22. Water security at the energy crossroads

Edward Byers
Newcastle University, United Kingdom

Water, sanitation, and energy are undoubtedly keystone components of civil infrastructure that enable cities to support populations; they are the foundations of civilisation. The growth of megacities is, however, rapidly depleting water resources and leading to declining levels of water security across the world. Failure of critical infrastructure services, such as water and energy, can cripple a city in a matter of hours and leave millions vulnerable.

Yet that which is most dear to us is now often subject to complex interactions before we are able to access it. Energy is used for pumping, transport and treatment of water and wastewater; water is used through most stages of energy production and generation. But most of the resources used are non-renewable, often involve pollution and bring us closer to the planetary boundaries defining the safe operating space of humanity (Rockström et al. 2009). Should we continue propagating the interdependencies between energy and water or should, in some cases at least, we be working to decouple these two crucial resources?

In the current system, increasing demands on one usually means increasing demands on the other. But there are alternatives and, hence, water security finds itself at the 'energy crossroads' through the multitude of options available for alleviating scarcity issues; options which may use disparate levels of energy. On the other hand, water security also meets energy at the crossroads in a future that is partly governed by the water-intensity of future energy systems.

Increasingly, the analysis of water supply options is conducted considering the energy intensity of exploiting that resource. A variety of capital-intensive options to meet marginal demands may be evaluated, including desalination, wastewater recycling, inter-basin transfers and increased storage capacity. The uncertainties in the performance and utility of each option may, however, be large. These variabilities are driven by the energy sector and stem from variation in demand growth, energy price fluctuation and dependency on climate-vulnerable water resources. These uncertainties, amongst others, present a challenge in predicting future operational expenditure, the majority of which is usually energy costs. In the United Kingdom, higher water-quality standards have resulted in a doubling of energy use since the 1990s, and this is set to rise (Council for Science and Technology (CST) 2009); lower river flows during the more frequent droughts projected under climate change will require more stringent wastewater treatment as receiving bodies will have less capacity to dilute effluent (Hall et al. 2012).

Supply	Energy intensity kWh/Ml	Source and notes
Conventional	500-900	Water UK 2010; Perrone et al. 2011. Variable on plant size.
Water recycling	2,500-6,500	Water UK 2010; Perrone et al. 2011. Depends on level of treatment, Primary, Secondary, Advanced.
Desalination • **Brackish** • **Sea water**	 9,500-22,000 34,000100,000	Perrone et al. 2011; WRA (2011) Variable on water salinity and technology, and some of the energy demand can be met through waste heat or solar PV.
Imported water	0.04	Derived from Sampson et al. 2007, into kWh/Ml/km distance/ ΣΔm positive elevation from source to treatment.

Figure 1: Ranges of energy intensity for different water supply options can vary by orders of magnitude. With depleted resources, however, energy intensive supply is increasingly competitive

Source: See table.

There is, however, great benefit in decoupling this nexus of water and energy use. One irony is that wastewater has a chemical energy content higher than the energy required to treat it, the former just needs to be harnessed (Heidrich et al. 2011). Increasingly, anaerobic digestion (AD) is being deployed around the world in both high-tech and low-tech configurations. AD is the breakdown of biodegradeable matter in the absence of oxygen and can be used to treat both solid and liquid waste. Biogas is one of the main byproducts and consists mostly of methane, which can be burnt for electricity generation, heating or cooking. AD applications in developed countries will play a small part towards energy security and low carbon energy supply, whilst flipping the energy balance of wastewater treatment. In less developed countries, AD can provide a meaningful step towards proper sanitation and associated health benefits, whilst free biogas used for cooking drastically reduces indoor air pollution, a killer of 1.5 million women and children each year (World Health Organization (WHO) 2006). Conversely, seawater desalination and long-distance transport and pumping, such as the California State Water Project and the Central Arizona Project, result in roughly ten times the energy intensity of conventional treatment facilities (Water Reuse Association (WRA) 2011) due to the long distances, evaporation losses and changes in elevation.

