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Energy requirements for water production, treatment, end use, reclamation, and disposal

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ABSTRACT

Energy is consumed at every stage of the cycle of water supply, treatment, use and disposal. The intensity of energy consumption (kW h/m^3) depends upon the specific technologies applied at each stage of the water cycle. For some technologies, the intensity may be relatively low, whereas the intensity of other technologies is substantially greater. This report surveys the available literature on energy intensity for water use in the municipal and agricultural sectors and separates the process into several stages. Water supply, water treatment, residential end use, wastewater treatment, and agriculture end use are considered. Representative values of the energy consumed per unit water are given for a broad range of processes. Water extraction and pumping from ground and surface sources is considered. The energy intensity of treatment required for different types of water source is found to vary widely between the extremes of relatively fresh surface waters, which use energy mainly in pumping, and seawater, which requires desalination. Energy usage for different methods of irrigation including pressurized as well as surface irrigation is studied. The energy intensity of residential end use is very high relative to other parts of the water supply cycle. Processes such as heating water, washing clothes and dishes, and cooking are briefly studied within the water end-use stage. Hot water usage is responsible for making end use the most energy intensive stage of the water cycle. Hot water use in different buildings is briefly reviewed. Wastewater treated with various processes is considered, and the energy intensity is found to be highest when advanced wastewater treatment methods are applied. Energy consumption in the agricultural sector, which is principally related to irrigation pumping, is generally of lower energy intensity than for the municipal treatment or end use.

Contents

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1. Introduction

Water is among the most basic and essential of human needs. Human beings not only consume water directly, but also use it in the production of food, for washing, sanitation, and for various industrial and domestic conveniences. The balance of water supply and demand is affected regionally by a broad range of factors including population growth, increasing urbanization, intergovernmental relations, political and policy choices, social factors, technological growth, and uncertainties of climate [1,2]. In addition to these issues, water consumption directly affects energy consumption. This energy consumption is the focus of the present paper.

The development of today's water treatment and distribution systems has been characterized by the US National Academy of Engineering as one of the greatest engineering achievements of the 20th century [3]. The infrastructure that provides water for agriculture, domestic consumption and sanitation requires extensive treatment and distribution systems that consume significant amounts of energy for pumping and purification. Further, various end uses of water, such as water heating, washing clothes and dishes, showering, and food preparation consume substantial amounts of energy. Water conservation is therefore directly linked to energy conservation. Alternative choices of water supply, treatment, end use and reuse can have very different implications for energy demand.

The "water–energy nexus" has garnered much attention recently. It includes both the energy consumption of water supply mentioned above and the water consumption of energy production processes [4–8]. Perrone et al. [5] proposed a "water–energy nexus model" to analyze the energy expended by a community to extract, treat, and discharge water as well as to analyze the amount of water used in the production of energy. In the present article, the consumption of energy for production, treatment, distribution, end-use, reclamation and disposal of wastewater is assessed taking into account processes, appliances and technologies.

1.1. Present scenario of water use in different sectors

Table 1 shows the water withdrawals, in cubic kilometers per year, by various sectors of use from various regions of the world. The contrasts are significant. Asia's water consumption is largely agrarian while North America and Europe withdraw more water for the industrial sector [9,10], which includes water withdrawn for thermal power plant cooling. From Table 1, industrial water use including power production accounts for 20% of total worldwide water use while use in the residential sector uses only 10% [9].

1.2. Background on water–energy life cycle

Wilkinson [8] outlined the major energy consuming components in the water life cycle. Since then, several studies have been

Table 1
Water withdrawals in different sectors [9].

Region	Available surface and ground water resources	Total water with drawn	**Volume of water withdrawals (Gm^3/year)**					Withdrawal as percent of renewable resource
			Agriculture		Industry		Domestic	
			Volume	Percent	Volume	Percent	Volume	
Africa	3,936	217	186	86	9	4	22	5.5
Asia	11,594	2378	1936	81	270	11	172	20.5
Latin America	13,477	252	178	71	26	10	47	1.9
Caribbean	93	13	9	69	1	8	3	14
North America	6,253	525	203	39	252	48	70	8.4
Oceania	1,703	26	18	73	3	12	5	1.5
Europe	6,603	418	132	32	223	53	63	6.3
World	43,659	3829	2663	70	784	20	382	8.8