Imperial College London

NERC SCIENCE OF THE ENVIRONMENT

The Role of End-Use in Integrated Urban Energy and Water System Dynamics

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MOTIVATION

The global trend of urbanisation is concentrating an increasing demand for services in cities. Those services require both energy and water, the supply chains of which are also intricately linked (Fig. 1). While the global demand for energy and freshwater increases, these resources are posing limits due to availability or through environmental pressure e.g. global warming.

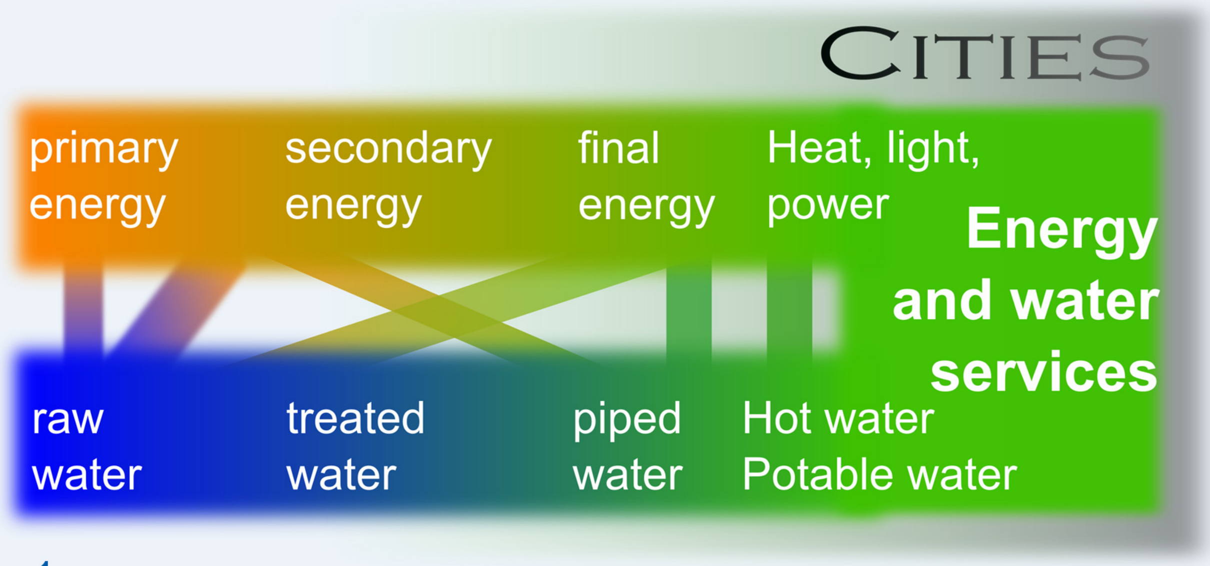

Figure 1
Scheme of the linkages between water and energy, from extraction through supply to urban end-use services

End-use energy and water demand are traditionally considered separately in urban dynamics, although there are strong linkages (Fig. 2). This work investigates the role of end-use in the dynamics of urban energy and water systems, taking into account all linkages between both.

