

# Introduction

At a very young age, children are taught that electricity and water don't mix. Every hair dryer sold in America has a tag attached to the cord warning of the dangers. While no one would dispute the wisdom of such caution, it is important to recognize that from a resources standpoint, energy and water are inextricably linked. As many have pointed out, it takes water to produce energy and it takes energy to deliver, treat and heat water.



In the winter of 2011, a group of faculty and students at Stanford University began to explore the relationship between water and energy. This broad topic has enjoyed almost 20 years of evaluation and analysis, and this group wanted to better understand what it is we currently know, what it is we don't know and what further research might contribute to informing the future management of both resources. Because the nature of both water and energy intersects with so many aspects of the economy, society and the environment, it became clear that one must approach these questions from an interdisciplinary perspective. Several meetings were held to explore ideas about what might be a helpful initial step, and what resulted is this literature review on the water and energy nexus. This review reflects the work of a number of people, but it is fundamentally a student product.

We began by exploring academic, government and private research, compiling more than 650 separate

publications. This is not an exhaustive list of research about the connections between water and energy, but we feel confident that we have identified and investigated the bulk of existing research. Once this literature was assembled, we set about organizing our review of the literature around two intertwining life cycles: water's use of energy and energy's use of water.

By organizing around these cycles, and in the case of water for energy around the different types and uses of energy, we were able to focus on the water and energy intensity of different steps, as well as the various technologies, economic factors and policies involved. Each of the individual sections of this report may be read independently or in sequence. The end users of both water and energy are generally the same, so our end use section (currently under development) brings the two life cycles together. We wish to especially acknowledge the work of Professor Robert Wilkinson of the Bren School of Public Policy, University of California at Santa Barbara, who graphically depicted the life cycle device for organizing discussions around the nexus of water and energy. Peter Gleick originally developed the analytical approach of the water and energy life cycle in 1994. Undoubtedly, there are some gaps in our approach and coverage of this subject, as well as some redundancies. We fully accept and acknowledge these shortcomings.

While we encourage readers to delve deeply into the review and corresponding analysis, we would like to point out several conclusions at the outset. The first of these is that much of the water and energy data

that underlie and support the research and analysis of this subject are old and out of date or have not even been collected. More data collection, monitoring and independent analysis need to be undertaken, particularly by the federal government. A second conclusion is that private industry and local agencies control a great deal of data and independent verification is extremely hard to achieve. A third conclusion is that, perhaps due in part to the limits of data and information, most researchers still rely on a small body of data and methods, in particular, from Gleick's seminal work in 1994. Lastly, it is clear that where there have been rapid advances in technology (e.g., hydraulic fracturing and

directional drilling), research and analysis have had a hard time keeping up.

In publishing this literature review, we wanted to produce something that helps describe a baseline of knowledge about the nexus of water and energy. As with any literature review, this document began to become obsolete almost immediately. New publications have been produced and meetings held since we concluded our research, and others will soon follow. Our hope is to update this literature review on a somewhat regular basis, capturing those elements we might have missed and others that are forthcoming.

## Acknowledgments

The principal author of this literature review was Paul Vidal de la Blache. The only thing more remarkable than the fact that Paul researched and wrote sections of this report in his second language of English is the fact that he did so while taking a full course load in fulfillment of his master's degree in engineering. Stacy Kourlis, a law student at the time, also wrote several subsections of this report, focusing on legal and policy issues.

We would like to deeply thank the reviewers, Emily Grubert, Heather Cooley, Laurie Park and Eric Byous, for their suggestions, which greatly improved this literature review. We did our best to reflect their suggestions; any failure to do so is entirely the fault of the editors.

Dr. Cynthia Truelove and Andrew Fahlund served as authors of several subsections as well as editors and advisers to the project. Dr. Truelove was the author of the executive summary. Janny Choy also served as an editor and leader of the design and production phase of this project. Jodee Schwan, Paula

Wetzel, Terry Nagel and several others contributed significantly to the administration and management of this project, and we would not have been able to complete it without them. The team would also like to acknowledge several advisers who also contributed to the organization and content of this document and provided extensive comments and feedback: Barton "Buzz" Thompson, Dr. Lynn Orr, Dr. Robert Wilkinson and Dr. David Freyberg.

We would like to thank and recognize the generosity and support of the S.D. Bechtel Jr. Foundation for its financial contribution to this project. Finally, we would be remiss if we did not recognize and applaud the hundreds of scholars, researchers and authors of the more than 650 papers that were reviewed in the course of this report. Their efforts to explore and evaluate the many connections between water and energy have been pioneering, and we believe they will ultimately prove invaluable to future resource managers and efforts to achieve a more sustainable future.