Water, Energy, and Soil Sustainability

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Modern societies in developed nations have become accustomed to a readily available supply of both water and energy. Water and energy resources, however, are interrelated. The production of energy and clean water and are deeply intertwined: production of electricity requires water, and production of clean water requires electricity. Despite this interrelation, their influence upon each other has rarely been considered. A continuation of the same does not bode well for the future. Demand for both is growing while supply is constrained by limited resource availability, high costs, and the impacts of climate change. These linked problems are sometimes referred to as the "water–energy nexus"[1].

The US Census Bureau projects that the national population will balloon from 282 million people in 2000 to 364 million by 2030 and 420 million by 2050[2]. The US Department of Energy (DOE) estimates that total electricity consumption will grow at an annual rate of 1.3% per year or from 3821 billion kilowatt-hour (kWh) in 2006 to 5149 billion kWh by 2030[3]. If the projection is accurate it suggests that that national electricity demand will actually double before 2050.

The increased demand for electricity does not only stress energy supplies and resources. It places even greater stress on national water supplies and by association food production. The US Department of Interior calculates that due to an increasing frequency and duration of droughts throughout the country, demands for water in many basins will exceed available supply even in normal years, especially for those living on the West Coast (water shortages nation-wide can also result from low water quality due to toxic contamination, lack of availability due to salt water intrusion of aquifers, and low quality and lack of availability due to malfunctioning water pumping, purification, and treatment systems).

Increasingly, there are national calls for joint water and energy resource management. In the U.S., the Energy and Water Research Integration Act, for example, was formulated ''to ensure consideration of water intensity in the Department of Energy's energy research, development, and demonstration programs to help guarantee efficient, reliable, and sustainable delivery of energy and water resources''[4]. Despite these efforts, government and state agencies are fragmented[5] and many federal research agencies, as well as various academic and professional researchers, have each warned that power plant additions could complicate water management efforts[6].

These warning are backed up by ominous statistics. Thermoelectric power plants – power stations that combust coal, oil, natural gas, biomass, and waste to produce electricity, or fission atoms in a nuclear reactor – use water by ''consuming'' and ''withdrawing'' it. The industry average is estimated 25 gal of water for every kWh generated, or 0.5 gallons consumed and 24.5 withdrawn per kWh[7]. Relying on industry averages to assess likely water use, coal-fired power stations generated 1957 billion kWh in 2006, meaning that they used almost 58 trillion gallons of water. Nuclear facilities generated 787 billion kWh and used about 34 trillion gallons. Natural gas plants produced an additional 877 billion kWh and consequently used slightly more than 12 trillion gallons [8]. Utilizing the most recent data available from the US Geologic Survey, thermoelectric power plants used more than 190,000 million of gallons of water per day, or 47% of the country's total[9]. This means that on average thermoelectric power plants used more water than the entire country's agricultural and horticultural industry, which covers the nation's irrigation, frost protection, field preparation, cropping, self-supplied landscaping, and maintenance of golf courses, parks, nurseries, cemeteries, and landscaping needs.

To put these differing numbers in perspective, researchers from the National Energy Technology Laboratory projected that Americans use about three times as much water turning on their lights and running appliances than they use by taking showers or watering their lawns[10]. How much water is available? This is difficult to estimate exactly as water production and distribution has been localized on a regional level and thus a market based accounting, as exists for crude oil, does not exist. It has been estimated, however, that droughts are likely to affect the 66% of Americans whose communities depend on surface water, most severely occurring in the Southwestern part of the United States[11].

The State of Hawaii provides a unique laboratory for efforts that address the water-energy-food nexus. Isolated, surrounded by sea water and without any carbon based energy supplies, Hawaii will face the full brunt of energy-water-food nexus this century. Recently, the University of Hawaii at Manoa awarded a million dollar seed grant to a team of university researchers to create a program on Water, Energy, and Soil Sustainability (WESS). Managed out of the Hawaii Natural Energy Institute, the program is evaluating technologies both in the lab and at demonstration scale with partner companies that cogenerate energy and clean water or provide low-energy solutions to water treatment or disinfection. We are also exploring methods to convert carbon solid wastes into soil amendments that improve soil productivity and water retention. These on-going projects will be discussed along with highlights of potential future applications relevant to electrochemists.

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