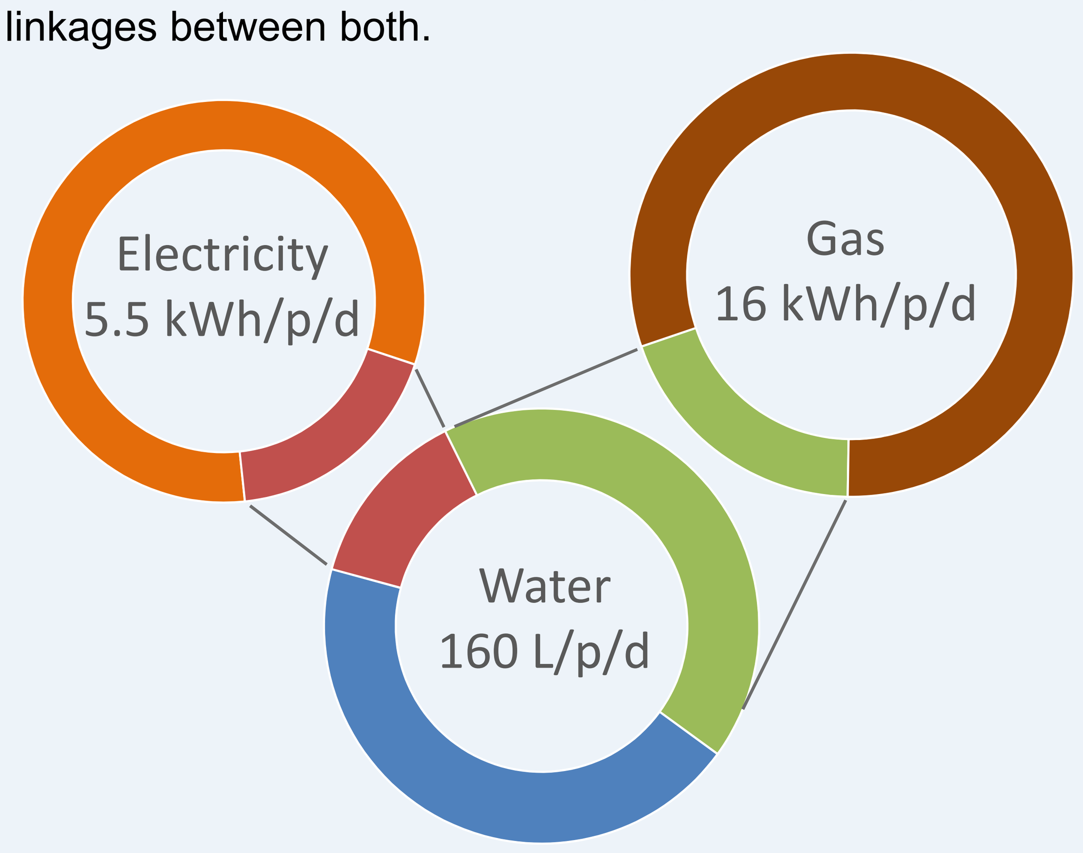

Figure 2
Indicative residential water and energy use in the UK, with linkages. Based on Kemper Gubetich (2015)

METHOD

The System Dynamics (Sterman, 2000) method is used to map and understand the structure and dynamics of the resulting system. It involves 2 main diagrams:

1. Causal loop diagram which incorporates all possible influences (+/-) (Fig. 3).
2. Stock-and-flow diagram, representing the mathematics of the system dynamics.

