



Global Business & Development Law Journal

Volume 22

Issue 2 Symposium: *Critical Intersections for Energy & Water Law: Exploring New Challenges and Opportunities*

Article 6

1-1-2010

Water Supply, Desalination, Climate Change, and Energy Policy

Robin Kundis Craig
Florida State University College of Law

Follow this and additional works at: <https://scholarlycommons.pacific.edu/globe>



Part of the [Water Law Commons](#)

Recommended Citation

Robin K. Craig, *Water Supply, Desalination, Climate Change, and Energy Policy*, 22 PAC. MCGEORGE GLOBAL BUS. & DEV. L.J. 225 (2009).

Available at: <https://scholarlycommons.pacific.edu/globe/vol22/iss2/6>

This Article is brought to you for free and open access by the Journals and Law Reviews at Scholarly Commons. It has been accepted for inclusion in Global Business & Development Law Journal by an authorized editor of Scholarly Commons. For more information, please contact mgibney@pacific.edu.

Water Supply, Desalination, Climate Change, and Energy Policy*

Robin Kundis Craig**

ABSTRACT

In the context of water supply, “[w]ater is energy.” Once we acknowledge the energy demands of supplying fresh water, two aspects in the intersection of energy and water in water supply also become important. First, there are always tradeoffs among energy use, economic costs and benefits, social benefits, and environmental costs (the recent impacts from climate change included) in providing for water supply. Second, as a matter of governance, the political and legal mechanisms currently available for establishing water and energy policies cannot feasibly consider all of these relevant tradeoffs explicitly and coherently.

This article explores the water supply-energy matrix through the lens of desalination, an increasingly popular water supply technology both in the United States and throughout the world. It begins by reviewing current and projected future water shortages that are prompting increased interest in desalination, both in the United States and worldwide. The article then looks at desalination as a water-supply solution in terms of cost and environmental impact. In particular, it explores the energy demands of desalination, concluding in an examination of two types of alternative energy desalination—wind-powered desalination and solar-powered desalination. Ultimately, wind and solar energy may provide climate-friendly desalination and a consistent productive use for these sporadic alternative sources of electricity, particularly when one considers water to be a form of energy storage.

* This article is part of a Symposium issue containing papers originating in a conference entitled, “Critical Intersections for Energy & Water Law: Exploring New Challenges and Opportunities.” The Conference, which was held in Calgary, Alberta, May 20-21, 2009, was co-sponsored by the University of Calgary Faculty of Law, the Pacific McGeorge Institute for Sustainable Development, and the UNESCO Centre for Water Law, Policy, and Science, University of Dundee. Additional papers from this conference can be found elsewhere in this Symposium issue as well as in a companion volume to be published by the International Bar Association in the Journal of Energy & Natural Resources Law.

** Attorneys’ Title Professor of Law and Associate Dean for Environmental Programs, Florida State University College of Law, Tallahassee, Florida. This article derives from my presentation at the “Critical Intersections for Energy and Water Law: Exploring New Challenges and Opportunities” Conference held at the University of Calgary on May 20-21, 2009, and I thank Alastair Lucas, Gregory Weber, and Patricia Wouters for inviting me to participate. I’d also like to thank Susan Marks and Sally Powis at the University of Calgary Faculty of Law for their handling of the conference details. The author may be reached by e-mail at: rcraig@law.fsu.edu.

The article concludes that trying to definitively establish whether desalination as “good” or “bad” misses the point. Desalination is one water supply technology among many. Each involves tradeoffs among human needs for fresh water, energy requirements and economic costs of supplying fresh water, environmental impacts from removing water from natural systems and disposing of water-related wastes, social benefits and impacts, and, most recently, climate change issues. Because desalination is a new or unusual water supply technology in most places, and because it comes with glaringly obvious energy and environmental concerns, the increased use of desalination may have the salutary effect of encouraging full and public consideration of water and energy needs and the potential social and environmental impacts of water supply.

TABLE OF CONTENTS

I. INTRODUCTION	227
II. WATER SHORTAGES IN THE UNITED STATES AND WORLDWIDE, PRESENT AND FUTURE	230
III. DESALINATION AS A WATER SUPPLY SOLUTION.....	234
A. <i>A Brief History of Desalination</i>	234
B. <i>Desalination Techniques</i>	236
1. <i>Thermal Distillation Methods</i>	236
2. <i>Membrane Filtration Methods</i>	237
3. <i>Other Desalination Methods</i>	238
C. <i>Economic Costs of Desalination</i>	238
D. <i>Potential Environmental Impacts of Desalination</i>	241
E. <i>Global Desalination</i>	243
F. <i>Desalination in the United States</i>	245
IV. THE ENERGY COSTS OF DESALINATION AND ALTERNATIVE ENERGY POSSIBILITIES	247
A. <i>Current Desalination and Energy Consumption</i>	247
B. <i>Desalination Using Alternative Sources of Energy</i>	251
1. <i>Wind Power Case Study: Kwinana Desalination Plant, Perth, Australia</i>	251
2. <i>Solar Power Case Studies: Teatro Del Agua, Spain, and Masdar, United Arab Emirates</i>	253
C. <i>Desalination as a Better Use of Alternative Energy Sources?</i>	254
V. CONCLUSION.....	255

I. INTRODUCTION

In the context of water supply, “[w]ater is energy.”¹ Some kind of energy is always necessary to remove water from its natural place, to carry it to human settlements, and to apply it to human purposes, whether that energy be the labor of children and women² or the vast amounts of electricity that California’s Central Valley Project uses to transport water from northern California to southern California.³

Once we acknowledge the energy demands of supplying fresh water, two other aspects of the intersection of energy and water in water supply also become important. First, there are always tradeoffs among energy use, economic costs and benefits, social benefits, and environmental costs in providing for water supply—including, most recently, climate change considerations. In developing countries, for example, the provision of a village well may involve greater upfront monetary costs to the villagers than relying on women and children to draw water. However, wells and pump systems can also free girls to be educated and provide women with jobs and status—social tradeoffs that need to be part of the energy/water cost-benefit analysis. Similarly, California’s Central Valley Project provides water to Los Angeles and San Diego and makes much of the agriculture in California possible. Although the dams in the system can generate 5.6 billion kilowatt-hours of electricity per year, the system creates enormous environmental costs in northern California and arguably constitutes an unfair subsidy to certain sectors of California’s economy.⁴

Second, as a matter of governance, the political and legal mechanisms currently available for establishing water and energy policies cannot consider all of these relevant tradeoffs explicitly and coherently. Indeed, in the United States, the very concept of developing energy and water policies together is relatively new and not fully implemented at any level of government—national, state, or local. Moreover, even without the energy complication, water management is a

1. Debbie Cook, *Desalination—Energy Down the Drain*, DAILY KOS, Mar. 3, 2009, <http://www.dailykos.com/story/2009/3/3/104131/0678>.

2. See DIV. FOR THE ADVANCEMENT OF WOMEN, U.N. DEP’T OF ECON. & SOC. AFFAIRS, WOMEN AND WATER 10 (2005) (noting that according to the United Nations, for example, one study has indicated that women in developing countries can expend over 30 percent of their daily caloric intake collecting water); see also Staff Report, International Atomic Energy Agency, Women & Water: Women’s Day Celebrations in Vienna Highlight Key Connections (Mar. 8, 2007), <http://www.iaea.org/NewsCenter/News/2007/womenday2007.html> (“In many developing countries, women and girls walk on average six kilometres [sic] each day to fetch water. They carry around 20 kilograms—the equivalent of a cabin luggage—on their heads.”).

3. Power Drain: Big Ag’s \$100 Million Energy Subsidy, ENVTL. WORKING GROUP, May 29, 2007, <http://www.ewg.org/book/export/html/20984> (noting that the 400-mile long Central Valley Project uses about 1 billion kilowatt-hours of electricity per year).

4. See *id.* (noting that the electricity it takes to move water around the Central Valley Project for one year would be enough to power all the homes in Chico for over 18 months).

classic example of regulatory fragmentation, often leading to uncoordinated and detrimental results.⁵

New developments in water supply, however, may increasingly force—or at least encourage—governments to comprehensively consider the full panoply of tradeoffs involved in supplying fresh water to human populations. Specifically, the world is facing a fresh water crisis, and countries around the world are increasingly turning to desalination out of necessity to provide fresh drinking water.⁶

In most of these places, desalination is a new or unusual water supply technology that comes with glaringly obvious energy and environmental concerns. As a result, increased use of desalination generally encourages full and public consideration of water and energy needs and the potential social and environmental impacts of water supply.⁷

Accessible fresh water supplies are running short around the world, a result of increasing populations and overuse of readily usable supplies such as rivers and underground aquifers.⁸ As the United States National Research Council (NRC) has stressed,

As population and regional economies grow in the future and as the importance of providing water to support environmental services becomes more widely appreciated, the overall pressure on the nation's limited water resources will continue to intensify. Simultaneously, interest in finding novel means of managing these pressures will also intensify as the limitations of traditional infrastructure solutions are becoming better understood.⁹

Governments' increasingly common decision to turn to desalination, in part, reflects the realities of the Earth's water. As the NRC observed in 2008, "[n]early all of the Earth's water is found in the world's oceans, while only about 2.5

5. See Robin Kundis Craig, *Climate Change, Regulatory Fragmentation, and Water Triage*, 79 U. COLO. L. REV. 825, 834-37 (2008) (noting that water at any interstate watershed will be subject to multiple federal and state authorities).

6. HEATHER COOLEY ET AL., PAC. INST. FOR STUDIES IN DEV., ENV'T & SECURITY, *DESALINATION, WITH A GRAIN OF SALT: A CALIFORNIA PERSPECTIVE* 9, 11 (Ian Hart ed., 2006).

7. For example, on May 13, 2009, California and federal regulators finally fully approved the Carlsbad Desalination Plant, to be built just north of San Diego, after six years of public debate and scrutiny. Steve Gorman, *Desalination Plant Clears Final California Hurdle*, REUTERS, May 14, 2009, <http://www.reuters.com/article/environmentNews/idUSTRE54D6M420090514?pageNumber=1&virtualBrandChannel=0>.

8. See, e.g., COOLEY ET AL., *supra* note 6, at 2 ("Interest in desalination has been especially high in California, where rapidly growing populations, inadequate regulation of the water supply/land-use nexus, and ecosystem degradation from existing water supply sources have forced a rethinking of water policies and management. In the past five years, public and private entities have put forward more than 20 proposals for large desalination facilities along the California coast . . .").

