CONTENTS

ARTICLE

Troubled Waters: The Quest for Electricity in Water-Constrained China, France, India, and the United States ....................... Benjamin K. Sovacool, Sara Imperiale, Alex Gilbert, Jay Eidsness, and Brian Thomson ..... 409

STUDENT ARTICLES

From Broken Promises to Sustainable Forestry: Regulation of Private Forests in Liberia ......................... Akiva Fishman 451

The Waste Treatment Exclusion and the Dubious Legal Foundation for the EPA’s Definition of “Waters of the United States” ....................... Scott Snyder 504
TROUBLED WATERS: THE QUEST FOR ELECTRICITY IN WATER-CONSTRAINED CHINA, FRANCE, INDIA, AND THE UNITED STATES

BENJAMIN K. SOVACOOL, SARA IMPERIALE, ALEX GILBERT, JAY EIDSNES & BRIAN THOMSON*

Electricity is necessary for maintaining standards of living in advanced economies, such as the United States and France, and is equally crucial to poverty reduction strategies in developing economies, such as China and India. Yet in the coming decades, the water needed to generate electricity will become increasingly scarce. Relying on a series of GIS-based cartographic assessments tied to specific estimates of growth in electricity demand, population, and water resource use, this article examines the electricity-water nexus through four unique case studies: the North China Grid, the Indian power grid, the French power grid, and the ERCOT grid in Texas. In each case, our analysis shows how “business as usual” trends will lead to potentially catastrophic shortages of water, electricity, or both by 2040. All is not lost, however, as the article concludes by providing a variety of legal and technological recommendations for how policymakers in each of our case studies—and indeed elsewhere—can successfully avert these crises.

TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTRODUCTION</td>
<td>410</td>
</tr>
<tr>
<td>I. THE ELECTRICITY-WATER NEXUS</td>
<td>411</td>
</tr>
<tr>
<td>II. MAPPING FOUR ELECTRICITY-WATER CRISIS AREAS</td>
<td>417</td>
</tr>
<tr>
<td>A. The North China Grid</td>
<td>418</td>
</tr>
<tr>
<td>B. The French National Grid</td>
<td>424</td>
</tr>
<tr>
<td>C. The National Indian Grid</td>
<td>428</td>
</tr>
<tr>
<td>D. The Electric Reliability Council of Texas Grid</td>
<td>433</td>
</tr>
<tr>
<td>III. ELECTRICITY-WATER NEXUS SOLUTIONS</td>
<td>438</td>
</tr>
</tbody>
</table>

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INTRODUCTION

Imagine if, in 1924, the Coolidge Administration had been able to warn President Roosevelt about the attack on Pearl Harbor in 1941. Or if President Nixon had been able to predict the 1986 Challenger disaster, or President Reagan the September 11, 2001 terrorist attacks on the Pentagon and World Trade Center. Consider, if these leaders had possessed advanced knowledge, how different our world might be.

In a fortuitous twist of fate, in 2014 we are able to foresee with some analytical rigor the likelihood of a major crisis in 2040. We know, to a reasonable degree, where this crisis will occur, and we have all of the necessary preventative tools at our disposal. The only thing impeding us from acting to avert this crisis is a combination of shortsighted thinking and fragmented decision making.

The problem, simply put, is that existing and planned electricity supply—generally from thermoelectric power plants, facilities that combust fuels or cause the fission of atoms—depends too heavily on assumptions of widespread, abundant water resources. Due to its perceived cheapness and abundance, water is often overlooked as a critical constraint in electricity and energy decisions, one that when included challenges us to think more broadly about integrated resource planning, reliability challenges, and resource selection. This article assesses the electricity-water nexus in four different locations: the North China Grid, the Indian power grid, the French power grid, and the Electric Reliability Council of Texas (ERCOT) grid. Our analysis
shows how “business as usual” trends will lead to potentially catastrophic shortages of water, electricity, or both by 2040. To make this point, Part I of the article introduces readers to the electricity-water nexus (EWN); the extent to which power generation depends on water availability.

Part II uses the EWN to demonstrate how water may become a key limitation to thermoelectric power generation in case studies of the four locations. Each case reveals something different about the electricity-water nexus: China, the sheer quantity of water needed to meet future electricity demand; France, the water-related vulnerability of nuclear power units; India, the water vulnerabilities of coal-fired power; and Texas, the significance of wind energy and natural gas in enabling power providers there to generate electricity in times of drought while reducing water dependencies. Our analysis is based on current measurements and future projections of water use, population, and power demand through 2040, and is presented with a collection of digital maps made with Geographic Information Systems (GIS) software.

Finally, Part III of the article recommends several regulatory and technical solutions to avert EWN crises by reducing water vulnerabilities at thermoelectric power plants. These solutions include, among others, incorporating water as a resource constraint in integrated resource planning, refining and developing alternative cooling technologies, promoting energy efficiency, and deploying electricity generation technologies that are minimally water dependent, including wind and solar.

