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A review of the water-energy nexus

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ABSTRACT

Water and electricity are fundamentally linked. At a basic level electricity generation requires water, and water treatment and transportation use electricity. Historically, there has been little reason to understand the nature of these links, due largely to the presumption that water was not a threat to energy security, nor electricity a threat to water security. This presumption is now being challenged. Industry reforms, increasing demand, and more recently climate change – are bringing into sharp focus the links between water and electricity in unprecedented ways. General awareness of the links between water and electricity is increasing daily, as the ramifications of the links are being felt the world over:

Society's ability to deal with the challenges and uncertainties arising from the links between water and electricity is being hindered by limited understanding of the nature of the links, and seeming lack of policy tools to effectively analyze them. This paper reviews comprehensively the links between water and electricity. Presents a classification system for identifying links. Using the classification system, this study further discusses these links by drawing upon examples from literature and follows with a synopsis of the nature of these links. With this background, the paper reviews and compares water-energy studies in terms of scope, objectives, methodologies and key findings, discusses major limitations of these studies and identifies important areas that would benefit from more in-depth research.

This research contends that this type of approach is unsuitable in the longer term, particularly when examining complex and multidimensional issues like the water-energy nexus.

This work suggests that the nature of the nexus should and can be explored from a wider perspective, by developing a suitable integrated methodological framework to serve as a platform for such exploration. The purpose of this paper, therefore, is to outline the development of such a framework. Introduces Integral Theory and discusses how Integral Theory has shaped the development of the methodological framework employed in this research. Presents the framework and describes the suite of methods.

Contents

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1. Introduction

The interdependency between the world's two most critical resources: water and energy, is receiving more and more attention from the academia as well as the general public. A comprehensive and in-depth understanding of the water-energy nexus is essential to achieve sustainable resource management. Following the structure of hierarchy of knowledge, this paper reviewed the evolution and progress of information, methodology, knowledge, and wisdom that have grown out of this field throughout the past 40 years. By synthesizing previous work, the paper identified existing knowledge gaps, as well as directions and challenges for prospective research. System dynamics, featuring framing, understanding, simulating, and communicating dynamic behaviors within interrelated social, managerial, economic, and ecological systems over time, is proposed to be a promising research approach that could facilitate our understanding in the field of water-energy nexus in the future.

2. Emerging links between water and electricity

The links between water and electricity are many and varied, connecting different functions in both industries. To assist with reviewing emerging links, this research divides the functions of both industries into 'Production', 'transportation' and 'Consumption' categories. This classification system shows the common flow sequence in the water and electricity industries, from the Environment – the source of water and primary energy – to the end users. Functions close to the Environment, such as primary energy and secondary energy, wholesale electricity generation, bulk water supply, and desalination are placed in the 'Production' category. Functions close to the end users, such as retail supply of water and electricity, wastewater treatment, embedded generation, and end users are placed in the 'Consumption' category. The 'transportation' category includes transmission and distribution of electricity, and extraction, transfer, conveyance, distribution, and collection of water and wastewater (Fig. 1).

The links between water and electricity in this study are similarly classified into 'Production', 'transportation' and 'Consumption' categories depending on the industry functions involved. An example of a Consumption link is electricity consumed to treat wastewater. **(Links that occur across categories are assigned to the category that receives the water or electricity)**. For example, recycled water (Consumption category) used for cooling purposes in a thermal power station (Production category) is considered as a Production link.

Fig. 2 illustrates this classification system and identifies key links in each category. These links are discussed in the sub-sections that follow.

2.1. Production links

Production links, as identified in Fig. 2 include: water collected during mining; water for electricity generation; water for alternative energy production; and electricity for desalination.

2.2. Transportation links

Transportation refers to the network functions in the water and electricity industries. For water, this includes groundwater extraction, bulk surface water transfers, retail water distribution and wastewater collection. It is estimated that pumping water consumes up to seven per cent of energy produced worldwide. In contrast, the transportation functions of the electricity industry – transmission and distribution – consume negligible amounts of water, and this would be dominated by potable water consumed by employees [1].

2.3. Consumption links

Consumption links include water and electricity cross subsidies, electricity for water and wastewater treatment, decentralized electricity systems, and water and electricity consumption by end users.

3. Nature of nexus

The above-mentioned discussion clearly illustrates that water and electricity are inextricably linked and that these links occur in all three categories – Production, transportation and Consumption. The implications of the nexus are being felt the world over, as increasing pressures of drought, climate change, industry reform and a rise in demand for water and electricity, intensify this interaction.

It is also clearly evident from the above discussion that the nexus is multidimensional in nature. This research classifies the dimensions as: environmental, technological, economic, political and social. The many examples and case studies cited above also suggest that these dimensions influence each other, quite often antagonistically. In order to develop a greater understanding of the nature of the nexus, the following section analyses each of the dimensions in turn, and draws largely from the discussion in the preceding section.

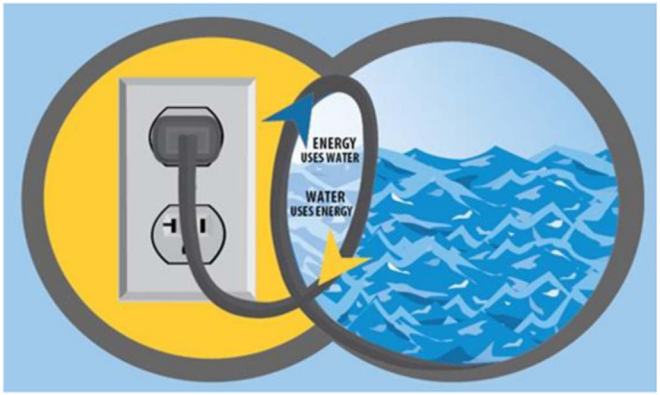

Fig. 1. Links between water and electricity.