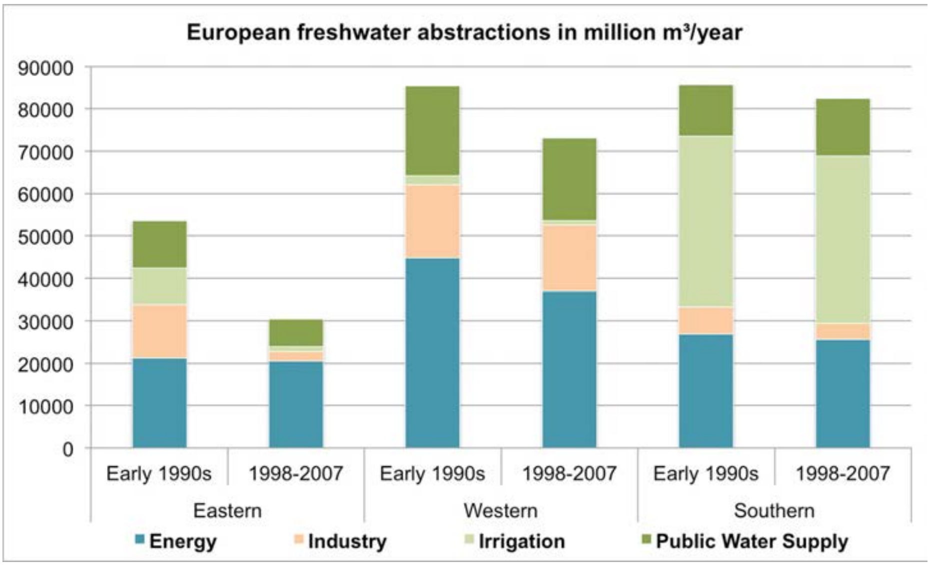

Figure 2: Freshwater abstractions by the energy sector are decreasing, yet the proportions remain substantial

Source: EEA 2010.

In many countries, energy is produced by thermoelectric power stations on surface waters abstracting proportions of cooling water far exceeding those taken for public water supply and often matching agriculture (United Kingdom: 56 per cent, United States: 41 per cent, Europe: 45 per cent; see Figure 2 for further details on Europe). Most is returned, but evaporative losses from cooling towers can reduce this amount by 75 per cent. Energy demands are growing, thermal efficiencies are not improving rapidly enough, and power plants with carbon capture and storage (CCS) increase water consumption in the order of 80 per cent (National Energy Technology Laboratory (NETL) 2009). The strong prospects for shale gas and coal with CCS look set to lock electricity supply into another half-century of water-thirsty power plants. Even the fuels used require water for extraction and processing, leading to contamination. In recent years, thermoelectric nuclear and fossil fuel plants in the United States, Europe and China have faced output reduction and even shutdown due to low river flows and high water temperatures (Averyt et al. 2012; Pan et al. 2012 *Economist* 2013), a problem that is expected to worsen with climate change (van Vilet et al. 2012). Alternatives to water-intensive energy supply do exist, mostly in the form of some renewables and more strategic siting of power stations and grid balancing. But in order to play the crucial role of increasing both energy and water security, the benefits of the options need to be recognised in planning processes, alongside caveats that may include lower efficiencies and higher costs.

Capital investment projects in both sectors lock in decisions for decades that span considerable uncertainty. Short-term demand reductions and market mechanisms can ameliorate cross-sector risks, but the resource interdependencies will remain. Thus long-term planning that reduces critical resource interdependencies and improves performance under wide ranges of uncertainty, such as climatic changes or geo-political risks, is needed.

In its current state, the energy sector poses unacceptable risks to the public water supply and agriculture sectors that must be addressed with robust decisions encompassing sustainability, security of supply and affordability. Whilst the challenges facing each sector of the water–energy–food nexus are great in themselves, decision-makers must recognise the win-win-win opportunities that are presented by tackling them together, which are elegantly summed up by Wangari Maathai (2012), 'Our planet is finite, our fates are intertwined, our choice is clear — stand together or fall divided.'

Edward Byers is a PhD student at the School of Civil Engineering & Geosciences at Newcastle University and Topic Editor, Energy of the Global Water Forum. His research focuses on UK infrastructure transitions in the water-energy nexus. He is affiliated with the Infrastructure Transitions Research Consortium and the Tyndall Centre for Climate Change Research and can be contacted at e.a.byers@ncl.ac.uk.