9. COMM. ON ADVANCING DESALINATION TECH., NAT'L RESEARCH COUNCIL OF THE NAT'L ACADS., *DESALINATION: A NATIONAL PERSPECTIVE* 39 (2008), available at http://www.nap.edu/openbook.php?record_id=12184&page=R1 [hereinafter *DESALINATION: A NATIONAL PERSPECTIVE*].

percent exists as freshwater”¹⁰ Thus, a Pacific Institute report noted in 2006 that desalination has long been considered “the Holy Grail of water supply, [offering] the potential of an unlimited source of fresh water purified from the vast oceans of salt water that surround us. The public, politicians, and water managers continue to hope that cost-effective and environmentally safe ocean desalination will come to the rescue of water-short regions.”¹¹ Nevertheless, “[w]hile seawater desalination plants are already vital for economic development in many arid and water-short areas of the world, many plants are overly expensive, inaccurately promoted, poorly designed, inappropriately sited, and ultimately useless.”¹²

As noted, one of the environmental and resource concerns that desalination raises is energy consumption.¹³ Of course, conventional methods of water supply storage, transportation, and treatment consume significant amounts of energy. California provides an admittedly extreme example, given the extensive transportation involved.¹⁴ “The California Energy Commission (2005) estimate[d] that the water sector in California used 19% and 32% of total electricity and natural gas use, respectively, in 2001. Substantial quantities of diesel were also consumed in California’s water sector.”¹⁵

Nevertheless, a commitment to desalination is currently a commitment to a particularly energy-intensive way of providing water, even in places like California. California’s proposed desalination plants “would increase the water-related energy use [in the state] by 5% over 2001 levels.”¹⁶ Reverse osmosis treatment of seawater, the most common process of desalination in North America, currently consumes about ten times as much energy as normal water supply processes.¹⁷ Thus, this “Holy Grail” for water supply solutions necessarily involves an evaluation of the concurrent energy demands.

This article provides an overview of the energy issues raised by the increased use of desalination. Part I provides a review of the current and projected future water shortages in the United States and worldwide that are prompting increased interest in desalination. Part II looks at desalination as a water-supply solution. It

10. *Id.* at 13.

11. COOLEY ET AL., *supra* note 6, at 1; *accord id.* at 9 (“Because of growing concerns about water scarcity and quality, and disputes over allocations of scarce water resources, a tremendous amount of effort has been devoted to developing technologies to desalinate the vast quantities of seawater available.”).

12. *Id.* at 1.

13. *See id.* at 72; *see also* DESALINATION: A NATIONAL PERSPECTIVE, *supra* note 9, at 108-09 (noting that other environmental concerns include entrainment of marine organisms at the intake pipe and disposal of the resulting brine).

14. “Because of climate, geology, topography, and long water conveyance routes, the energy use for capture, transportation, and treatment in California is higher than the national average of 3.5 percent of electrical energy consumed.” DESALINATION: A NATIONAL PERSPECTIVE, *supra* note 9, at 141 (citation omitted).

15. COOLEY ET AL., *supra* note 6, at 72.

16. *Id.*

17. DESALINATION: A NATIONAL PERSPECTIVE, *supra* note 9, at 142.

provides both a brief history of the technologies used in desalination, the economic costs, and potential environmental impacts, as well as current trends in desalination use, both world-wide and in the United States. Part III then looks at the energy demands of desalination. It suggests that two types of alternative energy desalination—wind-powered desalination and solar-powered desalination—may provide both a climate-friendly desalination process and a productive use for these “green” but sporadic alternative sources of electricity. This article concludes that an attempt to definitively establish desalination as “good” or “bad” misses the point. Desalination is one water supply technology among many, all of which involve tradeoffs among human needs for fresh water, energy requirements and economic costs of supplying fresh water, environmental impacts from removing water from natural systems and disposing of water-related wastes, and social benefits and impacts.

II. WATER SHORTAGES IN THE UNITED STATES AND WORLDWIDE, PRESENT AND FUTURE

In the last few years, news about water shortages in the United States has repeatedly made headlines. For example, in October 2007, the Associated Press reported that, “[a]cross America, the picture is critically clear—the nation’s freshwater supplies can no longer quench its thirst.”¹⁸ Similarly, an April 2008 estimate projected that at least thirty-six states would face water shortages within five years.¹⁹ Individual threatened states include California, Georgia, and Florida, while “threatened regions include the Midwest, where the Great Lakes are shrinking, and upstate New York, where reservoir levels have fallen to record lows.”²⁰ In the high plains region, farmers “tapping the Ogallala Aquifer [-] have progressively seen their wells dry up. The aquifer is the largest in the United States and sees a depletion rate of some 12 billion cubic meters a year, a quantity equivalent to 18 times the annual flow of the Colorado River. Since pumping started in the 1940s, Ogallala water levels have dropped by more than 100 feet (30 meters) in some areas.”²¹

From a global perspective, reliable access to fresh water is a widely recognized humanitarian and human rights problem. According to the World Health Organization (WHO), “[w]ater scarcity affects one in three people on every continent of the globe.”²² Water scarcity originates from two sources—

18. Brian Skoloff, *Much of US Could See a Water Shortage*, TRUTHOUT, Oct. 26, 2007, <http://www.truthout.org/article/much-us-could-see-a-water-shortage?print>.

19. David Gutierrez, *At Least 36 U.S. States Face Water Shortage*, ALTERNET, Apr. 15, 2008, <http://www.alternet.org/story/82378/>.

20. *Id.*; see also Keith Schneider, *U.S. Faces Era of Water Scarcity*, CIRCLE OF BLUE, July 9, 2008, <http://www.circleofblue.org/waternews/2008/world/us-faces-era-of-water-scarcity/> (discussing the same problems).

21. Schneider, *supra* note 20.

22. World Health Organization, *Water Scarcity: 10 Facts About Water Scarcity: Fact #2*, Mar. 2009,

physical scarcity or economic/distributional scarcity.²³ WHO further reports that “[a]lmost one fifth of the world’s population (about 1.2 billion people) live in areas where the water is physically scarce.”²⁴ Although the Middle East and Africa are certainly among the most vulnerable places, physical water scarcity is not limited to developing countries. For example, “Australia is in the midst of a 30-year dry spell, and population growth in urban centers of sub-Saharan Africa is straining resources. Asia has 60 percent of the world’s population, but only about 30 percent of its freshwater.”²⁵

Climate change is expected to make water shortages even worse in many parts of the world. In 2007, the Intergovernmental Panel on Climate Change (IPCC) projected that up to two billion people worldwide could be facing water shortages by 2050. This impact is equally acute in the United States as it is worldwide:

Coastal states like Florida and California face a water crisis not only from increased demand, but also from rising temperatures that are causing glaciers to melt and sea levels to rise. Higher temperatures mean more water lost to evaporation. And rising seas could push saltwater into underground sources of freshwater.²⁶

Moreover, California and other Pacific and northern states are already suffering from diminished snowpacks, reducing the amount of water available from snowmelt.²⁷ The Colorado River, which supplies much of the arid U.S. Southwest with water, “will probably provide less water in coming years as global warming shrinks its flow.”²⁸ Farther east, “[d]eclining water levels affect the Great Lakes. . . . In a paper published last year, scientists projected that over the next three decades or so, water levels in Lake Erie, which supplies drinking water to more than 11 million people, could fall three to six feet as a result of climate change.”²⁹ Finally, rising sea levels will likely contaminate surface waters and aquifers in coastal states like California and Florida.

The United States provides a smaller-scale view of climate-change-driven water supply problems that will occur worldwide. For example, a recent report by the Pacific Institute and the United Nations Global Compact concluded that:

<http://www.who.int/features/factfiles/water/en/index.html> (follow “Read the fact file” hyperlink, then click on “2.”)

23. See *id.* Fact #3 (follow “Read the fact file” hyperlink, then click on “3.”)

24. *Id.*

25. Skoloff, *supra* note 18.

26. *Id.*; accord Gutierrez, *supra* note 19.

27. See Skoloff, *supra* note 18 (noting that the snowpack of the Sierra Nevada is melting faster each year).

28. *Id.*

29. Schneider, *supra* note 20.

Climate change will affect water scarcity and sustainable supply. It will:

- Increase water shortages due to changes in precipitation patterns and intensity. In particular, the subtropics and mid-latitudes, where much of the world's poorest populations live, are expected to become substantially drier. Reduced precipitation in some arid regions could trigger exponentially larger drops in groundwater tables.
- Decrease natural water storage capacity from glacier/snowcap melting, and subsequently reduce long-term water availability for more than one-sixth of the world's population that live in glacier- or snowmelt-fed river basins, including major regions of China, India, Pakistan and the western U.S.
- Increase the vulnerability of ecosystems due to temperature increases, changes in precipitation patterns, frequent severe weather events, and prolonged droughts. These factors, in turn, will further diminish the ability of natural systems to filter water and create buffers to flooding.
- Affect the capacity and reliability of water supply infrastructure due to flooding, extreme weather, and sea level rise. Most existing water treatment plants and distribution systems were not built to withstand expected sea level rise and increased frequency of severe weather due to climate change. Furthermore, climate change will concentrate snowmelt and precipitation into shorter time frames, making both water releases more extreme and drought events more sustained. Current infrastructure often does not have the capacity to fully capture this larger volume of water, and therefore will be inadequate to meet water demands in times of sustained drought.
- Impair non-consumptive water uses, including transportation on inland waterways such as the Mississippi River in the U.S. and Rhine River in Europe, where freight transport has already been disrupted due to floods and droughts. Tourism sectors that are dependent on the availability of water or snow are also vulnerable to water scarcity due to climate change. Freshwater fisheries, many of which supply food to the world's poorest populations, also depend on abundant, high quality water resources to remain productive.³⁰

These water supply and water shortages have various relationships to energy. To illustrate, in April 2009, water shortages in the U.S. corn-belt led several to

30. Jason Morrison et al., *Pac. Inst., United Nations Global Compact, Climate Change and the Global Water Crisis: What Businesses Need to Know and Do 2* (2009), available at http://www.unglobalcompact.org/docs/issues_doc/Environment/ceo_water_mandate/UNGC-PI_climate-water_whitepaper_FINAL.pdf (footnotes omitted).

question the wisdom of growing corn—"a particularly thirsty plant"—for biofuels, especially because the production of ethanol is also water-intensive.³¹

