

Can China reduce energy for water? A review of energy for urban water supply and wastewater treatment and suggestions for change

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ABSTRACT

Energy use represents one of the main costs in water supply and wastewater treatment in China and is also a major contributor to greenhouse gas emissions. This paper has two aims. Firstly, it presents the first complete review of the growing body of literature on energy for water in urban China. Secondly, it identifies the most feasible suggestions for reducing and recovering energy in China's urban water systems based on the literature. The review finds wastewater is the area with most potential for net energy and emissions reduction. Anaerobic sludge digestion is commonly used in thousands of plants across the world, but it is applied in fewer than 3% of Chinese wastewater treatment plants. Many Chinese plants are large enough to make anaerobic digestion feasible and could potentially offset around 50% of their energy use by using the heat and power produced by burning biogas. Energy recovery can be increased through co-digestion and increasing primary sludge collection, or by using heat pumps to transfer energy in wastewater to nearby buildings. Land application of sludge can be used to significantly cut greenhouse gas emissions associated with wastewater sludge, almost all of which is currently landfilled or dumped without stabilisation in China. In water supply, minimising water leakage and increasing the efficiency of water pumping in high-rise buildings are practical ways to reduce net energy use for conventional water supply. In cases when water is scarce and cannot be transferred between provinces using gravity, wastewater reclamation combined with energy recovery is the least energy-intensive alternative water source and should be supported by strong government policy.

1. Introduction

Energy use within the water sector in China is an issue of increasing importance. Use of electricity for pumping and treatment is one of the major contributors to emissions of greenhouse gases and air pollution by the water sector, since most electricity in China is coal-generated [1,2]. It is generally also the largest cost faced by this sector [3–5]. The quantity of water produced and wastewater treated in China has increased significantly over the past two decades, but efforts to reduce net energy use for these processes, particularly through energy recovery during wastewater treatment, lag behind other countries [5–7]. Water-scarce urban areas in China are increasingly turning to alternative water sources, which generally require more energy to source and treat than conventional water resources [8].

This review poses the question: can China reduce net energy for water in urban areas? The review has two main aims. Firstly, it aims to

present a thorough review of energy for water in urban areas of China, including both conventional and alternative water sources and all stages of wastewater treatment. The definition of energy for water used in this study excludes energy for processes where the main output is not water [9]; for example, it does not include energy for water end use (e.g. heating water for showering) or energy embedded in construction materials and chemicals associated with the water system. The study focuses on China's urban water system, which is most well represented in the literature and is of particular interest due to rapid urbanisation. Secondly, the review aims to present the most feasible and applicable methods in which China can reduce net energy for water, either through efficiency measures (e.g. pumping efficiency), energy recovery (e.g. recovery of organic energy) or energy offsetting (e.g. production of solar power).

Abbreviations: AAO, anaerobic-anoxic-oxic; AO, anoxic-oxic; AS, activated sludge; BPBT, booster pump and break tank; COD, chemical oxygen demand; COP, coefficient of performance; CHP, combined heat and power plant; EPB, entirely pressurised booster; GDP, gross domestic product; GWe, gigawatt electric; LT-MED, low temperature multi-effect distillation; n/a, not available or not applicable; SBR, sequencing batch reactor; SNWTP, South-North Water Transfer Project; SS, suspended solids; SWRO, seawater reverse osmosis; WSHP, water source heat pump

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1.1. China's urban water system

The main sources of water for urban areas of China are locally sourced surface water and groundwater. In response to problems of water scarcity, these sources are supplemented with reclaimed wastewater, desalinated water, water transferred between provinces and, in some cases, rainwater harvesting. In terms of water sourcing, groundwater abstraction and water transfer that involves lifting are the most energy intensive methods. Treatment tends to be a low energy user within the water supply process, unless source water is seawater or wastewater. Distribution is a major energy user, particularly in cases where users reside in the upper levels of high-rise buildings.

Wastewater is generally treated in aerobic activated sludge plants in China, with the main technologies being anaerobic-anoxic-oxic, oxidation ditch, traditional activated sludge, sequencing batch reactor and anoxic-oxic. Wastewater may pass through pretreatment and primary treatment, although primary sedimentation is not used in many cases. Main energy users for conventional wastewater treatment are influent pumping and aeration. An increasing volume of wastewater goes through tertiary treatment in China, which may involve the standard process used in drinking water treatment (i.e. coagulation, filtration and sedimentation) or more advanced processes (i.e. membrane filtration). Total energy use for tertiary treated wastewater varies according to the treatment processes but tends to be much greater than energy for secondary treated water. Sludge from primary and secondary stages is generally thickened, conditioned and dewatered. Within sludge treatment, dewatering is the highest energy user, unless plants use anaerobic digestion, in which case anaerobic digestion is the highest energy user but can lead to a net energy gain. Most treated sludge is landfilled or dumped without being stabilised, which means direct emission of greenhouse gases is the major issue within sludge disposal.