I. THE ELECTRICITY-WATER NEXUS

Intense water use may cause conventional electricity generators to become obsolete in the near future in places of water stress and water scarcity.\(^1\) As one independent study recently

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\(^1\) The term “use” denotes water withdrawals and consumption for both the production and combustion of various electricity fuels. The term “water stress” refers to when annual water supplies drop below 1,700 cubic meters per person per year. The term “water scarcity” refers to when water supplies drop below 1,000 cubic meters per person per year. See Benjamin K. Sovacool & Kelly E. Sovacool, Identifying Future Electricity-Water Tradeoffs in the United States, 37 ENERGY POL’Y 2763, 2764 (2009) (“Thermoelectric power plants—power stations that combust coal, oil, natural gas, biomass, and waste to produce electricity, or fission atoms in a nuclear reactor—use water by ‘consuming’ and ‘withdrawing’ it. These plants ‘withdraw’ water from rivers, lakes, and streams to cool equipment before returning it to its source, and they ‘consume’ water...
summarized, “Water and electricity are inexorably linked and mutually dependent, with each affecting the other’s availability. Electricity is required to supply, purify, distribute, and treat water and wastewater; water is needed to generate electricity and to extract and process fuels used to generate electricity.” Water is also becoming a salient energy security concern internationally among energy experts. One broad-ranging survey of 2,167 energy experts in ten countries, including the United States, Japan, China, India, and Saudi Arabia, found that “enhancing the availability and quality of water” was the highest rated energy security dimension among sixteen choices. Respondents rated it more highly than the security of fossil fuel and uranium supplies, promoting energy efficiency, and responding to climate change, among others.

Studying water in this capacity is not merely an academic venture, as these recent, real world consequences demonstrate:

- In 2006, “[a] heat wave forced nuclear plants [throughout the Midwestern United States] to reduce their output because of the high water temperature of the Mississippi River”; 
- In 2007, the Tennessee Valley Authority had to curtail its hydroelectric generation during a drought and also operate nuclear and fossil fuel plants at partial capacity in the Southeastern United States;
- In 2008, the government of China abandoned dozens of anticipated coal-to-liquids projects due to concerns that “they would place heavy burdens on scarce water resources”; 
- In 2009, electricity supply to some parts of Southern Iraq
dropped by 50 percent because of falling surface water levels of the Euphrates river;\(^8\)

- In 2010, extended droughts brought on by the El Niño weather phenomenon reduced hydroelectricity generation in the Philippines and Vietnam for several months, resulting in blackouts throughout both countries;\(^9\)

- In 2011, Chinese provinces along the Yangtze River had to ration electricity due to drought-restricted hydroelectric generation and coal mining;\(^10\)

- In 2012, a delayed monsoon raised electricity demand for irrigation and simultaneously reduced hydroelectricity generation, contributing to blackouts that affected more than 600 million people in India;\(^11\)

- In 2013, operators in Panama had to declare a “state of emergency” after a drought impaired electricity production from the country’s hydroelectric dams, leading to energy-saving measures such as the closure of public schools and shortening of hours at government offices for three days;\(^12\)

- Most recently, in July, 2013, Pacific Gas & Electric, a large electric utility in California, had to shut down one of its large reactors at the Diablo Canyon nuclear power plant because it could not operate during a heat wave.\(^13\)

This is just a short list of how water and electricity generation interact; there are countless other examples. As laid out by one peer-reviewed study, this strongly implies that “[f]ailure to consider the interdependencies of energy and water introduces vulnerabilities whereby constraints of one resource introduce

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\(^9\) INTERNATIONAL ENERGY AGENCY, supra note 5, at 513.

\(^10\) Id.

\(^11\) Id.

\(^12\) Panama Takes Measure to Save Power as Drought Hits Output of its Hydroelectric Plants, FOX NEWS (May 8, 2013), http://www.foxnews.com/world/2013/05/08/panama-takes-measure-to-save-power-as-drought-hits-output-its-hydroelectric/#ixzz2X3Od3K3i.

constraints in the other. That is, droughts and heat waves create water constraints that can become energy constraints. "14

Why does electricity production use so much water? Conventional thermoelectric power plants—those that combust fuel or fission atoms, unlike those that capture sunlight, wind, or falling water—need millions of gallons of water for the condensing, or cooling, portion of the thermodynamic cycle.15 Many conventional power plants employ one of two types of wet cooling: once-through or re-circulating.16 Once-through cooling systems withdraw water from a source, circulate it, and return it to the surface body.17 Re-circulating, “wet tower” or closed-loop systems, withdraw water and then recycle it within the power system rather than discharging it.18 Although often cost-prohibitive—including an energy penalty—and not yet widely used, alternatives such as dry cooling and hybrid wet-dry cooling systems play a niche role in water stressed regions.19 “Dry” cooling systems are useful in arid areas because they rely on air as the primary coolant medium, rather than water.20 “Hybrid” systems incorporate both wet and dry cooling, allowing for operational flexibility in response to changes in water availability.21

