
Total savings per strategy



- Water savings depends to the adoption rate and end-use.
  - S3, S5, S7, S9 save 2% of freshwater when 10% of households in toilet flushing
  - S4, S6,S8, S10 up to 8% adopted in 50% households for toilet flushing.
  - S1,S2 save <0.5% when adopted in 10% households for urban irrigation
- Centralised reuse: Increases eutrophication and reduces overall BOD removal
- Reuse strategies consume more energy, especially in systems with 50% adoption rate.

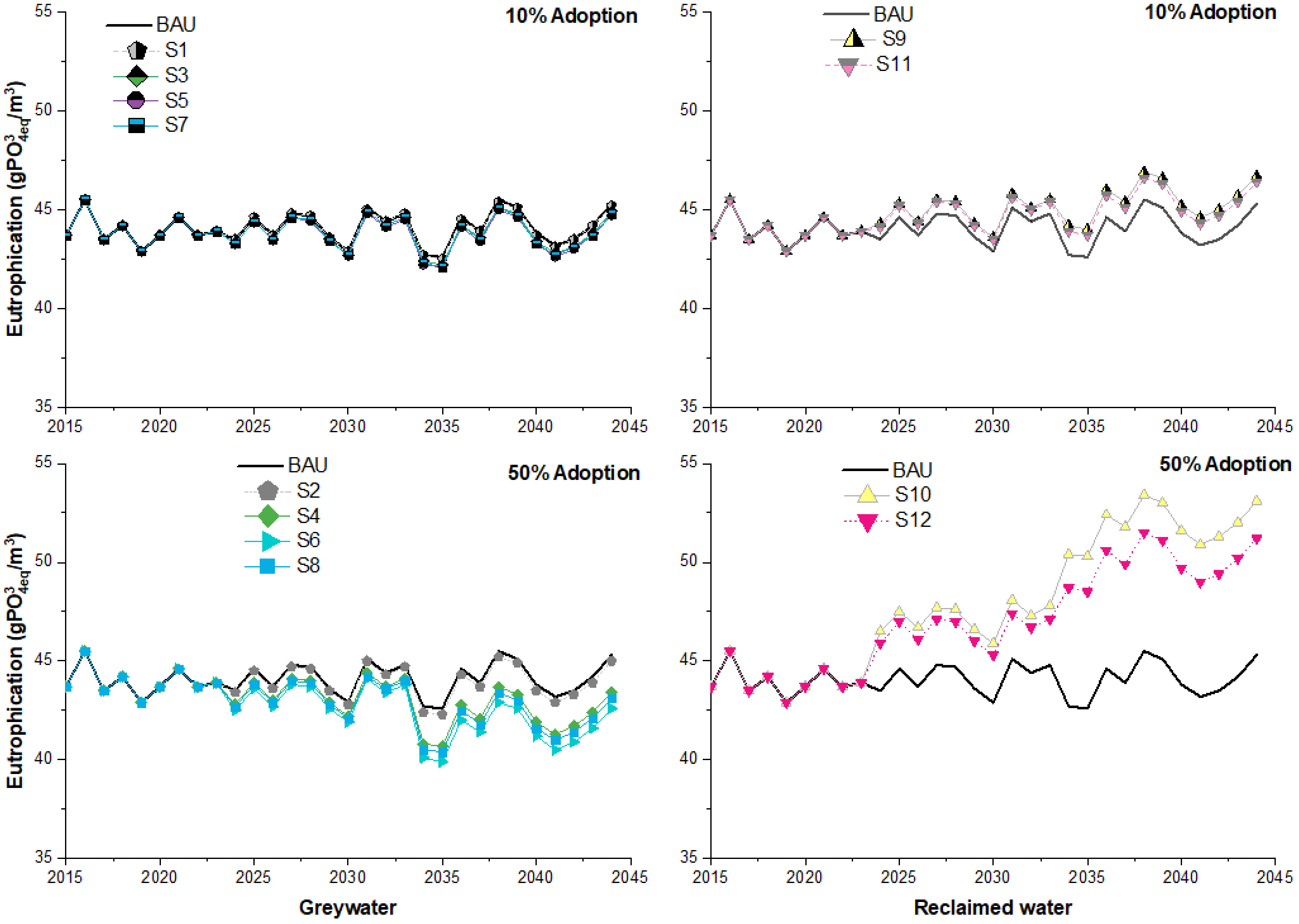
Energy consumption

- Water reuse affects energy consumption due to additional treatment and distribution
- The highest energy consumption are for toilet flushing-50% adoption
- S6>S4>S10>S8; for technologies MBR, RBC, Wetlands and centralised reuse.
- The strategy S2 (irrigation, 50%, sand filter) has equal energy consumption compared to BAU (0.623 kWh/m³).