2. Water supply

The total volume of water supplied in China and the energy used to supply it have both increased over the last 15 years. Electricity used for water supply increased from 8.9 billion kWh in 2001–12 billion kWh in 2014 and the volume of water supplied increased from 27 billion cubic metres in 2001–41 billion cubic metres in 2014 [10,11]. The electricity use per cubic metre of water supplied has decreased slightly over this time, from 0.33 kWh/m³ to 0.29 kWh/m³ [10,11]. Fig. 1 shows the electricity intensity of urban water supply at provincial level for 2011. Electricity use for urban water supply was estimated to be 0.22% of

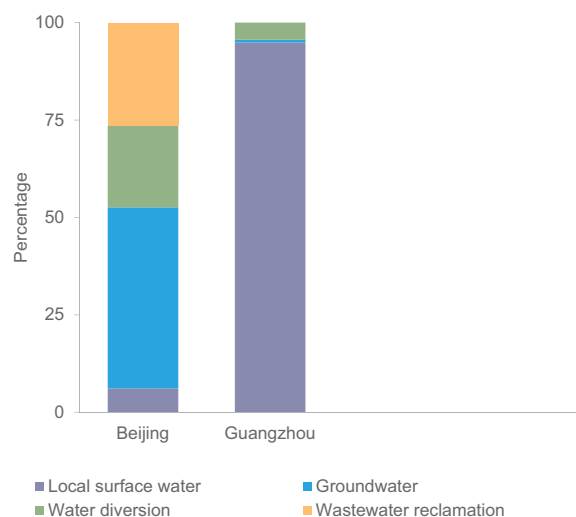


Fig. 2. Water sources used in Beijing (northern China) and Guangzhou (southern China) in 2015 [14,15]. Water diversion involves long-distance transfer via the SNTWP in the case of Beijing and short-distance transfer from Dong River in the case of Guangzhou. 'Emergency water supply' is listed as a fifth source of water for Beijing by the Beijing Bureau of Statistics, but this is excluded in the figure.

China's total electricity use in 2011 [12].

2.1. Sourcing water

2.1.1. Groundwater abstraction

Groundwater water accounts for just under one fifth of water withdrawals in China, with reliance on groundwater varying significantly between north and south. The country withdrew a total of 594.2 billion cubic metres of fresh water in 2015, of which 484.9 billion cubic metres (81.6%) was surface water and 106.9 billion cubic metres (18.0%) was groundwater [13]. Of the total water withdrawn in 2015 (598.1 billion cubic metres, including non-fresh water), 79.4 billion cubic metres (13.3%) was withdrawn from the public distribution network in urban areas (including for use by urban industries and urban agriculture) [13]. Fig. 2 shows the significant difference in groundwater use between two major cities in the north and south of China.

Most of the energy used for groundwater extraction is for pumping

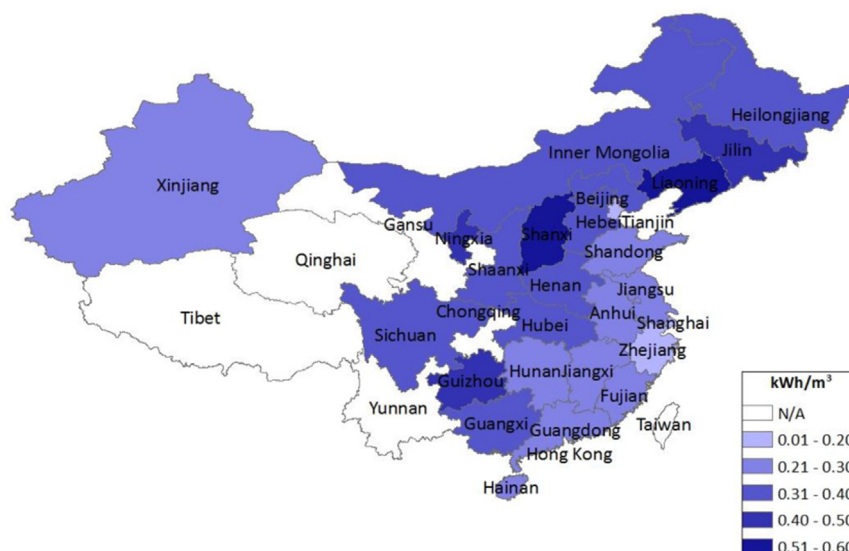


Fig. 1. Energy intensity of urban water supply in China in 2011 [12].

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