However, water-related energy policy choices also extend to the methods of supplying citizens, industry, and agriculture with fresh water. In the U.S. and elsewhere, this water-energy connection is becoming more pointed with the increasing reliance on desalination as a source of freshwater supply.³² For example, between 2001 and 2006, "public and private entities have put forward more than 20 proposals for large desalination facilities along the California coast If all of the proposed facilities were built, the state's seawater desalination capacity would increase by a factor of 70, and seawater desalination would supply 6% of California's year 2000 urban water demand."³³ In May 2009, Poseidon Resources received the final approval for one of the first of these new plants in Carlsbad, California. At a construction cost of \$300 million, it will employ reverse osmosis to produce fifty million gallons of drinkable water a day.³⁴ The facility expects to rely on roof solar panels for less than five percent (700 to 800 megawatt hours) of its electricity requirements; investments in reforestation and carbon offsets will mitigate greenhouse gas emissions from the plant but not reduce its demand for conventional electricity.³⁵ Poseidon Resources also has plans to build another fifty-million-gallon-per-day desalination plant in Huntington Beach, California.³⁶

Australia is also turning to desalination to supply water in a time of severe drought. In 2000, the national government published its National Action Plan for Salinity and Water Quality, which identified twenty-one priority regions in Australia where water supplies have salinity contamination.³⁷ The plan expired on June 30, 2008,³⁸ but it identified and promoted the use of desalination in Australia.³⁹ For example, on Australia's western coast, the city of Perth now relies on the Kwinana desalination plant for water. In 2007, when the desalination plant became operational, "the city ha[d] seen a 21 percent decline

31. Carey Gillam, *Water Shortage Clouding U.S. Biofuel Future*, CALGARY HERALD, Apr. 14, 2009, <http://www.freerepublic.com/focus/news/2229088/posts>.

32. See Press Release, National Acads., *Desalination Can Boost U.S. Water Supplies, But Research Needed to Understand Environmental Impacts, Lower Costs* (Apr. 24, 2008), available at <http://www8.nationalacademies.org/onpinews/newsitem.aspx?RecordID=12184> ("Recent advances in technology have made removing salt from seawater and groundwater a realistic option for increasing water supplies in some parts of the U.S., and desalination will likely have a niche in meeting the nation's future water needs").

33. COOLEY ET AL., *supra* note 6, at 2.

34. Gorman, *supra* note 7.

35. Emma Ritch, *Largest Desalination Plant in Western World Gets Go-Ahead*, CLEANTECH GROUP L.L.C., Aug. 26, 2008, <http://www.cleantech.com/news/print/3305>.

36. *Id.*

37. Australian Gov't, *What Is the National Action Plan for Salinity and Water Quality?*, <http://www.napswq.gov.au/napswq/index.html> (last visited Nov. 12, 2009).

38. *Id.*

39. AGRICULTURE, FISHERIES & FORESTRY—AUSTL., SUMMARY REPORT: INTRODUCTION TO DESALINATION TECHNOLOGIES IN AUSTRALIA 2, (2002), available at <http://www.environment.gov.au/water/publications/urban/pubs/desalination-summary.pdf>.

in rainfall” over the previous decade, while “the stream flow into dams—the actual amount running into storage—dropped about 65 percent, according to Malcolm Turnbull, Australia’s minister for the environment and water resources.”⁴⁰ “Other water-stressed seaside cities in Australia are taking a serious look at desalination, as traditional water sources dry up because of lack of rain.”⁴¹

According to Australian news reports, “[d]esalination is at the heart of Western Australia’s approach to satisfying the thirst of a booming population that lives on the edge of a desert.”⁴² The Australia National Water Commission reported in late October 2008 that Australian governments had committed over AU\$7.5 billion to desalination plants.⁴³ “The desalination of seawater has become an important source of drinking water for Australia’s coastal cities. By 2013 a total of approximately 460 giganlitres per annum (GL/yr) of drinking water will be produced from desalination plants operating in Melbourne, Sydney, Perth, Adelaide and parts of south-east Queensland.”⁴⁴

III. DESALINATION AS A WATER SUPPLY SOLUTION

A. A Brief History of Desalination

Desalination has a fairly long history, although its use for water supply was limited until the mid-twentieth century. As the Pacific Institute has observed, “[t]he idea of separating salt from water is an ancient one, dating from the time when salt, not water, was a precious commodity. As populations and demands for fresh water expanded, however, entrepreneurs began to look for ways of producing fresh water in remote locations and, especially, on naval ships at sea.”⁴⁵ Desalination began when people boiled seawater and collected the freshwater steam. Indeed, as early as 200 A.D., “sailors began desalinating seawater with simple boilers on their ships.”⁴⁶

40. Michael Sullivan, Australia Turns to Desalination Amid Water Shortage, NAT’L PUB. RADIO, June 18, 2007, <http://www.npr.org/templates/story/story.php?storyId=11134967> [hereinafter *Australia Turns to Desalination*].

41. *Id.*

42. Phil Mercer, *Desalination Schemes Stir Debate in Parched Australia*, VOANEWS, Feb. 18, 2009, <http://www.voanews.com/english/archive/2009-02/2009-02-18-voa30.cfm?moddate=2009-02-18>.

43. National Water Commission, Austl., Desalination and Australia’s Long-Term Water Security, Oct. 30, 2008, available at <http://www.nwc.gov.au/www/html/902-desalination-and-australias-long-term-water-security.asp?intSiteID=1>.

44. UNESCO Ctr. for Membrane Sc. & Tech., Univ. of N.S.W., Emerging Trends in Desalination: A Review viii (2008), available at [http://www.nwc.gov.au/resources/documents/Waterlines_-_Trends_in_Desalination_-_REPLACE_\(2\).pdf](http://www.nwc.gov.au/resources/documents/Waterlines_-_Trends_in_Desalination_-_REPLACE_(2).pdf) [hereinafter *Australia Desalination Review*].

45. COOLEY ET AL., *supra* note 6, at 11; see also Michael Schirber, *Why Desalination Doesn’t Work (Yet)*, LIVESCIENCE, June 25, 2007, http://www.livescience.com/environment/070625_desalination_membranes.html (“Desalination technology has been around for thousands of years . . . Even Aristotle worked on the problem. . . . Back in the 4th century B.C., Aristotle imagined using successive filters to remove the salt from seawater.”).

46. Schirber, *supra* note 45.

Initially, desalination was most important in places that had few other options for securing a supply of fresh water. The NRC summarized in 2008:

Sir Richard Hawkins reported in 1662 that during his voyages to the South Seas, he had been able to supply his men with fresh water by means of shipboard distillation. In 1852, a British patent was issued for a distillation device. The island of Curaçao in the Netherlands Antilles was the first place to make a major commitment to desalination, and plants have operated there since 1928. In 1938, a major seawater desalination plant was built in what is now Saudi Arabia.⁴⁷

Funding for research into desalination peaked in the third and early fourth quarters of the twentieth century, and “[i]n 1977, the U.S. spent almost \$144 million for desalination research, and additional funding was committed to desalination programs in other countries, including the Persian Gulf and Japan.”⁴⁸

Over the last decade, the main legal vehicle for encouraging desalination development in the U.S. has been the Water Desalination Act of 1996.⁴⁹ As originally enacted, this Act authorized \$30 million over six years for desalination research and studies and an additional \$25 million to fund desalination demonstration projects.⁵⁰ While Congress appropriated only a fraction of this authorized funding,⁵¹ the Act has been renewed repeatedly—most recently, through 2011.⁵² Congress has also funded a number of individual desalinated projects directly.

47. DESALINATION: A NATIONAL PERSPECTIVE, *supra* note 9, at 19 (citations omitted).

48. COOLEY ET AL., *supra* note 6, at 11-12 (citation omitted). As this article indicates, in the United States, legislation and funding for desalination has waxed and waned:

In the 1960s, Senator and then President John F. Kennedy strongly supported the idea of large-scale commercial desalination. Such a system “can do more to raise men and women from lives of poverty than any other scientific advance.” An early version of modern distillation plants was built in Kuwait in the early 1960s. In the early 1970s, the federal Saline Water Conversion Act (PL 92-60) created the Office of Water Research and Technology, which focused on desalination efforts associated with designing and building the Yuma Desalting Plant, as required by the Colorado River Basin Salinity Control Act of 1974 (PL 93-320). Many of the advances in membrane technologies used in this plant and more advanced reverse osmosis (RO) plants have their roots in publicly funded research and development programs. . . .

In 1982, the Reagan administration cut federal funding for non-military scientific research of almost every kind, including desalination work, and the Office of Water Research and Technology was closed. The next 14 years saw limited U.S. support for desalination, with the exception of some work on water-treatment technologies supported by the U.S. Bureau of Reclamation.

49. Water Desalination Act, Pub. L. No. 104-298, 110 Stat. 3622 (1996).

50. *Id.* at §§ 3, 4, 8, 110 Stat. at 3622-24.

51. COOLEY ET AL., *supra* note 6, at 12 (noting that Congress appropriated only \$2.5 million in the fiscal year 1999 and only \$1.3 million in the fiscal year 2000).

52. See Consolidated Appropriations Resolution, Pub. L. No. 108-7, § 210, 117 Stat. 11 (2003); Energy and Water Development Appropriations Act, 2006, Pub. L. No. 109-103, § 206, 119 Stat. 2247, 2268 (2005); Revised Continuing Appropriation Resolution, 2007, Pub. L. 110-5, § 20312, 121 Stat. 8, 19 (2007).

B. Desalination Techniques

Typically, desalination techniques remove salts from seawater or brackish water to leave fresh water behind.⁵³ Two general techniques represent almost all the existing desalination capacity: a form of evaporation, referred to as thermal distillation, and membrane filtration.⁵⁴

1. Thermal Distillation Methods

The NRC reported in 2008, “[t]he earliest commercial plants used mostly large-scale thermal evaporation or distillation of seawater. Major facilities were first built in the Persian Gulf region, where excess or inexpensive energy was available and where natural sources of freshwater are relatively scarce.”⁵⁵ Thermal distillation remains an important desalination technique, producing about forty percent of the desalinated water used worldwide.⁵⁶

“The basic concept of thermal distillation is to heat a saline solution to generate water vapor. If this vapor is directed toward a cool surface, it can be condensed to liquid water containing very little of the original salt.”⁵⁷ Several thermal distillation techniques now exist. Multi-stage flash distillation (MSF) takes advantage of lower pressures to “flash” evaporate pure water out of a stream of brine as it passes through a series of chambers, each kept at successively lower pressures.⁵⁸ Multiple effect distillation (MED) is a multi-chamber (or “effect”) thin-film evaporation process, where the vapor formed in one chamber condenses in the next, providing heat for further evaporation.⁵⁹ Finally, mechanical vapor compression (MVC) is a form of vapor compression evaporation⁶⁰ (VC or VCE), which compresses water vapor with either a mechanical compressor or a steam injector to generate heat to evaporate seawater or brackish water.⁶¹

53. DESALINATION: A NATIONAL PERSPECTIVE, *supra* note 9, at 15.

54. See *The Arid West—Where Water Is Scarce—Desalination—A Growing Watersupply Source*, LIBRARY INDEX, <http://www.libraryindex.com/pages/2644/Arid-West-Where-Water-Scarce-DESALINATION-GROWING-WATERSUPPLY-SOURCE.html> (last viewed Apr. 17, 2009) [hereinafter *The Arid West*].

