A thirst for power: A global analysis of water consumption for energy production

Edward Spang
University of California, Davis, United States

Discussion Paper 1246 October 2012

This article analyzes the water requirements of national-level energy systems. The water consumption for energy production (WCEP) indicator is defined and calculated across 158 countries. The results show that heavy producers of fossil fuels and biofuels demonstrate greater intensity of energy-based water consumption.

Keywords: water-energy nexus, water security, energy systems, energy policy, water consumption, fossil fuels, biofuels, renewable energy.

Water and energy resource systems are fundamentally interrelated. Secure and reliable access to both resources is critical to basic survival, as well as ongoing economic development, at all scales and in every region of the world. At the most basic level, water is required in the production of energy, and energy is required in the treatment and transport of water – a linked relationship known as the water-energy nexus. While both sides of the water-energy nexus merit attention for improving resource use, this research effort focuses on the water requirements of energy systems and the associated implications for national water security.

As competition for finite freshwater resources intensifies around the world, it is increasingly important to balance the demand for water across multiple sectors while also protecting ecosystems.[1] Understanding the water demand of energy systems is fundamental to overall national water security since the production of energy requires significant

Suggested Citation: Spang, E. 2012, 'A thirst for power: A global analysis of water consumption for energy production', GWF Discussion Paper 1246, Global Water Forum, Canberra, Australia. Available online at: http://www.globalwaterforum.org/2012/10/23/a-thirst-for-power-a-global-analysis-of-water-consumption-for-energy-production/.

quantities of freshwater. While agricultural demand dominates overall demand for water in many regions of the world,[2] the demand for water from the energy sector can be a major competitor. In the United States, it is a relatively even split between water withdrawals for irrigating crops (40% of total) and for cooling thermoelectric power plants (39%).[3] Further, the division between agricultural and energy-based demand for water is no longer straightforward as irrigated crops are increasingly being converted to biofuels in many regions.[4]

The quantity of water consumed by the energy sector varies substantially by the technology deployed for fuel extraction and processing (fossil fuels, nuclear fuels, and biofuels) as well as electricity production (thermoelectric and renewable technologies). As a regional portfolio of energy production technologies changes or expands, there is an associated fluctuation in the burden on local water resources. Figure 1 (see footnotes) represents a consolidation from the literature of water consumption estimates for a variety of energy technologies (note that the estimates are provided in log scale to show variability within and across technology categories).

Given the potential impacts of energy policy decisions on regional water security, the application of metrics to assess the water burden of national energy portfolios is underdeveloped. Most of the literature has focused on estimating the water consumption of specific energy technologies (see sources listed for Figure 1); country-level or regional analyses of water consumption across a complete energy portfolio;[13,14] or, a global analyses of water consumption by a single energy type.[15] However, a clear estimation of water consumption for complete national energy portfolios at the global scale does not currently exist.

This research addressed this knowledge gap by synthesizing and expanding previous work to develop a global distribution of water consumption by national-level energy portfolios. The water consumption for energy production (WCEP) indicator was defined and calculated to quantify the relative water use of 158 national energy systems. WCEP is an estimation of freshwater consumption across all energy categories, including fossil fuels, nuclear fuels, biofuels, and electricity production. Hydroelectricity is not included in the analysis because its associated water consumption (often defined as the estimated evaporation from the reservoir) is only partially linked to energy consumption. The majority of dams serve multiple purposes, including the essential water security services of flood control and water storage.[16] An overview of the global results of the WCEP assessment is provided in map form in Figure 2 below.

The results of the research estimate global WCEP at approximately 45 billion cubic meters of water per year. Of course, there is high variability in the WCEP across the 158 countries that were assessed (ranging from nearly zero to 12.6 billion cubic meters). As expected, the countries that are both larger in size and economic activity had the highest WCEP values. In terms of the per capita estimates for WCEP, the countries that were heavy producers of fossil fuel or biofuels demonstrated greater intensity of energy-based water consumption (see Figure 3 in footnotes). These results suggest that the economic imperative to develop fossil fuels drives higher WCEP, even in countries that lack sufficient water supplies. Meanwhile, biofuels require so much water that any national commitment to their production has significant water consumption implications.

While these results are based on a comprehensive review of currently available data, future research in this area could be significantly enhanced through better data and widespread adoption of consistent reporting mechanisms. Additional opportunities to expand the field include increasing the resolution of the study regions, characterizing WCEP trends over time, and exploring innovative policy approaches to managing national WCEP effectively.

This research contributes an improved set of metrics to characterize the baseline conditions of integrated water-energy systems. By benchmarking water consumption for energy to standard measures, policy makers can better understand and track the status of this coupled system. They are then able to set targets to minimize water consumption or at least understand some of the water implications of particular energy policy initiatives. Given the critical role that the monitoring of greenhouse gas emissions has played in shaping energy portfolios, it is time to similarly incorporate water consumption implications into energy portfolio planning.