References

Averyt K., Fisher J., Huber-Lee A., Lewis A., Macknick J., Madden N., Rogers J. and Tellinghuisen, S., 2011. *Freshwater Use by US Power Plants: Electricity's thirst for a precious resource*, Union of Concerned Scientists, Cambridge, MA.

Council for Science and Technology (CST), 2009. 'Improving innovation in the water industry: 21st century challenges and opportunities', United Kingdom. Available from: http://www.bis.gov.uk/assets/cst/docs/files/whats-new/09-1632-improving-innovation-water-industry.

Economist, 2013. 'Water: all dried up'. 12 October. Available at: http://www.economist.com/news/china/21587813-northern-china-running-out-water-governments-remedies-are-potentially-disastrous-all.

European Environment Agency (EEA), 2010. 'Water abstractions for irrigation, manufacturing industry, energy cooling and Public Water Supply: early 1990s and 1997–2007', Available from: http://www.eea.europa.eu/data-and-maps/figures/water-abstractions-for-irrigation-manufacturing-industry-energy-cooling-and-public-water-supply-million-m3-year-in-early-1990s-and-the-period-1997.

Hall, J.W., Henriques, J.J., Hickford, A.J., Nicholls, R.J., 2012. *A Fast Track Analysis of Strategies for Infrastructure Provision in Great Britain: Technical report*. Environmental Change Institute, Oxford.

Heidrich, E.S., Curtis, T.P. and Dolfing, J., 2011. 'Determination of the internal chemical energy of wastewater', *Environmental Science & Technology* 45(2):827–32.

Maathai, W., 2012. 'Cancun must be about more than climate change', *Guardian*. Available from: http://www.guardian.co.uk/commentisfree/cif-green/2010/nov/26/cancun-climate-change-conference.

National Energy Technology Laboratory (NETL), 2009. 'Water requirements for existing and emerging thermoelectric plant technologies'. US Department of Energy.

Pan, L., Liu, P., Ma, L., Li, Z., 2012. 'A supply chain based assessment of water issues in the coal industry in China', *Energy Policy* 48:93–102.

Perrone, D., Murphy, J. and Hornberger, G.M., 2011. 'Gaining perspective on the water energy nexus at the community scale', *Environmental Science & Technology*, 45(10):4228–34.

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin III, F. S., Lambin, E., Lenton, T.M., Scheffer, M., Folke, C., Schellnhuber, H., Nykvist, B., De Wit, C.A., Hughes, T., van der Leeuw, S., Rodhe, H., Sörlin, S., Snyder, P. K., Costanza, R., Svedin, U., Falkenmark, M., Karlberg, L., Corell, R.W., Fabry, V.J., Hansen, J., Walker, B., Liverman, D., Richardson, K., Crutzen, P. and Foley, J., 2009. 'Planetary boundaries: exploring the safe operating space for humanity', *Ecology and Society* 14(2):32.

Sampson, D.A. and Gober, P., 2007. 'The central Arizona water-energy nexus : WaterSim 3.5.5', Global Institute of Sustainability, Arizona State University. Available from: http://sustainability.asu.edu/docs/symposia/symp2009/Sampson_Gober.pdf.

van Vilet, M.T.H., Yearsley, J.R., Ludwig, F., Vögele, S., Lettenmaier, D.P. and Kabat, P., 2012. 'Vulnerability of US and European electricity supply to climate change', *Nature Climate Change* 1546, Advance Online Publication, 3 June 2012. Available from: 10.1038/NCLIMATE1546.

Water Reuse Association (WRA), 2011. 'Seawater desalination power consumption', Available from: http://www.watereuse.org/sites/default/files/u8/Power_consumption_white_paper.pdf.

Water UK, 2010. 'Sustainability indicators 2009/2010', London. Available from: http://www.water.org.uk/home/news/press-releases/sustainability-indicators-09-10/sustainability-2010-final.pdf.

World Health Organization (WHO), 2006. 'Fuel for life. Household energy and health', Geneva. Available from: http://www.who.int/indoorair/publications/fuelforlife.pdf.

This text taken from *Global Water: Issues and Insights* by R. Quentin Grafton, Paul Wyrwoll, Chris White and David Allendes, published May 2014 by ANU Press, The Australian National University, Canberra, Australia.