55. DESALINATION: A NATIONAL PERSPECTIVE, *supra* note 9, at 15.

56. COOLEY ET AL., *supra* note 6, at 16; see also DESALINATION: A NATIONAL PERSPECTIVE, *supra* note 9, at 73. (“Thermal processes, such multistage flash (MSF), multiple effect distillation (MED), and mechanical vapor compression (MVC), account for 43 percent of the online capacity for desalination worldwide.”)

57. DESALINATION: A NATIONAL PERSPECTIVE, *supra* note 9, at 72.

58. *Id.* at 266.

59. *Id.* at 265.

60. *Id.* at 265.

61. *Id.* at 268; see also *The Arid West*, *supra* note 54 (describing distillation techniques).

2. Membrane Filtration Methods

Membrane desalination techniques are essentially filtering, as opposed to evaporation, techniques. Some membrane techniques, such as reverse osmosis (RO) and nanofiltration (NF), are membrane processes driven by pressure, while electrodialysis (ED) and electrodialysis reversal (EDR) techniques rely on electricity to separate salts from water.⁶²

More specifically, RO applies pressure to dissolve water into a nonporous membrane, leaving most of the salts (and larger organic contaminants) behind in the waste concentrate.⁶³ Pores in the membranes used in NF are usually smaller than 0.001 micrometers, and pressure-driven removal is combined with sieving and solution/diffusion to soften water and remove organics, sulfate, and some viruses.⁶⁴ Ultrafiltration (UF), in turn, uses membranes with pores of 0.002 to 0.1 micrometers to remove “contaminants that affect color, high-weight dissolved organic compounds, bacteria, and some viruses.”⁶⁵ Finally, microfiltration (MF) uses membranes with pores of 0.03 to 10 micrometers and lower pressures than NF or UF “to reduce turbidity and remove suspended particles, bacteria, and algae.”⁶⁶

In contrast, ED relies on the fact that most salts ionize to use electricity to drive the membrane filtration. Specifically, a direct voltage current transfers salt ions through special ion-exchange membranes, leaving fresh water behind.⁶⁷

Membrane processes can generate substantial amounts of fresh water. According to the NRC, “[t]ypically, 35 to 60 percent of the seawater fed into a membrane process is recovered as product water. For brackish water desalination, water recovery can range from 50 to 90 percent, depending on initial salinity and the presence of sparingly soluble salts and silica, although recovery is typically between 60 and 85 percent.”⁶⁸ Importantly in the U.S., membrane desalination, regardless of whether used on seawater or brackish water, can generate fresh water with 500 ppm TDS or less of dissolved solids (salts),⁶⁹ meeting the Environmental Protection Agency’s (EPA’s) recommendation for drinking water.⁷⁰

62. DESALINATION: A NATIONAL PERSPECTIVE, *supra* note 9, at 73.

63. *Id.* at 76 box 4-4.

64. *Id.*

65. *Id.*

66. *Id.*

67. *Id.*

68. *Id.* at 73, 76 (citation omitted).

69. *Id.* at 76.

70. *See id.* at 14.

3. Other Desalination Methods

Although less common, other desalination methods exist. In ion exchange desalination, salty water passes through two types of ion exchanger beads that de-salt and de-ionize the water.⁷¹ As the NRC has noted, “[i]on exchange is mainly used for water softening and demineralization, and applications of ion exchange at the municipal level are limited. . . . This process makes economic sense compared to other desalination processes only where there is a small amount of salt to be removed from the water. Therefore, the major application of ion exchange has been in the field of production of ultrapure water.”⁷²

Hybrid desalination methods combine thermal distillation and membrane methods to improve efficiency or reduce energy costs, often by co-locating with a power plant.⁷³ “Fujairah in the United Arab Emirates is one facility of this type, with a total water production of 454,000 m³/day (120 MGD). Two-thirds of the production capacity is provided by MSF units, with the remaining capacity provided by seawater and second-pass brackish-water RO units. The facility also has the capacity to use warm MSF cooling water as part of the feedwater to increase the permeability of the RO process during winter months.”⁷⁴

C. Economic Costs of Desalination

Costs of desalination can vary considerably, depending on the conditions of the location, the desalination technique employed, and the salinity of the water. For example, the NRC explained in 2008 that thermal distillation techniques still make sense economically in the Middle East, but not in other places:

[T]hermal processes have been and continue to be a logical regional choice for desalination in the Middle East for several reasons. First, the seas in the region are very saline, hot, and periodically have high concentrations of organics, which are challenging conditions for RO [reverse osmosis] desalination technology. Second, RO plants are only now approaching the large production capacities required in these regions. Third, dual-purpose cogeneration facilities were constructed that integrated the thermal desalination process with available steam from power generation, improving the overall thermodynamic efficiency by 10-15 percent. For these reasons combined with the locally low imputed cost of energy, thermal processes continue to dominate the Middle East. In other parts of the world, where integration of power and water

71. *Id.* at 95.

72. *Id.*

73. *Id.* at 96.

74. *Id.*

generation is limited and where oil or other fossil fuels must be purchased at market prices, thermal processes are relatively expensive.⁷⁵

In contrast to the Middle East, “[i]n the United States, thermal processes are primarily used as a reliable means to produce high-quality product water (•25 ppm TDS) for industrial applications, because distillation processes are very successful at separating their target—dissolved salts—from bulk feedwater.”⁷⁶

The costs of desalinating seawater are generally higher than the costs of desalinating brackish water. Of course, that distinction begs for definitions of various kinds of salinity. The NRC provided a compact set of salinity definitions in 2008:

Water with greater than 2,000 to 3,000 mg/L [milligrams per liter] total dissolved solids (TDS) is considered too salty to drink or to grow most crops. The World Health Organization considers water with TDS concentrations below 1,000 mg/L to be generally acceptable to consumers, although it notes that acceptability may vary according to circumstances. The U.S. Environmental Protection Agency (EPA) notes that drinking water with TDS greater than 500 mg/L can be distasteful. Brackish water has a salinity between that of fresh- and seawater. In more than 97 percent of seawater in the world the salinity is between 33,000 and 37,000 mg/L, although the Persian Gulf has an average TDS of 48,000 mg/L. Water with salinity greater than that of seawater is called brine.⁷⁷

Even with these variables, however, desalination is almost always more expensive than conventional water supply methods.⁷⁸ The NRC reported in 2008:

Experience to date suggests that desalinated water cannot be delivered to users in California for anything less than the cost of production, which our research indicates is unlikely to fall below the range of \$3.00 to \$3.50 per thousand gallons (\$/kgal) (roughly \$0.79 to \$0.92 per cubic meter (\$/m³)) for even large, efficient plants. Because the cost of production can be as high as \$8.35/kgal (\$2.21/m³), the cost of delivered water could be in the range of \$9 to \$10/kgal (\$2.37 to \$2.64/m³). This wide range is caused by the factors discussed below and the large variation in the cost of water distribution among service areas. Even the low end of this range remains above the price of water typically paid by

75. *Id.* at 90 (citation omitted).

76. *Id.*

77. *Id.* at 14 (citations omitted).

78. See Benjamin Radford, *The Water Shortage Myth*, LIVESCIENCE, June 23, 2008, <http://www.livescience.com/environment/080623-bad-water-shortage.html> (“Large-scale desalination can be done, but it is expensive.”); see also *The Arid West*, *supra* note 54.

urban water users, and far above the price paid by farmers. For example, growers in the western United States may pay as little as \$0.20 to \$0.40/kgal (\$0.05 to \$0.10/m³) for water. Even urban users rarely pay more than \$1.00 to \$3.00/kgal (\$0.26 to \$0.79/m³).⁷⁹

Worldwide, the first-year costs for RO plants have ranged from US\$1.70 per thousand gallons in Singapore to US\$5.60 per thousand gallons in the Bahamas and US\$5.40 in Cyprus.⁸⁰ Costs of water produced by thermal distillation methods run from about US\$2.65 per 1000 gallons at an MSF plant in Abu Dhabi to US\$5.03 to \$6.93 per 1000 gallons at a thermal distillation plant in Kuwait.⁸¹ Nevertheless, in 2008, the Australia National Water Commission emphasized that the costs of desalination have been decreasing:

The cost of producing drinking water via seawater desalination has steadily declined since the first large-scale thermal plants were commissioned in the Arabian Gulf in the mid 1950s. Although little historical cost data is available in the public domain, the cost of production, or water tariff, for thermal plants has been estimated to decrease from close to US\$9.0/m³ in the later 1950s to US\$0.7/m³ reported in 2000 for the Taweelah A1 & A2 plants in Abu Dhabi. A similar cost trend can be gleaned from tariffs reported for reverse osmosis desalination plants, which range from US\$1.55/m³ in 1991 at Santa Barbara, California to US\$0.8 in 2000 at Trinidad, down to US\$0.63/m³ in 2003 in Ashkelon, Israel.⁸²

In addition, drought and shortages can make desalination competitive with other water-supply options. In California, water produced at desalination plants generally ranges in price from \$1,000 to \$4,000 per acre-foot, while traditional sources supply water at \$27 to \$269 per acre-foot, and new non-desalination sources can deliver water for \$600 to \$700 per acre-foot.⁸³ (As a comparison, the much-delayed and over-budget Tampa Bay Water desalination plant in Florida finally delivered water for \$1100 per acre-foot, but Poseidon is hoping to deliver water from the Carlsbad plant for \$677 per acre-foot).⁸⁴

Nevertheless, shortage can significantly alter these price comparisons. Case in point: in a 1988 drought the City of Santa Barbara, California, which traditionally depended solely on its own reservoir for water, paid \$2,300 per acre-

79. COOLEY ET AL., *supra* note 6, at 39 (citations omitted).

80. *Id.* at 40.

81. *Id.* at 40 n. 12.