The author of this article was awarded first prize in the 2012 Global Water Forum Emerging Scholars Award. The other finalists' entries and details regarding the Award can be found here.

A thirst for power: A global analysis of water consumption for energy production

Figures

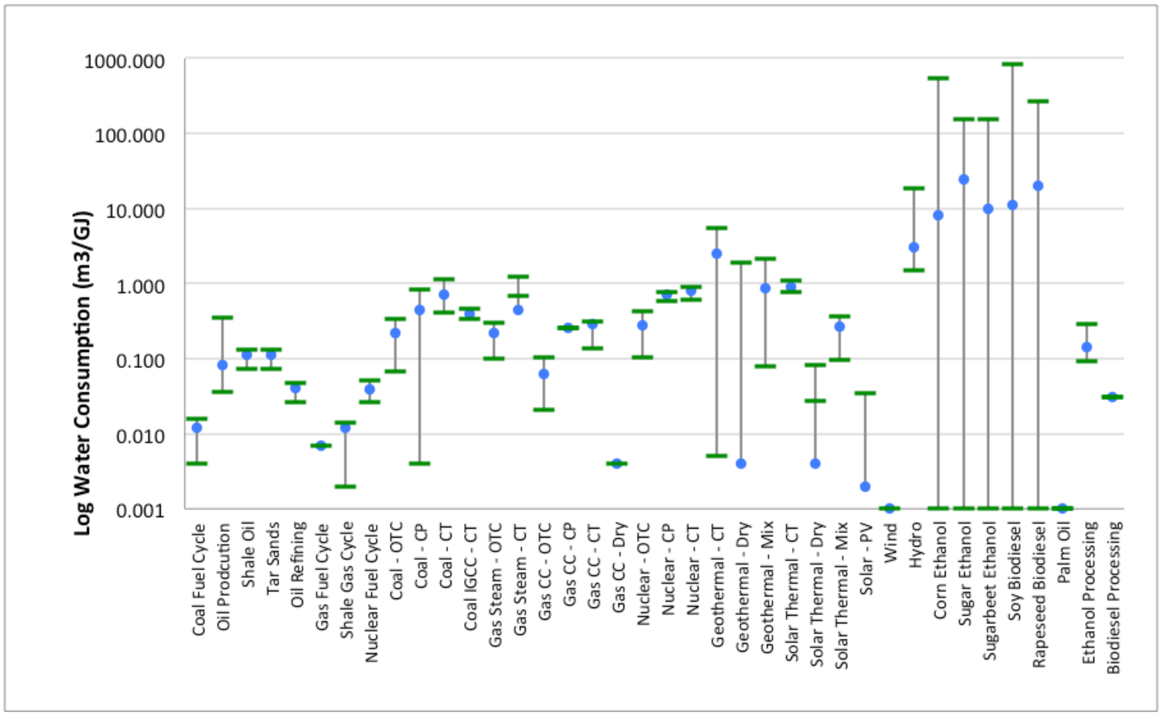

Figure 1. Water consumption coefficients for energy technologies (log scale)[5,6,7,8,9,10,11,12]