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16 ELEC. POWER RESEARCH INST., WATER & SUSTAINABILITY (VOLUME 1): RESEARCH PLAN 2-12 (2002), available at http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001006784 (showing that most power plants use either once-through cooling or cooling ponds, i.e. recirculating).
17 Id. at 2-11.
18 Id. at 2-11.
20 DRY COOLING, supra note 19, at 9; TUNCAY YILMAZ ET AL., AN ALTERNATIVE COOLING SYSTEM FOR HOT, ARID REGIONS (1998) available at http://eng.harran.edu.tr/~hbulut/KUweyt_Paper.pdf (“A number of studies have shown that evaporative cooling systems have the potential to satisfy comfort conditions especially in arid regions and can be applied to both commercial and residential buildings.”).
21 INTERNATIONAL ENERGY AGENCY, supra note 5, at 508.
Coal plants use water to clean and process fuel, and many types of thermoelectric power plants lose water through evaporation. Table 1 illustrates that coal-fired power plants, which account for about 40 percent of the electricity generated in the United States and even more in China, require a range of 27 to 40 gallons of water to produce one kilowatt hour (kWh) of electricity, depending on the power plant technology. A conventional 500 megawatts (MW) coal plant, for instance, consumes about 7,000 gallons of water per minute, or the equivalent of 17 Olympic-sized swimming pools every day. The coal-fired 1,800 MW San Juan Generating Station, operated by Public Service Company of New Mexico, uses 7.3 billion gallons of water per year from the San Juan River. Given that the electric utility sector as a whole generated 3,749 terawatt hours (TWh) in 2011 and required 25 gallons per kWh, power plants collectively needed 93.7 trillion gallons of water in the United States that same year.

As Table 1 also illustrates, nuclear reactors require massive supplies of water to cool reactor cores and spent nuclear fuel rods. Because much of the water is turned to steam, substantial amounts are lost entirely to the local water cycle. One nuclear plant in Georgia withdraws an average of 57 million gallons every day from the Altamaha River, and actually consumes only 33 million gallons per day.

23 ELECTRIC POWER RESEARCH INST., supra note 16, at 2-11 (identifying water being “consumed,” which is water lost through evaporation).
27 Sovacool & Sovacool, supra note 1, at 2764.
28 This figure is the result of multiplying the 3,749 TWh, supra note 26, times the 25 gallons per KWh, supra note 27.
gallons per day because of losses from water vapor.\(^{29}\)

<table>
<thead>
<tr>
<th>Withdrawals</th>
<th>Consumption</th>
<th>Total</th>
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</thead>
<tbody>
<tr>
<td>(Combination/Downstream)</td>
<td>(Production/Upstream)</td>
<td></td>
</tr>
<tr>
<td>Nuclear</td>
<td>43</td>
<td>0.4</td>
</tr>
<tr>
<td>Coal (mining)</td>
<td>35</td>
<td>0.5</td>
</tr>
<tr>
<td>Coal (charry)</td>
<td>35</td>
<td>0.3</td>
</tr>
</tbody>
</table>
| Biomass/ 
  waste | 35 | 0.5 | 0.03 | 0.03 | 35.3 |
| Natural Gas | 13.75 | 0.1 | 0 | 0.01 | 13.9 |
| Solar Thermal | 4.5 | 4.6 | 0 | 0 | 9.1 |
| Hydroelectric | 0 | 0 | 0 | 4.5 | 4.5 |
| Geothermal 
  (steam) | 2 | 1.4 | 0 | 0 | 3.4 |
| Solar PV | 0 | 0 | 0 | 0.3 | 0.3 |
| Wind | 0 | 0 | 0 | 0.2 | 0.2 |
| Energy Efficiency | 0 | 0 | 0 | 0 | 0 |

Outside of the United States, many power plants are just as thirsty. In India, the average coal-fired thermal power plant consumes as much as 7 cubic meters of water (about 1,800 gallons) per MW per hour, meaning a plant drains the equivalent amount of an Olympic size swimming pool every 20 to 40 minutes.\(^{31}\) In China, thermal power plants collectively utilize enough energy to pump more than 34 million gallons of water per minute.\(^{32}\) In France, the 3,000 megawatt electrical (MWe)\(^{33}\) Civaux Nuclear Power Plant can only operate safely and reliably when it stores at least 20 billion liters, or 5.3 billion gallons, of


\(^{30}\) Sovacool & Sovacool, supra note 1, at 2771.


