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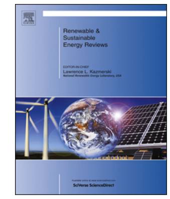

Energy and water autarky of wastewater treatment and power generation systems

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ABSTRACT

The energy-water nexus of the water supply, wastewater treatment and power generation systems has been well discussed. It is very clear that one source cannot be produced or supplied without involving the other source. Since the two systems are intertwined with mutual needs, it is difficult to resolve the issues associated with them in isolation. However, combined solutions through integrated approaches may not be feasible in all situations. Therefore, it is important to consider the energy or water autarky (self-sufficiency) of these systems. If these systems can achieve autarky for the energy and water needs independently, such configurations can be considered sustainable. This review paper presents the energy and water needs for water supply, wastewater treatment, and power generation systems and critically examines the potential opportunities for achieving energy and water autarky in these systems. A detailed view of the water supply and wastewater treatment systems' energy footprint was presented and similarly the water footprint of various power plants. Different approaches for achieving energy autarky in the wastewater treatment systems as well as approaches for water autarky in the power generation systems were discussed. It is imperative that future developments should consider an integrated design approach to improve the overall system autarky by communicating between the two individual systems, by considering synergistic energy-water production, by collaborating resources planning and energy-water infrastructure synergies supported by science and system-based natural resource policies and regulations.

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1. Introduction

Providing affordable drinking water sources and reliable wastewater treatment have become major challenges in many parts of the world [1]. Escalating energy demands for wastewater treatment due to population growth and high living standards and the water demands for power generation combined with environmental degradation present complex and intertwined concerns for many local governments [2,3]. On the other hand, water withdrawals for various uses have increased by 2–3 times that of population growth mainly linked with high living standards and urbanization [4]. It is important now to examine the autarky of the individual systems in terms of energy and water resources. The autarky of the system defines the use of external sources required to sustain the processes intended for certain benefits. For example, wastewater treatment requires between 0.3 and 0.6 kW h/m^3 while the same contains an energy content equivalent to 10 times that required for treatment [5–7]. Therefore, it is logical and rational to develop process configurations that would allow for extraction of this hidden energy to improve the self-sufficiency of the processes. Similar approaches can be implemented for power generation systems as well. In this review article, the potential for self-sufficiency of water-energy systems to provide a sustainable solution is discussed. The self-sufficiency of these systems can be defined as the ability to support each other with minimal dependence on new resources. Utilizing renewable energy sources would further advance their independence from fossil-derived electricity. This paper will first describe the energy usage patterns in water and wastewater treatment systems and the water requirements for power generation systems followed by an analysis and discussion of potential pathways for achieving autarky among the systems for both water and energy production.

2. Energy for water supply and wastewater facilities

Out of 200,000 drinking water treatment systems in U.S., about 25% of the systems serve 25 or more people throughout the year [8]. About 85% of the U.S. population is served by nearly 5% of large-scale drinking water systems; the remaining 95% include a large number of small and very small systems serving 3300 persons or fewer. Most of these systems are owned and operated by Public agencies while a small number are privately operated. On the other hand, over 75% of the U.S. population (~223 Millions) is served by nearly 16,583 public wastewater treatment plants [9]. Nearly 70% of the facilities are small, serving only 10% of the U.S. population and 22% are large (with flow greater than 1 million gallons per day, MGD) and serve over 85% of the population. Both water and wastewater systems require energy in the form of electricity for collection, conveyance, treatment, and distribution for end use or consumption and disposal.

Fig. 1 shows the range of energy requirements for treating different water sources. Conventional water treatment process via coagulation-flocculation-sedimentation-filtration involves energy consumption between 0.25 and 1.0 kW h/m^3 from river water and groundwater sources and most of it accounted for pumping, transportation and distribution. It is interesting to note that the wastewater treatment requires energy in the range of 0.5–2.0 kW h/m^3,

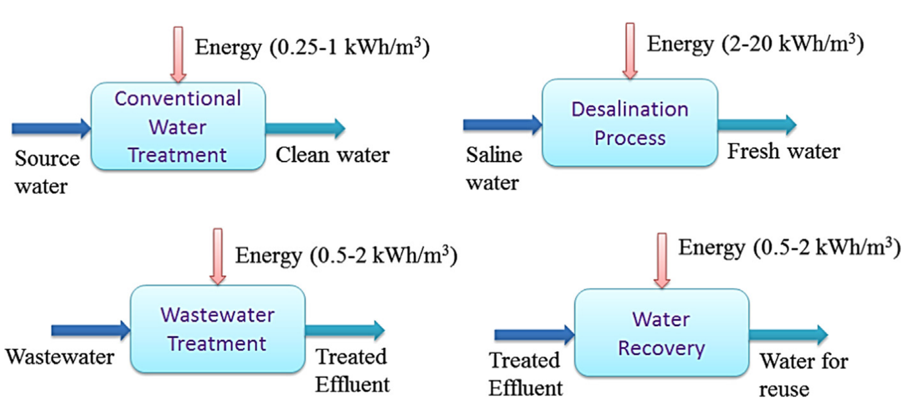

Fig. 1. Energy requirements for water production from different water sources (1 kW h/m^3 = 12,922 BTU/1000 gal).

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