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The Nexus approach for water utilities: A case study from South West UK

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Introduction

The delivery of drinking water and wastewater services are inextricably linked to a significant demand for energy and key resources arising from the natural environment [1]. Further, it is becoming evident that the growing pressures of climate change and population growth heighten the need for efficiency and integrated solutions [2,3].

Within this context the UK water industry regulators expect drinking water and wastewater service providers to undertake suitable planning actives to ensure the ongoing delivery of services. In 2007 the Water Resource Management Planning Regulations came into force enacting amendments to the Water Act, which for the first time placed a statutory obligation on water companies to prepare and maintain a Water Resource Management Plan (WRMP). The primary objective of the WRMP being to communicate a water company's intention to manage the balance of supply and demand of drinking water over a 25 year time horizon [4]. It is now expected a similar obligation will be placed upon wastewater service providers in the near future. In anticipation of this requirement, many wastewater companies have prepared and published draft plans following the newly introduced framework for Drainage and Wastewater Management Plan (DWMP) [5]. While the WRMP and DWMP are not formally aligned, there are numerous linkages between the provisions of the two services. Consequently an integrated approach to planning is likely to improve the overall service level.

The Water-Energy-Food-Land-Climate Nexus as a conceptual framework to examine the interdependencies arising from the supply of resources has gained increasing prominence in academic research. However, despite the growing body of literature few real-world case studies, or examples of the practical application of the approach are available [6,7]. The work to be presented will outline the development of the south-west UK case study for the SIM4NEXUS project, as undertaken by South West Water Ltd (SWW) and The University of Exeter. The nexus approach aims to develop a holistic and comprehensive understanding of how the supply and consumption of energy, food and water interact within the context of a changing climate and population growth.

Focusing on SWW's operational area, the case study addresses how legislation, policy and strategic planning can be aligned to:

1. Support sustainable agriculture and the provision of water and wastewater services in a region with significant environmental sensitivities and the UK's largest tourism region.

2. Recognise the need for resilience in the face of climate change, population growth and an increasingly competitive market place.

Methods and Materials

Findings from the case study are being used to develop a Systems Dynamic Model (SDM) of the linkages between water, land, food, energy, and climate in the South West region. The SDM will facilitate detailed scenario-based analysis and learning opportunities which will support both business planning and stakeholder engagement. Furthermore, SWW intends to use the project outputs to influence regulator policies and demonstrate a strategic approach to business planning that considers "end-to-end" resource management.

Specific areas of investigation that the SDM will facilitate include: (a) end-to-end resource management; (b) improved utilisation and deployment of low carbon energy; (c) the impact of land use change and farming practices; (d) resilience to climate change and population growth

Discussion

The SDM is being developed to analyse the impact of policy decisions influencing individual sectors over a time horizon of 2020 to 2050 by integrating data from existing thematic models[8]. Impact analysis will be achieved by manipulation of control variables embedded within the model which simulate the policy objectives that have been identified as being relevant to each sector. Core objectives of the broader project are to support efficient resource management and decarbonisation. Therefore the two primary performance metrics are: (a) Total CO2 emissions; (b) the ratio between the total resources supplied by each sector and resources directly consumed by societal demand. Within each sector more specific objectives and metrics are considered, based on the priorities identified by the case study. The water sector, for example, is highly concerned about strategic storage of raw water, and sustainable rates of abstraction from surface water bodies, these variables, therefore, become performance metrics which are tracked over time.

From a functional perspective, the SDM assumes a demand-led philosophy, whereby the flow of resources to meet direct societal demands, and the flow of resources between individual sectors are the primary factors. The primary model is subdivided into two structurally identical nexus models, describing the interactions between society and all Nexus sectors for Devon and Cornwall. The use of individual nexus models per regional boundary enables region-specific data to be applied so that the unique circumstances of each county can be taken into consideration.

The water sector submodel is subdivided into drinking water and wastewater supply chains which when linked via raw water resources describe the urban water cycle. The primary objective is one of supply and demand balance based upon resource recharge, storage and demand. For both drinking water and wastewater several operational characteristics are directly linked to flow rate. Within the model these are; chemicals demand, sludge production and energy demand. Historical data will be used to determine the correlation between flow and these three characteristics for the specific treatment sites within the spatially defined boundaries.

The energy sector sub model seeks to examine the balancing of supply and demand within the region of electrical and thermal energy. All forms of renewable energy generation within the south-west region are included as are all forms of fossil fuel and grid electricity import. The energy subsector model is the only example of a supply lead philosophy taking precedence within the SDM. The supply lead approach is appropriate due to the nature of renewable energy generation, in that for the majority of cases energy is generated as the resource becomes available.

The land sector submodel is of particular importance because all activities occur on the land, but few policies are explicitly made on land management. The model approach is to assume that the total available land resource within the spatial boundary is finite and only exists in one of seven states, the model then attempts to describe the transition from one state to another. GIS analysis will be used to determine the total area of land within the spatial boundary under each of the seven used types. This is a highly simplified model and intentionally aggregates particular land types.

The food sector sub model examines the production of raw foodstuffs, i.e. the cultivation of crops or cattle, and the processing of those raw foodstuffs into marketable food products. The sub model is divided into six modules each dealing with a particular aspect of the food sector.

Conclusion

The use of the systems dynamics methodology is well suited to the complex interactions of the urban water cycle and larger water-energy-food nexus. The technique has also proven to be highly versatile when integrating data from multiple sources and modelling seemingly disparate systems. The development of the model has provided significant insight into the causal relationships between material flows and operational or policy decision making.

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