\(^{33}\) In the electric power industry, megawatt electrical (MWe or MW(e)) is a term that refers to electric power, while megawatt thermal or thermal megawatt (MWe, MWt) refers to thermal power. INT’L ATOMIC ENERGY ASSOC. GLOSSARY OF TERMS IN POWER REACTOR INFORMATION SYSTEM REPORTS, http://www.iaea.org/PRIS/Glossary.aspx (last visited Apr. 23, 2014).
water upstream in reservoirs to ensure adequate supply through droughts.34

II. MAPPING FOUR ELECTRICITY–WATER CRISIS AREAS

Unfortunately, the water-intensity of the electricity sector poses major challenges for regions of the globe experiencing rapid, simultaneous growth in population and demand for electricity and water. To illustrate the severity of these trends, this section of the article uses a series of GIS-based maps and integrated projections about electricity supply and demand, population growth, and water resource use from 2010 to 2040 to present four case studies. The data for the case studies are summarized in Table 2.35 Each case study describes a grid where the electricity-water nexus may induce significant crises in the coming decades: the North China Grid, the national grids in France and India, and ERCOT in Texas.

Table 2: Key Electricity and Water Statistics for the North China Grid, France, India, and ERCOT (Texas)

| Source: Institute for Energy & the Environment, Vermont Law School36 |

Our primary method of data collection for this article is a


35 PAUL FAETH, ET AL., A CLASH OF COMPETING NECESSITIES: WATER ADEQUACY AND ELECTRIC RELIABILITY IN CHINA, INDIA, FRANCE, AND TEXAS (2014), available at https://www.cna.org/research/2014/clash-competing-necessities; PAUL FAETH & BENJAMIN K. SOVACOOL, CAPTURING SYNERGIES BETWEEN WATER CONVERSATION AND CARBON DIOXIDE EMISSIONS IN THE POWER SECTOR (2014), available at https://www.cna.org/sites/default/files/research/EWCEWNRecommendationsReportJuly2014FINAL.pdf. This data derives from a collaborative research project undertaken with the authors, the Regulatory Assistance Project (RAP) in Montpelier, Vermont, and the Center for Naval Analysis (CNA) in Alexandria, Virginia. This data has been compiled and coded for the report.

36 Id.
database we constructed to estimate existing and future electricity
capacity, fuel mix, and water resource needs (both by type of
demand and overall volume) across our four case studies from
2010 to 2040. To build this database, we started by collecting data
from the International Energy Agency and U.S. Energy
Information Administration but quickly identified a series of data
holes. We “filled” these holes through a complex process of
contacting experts across our four case studies and verifying data
with both officials and colleagues, a process explained in greater
detail in a forthcoming report.37 We then supplemented our
database with a number of secondary sources that we reference
below. The datasheets involved in our analysis (and key inputs for
our four figures presented in this article) are fully available to the
public.38

A. The North China Grid

    China is the world’s largest energy consumer,39 the biggest
emitter of carbon dioxide,40 fifth largest producer of oil,41 seventh
largest producer of natural gas,42 and the largest miner of coal.43
Over the past ten years, 70 million new jobs were created in the
Chinese economy.44 The country now leads the world in markets
for automobiles, steel, cement, glass, housing, power plants,
renewable energy, highways, rail systems, and airports.45 China’s
economy is growing so fast that analysts anticipate its GDP will
grow from $6 trillion in 2010 to $9 trillion by 2015.\textsuperscript{46} If it sustains that rate of growth, China will overtake the United States as the world’s biggest economy sometime in the 2020s.\textsuperscript{47} In order to feed this growth, energy use in China grew a staggering 146 percent between 1990 and 2008.\textsuperscript{48}

Like the United States, China is a massive country with distinct geography fragmenting the landmass into discrete regions. Though the country is home to roughly one-quarter of the world’s population, most Chinese live in urban areas.\textsuperscript{49} Sprawling metropolitan areas characterize the eastern seaboard where some coastal population densities average between 110 and 1,600 people per square kilometer in rural areas and as high as 2,000 people per square kilometer in urban areas.\textsuperscript{50} Multiple cities, such as Beijing, Shanghai, and Guangzhou, rank within the 25 largest in the world.\textsuperscript{51} Energizing a population of this scale requires robust electricity transmission and generation infrastructure. The State Grid Corporation of China (“SGCC”) is responsible for building and operating the Chinese power grids and providing secure and reliable power for its customers.\textsuperscript{52} The SGCC is divided into five regional power grid companies, the North Grid, the Northeast Grid, the Northwest Grid, the East Grid, and the Central Grid, with each grid containing provincial electric power companies.\textsuperscript{53} Within each grid are numerous generation facilities deriving energy from various fuels. The SGCC manages and facilitates intra and inter-regional flows of electricity aimed at preventing regional power

\textsuperscript{46} Id. at 733.
\textsuperscript{47} Id.
\textsuperscript{48} INT’L ENERGY AGENCY, 2010 KEY WORLD ENERGY STATISTICS 48 (2010).
\textsuperscript{51} Id.
outages and reducing transmission line loss.  

The North China Grid serves the municipalities of Beijing and Tianjin as well as the provinces of Hebei, Shanxi, Shandong, and parts of Inner Mongolia. In terms of its size, the North China Grid serves nearly 250 million people, nearly a quarter of China’s population. According to the most recently available data, the North China Grid Company Limited operated a grid constituting 247,840 MW of capacity in 2010, but this is projected to jump to 631,444 MW of capacity by 2040. Most of that growth will occur in Shanxi, Shandong, and Tianjin Provinces, as Figure 1 shows. Rapid growth is not unique to the North China Grid; the International Energy Agency (IEA) projects a near doubling of China’s domestic electricity generation by 2035. Unlike our other case studies, capacity growth in the North China Grid is not driven by the construction of new power plants, but rather by increasing capacity at existing facilities.

