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Water–energy–pollution nexus for growing cities

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ABSTRACT

Most recognised global challenges of modern times are related to energy production and consumption. The trends of energy demand for a growing world population and global urbanisation have raised serious concerns, and they are often termed as "global challenges" that include climate change, pollution and demands of clean water, food and energy. In thematic debate of the 2013 UN General Assembly in New York on "Sustainable Development and Climate Change: Practical Solutions in the Energy–Water Nexus" it was highlighted that adequate attention should be given to the importance of inter-linkages between water and energy sectors in framing the post-2015 development agenda. In fact, the implications of energy consumption in the modern world go beyond these boundaries. Therefore we argue that there is a need for establishing a broader nexus – "water–energy–pollution" – where implications of energy production, related water consumption and environmental pollution (air and water) are embedded. The notion of this integrated nexus can play an important role in systemic appraisal of energy production and consumption in growing urban environments.

1. Introduction

The Director General of the United Nations (UN) Industrial Development Organisation suggested in the 2013 Oslo Conference that the "new UN Development Goals for 2030" should include halving the

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number of premature deaths caused by indoor and outdoor pollution. Planners and policy makers increasingly recognise the importance of an integrated approach for managing the urban environment so that size, economic activity and population of growing cities can expand further without compromising public health and the urban way of life. Nonetheless, challenges in urban management are overwhelmingly addressed within disciplinary boundaries, showing a clear need for developing research around a broader, water–energy–pollution, nexus that can represent key interdependencies of urban activities. This approach is important because water, energy, and pollution in urban environments are often managed in isolation rather than as an integrated system. As a result the feedback, synergies and trade-offs between the components of urban system are still poorly understood.

The dependence of the energy sector on water resources is a two-way process. For instance, the energy production process often relies on the availability of water, and the production of clean water requires energy. This water–energy nexus is well appreciated by the experts of various disciplines (Hightower and Pierce, 2008). Furthermore, the use of water in fossil fuel based energy production as well as for domestic and industrial applications result in water pollution; the remediation of water pollution again requires energy in order to reuse or to discharge clean water back into natural water reserve (Grant, 2012). The story of the energy–pollution nexus is similar, but is much less discussed in an integrated manner (Kumar and Morawska, 2013). For example, the production of energy from the combustion of carbon-based or renewable fuels is bound to generate both *climate* (i.e., greenhouse gases, GHG, such as carbon dioxide, CO_2; nitrogen oxide, N_2O; methane, CH_4) and *health* emissions (e.g., particulate matter, PM; sulphur dioxide, SO_2; and nitrogen dioxide, NO_2; carbon monoxide, CO). The effect of these emissions on climate change (Vardoulakis and Heaviside, 2012), public health (Rückerl et al., 2011; Heal et al., 2012) and integrity of built infrastructure (Kumar and Imam, 2013; Tiwary and Kumar, 2014) have been well established. Since energy generates both air and water pollution during its production and consumption, we argue that it might be possible to investigate an integrated nexus that can help in understanding dynamic interrelations and quantitative indicators for water and the pollution (air and water) produced per unit of energy produced/consumed in urban environments (see Fig. 1). A framework for such a nexus would provide insight into the implications of the energy demand, economics and industrial growth, beyond the existing discrete indicators of sector specific energy demand and environmental impacts such as water–energy nexus (Yang and Goordrich, 2014), energy–pollution nexus (Kumar and Morawska, 2013) or food–water–energy nexus (Rasul, 2014). We envision that the water–energy–pollution nexus can incorporate the key elements of urban environments in local or regional settings. Hence, the integrated nexus can be used to assess the true impact of energy production/consumption on the natural environment and quality of life in urban settlements. We believe that this could also open a way forward in achieving a holistic framework for global sustainability.

2. Relevance to growing cities

The notion of a water–energy–pollution nexus can be put into the perspective of growing cities to realise its potential benefits. As on 01 April 2014, there were 30 cities worldwide with 10 million or more inhabitants (referred as megacities) and 23 of them are in developing countries (City Population, 2014). Megacities are always considered as a significant contributor to the economy as well as a large sink of energy. A number of cities are likely to turn into megacities, and the megacities into super-cities (with over 40 million population), in the future due to rapid population growth and urbanisation across the world (Kumar et al., 2013, 2014). Recent estimates suggest that 10 new cities, with population exceeding 7 million, per year are expected to emerge over the next two decades (WEC, 2010). The United Nations estimates suggest that urban populations will comprise 67% of the total global population by 2050 (UN, 2011). Cities for housing the growing world population of the future are built now, which also offer the opportunity to employ rational approaches to achieve global sustainability (Bettencourt, 2013). In order to meet the future demands of energy, water, and food of a highly urbanised world, it is essential to apply an integrated approach to: (i) energy generation and consumption, (ii) water for building and industrial use, and (iii) pollution control for replenishing the natural resources and preserving public health (Fig. 1). The rapid urbanisation across the world