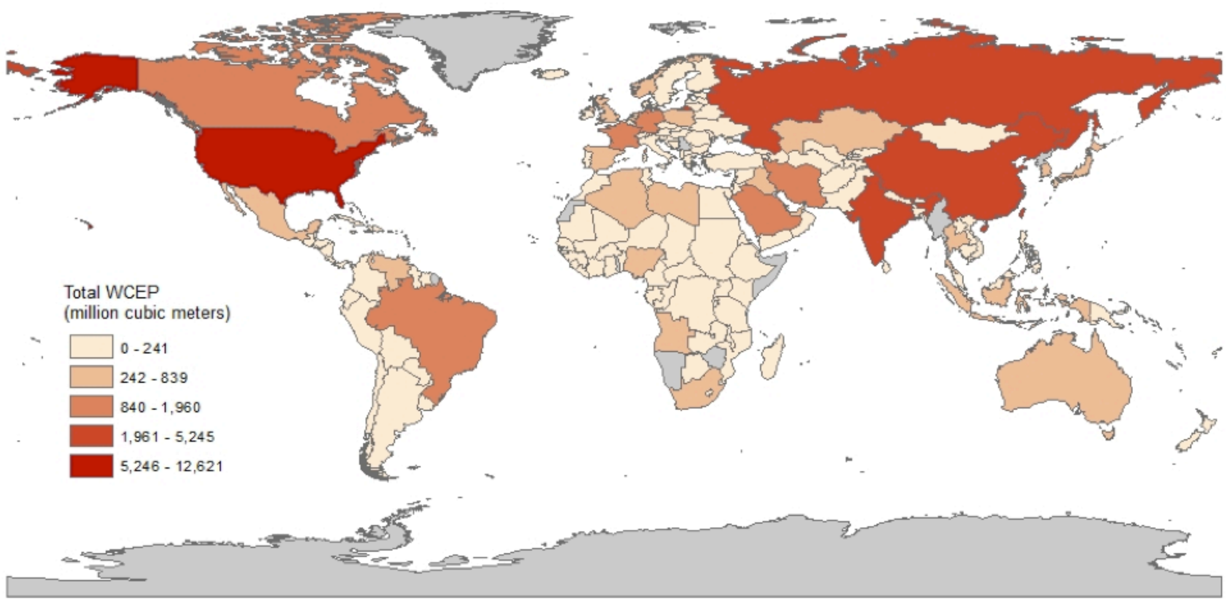

Figure 2. International results map for WCEP calculations

GLOBAL WATER FORUM

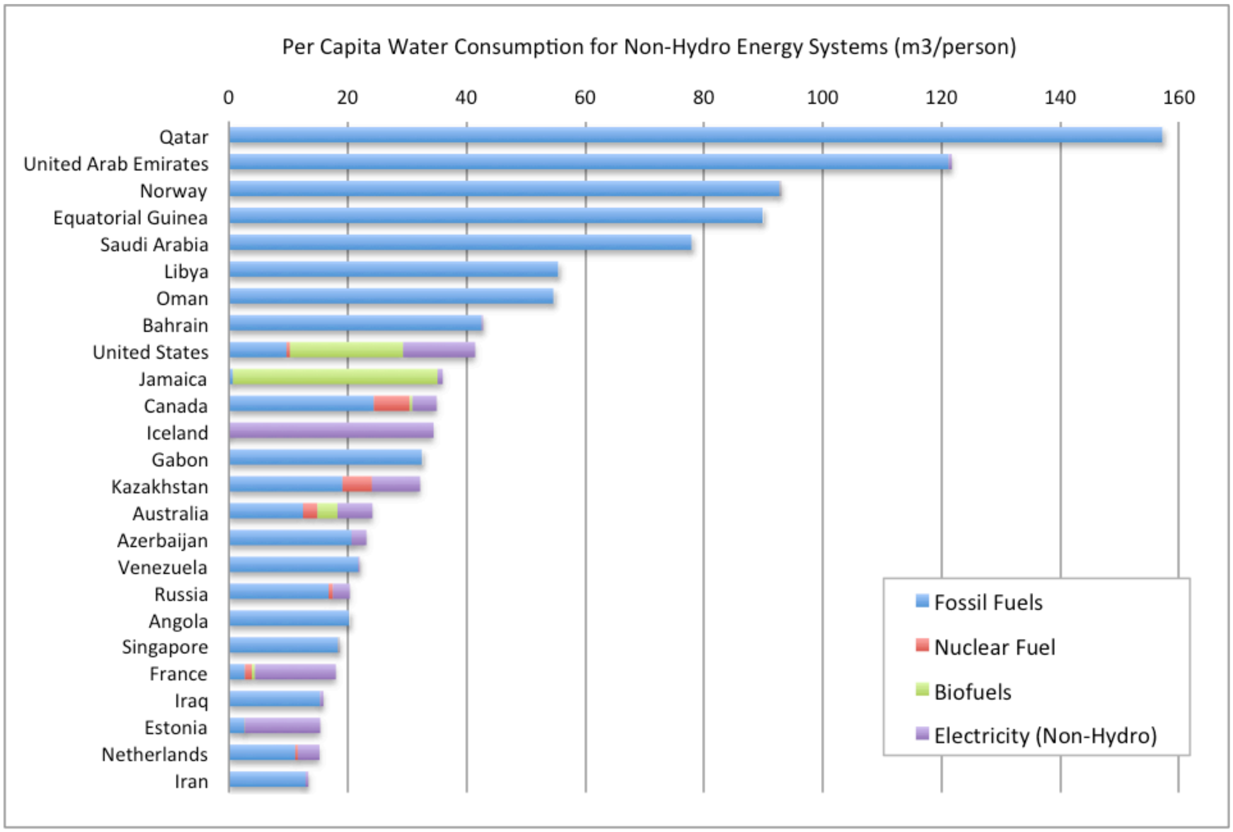

Figure 3. Per capita water consumption for non-hydro energy systems (m³/person)