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56 See Prefectures of China, STATOIDS, http://www.statoids.com/ycn.html (last visited Apr. 17, 2013) (showing current populations for China’s prefectures that can be used to calculate rough population in the North China Grid).
Figure 1: Projected Changes in Installed Electricity Capacity in the North China Grid, 2010–2040 (MW)

Note: The map shows negative growth in electricity capacity in red and orange (light shaded areas) and positive growth in the green areas (darker shaded areas in black and white).

Source: Institute for Energy & the Environment, Vermont Law School, designed by Stone Environmental.\textsuperscript{60}

Additionally, much of the capacity in the North China Grid is coal fired, and the majority of China’s coal production is in the region.\textsuperscript{61} Shanxi and Inner Mongolia account for almost half of China’s total coal production.\textsuperscript{62} Chinese production levels in 2010 dwarfed the United States, the second largest producer, by more than three to one.\textsuperscript{63} Unsurprisingly, China’s dependence on coal

\textsuperscript{60} Drawn from data available in \textsc{Regulatory Assistance Project, supra note 35.}
\textsuperscript{61} \textsc{U.S. Energy Information Administration, supra note 43.}
\textsuperscript{63} \textsc{International Energy Outlook, supra note 58, at 73.}
production leads to high levels of coal generating capacity in the North China Grid. For example, Shandong Province consumes the most coal per province in China, more than three times the national average.  

Recent figures indicate fossil fuel generation—coal and a minor amount of natural gas—accounted for over 95 percent of generation across the entire North China Grid. Rather than reduce regional coal dependency, China’s Twelfth Five-Year Plan (2011–2015) explicitly aims to increase rates of coal extraction. Production of coal nationwide already tripled between 2000 and 2010; government projections suggest that China will need to add another billion tons of coal production annually by 2020, requiring an additional 30 percent increase this decade.

In terms of water, China has only 6 percent of the planet’s water resources but almost 20 percent of the world’s population. China’s per capita water resources of 2,200 cubic meters, or 581,000 gallons, is approximately one quarter of the global average, and it also means China is one of the 13 countries with the least per capita resources. Water efficiency in China is also comparatively poor, requiring four times more water per unit of GDP than a country like the United States. China’s role as the world’s largest producer of grain, a water intensive crop, only heightens efficiency concerns. Table 2 shows that overall water demand within the North China Grid will likely jump by a factor of 4.6 between 2010 and 2040.

Exacerbating China’s water challenges, the country’s resources are not evenly distributed. Southern China, with 55 percent of the country’s population and 84 percent of its water resources, is home to only 40 percent of cropland; northern China, however, supports 45 percent of the population and 60 percent of

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64 U.S. ENERGY INFORMATION ADMINISTRATION, supra note 43.
65 See supra Table 2.
67 Schneider et al., supra note 44, at 716.
68 MU YANG & SIOW SONG TENG, CHINA’S LOOMING WATER CRISI...es.pdf.
69 Id.
70 RESPONSIBLE RESEARCH, WATER IN CHINA: ISSUES FOR RESPONSIBLE INVESTORS 11 (Lucy Carmody ed., 2010).
all cropland with a mere 16 percent of the country’s water.\textsuperscript{72} Inner Mongolia, an area roughly equal to the size of France and Ukraine, is projected to host three \textit{times} more coal-fired capacity than the entire European Union by 2015.\textsuperscript{73} However, the National Bureau of Statistics warns that the total water resources available to China have actually \textit{dropped} by 13 percent from 2000 to 2010.\textsuperscript{74}

Two independent assessments beyond our own confirm the likelihood of future water conflicts. The first, from the nonprofit group Circle of Blue, looked at the confluence of coal use, water use, and economic growth for China as a whole (rather than the North China Grid).\textsuperscript{75} The study projected a 30 percent increase in coal use from 2010 to 2020, \textsuperscript{76} but noted that an increase of that magnitude will \textit{double} the water use of the electricity sector.\textsuperscript{77} The assessment also cautioned that a changing climate will interrupt snowfall in the northern regions dependent on snowmelt as a source of water for coal mining and coal generation.\textsuperscript{78} Circle of Blue concluded, “there is considerable evidence of a potentially ruinous confrontation between growth, water, and fuel already visible across China and virtually certain to grow more dire over the next decade.”\textsuperscript{79}