82. AUSTRALIA DESALINATION REVIEW, *supra* note 44, at ix, para. 9.

83. *The Arid West*, *supra* note 54.

84. Kathryn Kranhold, Water, Water, Everywhere . . . Seeking Fresh Sources, California Turns to the Salty Pacific, but Desalination Plants Face Criticism on Environment, Costs, WALL ST. J., Jan. 17, 2008, at B1, available at <http://online.wsj.com/article/SB120053698876396483.html>.

foot of water and faced costs of \$1,300 per acre-foot if it decided to permanently join the California Water Project.⁸⁵ Instead of paying these fees, it opted to build its own emergency desalination plant.⁸⁶

D. Potential Environmental Impacts of Desalination

Many of the environmental concerns related to building desalination plants are the same concerns that arise any time a major facility is built in a coastal zone. Construction must consider the location of the facility; the effects of construction on coastal ecosystems, such as wetlands, mangroves, and estuaries; and disposal of wastes, including trash and sewage generated by the human operators. While significant, these concerns are, for the most part, no different for desalination plants than for construction of any other major facility in a coastal zone.⁸⁷

However, desalination plants do create two environmental concerns particular to their operations. First, the intake of brackish water or seawater can have environmental impacts, such as entrainment and impingement of fish and other organisms, or alteration of nearshore currents.⁸⁸ Relying on WHO, the Australia National Water Commission recently summarized impacts of “potential causes of concern for seawater sources,” including “[i]ncreased organic loadings associated with fish kills or decomposing marine life” and “[t]he trapping or blocking of intake screens by aquatic organisms, or by the passage of these organisms through screens and into and potential coloni[z]ation of the process equipment.”⁸⁹ Potential impacts on fresh water surface sources are similar, though using aquifers for desalination also raises the risk of groundwater contamination.⁹⁰

Desalination plants can use a variety of techniques to mitigate or eliminate these impacts. At the Kwinana desalination plant in Australia, “[t]he water is sucked in through a pipe about 650 feet offshore in Cockburn Sound, at a rate of about 0.1 meters per second That is slow enough to let the fish escape, but fast enough to provide nearly 40 million gallons of drinking water each day—roughly 20 percent of Perth’s daily consumption.”⁹¹ In contrast, the Tampa Bay desalination plant in Florida is co-located with an electric power plant and takes water for desalination from the electric plant’s spent cooling water.⁹² Of course,

85. *The Arid West*, *supra* note 54.

86. *See* Kranhold, *supra* note 84.

87. *See* AUSTRALIA DESALINATION REVIEW, *supra* note 44, at 16 (describing important coastal siting considerations for desalination plants).

88. *Id.* at 16.

89. *Id.* at 14.

90. *Id.*

91. Sullivan, *supra* note 40.

92. Tampa Bay Water, *How the Plant Works*, http://www.development.tampabaywater.org/facilities/desalination_plant/how_the_plant_works.aspx (last visited Dec. 16, 2009).

that just shifts the environmental issues regarding water intake to the power plant, but in the United States power plant cooling water intake is regulated pursuant to the federal Clean Water Act.⁹³

The second and more difficult environmental issue is disposal of the brine that desalination creates. In April 2008, for example, the Kwinana plant was operating at one-sixth its normal capacity because of low oxygen levels in Cockburn Sound, where the brine is released.⁹⁴

In 2008, the Australia National Water Commission summarized the potential environmental concerns with brine disposal as follows:

The environmental impact of brine discharge into marine environments is a key issue for coastal desalination plants. However, the majority of current international knowledge relates specifically to a few heavily impacted and relatively enclosed water bodies, including:

- the Mediterranean Sea
- the Red Sea
- the Persian Gulf

Many marine organisms are highly sensitive to variations in salinity. For example:

- echinoderms appear to have been severely impacted in an area close to a Mediterranean SWRO discharge
- seagrasses, such as Mediterranean *Posidonia* and their associated ecosystems, appear to have been impacted in some regions

Because a dense, hypersaline plume will tend to sink and disperse slowly, biota likely to be affected are bottom-dwelling or non-mobile species that live on or are physically attached to the reef. These include fan corals, sponges, stalked and sessile ascidians, anemones and attached algae.

At present, there is little information available on the salinity tolerances of these species or their responses to chemicals contained in the discharge plume. The impacted zone for a 500 ML/d plant under quiescent conditions is assumed to be about 0.5 hectares.⁹⁵

However, the report also stressed that studies at the Kwinana plant in Australia, the Tampa Bay plant in Florida, and the Carlsbad plant in California had revealed no significant environmental impacts from seawater brine disposal. The Tampa Bay plant in particular avoids many environmental problems with its brine by diluting its discharge with the co-located electric power plant's cooling

93. 33 U.S.C. § 1251 (2009); *see also* *Entergy Corp. v. Riverkeeper, Inc.*, 129 S. Ct. 1498, 1502-05 (2009) (describing the problems of impingement and entrainment in cooling water intake systems and describing the Environmental Protection Agency's regulations to reduce those environmental impacts).

94. *Pollution Fears Force Output Cut in Desal Plant*, ABC NEWS, Apr. 18, 2008, <http://www.abc.net.au/news/stories/2008/04/18/2220484.htm>

95. Australia Desalination Review, *supra* note 44, at 17.

water. This results in a product roughly two times as saline as the bay, but dilution with up to 1.4 billion gallons of water daily from Tampa Electric's Big Bend Power Station prior to release assures that it does not increase the bay's salinity. Average plant discharge salinity is only 1.0 to 1.5 percent greater than that of Tampa Bay. Such a slight increase falls well within annual natural fluctuations in the Bay's salinity, which varies from 16 to 32 parts per thousand, up to 100 parts per thousand, depending on the weather and the season.⁹⁶

More significant environmental impacts occur at inland desalination facilities (like those desalinating brackish or contaminated surface water), where ocean disposal of brine is not feasible. Freshwater systems are more sensitive to impacts from the highly saline brine, and the common land disposal option can potentially lead to contamination of the land and surrounding water by salt.⁹⁷

E. Global Desalination

A 2006 study by the Pacific Institute stated that "[g]lobal desalination water production capacity has been increasing exponentially since 1960 to its current value of 42 million m³/day [cubic meters of fresh water per day] Of this global cumulative desalination capacity, approximately 37 million m³/day is considered to be operational."⁹⁸

Desalination is widespread among the nations of the world. As of January 2005, approximately 130 countries were using some form of desalination and over 10,000 desalination units able to produce at least 100m³/day were in place.⁹⁹ In 2005, eighteen different countries contributed more than 1% of the total global desalination capacity: Saudi Arabia (about 6.5 million m³/day installed capacity); United States (about 6.0 million m³/day installed capacity); United Arab Emirates (about 4.8 million m³/day installed capacity); Spain (about 2.4 million m³/day installed capacity); Kuwait (just under 2 million m³/day installed capacity); Japan (about 1.2 million m³/day installed capacity); Libya (about 800,000 m³/day installed capacity); Korea (about 800,000 m³/day installed capacity); Qatar (about 800,000 m³/day installed capacity); Italy (about 700,000 m³/day installed capacity); Iran (about 700,000 m³/day installed capacity); China (about 600,000 m³/day installed capacity); Israel (about 600,000 m³/day installed capacity); Bahrain (about 600,000 m³/day installed capacity); Algeria (about 500,000 m³/day installed capacity); India (about 500,000 m³/day installed capacity);

96. Tampa Bay Water, *How the Plant Works (Continued)* http://www.development.tampabaywater.org/facilities/desalination_plant/how_the_plant_works3.aspx (last visited Dec. 16, 2009); Neda Simeonova, *Long Time Coming*, 48 WATER & WASTES DIGEST NO. 2, (2008), <http://www.wwdmag.com/Long-Time-Coming-article8976>.

97. See AUSTRALIA DESALINATION REVIEW, *supra* note 44, at 18.

98. DESALINATION: A NATIONAL PERSPECTIVE, *supra* note 9, at 19.

99. COOLEY ET AL., *supra* note 6, at 19.

Mexico (about 450,000 m³/day installed capacity); and Iraq (about 400,000 m³/day installed capacity).¹⁰⁰

These numbers indicate that “desalination is an important water source in parts of the arid Middle East, Persian Gulf, [and] North Africa”¹⁰¹ At least “[h]alf of the world’s desalination capacity is in the Middle East/Persian Gulf/North Africa regions.” Saudi Arabia in particular relies extensively on desalination for its drinking water.¹⁰² While not contributing greatly to total world capacity, desalination is also an important local source of fresh water in “locations where the natural availability of fresh water is insufficient to meet demand and where traditional water-supply options or transfers from elsewhere are implausible or uneconomical.”¹⁰³ The Caribbean is an example of just such a place.¹⁰⁴

These figures notwithstanding, desalination remains a relatively insignificant source of fresh water overall. “[G]lobally, installed desalination plants have the capacity to provide just three one-thousandths (0.3%) of total world freshwater use.”¹⁰⁵

There is indication, however, that use of desalination worldwide may be increasing. Various regions in Australia have been suffering from severe drought and water shortages in the twenty-first century, prompting Perth, in Western Australia, to turn to desalination.¹⁰⁶ Driven by drought, declines in stream flow, and a rapidly growing population,¹⁰⁷ it began building its first desalination plant, the Kwinana plant, in 2006 and immediately considered a second one.¹⁰⁸ “Other water-stressed seaside cities in Australia”—such as Sydney—“are taking a serious look at desalination, as traditional water sources dry up because of lack of rain.”¹⁰⁹ Similarly dry countries, such as Oman and Spain, are also pursuing desalination options.¹¹⁰ In 2006, the Singapore-Tuas Seawater Desalination Project became “the largest of its kind in Asia and one of the largest in the world,

100. *Id.* at 21 fig. 4.

101. *Id.* at 11.

102. *Id.* at 20; see also *The Arid West*, *supra* note 54 (“Sixty percent of desalination plants are located in the Middle East. As of 2005 Saudi Arabia had twenty-seven plants desalinating 70% of the country’s drinking water.”).

103. COOLEY ET AL., *supra* note 6, at 11.

104. *Id.*; see also *id.* at 20 (“It is important to note that many smaller island communities . . . rely on desalination for a large fraction of their total water need.”).

105. *Id.* at 19; see also DESALINATION: A NATIONAL PERSPECTIVE, *supra* note 9, at 15-16 (citations omitted) (“Worldwide, the online capacity for desalination now exceeds 37 million cubic meters of water per day (30,000 acre-feet per day or 10,000 million gallons per day), although this sum represents only about 0.3 percent of total freshwater use.”).