References

1. Palaniappan, M., and P. H Gleick. "Peak Water." In *The World's Water*. Vol. 2009. Washington, D.C.: Island Press, 2008.
2. UNESCO. 2003. *Water for People – Water for Life*. World Water Development Report. New York: UNESCO : Berghan Books.
3. DOE. 2006. *Energy Demands on Water Resources: Report to Congress on the Interdependency of Energy and Water*. Washington, D.C.: U.S. Department of Energy (DOE).
4. Gerbens-Leenes, W., A. Y. Hoekstra, and T. H. van der Meer. 2009. "The Water Footprint of Bioenergy."*Proceedings of the National Academy of Sciences* 106 (25) (June 23): 10219 –10223. doi:10.1073/pnas.0812619106.
5. Gleick, P. H. 1994. "Water and Energy." *Annual Reviews in Energy and the Environment* 19 (1): 267–299.
6. Fthenakis, V., and H. C. Kim. 2010. "Life-cycle Uses of Water in U.S. Electricity Generation." *Renewable and Sustainable Energy Reviews* 14 (7) (September): 2039–2048.
7. Mekonnen, M. M, and A. Y Hoekstra. 2010. *The Green, Blue and Grey Water Footprint of Crops and Derived Crop Products*. Value of Water Research Report Series. Delft, The Netherlands: UNESCO.
8. Mielke, E., L. Anadon, and V. Narayanamurti. 2010. *Water Consumption of Energy Resource Extraction, Processing, and Conversion*. Discussion Paper. Discussion Paper Series. Harvard Kennedy School.
9. Macknick, J., R. Newmark, G. Heath, and K. C. Hallett. 2011. *A Review of Operational Water Consumption and Withdrawal Factors for Electricity Generating Technologies*. Golden, CO: National Renewable Energy Laboratory (NREL).
10. Wu, M., M. Mintz, M. Wang, and S. Arora. *Consumptive Water Use in the Production of Ethanol and Petroleum Gasoline*. Argonne, IL: Argonne National Laboratory (ANL), 2009.
11. NREL. "Energy Technology Cost and Performance." *National Renewable Energy Laboratory*, 2010.

http://www.nrel.gov/analysis/capfactor.html.
12. Mittal, A. *Energy-Water Nexus: Many Uncertainties Remain About National and Regional Effects of Increased Biofuel Production on Water Resources*. Washington, D.C.: Government Accountability Office (GAO), 2010.
13. DOE 2006.
14. Elcock, D. 2010. "Future US Water Consumption: The Role of Energy Production." *JAWRA Journal of the American Water Resources Association* 46 (3).
15. Vassolo, S., and P. Döll. 2005. "Global-scale Gridded Estimates of Thermoelectric Power and Manufacturing Water Use." *Water Resources Research* 41 (4).
16. Briscoe, J. "Water Security: Why It Matters and What to Do About It." *Innovations: Technology, Governance, Globalization* 4, no. 3 (2009): 3–28.

About the author

Dr. Edward Spang is the Program Manager for the Center for Water-Energy Efficiency (CWEE) at the University of California, Davis. CWEE is a first-of-its-kind academic center that seeks to research, develop, and disseminate efficient technologies and system-based policies for the integrated conservation of water and energy resources. His doctoral research focused on the link between water and energy resources at the global level, including the critical importance of improving the efficiency of resource use in both sectors. His previous work included targeted studies and projects within each sector. As Project Coordinator of the MIT-Portugal Green Islands Project, Dr. Spang worked on energy system planning towards an integrated, clean energy future for the Azores archipelago of Portugal in partnership with multiple universities, government agencies, NGOs, local communities and corporate partners. Previous academic research projects focused on regional case studies of water systems and opportunities for improved water resource management in Central and South America. Dr. Spang holds a BA degree from Dartmouth College and an MALD and PhD from the Fletcher School, Tufts University. He can be contacted at esspang@ucdavis.edu.

About the Global Water Forum

The Global Water Forum (GWF) is an initiative of the UNESCO Chair in Water Economics and Transboundary Governance at the Australian National University. The GWF presents knowledge and insights from leading water researchers and practitioners. The contributions generate accessible and evidence-based insights towards understanding and addressing local, regional, and global water challenges. The principal objectives of the site are to: support capacity building through knowledge sharing; provide a means for informed, unbiased discussion of potentially contentious issues; and, provide a means for discussion of important issues that receive less attention than they deserve. To reach these goals, the GWF seeks to: present fact and evidence-based insights; make the results of academic research freely available to those outside of academia; investigate a broad range of issues within water management; and, provide a more in-depth analysis than is commonly found in public media.

If you are interested in learning more about the GWF or wish to make a contribution, please visit the site at www.globalwaterforum.org or contact the editors at editor@globalwaterforum.org.

GLOBAL WATER FORUM

A thirst for power: A global analysis of water consumption for energy production

GLOBAL WATER FORUM