The second study, from the IEA, noted that “China’s water resources are set to become more strained with the country’s ongoing urbanization” and that water scarcity is “a potential bottleneck to economic and social development.”\textsuperscript{80} The assessment warned that China’s regions of highest thermoelectric capacity, such as the North China Grid, are already water stressed or experiencing “absolute scarcity.”\textsuperscript{81} The IEA projects that water

\begin{thebibliography}{9}
\bibitem{74} Schneider et al., \textit{supra} note 44, at 716.
\bibitem{75} See generally id. (identifying the subject area for the Circle of Blue study).
\bibitem{76} \textit{Id.} at 725.
\bibitem{77} \textit{Id.} at 717.
\bibitem{78} \textit{Id.} at 716–17.
\bibitem{79} \textit{Id.} at 715.
\bibitem{80} \textit{International Energy Agency,} \textit{supra} note 5, at 518–19.
\bibitem{81} \textit{Id.} at 518.
\end{thebibliography}
withdrawals for energy production in China will rise almost 40 percent between 2010 and 2035, or by 40 billion cubic meters (10.5 trillion gallons). Overall water consumption is projected to rise by an even greater percentage during the same period—by 83 percent, a total of 14 billion cubic meters (3.7 trillion gallons). Water use at coal mines is also projected to increase by 18 percent; the IEA noted that “[w]ater requirements per tonne of coal produced are expected to rise as coal mining operations move deeper underground and washing becomes more widespread.” Lastly, the IEA cautioned that “[w]hile all existing nuclear plants in China use seawater for cooling, future plans include the development of inland nuclear power facilities . . . that will add to competition for scarce water resources where the plants are sited.”

B. The French National Grid

Slightly smaller than Texas but the largest nation in Western Europe, France is the tenth largest producer of electricity in the world and the eleventh largest consumer at 451.4 billion kWh with a population of approximately 62.8 million in 2009. Although only 20.5 percent of France’s total installed capacity in 2009 came from fossil fuels, due to its sheer economic size the country is the nineteenth biggest emitter of carbon dioxide in the world. France is also the largest net exporter of electricity in the world—it exports electricity to Switzerland, Italy, Germany, Belgium, Spain, and the UK. The majority of France’s 119 million kilowatt installed generating capacity comes from nuclear power, making it the most nuclear-reliant country in the world.

France is highly dependent on nuclear power, a water-

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82 Id. at 519.
83 Id.
84 Id.
85 Id. at 520.
87 Id.
89 U.S. CIA, supra note 86.
2014] TROUBLED WATERS 425

intensive process, partly because it has a paucity of primary energy resources. Its national coal reserves could barely cover consumption in the 1980s and domestic natural gas reserves were largely depleted during that same decade.90 France thus embarked on a centralized energy policy, run by state elites, oriented towards investments in nuclear infrastructure and technology.91 That reliance on nuclear power continues to this day, with 58 nuclear power plants meeting 78 percent of the country’s electricity needs through 63,130 megawatts of installed capacity.92 The electric grid’s high dependency on nuclear power means that some reactors serve peak instead of base-load power,93 sometimes closing down during the weekends due to a lack of demand.94 As a result, the French nuclear industry’s capacity factor is relatively low compared to other nations (“in the high 70s as a percentage”).95

Overall, France is expected to increase its thermoelectric capacity by more than 100,000 MW by 2040; the numbers are summarized by Table 2 above. Additional nuclear capacity constitutes 35 percent of total new generation capacity and includes plans to build two reactors of a new class—the 1650 MWe European Pressurized Reactor—in Flamanville and Penly, both on the northwest coast of Normandy.96 Collectively, French nuclear units are very water intensive compared to other types of power plants. French institutions divide water use between four sectors: energy, agriculture, industry, and residential or household use. Across the four sectors, water use is far from equal, with electricity production constituting approximately two-thirds of the total, far more than in any of our other sectors.97 Figure 2 maps the

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92 WORLD NUCLEAR ASSOCIATION, supra note 88; SOVACOOL ET AL., supra note 57.
93 See WORLD NUCLEAR ASSOCIATION, supra note 88 (noting that “in a coordinated system the nuclear fleet is capable of a degree of load following,” i.e., operating in a peaking capacity when needed).
94 Id.
96 WORLD NUCLEAR ASSOCIATION, supra note 88.
97 COMMISSARIAT GÉNÉRAL AU DÉVELOPPEMENT DURABLE, CHIFFRES ET STATISTIQUES: LES PRÉLÈVEMENTS D’EAU EN FRANCE EN 2009 ET LEURS
specific dynamics of water use for every district in France for 2009. France’s projected future reliance on thermoelectric power facilities makes it especially susceptible to water shortages.
Figure 2: Water Resource Use for France for 2009

Note: Darker areas of the map show greater per capita water usage, and the red parts of the pie charts indicate energy usage as a share of overall water usage.
Source: Institute for Energy & the Environment, Vermont Law School, designed by Stone Environmental.98

98 Drawn from data available in REGULATORY ASSISTANCE PROJECT, supra note 35.
C. The National Indian Grid

India is the fourth largest energy consumer in the world and a significant contributor of global greenhouse gas emissions. Yet, the average Indian citizen uses 15 times less energy annually than does a U.S. citizen, produces 17 times fewer greenhouse gas emissions, and uses 30 times less electricity. Similarly, India’s per capita energy consumption is lower than that of Africa. These discrepancies are in part explained by the fact that 25 percent of the Indian population, or 306 million people, live without access to electricity, and 66 percent, or about 818 million people, are dependent on solid fuels for cooking and household energy needs.