106. *Perth Seawater Desalination Plant, Seawater Reverse Osmosis (SWRO), Kwinana, Australia*, WATER-TECHNOLOGY.NET, <http://www.water-technology.net/projects/perth> (last visited Nov. 13, 2009) [hereinafter WATER-TECHNOLOGY.NET].

107. See Sullivan, *supra* note 40.

108. Water-Technology.net, *supra* note 106.

109. Sullivan, *supra* note 40.

110. *Id.*

accommodating 10% of Singapore's national water demand" with a production capacity of 136,380 m³/day (36 million gallons per day).¹¹¹

F. Desalination in the United States

In 1962, the town of Buckeye, Arizona, became the first city in the U.S. to depend exclusively on desalination for its water supply by relying on an electrodialysis plant that provided 650,000 gallons per day at a cost of about \$1.00 per 1670 gallons.¹¹² Five years later, "Key West, Florida, opened a flash-evaporation plant and became the first city in the United States to draw its freshwater from the sea."¹¹³

As of the first decade of the twenty-first century, over one thousand desalination plants operate in the United States, many in the "Sunbelt."¹¹⁴ The Pacific Institute noted in 2006 that "[d]esalination plants have been built in every state in the United States[,]" with reported installed capacity increasing about thirty percent between 2000 and 2005.¹¹⁵ Most desalinated water is used for municipal water supply, while eighteen percent goes to industry.¹¹⁶ Nevertheless, as is true globally, desalination supplies only a small fraction of the fresh water used in the U.S.: "[b]y January 2005, over 2,000 desalination plants larger than 0.3 MGD (100 m³/d) had been installed or contracted. These plants have a total installed capacity of only around 1,600 MGD (6.0 million m³/d)—less than four one-thousandths (0.4%) of total U.S. water use."¹¹⁷

Thirteen states provide at least one percent of the desalination capacity in the United States: Florida (2 million m³/day installed capacity); California (about 900,000 m³/day installed capacity); Arizona and Texas (each with slightly over 500,000 m³/day installed capacity); Virginia and Colorado (each with about 150,000 m³/day installed capacity); and Pennsylvania, Ohio, Alabama, North Carolina, Utah, Oklahoma, and Hawaii (each with 100,000 m³/day or less installed capacity).¹¹⁸ Currently, the largest desalination plant in North America is the \$158 million Tampa Bay Seawater Desalination Plant in Florida, which

111. *Black & Veatch-Designed Plant Wins Global Water Distinction*, WATERWORLD Apr. 7, 2006, <http://www.waterworld.com/index/display/article-display/252379/articles/waterworld/projects-contracts/black-veatch-designed-singapore-desalination-plant-wins-global-water-distinction.html>.

112. Thomas E. Stimson, *Fresh Water From the Sea: Can We Afford It?*, POPULAR MECHANICS, Aug. 1964 at 98.

113. *Id.*

114. Skoloff, *supra* note 18.

115. COOLEY ET AL., *supra* note 6, at 21.

116. DESALINATION: A NATIONAL PERSPECTIVE, *supra* note 9, at 22.

117. COOLEY ET AL., *supra* note 6, at 21; see also DESALINATION: A NATIONAL PERSPECTIVE, *supra* note 9, at 22 (citation omitted) (reporting that in 2005, the total capacity of 1,100 online desalination plants was "less than .01 percent of U.S. municipal and industrial water use.").

118. COOLEY ET AL., *supra* note 6, at 23 fig.8; see also DESALINATION: A NATIONAL PERSPECTIVE, *supra* note 9, at 22 (listing Florida, California, Arizona, and Texas as the four states with the largest capacities for desalination).

produces about twenty-five million gallons a day of drinking water through reverse osmosis.¹¹⁹ However, larger plants have been proposed for Huntington Beach and Carlsbad, California.¹²⁰ Indeed, the Carlsbad facility “would be the largest in the Western Hemisphere.”¹²¹

Other states, like Massachusetts, are jumping on the desalination bandwagon. In 2004, the Massachusetts cities of Swansea, Brockton, Hull, and North Shore were considering desalination as a water supply option.¹²² By May 2008, Brockton “inaugurated a brand-new, \$60 million reverse osmosis desalinization plant to supply a portion of its drinking water.”¹²³ Ironically, though Brockton receives four feet of rain a year, it is running short of fresh drinking water and will use the new plant to desalinate brackish water.¹²⁴

Although Brockton’s new plant is typical of desalination in the U.S., it is not necessarily typical of desalination in the world as a whole. For example, while thermal distillation processes provide about forty percent of the desalination capacity worldwide, “[i]n the United States, reverse osmosis and other membrane systems account for nearly 96 percent of U.S. online desalination capacity . . . and 100 percent of the municipal desalination capacity.”¹²⁵ Moreover, according to the NRC’s 2008 report, only eight percent of the water desalinated in the United States is seawater, while seventy-seven percent is brackish water.¹²⁶ A Pacific Institute study makes clear that the U.S. has not yet committed wholeheartedly to true seawater desalination:

Around half of all U.S. capacity is used to desalinate brackish water. Twenty-five percent of all U.S. capacity desalinates river water, which is relatively easy and cost-effective for industrial, power plant, or some municipal use. While seawater is the largest source globally, less than 120 MGD (0.45 million m³/d) of seawater, or less than 10% of U.S. capacity, is desalinated in the U.S. The remaining capacity is primarily dedicated to desalinating wastewater and pure water for high-quality industrial purposes.¹²⁷

119. Skoloff, *supra* note 114.

120. Ritch, *supra* note 35.

121. Kranhold, *supra* note 84.

122. See, *Ocean Water Desalting Plants Worry Environmentalists*, REDORBIT, Apr. 12, 2004, http://www.redorbit.com/news/science/54614/ocean_water_desalting_plants_worry_environmentalists/index.html.

123. Schneider, *supra* note 20.

124. *Id.*

125. DESALINATION: A NATIONAL PERSPECTIVE, *supra* note 9, at 20 (citation omitted); see also COOLEY ET AL., *supra* note 6, at 22. “Like the rest of the world, RO is the most common desalination technology used in the U.S., accounting for nearly 70% of the U.S. installed desalination capacity, or roughly 1,100 MGD (4.0 million m³/d) However, the second-most common desalination technology globally, MSF, is uncommon in the U.S.; only 1% of the total U.S. desalination capacity is based on MSF. By contrast, NF is much more common in the U.S., accounting for around 15% of total U.S. capacity. Of the 370 MGD (1.4 million m³/d) of water that is desalinated worldwide using NF, about 65% of it (nearly 240 MGD, or 0.89 million m³/d) occurs in the U.S.” COOLEY ET AL., *supra* note 6, at 22.

126. DESALINATION: A NATIONAL PERSPECTIVE, *supra* note 9, at 22, 24.

127. COOLEY ET AL., *supra* note 6, at 22.

Nevertheless, there are several signs that seawater desalination will become more common in the U.S.. As noted, California is increasingly turning to seawater desalination to address its ever-increasing water shortages,¹²⁸ and in March 2003, five major municipal water agencies there formed a coalition to lobby for federal legislation and financial assistance in hopes of encouraging construction of desalination plants.¹²⁹ Moreover, in February 2003, the U.S. Bureau of Reclamation and the U.S. Department of Energy released a “research road map” to guide investments and reduce the costs of desalination, postulating that “by 2020 desalination and water purification technologies can contribute significantly to ensuring a safe, sustainable, affordable, and adequate water supply for the United States.”¹³⁰ However, a nationwide commitment to seawater desalination for water supply purposes would have significant ramifications for U.S. national energy policies, as the next Part indicates.

IV. THE ENERGY COSTS OF DESALINATION AND ALTERNATIVE ENERGY POSSIBILITIES

A. *Current Desalination and Energy Consumption*

Water supply has never been energy-free. The NRC recognized in 2008 that “[w]ater resource management currently uses significant amounts of electrical and natural gas energy to capture, treat, and transport water[.]” and as a national average, this use accounts for approximately 3.5% of all electrical energy consumed in the U.S.¹³¹

“[D]esalination is an energy-intensive process that would add more demand. A comparison of energy use for different water sources . . . suggests that seawater [reverse osmosis] requires about 10 times more energy than traditional treatment of surface water.”¹³² Indeed, a study in California revealed that pumping groundwater from 120 feet below the surface uses 0.14 kilowatt hours per cubic meter of water (kWh/m³), while pumping groundwater from 200 feet below the surface uses 0.24 kWh/m³, treatment of surface water uses 0.36 kWh/m³, transportation of water from the Colorado River Aqueduct to San Diego (the farthest destination) uses 1.6 kWh/m³, and transportation of water from the

128. Kranhold, *supra* note 84.

129. *The Arid West*, *supra* note 54.

130. WATER SCI. & TECH. BD., NAT’L RESEARCH COUNCIL, REVIEW OF THE DESALINATION AND WATER PURIFICATION TECH. ROADMAP 20 (2004); see also McKinley Conway, *Desalination is the Solution to Water Shortages*, REDORBIT, May 2, 2008 http://www.redorbit.com/news/science/1367352/desalination_is_the_solution_to_water_shortages/index.html (advocating increased use of desalination in the U.S.).

131. DESALINATION: A NATIONAL PERSPECTIVE, *supra* note 9, at 141 (citation omitted). According to the California Energy Commission, California’s use of energy for “normal” water supply processes is much higher—“10% of all electricity production in California is consumed in moving water around the state; another 9% for treating, disposing, pumping, heating, cooling, and pressurizing water.” Cook, *supra* note 1.

