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Editorial

Exploring the dynamics of water innovation: Foundations for water innovation studies

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A B S T R A C T

The urgent need for innovation to address multifaceted and intertwined water-related challenges is becoming increasingly clear, acknowledged and responded to with cumulating sources and amounts of funding. Nevertheless, the water sector has been claimed to be less innovative than other sectors. This Special Volume on the dynamics of water innovation is based on the realization that, in general, there is a striking absence of academic studies on the dynamics of water innovation. This SV is therefore designed to lay the foundations for the field of water innovation studies, in an effort to integrate the emerging insights. Together, the contributions in this SV capture the current understanding of the dynamics of water innovation and provide insights into how the water innovation process can be fostered. The purpose of this introductory article is threefold, namely to frame the discussion on water innovation dynamics in order to contextualise the contributions of this SV, to provide systematic guidance for studying water innovation dynamics and to suggest the way forward for water innovation studies. It captures the extent of the field of water innovation studies with a review of the literature of the last three decades and frames water innovations. Based on five decades of innovation research and drawing on three areas (management, strategy and policy), we provide an innovation studies taxonomy that consists of four organising dimensions: type of innovation, stage of innovation, level of analysis and measurement. This taxonomy enables researchers to study the dynamics of water innovation from different combinations of conceptual and thematic angles, drawing on the field of innovation studies in a systematic fashion. Finally, we reflect on the way forward for water innovation studies with suggestions for future research.

1. Introduction

Water and the necessity for its sound management have been placed increasingly high on political and funding agendas. Access to water has been acknowledged as a fundamental human right by the United Nations General Assembly [see (UNGA, 2010)]. The need to take care of global freshwater resources and water-related ecosystems, to achieve universal and equitable access to drinking water and sanitation and to prepare for water-related disasters is firmly embedded in the targets of several of the United Nations Sustainable Development Goals (UNGA, 2015). The United Nations Secretary General and the President of the World Bank Group established the High Level Panel on Water[1] which called for "*a fundamental shift in the way the world looks at water*" (HLPW, 2016, p.1). Moreover, for the third year in a row, the World Economic Forum's annual Global Risks Report (WEF, 2017), which is based on the perceptions of world leaders and corporate decision-makers, placed environmental risks above economic risks, with water crises among the top three global risks. Already 10 years ago, UN-Water and the Food and Agricultural Organisation had argued that the world was facing a crisis when globally roughly 1.2 billion people experienced water scarcity problems (UN-Water & FAO, 2007).

From the perspective of water utilities, water-related challenges are primarily related to scarcity, quality and the allocation of water (e.g. RobecoSAM, 2015). According to estimates by the United Nations World Water Development Report 2016 (WWAP, 2016), 78% of the jobs constituting the global workforce are dependent on water; some even argue that '*there is no human activity that does not depend on water*' (Savenije, 2002, p.742). The challenges facing water management are multifaceted and intertwined, particularly when conceiving water management broadly: there are interrelated *social challenges* (population growth, urbanisation, migration, changing lifestyles, provision of water access (rural & urban), provision of sanitation & hygiene, water consciousness to improve water use efficiency), *technological* (tapping novel sources of freshwater, smart infrastructure, waterless design to reduce system dependence on water, usage efficiency technologies, water reuse and recycling), *economic* (ecosystems services, energy supply,

[1] consisting of 11 sitting Heads of State and Government and one Special Adviser and charged to champion to ensure commitment for the implementation of the 'water goal' (SDG6) and the achievement of other SDGs that rely on the development and management of water resources.

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ageing infrastructure, virtual water (water footprint), climate adaptation), *environmental* (flood risk, persistent drought, groundwater depletion, agricultural productivity and climate resilience, ecosystem pollution, waste management), and *political challenges* (governance,[2] water stress,[3] utility ownership models, watershed cooperation, system vulnerability, water rights) (Luebkeman, 2015; Weerdmeester et al., 2017a; Water JPI, 2016; Dietz et al., 2014). Moreover, a sound knowledge base and capacity at different levels (water professionals, organisations, enabling environment and society) to address these challenges and to sustain and improve water management through change and innovation are lacking in many developing countries (Wehn de Montalvo and Alaerts, 2013).

Analysists estimate the global water sector worth 1 trillion USD per year by 2025 (RobecoSAM, 2015). These prognoses are based on expectations that the demand for innovative solutions will grow: solutions enabling more efficient use of available water resources, enhancing the quality of (drinking) water, and improving water resource planning to reconcile the conflicting trends of rising demand for water and finite water resources (Pinsent Masons, 2011). On top of these, further solutions are needed for water resources management more broadly, especially in view of increasing water-related disasters owing to climate variability and change. Strategic efforts to address these challenges via research and innovation stress the need to distinguish between different types of water,[4] different water users[5] and different water (re-)use, the value of water and the value in water (HLPW, 2016; Weerdmeester et al., 2017a).