India has the world’s second largest population (more than 1.2 billion people), seventh largest landmass, and tenth largest economy (third largest when adjusted for purchasing power parity). In 2011, India’s GDP was slightly more than $1.87 trillion. With a young population—the median age is 26—analysts expect India to overtake China as the world’s most populated nation in 2025. India is expected to lead the world in

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101 Id.
105 U.S. CIA, supra note 104.
urban population growth, with 497 million more people living in its cities by 2050.\(^{107}\)

India’s growing economy and population are dramatically increasing demand for electricity. With an installed capacity of 189,000 MW in 2010, India is already the fifth largest consumer of electricity in the world.\(^{108}\) Coal-fired thermoelectric power plants produced about 71 percent of the country’s electricity in 2011–2012, with nuclear, hydropower, diesel and natural gas making up the remainder.\(^{109}\) India is both the third largest consumer and producer of coal in the world.\(^{110}\) Further, India’s electricity sector relies on low quality coal, rendering coal-fired electricity generation inefficient and necessitating the import of metallurgical coal.\(^{111}\) According to the Indian government’s economic survey, the gap in supply and demand of electricity was roughly 9 percent from 2007 to 2012, and, despite adding 55,000 MW of new generation capacity, the gap is expected to remain unchanged for the fiscal year beginning in April 2012.\(^{112}\) This shortfall for energy country-by-2020/article4624347.ece (last updated Apr. 17, 2013, 19:07 IST).

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\(^{107}\) India completed its last census in 2011, but did not make projections for future population growth. To project population growth out into the future, we used the United Nations Statistics Division’s projection of 1,627,029,000 for the national population in 2040. We then applied a uniform growth rate of 1 percent per year, which reflects that average rate of growth between 2011 and 2040. This is significantly lower than the 1.4 percent growth rate between 2000 and 2010 reported by the United Nations. This approach gives a rough estimate for growth in most provinces, but does not account for uneven growth rates in the various states. For example, it does not take into account that some states are losing population. The projected state level population growth rates were used to estimate future water demand.


\(^{109}\) Id. at 34 fig.11.


is daunting, with nearly 92,000 gigawatt hours (GWh) of demand going unmet.¹¹³

Therefore, India has planned to increase capacity by 613,000 MW by 2040, which is more than the planned increases in the entire North China Grid and French national grid combined.¹¹⁴ Figure 3 illustrates that during the period 2010–2040, India’s generation capacity is projected to grow exponentially. Currently, no state has an installed capacity of more than 6,200 MW, but by 2040 11 states are planned to have more than 10,000 MW of capacity.¹¹⁵ The state of Gujarat alone is expected to increase its capacity by 50,000 to 78,000 MW over the next 30 years.¹¹⁶

¹¹⁴ See supra Table 2.
¹¹⁵ Id.
The water-intensive nature of Indian electricity generation causes competition with other water-intensive sectors. The conflicts will likely worsen as national water use grows by more than 50 percent between 2010 and 2040, as projected in Table 2. The northwest and southern regions, where power plants are highly dependent on surface water, are especially vulnerable to water shortages. Indian power plants have had to shut down repeatedly during the driest months of the year when Indian rivers experience

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117 Id.
118 INTERNATIONAL ENERGY AGENCY, supra note 5, at 521.
low flow.\textsuperscript{119}

Our assessment is not the first to suggest troubling implications for the electricity-water nexus in India. At least three other independent studies have raised similar concerns. The first, a 2010 joint report from HSBC Bank and the World Resources Institute, warned that new investments in thermoelectric and hydropower plants are planned for the same regions of the country that suffer from the most water stress.\textsuperscript{120}

The second study, from the Prayas Energy Group in 2011, assessed environmental clearances for large coal- and natural gas-fired power plants totaling 192,913 MW of planned additions.\textsuperscript{121} It also assessed an additional 508,907 MW at various stages of the approval process: plants that were awaiting clearances, had terms of reference granted, or were awaiting terms of reference.\textsuperscript{122} The Prayas study noted that coal-based power plants represent 84 percent of these planned projects, and that such additions are more than \textit{six times} the current installed thermoelectric capacity of 113,000 MW.\textsuperscript{123} However, this added capacity will collectively increase the amount of water needed per year by an estimated 4.6 billion cubic meters (1.2 trillion gallons), and most of these plants are concentrated in areas that lack the water resources to support them.\textsuperscript{124}

The third study, from Greenpeace in 2012, argued that the more than 100 GW in thermoelectric capacity that India intends to add under its Twelfth Five Year Plan will require an additional 2.5

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\textsuperscript{119} Vladimír Smáňhtin \textit{et al.}, Taking into Account Environmental Water Requirements in Global-Scale Water Resources Assessments 4 (2004), available at core.kmi.open.ac.uk/download/pdf/6405183.pdf; AHN \& GRACZYK, \textit{supra} note 108, at 36 ("Hydro rich states in the northern region, including Himachal Pradesh, and Jammu and Kashmir, have a surplus of electricity during monsoon season, but face shortages during winter when precipitation is low.").