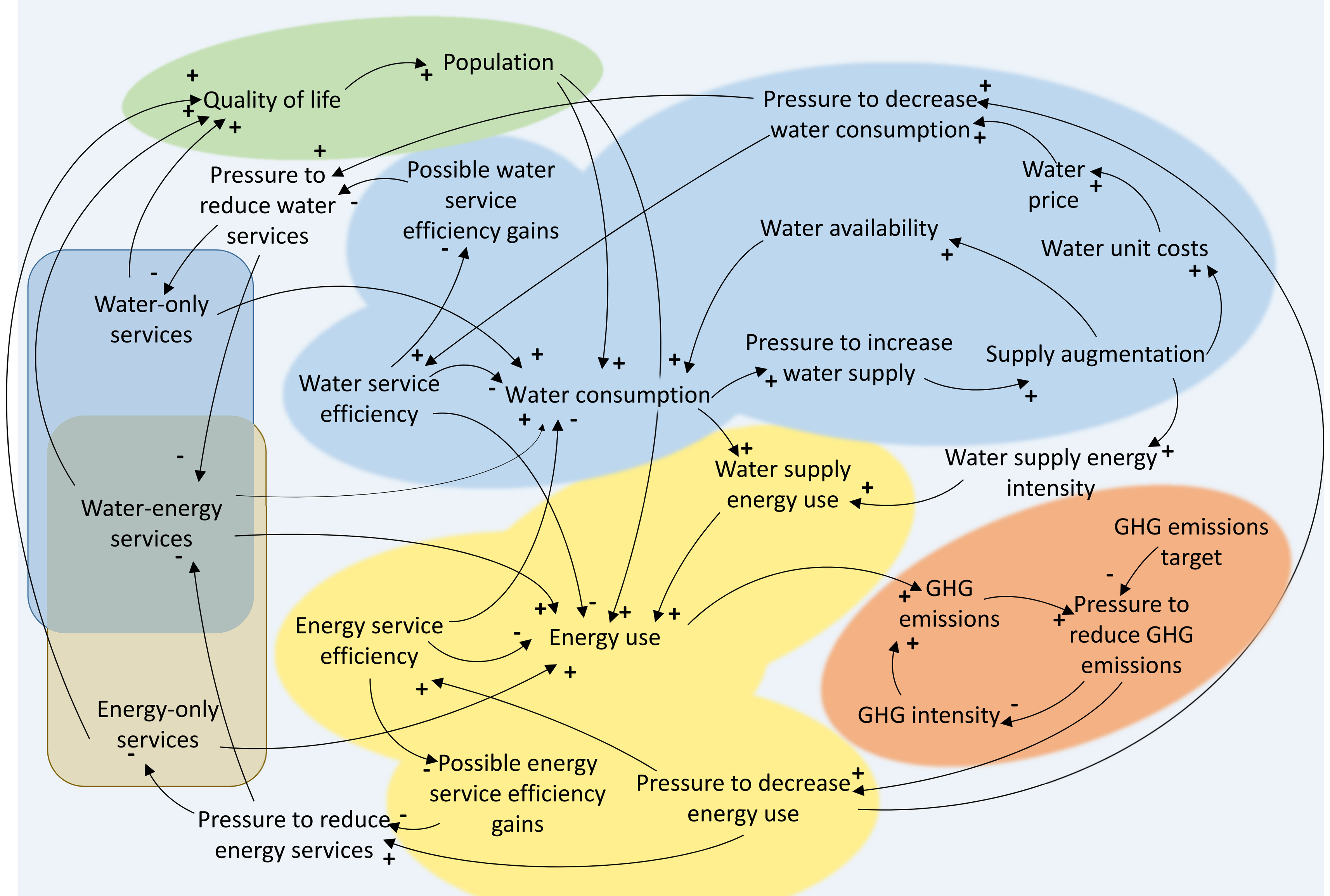

Figure 3
High-level representation of the Causal Loop Diagram for the integrated urban energy and water dynamics. Background colours indicate subsystems

IMPLEMENTATION

Different tools are used to facilitate modelling and analysis (Fig. 4):

- Vensim PLE for model structure and intuition
- PySD Python library for processing the model with varying inputs
- R and rPython package for advanced analysis and visualization