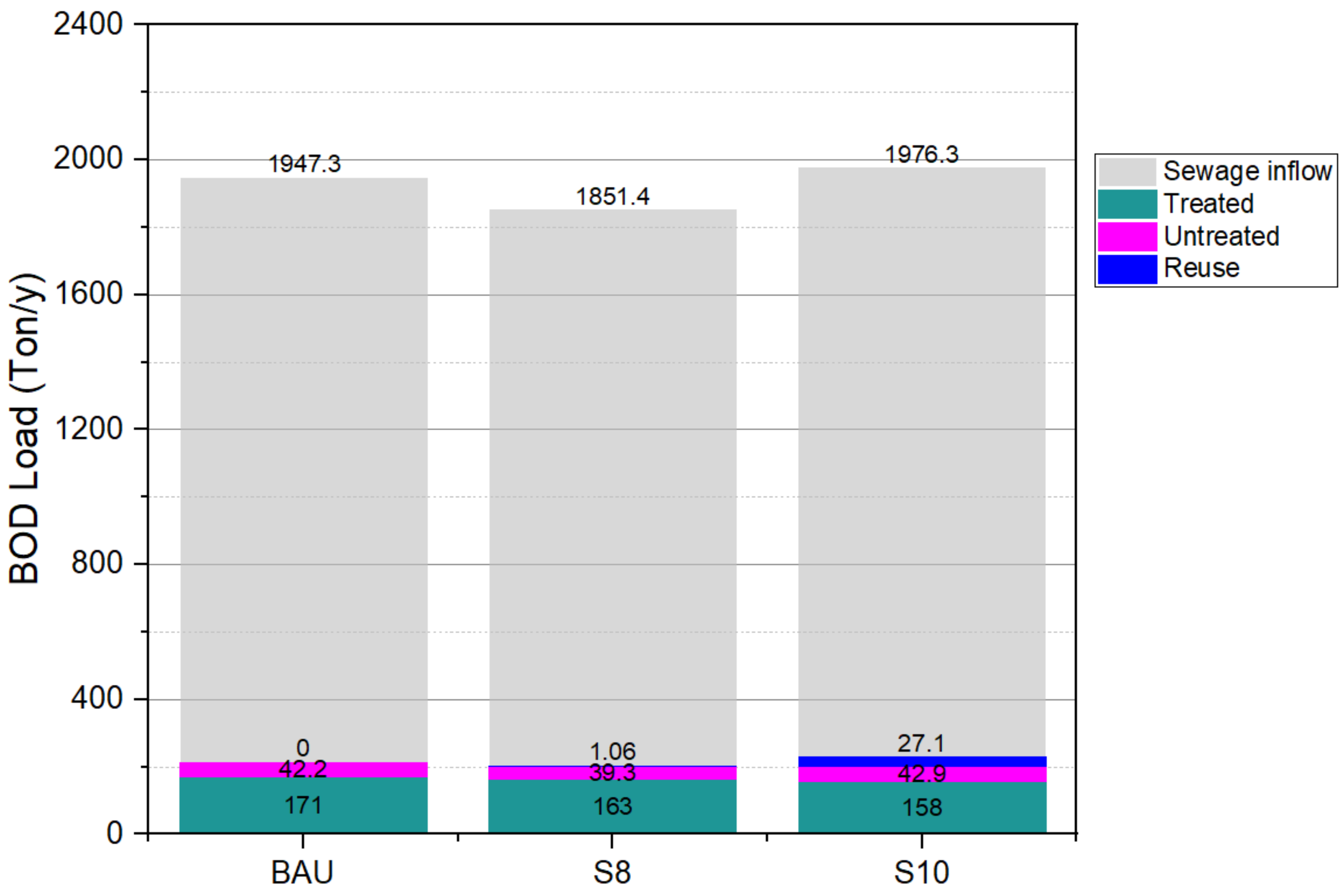


Comparison of eutrophication

- Eutrophication caused and avoided for C, N, P.
- GW strategies reduced eutrophication while centralised increased it.
- GW-50% (S4, S6,S8) reduce 3 gPO_{4eq}/m^3y and centralised water reuse, i.e. RW-50% (S10, S12), will increase 10 gPO_{4eq}/m^3y by 2040.



Comparison of BOD load in Strategies S8 and S10



S10: 50%- centralised-Industrial
S8: 50%-for toilet/irrigation
reduces BOD removal efficiency, while S8 (Decentralised) improves the efficiency

Main reasons:

- Increase inflow into sewerage in S10 compared to BAU would increase BOD mass flow
- Increase removal efficiency in S8 due to an external wetland will reduces BOD concentration.
- In S8 less concentration and less sewer flow will reduce BOD mass flow.

Total flows (m3)

Subsystem	Component	BAU	S8	S10
Sewerage	Sanitary sewage inflow	163,939,374.60	149,396,388.70	**164,529,228.26**

Conclusions

- There is strong connection between water-energy-Pollutant in urban water systems.
- Various centralised and decentralised water reuse strategies can be analysed in this framework.
- Analysis of water-energy-pollutant nexus was conducted by using Metabolism based approach (WaterMet^2).
- Long-term performance of water reuse schemes can be used effectively for strategies assessment and improvement of water-energy nexus in an integrated UWS
- Decentralised water reuse strategies can reduce eutrophication and increase BOD removal.

Acknowledgments

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Thanks for your attention!