The urgent need for water innovations is becoming increasingly clear, acknowledged and responded to with accumulating sources and amounts of funding. Examples in Europe include the Horizon 2020 programme (for research, development and innovation activities), the structural funds,[6] LIFE 2014–2020 (the EU's funding instrument for the environment and climate action), as well as grants for individual researchers by the European Research Council to undertake basic research. However, financial investment into the water sector is still far behind that of other sectors, such as the energy sector.[7] The water sector has also been reported to be less innovative than other sectors whereby innovation indicators suggest far less research and development (R&D) investment in the water sector[8] than other sectors (Ipektsidis et al., 2016). This image needs to be adjusted, given the sectoral patterns of innovation in the sector. The pattern of innovation in the water sector follows the natural path of sectors that are supplier-dominated (i.e. supply of equipment) and trading in bulk (Pavitt, 1984); in fact, its rate of R&D investment and valued added is higher than in other sectors with higher R&D intensity (Ipektsidis et al., 2016).

This Special Volume (SV) of the Journal of Cleaner Production (JCLP) is based on the realization that despite some efforts over the last two decades (e.g. Golay, 1988; Ferrucci, 1995; Garn, 1997; Gregg, 1989; Hon, 1993; Ishigure, 1991; Kiparsky et al., 2013; Krozer et al., 2010; Lobina, 2012; Martins and Williamson, 1994; Miller, 1990; Oka et al., 1996; Palfai et al., 1998; Partzsch, 2009; Peuckert et al., 2012; Robbins, 1998; O'Brien and Clemens, 1988; O'Loughlin, 1994; Hartman et al., 2017; Shupe, 1988; Njeru, 1995; Sirkiä, et al., 2017; Barripp et al., 2004; Bowmer, 2004; Chen, 1998; Matthews, 1997; Thomas and Ford, 2005; Daniell et al., 2014; Wehn and Evers, 2015; Mvulirwenande et al., 2017; Ngo Thu, H. and Wehn, 2016; Gharesifard and Wehn, 2016; Wehn et al., 2015; Pascual Sanz et al., 2013), relative to the scope of innovation studies, there is a striking absence of academic studies on the dynamics of water innovation, i.e. examining how relevant actors (fail to) interact to generate, finance, diffuse and apply water innovations and how these processes can be fostered, guided and steered; yet such insights are crucially needed in the face of urgent water-related challenges in developed and developing countries alike that require various types of innovation, both technological and non-technological: incremental improvements, adapted approaches as well as entirely new ways of interacting across stakeholders, basins, regions and related sectors. More than 50 years of research into the dynamics of innovation can provide existing insights about, models of and approaches for studying, innovation. These need to be applied carefully when studying the dynamics of water innovation, given the cross-cutting nature of water and the peculiarities of this sector - involving diverse stakeholders across multiple governance levels (Pahl-Wostl et al., 2010), sunk investments and risk averseness (Blokland et al., 1999), and monopolistic structures for the provision of water services and to safeguard water security.

This SV was designed to lay the foundations for the field of water innovation studies, as an effort to integrate the emerging insights regarding water innovations, both technological and other forms of innovations, and to bridge water and innovation-related research. The papers in this SV were selected from papers submitted to a competitive 'Call for Papers (CfPs) (Wehn and Montalvo, 2015), the authors of which argued that the cross-cutting nature of water as well as the urgent need to address the water-related challenges means that dynamic dialogue is urgently needed about water innovations to better inform and support the generation and diffusion of water innovations, globally. The contributions in this SV capture the current understanding of the dynamics of water innovation and provide insights into how the water innovation process can be fostered. The coherence of the papers in this SV stems from the fact that they draw from, and build upon, established literature and theories in the field of innovation studies and apply (and adjust) these to the study of water innovation.

The purpose of this introductory article is threefold, namely to frame the discussion on water innovation dynamics in order to contextualise the contributions of this SV, to provide systematic guidance for studying water innovation dynamics and to suggest the way forward for water innovation studies. Therefore, this introductory article is organised as follows. We capture the extent of the field of water innovation studies in Section 2 with a review of the literature of the last three decades. Section 3 frames water innovations while Section 4 frames innovation studies. Based on five decades of innovation research and drawing on three areas (management, strategy and policy), in Section 4, we provide an innovation studies taxonomy that consists of three organising dimensions (*type of innovation, stage of innovation and level of analysis*) as well as the cross-cutting *measurement* of innovation in evaluation and impact assessment terms. We contextualise the contributions of this SV in Section 5 and conclude with remarks

[2] referring to how decisions related to water are made, by whom and with what degree of integrity, accountability, transparency and inclusiveness.

[3] demand for water exceeds the available amount during a certain period.

[4] rain water, surface water, ground water, brackish water, saline water, grey water, etc.

[5] typically distinguishing between agriculture, industry and households, which present 70%, 20% and 10% share of water use, respectively.

[6] to remove social, economic and territorial disparities across the EU while making the EU more competitive.

[7] For example, over the period 2000–2013, investments in clean energy have largely exceeded those in the water sector industry for all investment types (e.g., venture capital and corporate ventures, bank investment) globally (Ajami et al., 2014). It is estimated that, globally, clean energy attracted total investments of 139 billion USD of which 59 billion USD on capital investment (Ajami et al., 2014). In contrast, the water sector attracted 8 billion USD of total investments of which 5 billion was in capital investment. In the US, total investment in clean energy reached 69 billion (of which 41 billion in capital investment) while the water sector attracted 1.5 billion USD of which 1.4 billion USD in capital investment.

[8] referring to the collection and distribution of water only.

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