132. DESALINATION: A NATIONAL PERSPECTIVE, *supra* note 9, at 141-42 (citation omitted).

San Francisco Bay Delta to San Diego (again, the farthest destination) uses 2.6 kWh/m³.¹³³ Brackish water desalination (without transportation) is more energy intensive than pumping groundwater at 0.3 to 1.4 kWh/m³. Seawater desalination (without transportation) is in its own category at an energy cost of 3.4 to 4.5 kWh/m³.¹³⁴ Thus, according to the Pacific Institute, “even in San Diego—the farthest point of delivery in the State Water Project and Colorado River Aqueduct systems—seawater desalination requires more energy than any other source of supply. Because energy embedded in imported water supplies is at a maximum in San Diego, seawater desalination is even more energy-intensive in relation to other options elsewhere in California.”¹³⁵

Desalination techniques vary amongst themselves in energy consumption, with seawater RO falling somewhere in the middle range. Among thermal distillation methods, multi-effect distillation uses 1.5 to 2.5 kWh/m³; multistage flash distillation uses 3 to 5 kWh/m³; and mechanical vapor compression uses 8 to 15 kWh/m³.¹³⁶ Of the membrane-based methods of desalination, seawater RO typically requires 2.5 to 7 kWh/m³;¹³⁷ brackish water RO uses 0.5 to 3 kWh/m³; nanofiltration uses less than 1 kWh/m³; and electrodialysis and electrodialysis reversal use about -0.5 kWh for every 1000 micrograms per liter of ionic species removed.¹³⁸ However, while “[t]he combined energy requirements of thermal technologies are greater than that of membrane processes, . . . MSF and MED are capable of using low-grade and/or waste heat, which can significantly improve the economics of thermal desalination Utilities in the U.S. have generally overlooked opportunities to couple thermal processes with sources of waste heat to produce desalinated water more economically.”¹³⁹

Energy consumption is itself an important consideration in the decision of whether to use desalination for water supply, especially in an era of climate change.¹⁴⁰ However, the energy demands of desalination techniques also affect

133. *Id.* at 142 tbl.5-2.

134. *Id.*

135. COOLEY ET AL., *supra* note 6, at 56 (footnote omitted).

136. DESALINATION: A NATIONAL PERSPECTIVE, *supra* note 9, at 78 tbl.4-2.

137. *Id.*

138. DESALINATION: A NATIONAL PERSPECTIVE, *supra* note 9, at 79, tbls.4-2 & 4-3.

139. DESALINATION: A NATIONAL PERSPECTIVE, *supra* note 9, at 93. This study noted that other parts of the world have benefited from this cogeneration possibility: “In the Middle East, the largest of the MSF and MED plants are built along with power plants and use the low-temperature steam exhausted from the power plant steam turbines. This “cogeneration” approach combines water production with the generation of electric power using the same fuel and offers a method to improve the energy efficiency of desalination plants while sharing intake and outfall structures. Large MSF distillers are commonplace in the Middle East largely because of cogeneration. In another example, many of the largest modern cruise ships select the thermal MED desalination process because MED requires 20 to 33 percent of the electrical energy of RO and because the heat energy it requires can be obtained from the ships’ propulsion engines.” *Id.*

140. COOLEY ET AL., *supra* note 6, at 7. “Desalination offers both advantages and disadvantages in the face of climatic extremes and human-induced climate changes. Desalination facilities may help reduce the dependence of local water agencies on climate-sensitive sources of supply. [However, e]xtensive development of desalination can lead to greater dependence on fossil fuels, an increase in greenhouse gas emissions, and a

the relative—and potentially variable—costs of desalination and the fresh water it produces:

Energy is the largest single variable cost for a desalination plant, varying from one-third to more than one-half the cost of produced water. . . . [E]lectrical energy use accounts for 44% of the typical water costs of an [reverse osmosis] plant, with the remainder from other operation and maintenance expenses and fixed charges (amortization of capital) Thermal plants use even more energy. . . . [I]n a very large thermal seawater desalination plant, energy costs account for nearly 60% of the typical cost of produced water. At these percentages, a 25% increase in energy cost would increase the cost of produced water by 11% and 15% for RO and thermal plants, respectively. Unless there is a way to greatly reduce the actual amount of energy used in desalination processes, the share of desalination costs attributable to energy will rise as energy prices rise.¹⁴¹

Energy demands of course vary with the particulars of the desalination plant. For example:

The specific energy for [reverse osmosis] desalination varies with the system used, the operational conditions (e.g., flux, recovery), and the quality of feedwater to the RO system. For seawater RO, the specific energy usage is typically about 3-7 kWh/m³ with energy recovery devices For brackish water RO, energy usage is comparatively lower, about 0.5-3 kWh/m³, because the energy required for desalination is proportional to the feedwater salinity Energy usage values should be taken cautiously because the “system” for which desalination energy use is calculated and reported (i.e., basic RO process only, or including other ancillary equipment or processes) varies in the literature.¹⁴²

As with many technologies, improvements in efficiency in desalination are both possible and occurring. “The reduction in energy use for [reverse osmosis] in the past 20 years has been remarkable . . . and has had a significant and direct effect on operating costs. Energy use of as low as 1.6 kWh/m³ is achievable using controlled, favorable conditions and commercially available state-of-the-art equipment including energy recovery devices, feed pumps, and low-pressure membranes.”¹⁴³ Developments such as energy recovery devices, which recover

worsening of climate change.” *Id.* Studies in California have recommended that new desalination plants be carbon neutral. *Id.*

141. COOLEY ET AL., *supra* note 6, at 41; see also Cook, *supra* note 1 (“In 2003, Water International estimated that 44% of the cost of desalination was the energy component.”).

142. DESALINATION: A NATIONAL PERSPECTIVE, *supra* note 9, at 77 (citations omitted).

143. *Id.* at 84-85 (citations omitted).

energy from the waste concentrate streams at RO plants, are increasing the energy efficiency of desalination plants.¹⁴⁴ Other techniques reducing energy consumption include forward osmosis, a membrane-based separation process relying on osmotic pressure to desalinate water; de-evaporation, which uses heat to desalinate a saline vapor; membrane distillation, which uses heated saltwater and membranes permeable to steam but not to liquid water; freeze desalination, which turns salt water to ice in order to freeze out the salts; and capacitive deionization, an electrosorption process that uses an electric field gradient to remove ions from water.¹⁴⁵

In 2008, researchers calculated a range of energy requirements for desalination at a global scale, assuming a peak world population of 9.2 billion people around 2050. Based on the fact that the most efficient RO desalination plants consume about 5 kWh/m³, the researchers constructed two scenarios, representing two potential extremes in desalination futures. At the low end, assuming that desalination efficiencies increase to 2.5 kWh/m³ and that, on average, each person uses 130 cubic meters of water per year (Denmark's current consumption rate), desalination could provide ten percent of the world's fresh water supply for thirty-four gigawatts (34 billion watts), or less than two percent of the 2005 average global energy production of 2100 gigawatts.¹⁴⁶ Conversely, if energy demands remain at 5 kWh/m³ and people consume water at the current high-end of U.S. consumption—1730 cubic meters of water per person per year—it would take 9100 gigawatts, more than four times the world's 2005 electricity production, to supply 100% of the world's fresh water.¹⁴⁷

While these calculations are just illustrative scenarios, they nevertheless suggest that water conservation and efficient use are as important for the future of desalination as increased energy efficiency in desalination technologies themselves.¹⁴⁸ Moreover, current electricity production is itself water-intensive,

144. *Id.* at 85-86.

145. *Id.* at 82-83 box 4-5 (citations omitted); see also *Energy Efficient Desalination Takes a Step Forward*, ENERGY DAILY, May 18, 2007, http://www.energy-daily.com/reports/Energy_Efficient_Desalination_Takes_A_Step_Forward_999.html (reporting on a new research collaboration effort to produce energy efficient membranes for reverse osmosis desalination); Energy Recovery Inc, *How it Works*, ENERGY RECOVERY, INC, http://www.energyrecovery.com/px_technology/how_it_works.php4 (last visited Apr. 17, 2009) (illustrating an energy recovery device); Emma Ritch, *Oasys Develops Energy-Efficient Osmosis for Desalination*, CLEANTECH GROUP L.L.C., Jan. 16, 2009, <http://cleantech.com/news/print/4065> (reporting that the Yale University spin-out company Oasys "has developed a low-cost, low-energy desalination and purification technology for seawater, wastewater, and industrial waste streams" using forward osmosis).

146. *Large Scale Desalination: Is There Enough Energy to Do It?*, LIGHTBUCKET, Apr. 4, 2008, <http://lightbucket.wordpress.com/2008/04/04/large-scale-desalination-is-there-enough-energy-to-do-it/>.

147. *Id.*; see also Kris De Decker, *Water Eats Energy: Desalination*, LOW-TECH MAGAZINE, Nov. 7, 2007, <http://www.lowtechmagazine.com/2007/11/water-eats-ener.html> (concluding that "if we count on the oceans to fulfill our future need [for fresh water], we have to find an extra 30,000 terawatt-hours of energy—twice the current global electricity production figure." This conclusion is based on assumptions that by 2050 the world will need another 5000 cubic kilometers of water and that it will all come from desalination).

148. See Cook, *supra* note 1 (arguing that increasing water use efficiencies is more important than pursuing desalination in securing water supply).

leading one analyst to conclude that the production of one cubic meter of fresh water from desalination will require 0.84 to 1.08 cubic meters of cooling water, suggesting that power plants would have to use salt water for cooling water if desalination is really to increase the overall fresh water supply.¹⁴⁹

Furthermore, desalination is currently far from energy efficient. “The theoretical minimum amount of energy required to remove salt from a liter of seawater using RO is around 2.8 kilojoules (or around 3 kilowatt-hours per thousand gallons (kWh/kgal) or 1 kilowatt-hour per cubic meter (kWh/m³)). Even the most efficient plants now operating use as little as 4 times the theoretical minimum; some use up to 25 times the theoretical minimum.”¹⁵⁰

B. Desalination Using Alternative Sources of Energy

The NRC recognized in its 2008 report on desalination that “[e]nergy sources other than fossil hydrocarbons can provide energy for desalination and thus avoid or significantly reduce greenhouse gas emissions.”¹⁵¹ Such sources include nuclear energy, hydroelectricity, and solar energy, all of which eliminate greenhouse gas emissions and significantly reduce the carbon footprint of desalination.¹⁵² “Other alternative energy sources such as biofuels (1.6 percent) are nearly neutral in terms of greenhouse gas emissions, and closed-loop geothermal systems can be essentially greenhouse gas-free. . . . [T]hermal desalination plants can utilize low-grade or waste heat resources and substantially reduce their prime energy demands.”¹⁵³

At present, there is a keen global interest in developing alternative energy sources to power desalination. Depending on local conditions, these include photovoltaic solar energy, heat-driven solar processes such as solar evaporation, closed geothermal projects, ocean thermal energy, and salinity-gradient solar ponds.¹⁵⁴ “Proposed mechanical-driven alternative energies for desalination include wind power, wave power, tides, and hydrostatic head.”¹⁵⁵

1. Wind Power Case Study: Kwinana Desalination Plant, Perth, Australia

According to researchers, “[w]ind-powered desalination is one of the most promising uses of renewable energies for seawater desalination.”¹⁵⁶ In addition to

149. See De Decker, *supra* note 147. Of course, as the author recognized, power plants do not actually consume all of the cooling water they use.