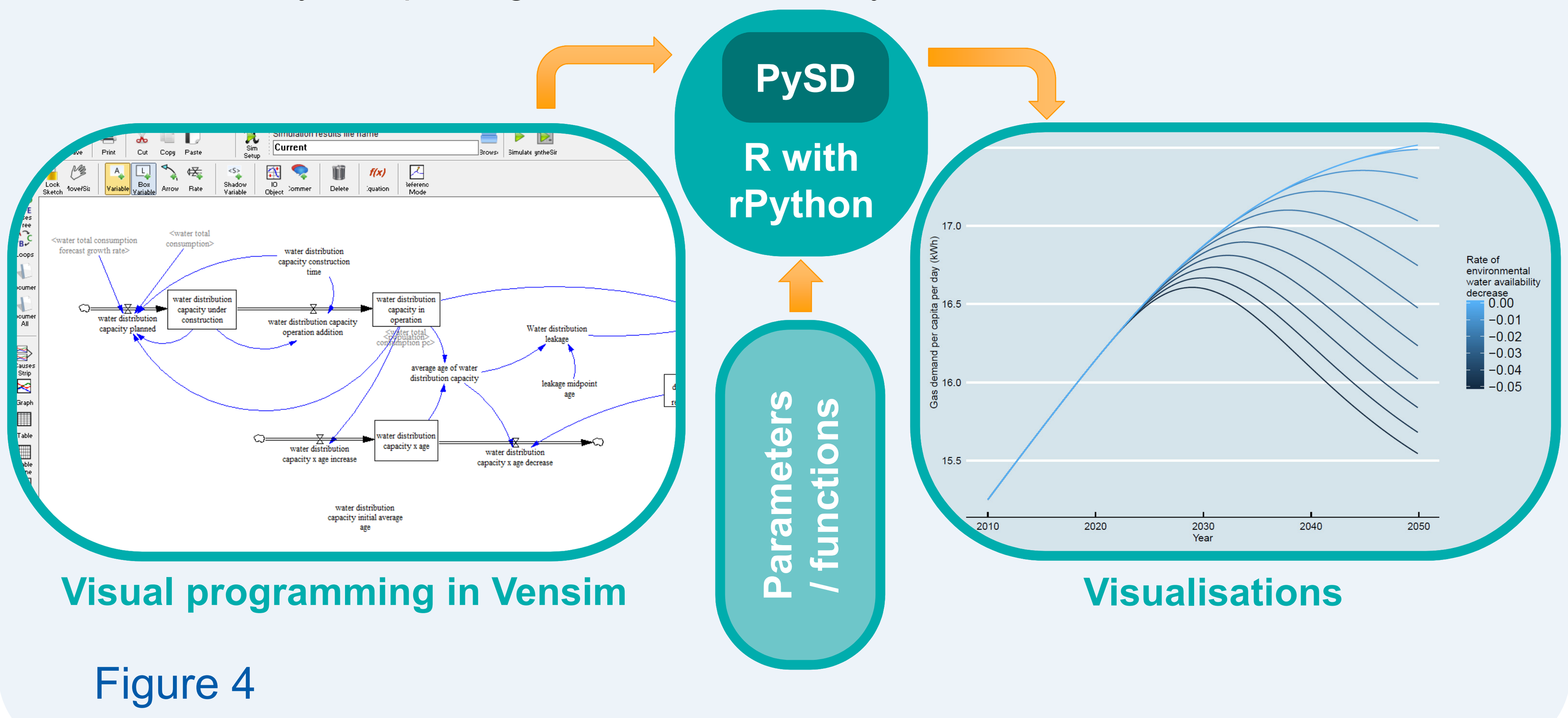

Figure 4
Schematic representation of the model workflow and integration

MODEL USE

The implementation permits easy adaptation from the London 2010 base case, by changing parameters, functional relationships and model structure, allowing to

- Investigate effect of policies in water/energy on energy/water system;
- Analyze uncertainty of outcomes;
- Find options tackling both water and energy issues;
- Avoid mono-focused solutions that exacerbate other problems;
- Inform water and energy planning for increasing service demand.

DATA REQUIREMENTS

- Water and energy use by service and sector (De Stercke et al., in press).
- Water sector characteristics (electricity use, leakage, average age of mains, …).
- Socioeconomic interactions of service and resource demand.
- Water and energy supply chains for the city.
- Processes of policy- and decision-making, and of planning.

FUTURE WORK

Expand and adopt model for other cities in situations different from UK' s (Fig. 5)

- Local water and energy storage
- Supply-constrained consumption and intermittent supply
- Different service provision
- Transitions to continuous-supply systems

Figure 5
Left: electric generator repair for back-up power during blackouts (Kashmir)
Right: water truck filled underground sump (red pipe) of a Mumbai building

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