150. COOLEY ET AL., *supra* note 6, at 42 (citations omitted) (footnote omitted).

151. DESALINATION: A NATIONAL PERSPECTIVE, *supra* note 9, at 142.

152. *Id.*

153. *Id.* at 142-143 (citation omitted).

154. *Id.* at 143.

155. *Id.* (citation omitted).

156. L. García-Rodríguez, et al, Economic Analysis of Wind-Powered Desalination, 137 DESALINATION 259, 259 (2001).

its promise of reduced emissions for the power generating sector,¹⁵⁷ in certain locations costs of wind power to drive desalination are becoming comparable with other energy costs in water supply:

Costs less than US \$0.05 per kWh have been achieved for some grid-connected wind generators, and costs of approximately \$0.03 per kWh are projected for a wind installation in Scotland in a region that has consistent, high-speed winds. . . . Onshore wind systems cost about 3 to 5 cents per kilowatt hour (kWh) and offshore wind systems are double the cost at 6 to 10 cents/kWh. However, these costs are projected to drop by 2020 to approximately 2 to 3 cents/kWh. Fossil fuel costs are estimated at 2 to 4 cents/kWh for natural gas and 3 to 5 cents/kwh for coal.¹⁵⁸

Illustrating the viability of wind-powered desalination is the Perth Seawater RO Plant opened in Kwinana, Australia. When this plant opened in 2006, it made Western Australia the first state in Australia to rely on desalination as a major source of public water supply.¹⁵⁹ The plant can produce 140,000 m³/day and supplies 1.5 million people with water, about 17-20% of Perth's needs, and it can expand to a capacity of 250,000 m³/day.¹⁶⁰ This desalination plant is "the largest of its kind in the southern hemisphere," costing AU\$387 million but anticipated to deliver water at a cost of AU\$1.17 per 1000 liters.¹⁶¹

Most importantly, the Kwinana desalination plant is "the biggest in the world to be powered by renewable energy."¹⁶² The plant's overall energy requirement is 24 megawatts of electricity, and it takes 4.0 to 6.0 kilowatt hours to produce 1000 liters of water.¹⁶³ This electricity comes from the 80-megawatt Emu Downs Wind Farm, which uses forty-eight turbines to generate electricity.¹⁶⁴ The Kwinana plant "is the first example of using alternative energy to power desalination at a large scale. The Perth wind farm is not a dedicated stand-alone power source; rather it feeds into the power grid from which the desalination plant contracts to withdraw its electrical power."¹⁶⁵

Use of the Emu Downs wind farm made the desalination plant acceptable to local environmentalists. According to National Public Radio in the U.S., "[e]nvironmentalists in Perth balked at the idea of using coal-fired plants to

157. American Wind Energy Ass'n., Fact Sheet: Wind Power and Climate Change, (June 8, 2009), http://www.awea.org/pubs/factsheets/Climate_Change.pdf.

158. Edward Spang, The Potential for Wind-Powered Desalination in Water-Scarce Countries 27-28 (Feb. 7, 2006) (unpublished M.A. thesis, Fletcher School, Tufts University), available at <http://fletcher.tufts.edu/research/2006/Spang.pdf>.

159. Water-Technology.net, *supra* note 106.

160. *Id.*; see *Australia Turns to Desalination*, *supra* note 40.

161. Water-Technology.net, *supra* note 106.

162. *Id.*

163. *Id.*

164. *Id.*

165. DESALINATION: A NATIONAL PERSPECTIVE, *supra* note 9, at 143.

provide power for the one here, forcing the Water Corp. to find a non-polluting, renewable alternative.”¹⁶⁶ Emu Downs is considered “among the top ten or twenty sites for this type of energy alternative in Australia.”¹⁶⁷

2. *Solar Power Case Studies: Teatro Del Agua, Spain, and Masdar, United Arab Emirates*

Solar energy is similarly considered a “clean” source of energy. Although still in the design stages, the Teatro del Agua Solar Desalination Plant in Spain’s Canary Islands will use solar panels to provide the heat for evaporation in a distillation and condensation desalination plant.¹⁶⁸ The plant is built directly over seawater, which both supplies the source of the water and cools the condensers.¹⁶⁹ The project is billed as a “low-cost, low-energy, carbon-neutral approach to desalination.”¹⁷⁰

The Teatro del Agua makes use of an elegant (and beautiful) architectural approach to what is, most basically, a form of thermal desalination:

The entire structure is oriented to the prevailing northeasterly wind off the ocean, exploiting the natural resources of the islands. Any shoreline location with wind coming off the sea could work the same way.

The design consists of a gigantic honeycomb lattice, with smaller grids in each section of the lattice. The entire structure is really a series of solar panels, evaporators and condensers.

First, hot salty air flows through the grid on the right, toward the blue tubes, which are the condensers. They are filled with very cold seawater pumped up from the deep ocean (that’s why it has to be next to a deepwater source, for the heat differential) with holes at the tops, under each solar panel “roof.”

Solar-powered fans blow the cold ocean spray out . . . against the prevailing warm sea wind coming through the grid. The combination of cold spray and warm air causes the salt to dry on the grid.

Once the warm, humid sea air, cleansed of salt, reaches the columns, it is rapidly cooled by the seawater inside each column. The resulting condensation drips down each column, sliding into containers at the bottom. It’s stored underground, producing “enough fresh water to

166. *Australia Turns to Desalination*, *supra* note 40.

167. *Id.*

168. Mike Chino, *Spain’s Stunning Teatro del Agua Solar Desalination Plant*, June 18, 2008, <http://www.inhabitat.com/2008/06/18/charles-patons-teatro-del-agua/>.

169. *Id.*

170. *Id.*

supply a city,” according to [the designer, Charles] Paton. That depends on the size of this desalination structure and the city size and population.¹⁷¹

There are similar proposals for solar desalination in other locations as well. For example, “[s]olar-powered desalination coupled with water reuse is a centerpiece of Masdar, an initiative in the United Arab Emirates to build the world’s first carbon-neutral city.”¹⁷² The city’s solar desalination plant is “expected to have a capacity of 10,000 cubic meters of water per day, which is enough to fill four Olympic-size swimming pools,” and to “produce two types of high quality water: one fit for drinking and one for personal uses such as showering and washing dishes.”¹⁷³ Construction of Masdar City is not expected to be complete until 2016, but residents may begin moving in as early as this year (2009).¹⁷⁴

C. Desalination as a Better Use of Alternative Energy Sources?

Using alternative energy sources, such as wind and solar for desalination may, paradoxically, also help to resolve (or at least transition through) some of the current practical difficulties of relying on these energy sources. Unfortunately, wind is gusty, making it inconsistent and thus an unreliable source of electricity in most locations. Germany’s experiences with wind power prompted Eon Netz, German grid manager, to comment that, “[e]lectricity generation from wind fluctuates greatly, requiring additional reserves of ‘conventional’ capacity to compensate; high-demand periods of cold and heat correspond to periods of low wind; only limited forecasting is possible for wind power; wind power needs a corresponding expansion of the high-voltage and extra-high-voltage grid infrastructure; and expansion of wind power makes the grid more unstable.”¹⁷⁵

Solar energy presents a similar problem regarding consistent energy supply.¹⁷⁶ For example, even in places like the Middle East, where sunshine is fairly consistent, the sun still shines only in the day, creating issues of electricity storage.

171. Susan Kraemer, *Desalination Using Sun, Wind and Sea*, MATTER NETWORK, Sept. 26, 2008, <http://featured.matternetwork.com/2008/9/desalination-using-sun-wind-sea.cfm> (alterations in original).

172. DESALINATION: A NATIONAL PERSPECTIVE, *supra* note 9, at 143.

173. Vesela Todorova, *Masdar Sets Water Efficiency Targets*, THE NATIONAL (May 1, 2008), available at <http://www.thenational.ae/apps/pbcs.dll/article?AID=/20080501/NATIONAL/388086841#>.

174. Amy Glass, *Masdar to Welcome First Residents Next Year*, ARABIAN BUSINESS.COM, May 13, 2008, <http://www.arabianbusiness.com/519167-masdar-to-welcome-first-residents-next-year>.

175. Eric Rosenbloom, *A Problem with Wind Power*, 1, Sept. 5, 2006, <http://www.aweo.org/ProblemWithWind.pdf>.

176. See CSIRO Australia, *Smarter Energy Storage for Solar and Wind Power*, SCIENCEDAILY, Nov. 29, 2007, <http://www.sciencedaily.com/releases/2007/11/071127101936.htm>.

Conversely, water is relatively easy to store, and suggests two potential future paths for linking energy policy and water policy. First, in the balancing of tradeoffs, and especially while electricity storage problems are still being resolved, alternative energy technologies might be productively directed toward water desalination. Such use might provide real-world facilities for testing and improving alternative energy technologies free from the supply issues that arise in trying to inject wind and solar electricity production into standard electricity grids. Second, in addition to desalinating water, such projects may discover ways to “store” solar and wind energy in the form of water—for example, by pumping water to uphill storage facilities, where the water then can be used as needed to generate electricity through more standard hydroelectric operations.

Thinking about water policy and energy policy together, in other words, may generate new and creative ways of thinking about both. Water supply issues in particular may provide opportunities for thinking outside the traditional energy policy constraints.

V. CONCLUSION

While water crises are (or are about to become) real in many parts of the world, they “cannot be addressed in isolation of our energy crisis.”¹⁷⁷ Desalination is such a potentially viable water supply option that countries such as Australia and the United States are increasingly employing to avert acute water crises and to supplement more traditional water supplies. Like all water-supply technologies, however, desalination encompasses a series of potential trade-offs among a traditional constellation of factors—water needs, energy supply, economic costs, environmental impacts, social benefits, and the relatively new consideration of climate change mitigation and adaptation. How exactly these factors trade off against each other will vary considerably from location to location, rendering desalination an attractive option in some locations and a wasteful option in others.

And that is precisely the point, not just for desalination but for all water supply decisions. Identifying and discussing the tradeoffs, variables, and variations inherent in providing fresh water in different locations should be an integral part of combined water and energy policies. As with most complex human problems, there are unlikely to be universal “first-best” panaceas for resolving the water supply/energy/climate change matrix. Yet desalination, like all other water supply technologies from buckets to pumps, must be on the table—if only because it may help inspire comprehensive and creative approaches to resolving these complexities in socially productive and environmentally productive ways.

177. Cook, *supra* note 1.

* * *