\textsuperscript{120} See Amanda Sauer \textit{et al.}, \textit{World Res. Inst.}, \textit{Over Heating: Financial Risks from Water Constraints on Power Generation in Asia} 4 (2010), available at http://pdf.wri.org/over_heating_asia.pdf ("74 GW—over half of existing and planned capacity for major power companies—is located in areas that are considered to be water scarce or stressed.").


\textsuperscript{122} \textit{Id}. at 2.

\textsuperscript{123} \textit{Id}. at v.

\textsuperscript{124} \textit{Id}. at 6.
\end{flushright}
to 2.8 billion cubic meters (660 billion to 739 billion gallons) of water per year. This is equivalent to the irrigation water for more than 400,000 hectares of farmland. The study explained that "[t]here seems to be no consideration of the cumulative impact of this water use when sanctioning projects . . . ."

D. The Electric Reliability Council of Texas Grid

Some have called Texas the “heart of darkness” and the “global energy capital” for its long history promoting fossil fuels. Today, a barrel of West Texas Intermediate is still the benchmark for global oil pricing, and the state’s 27 petroleum refineries account for 27 percent of nationwide capacity. The state also produces more than one-quarter (28 percent) of the country’s natural gas. In 2012, Texas was first among U.S. states for total energy production, crude oil production, natural gas production, and electricity generation. It was also first in the nation for its carbon dioxide emissions, and fifth in the country for coal production. However, Texas also led the country in the installed capacity of wind-powered electricity, and it was the first state to reach 10,000 MW of wind capacity in 2010. The Electric Reliability Council of Texas (ERCOT) Grid, nonetheless, is vulnerable to electricity and water crises because of its size and its susceptibility to droughts.

With a population of approximately 25 million people, projected to reach 41 million by 2050, and $1.3 trillion in GDP, Texas touts the second largest population and second largest economy of any state in the country, following California on both counts. ERCOT manages the flow of electric power to 85
percent of the state’s electric load and schedules power on 40,500 miles of transmission lines and more than 550 generation units totaling about 58,000 MW of operational capacity, almost 7 percent of the United States’ total installed capacity. As Figure 4 shows, ERCOT expects to add about 23,000 MW—equivalent to one-third of today’s installed capacity—by 2040, with most of these additions concentrated around Houston, the Dallas-Fort Worth Metroplex, and Austin. Indeed, these capacity additions make Texas first compared to all other states—that is, state planners intend to add more power capacity to the Texas grid between 2010 and 2030 than any other state surveyed.


136 See infra Table 4.
Texas, however, is prone to frequent droughts, meaning these capacity additions may exacerbate water shortages. During the summer of 2011, this powerhouse state found itself in the midst of the worst single-year drought on record.\textsuperscript{139} Severe heat accompanied the dry weather with thirteen locations recording at least 50 days above 100 degrees Fahrenheit.\textsuperscript{140} Figure 5 illustrates pervasive “exceptional drought” conditions in August of 2011. As air conditioners strained to cool buildings, demand for electricity broke records for days on end, topping 68,000 MW in early

\textsuperscript{138} \textit{Cf.} \textsc{Regulatory Assistance Project 60, supra note 35.}


August.141 These weather conditions brought the water-energy nexus to the forefront in ERCOT. Continuing drought conditions threatened to close 3,000 MW of thermoelectric capacity in 2011.142 In east Texas, some power plant owners were forced to pipe in water from other rivers so plants could continue to operate and meet electricity demand.143

![Figure 5: Drought Conditions in Texas on August 2, 2011](http://drought.unl.edu/dm)

Source: U.S. Drought Monitor144

The summer of 2011 was not an anomaly. In 2003, the Natural Resources Defense Council warned that parts of western Houston would face “severe shortage[s] of water in the future” even without accounting for new power plants.145 During the last

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143 Id.
145 NATURAL RES. DEF. COUNCIL, WHAT’S ON TAP? GRADING DRINKING WATER IN U.S. CITIES 146 (2003) (internal quotation marks omitted), available
serious drought in 1996, the agricultural sector suffered as water was diverted to supply power plants and drinking water systems.\(^{146}\) In June of that year, the water shortage caused agricultural losses for cotton, wheat, feed grains, cattle, and corn at a cost of $2.4 billion for Texas.\(^{147}\) An additional $4.1 billion was lost in agriculturally related industries such as harvesting, trucking, and food processing.\(^{148}\) Reduced irrigation also contributed to reduced vegetable production, with concomitant losses in jobs and income and drastic increases in the price of food.\(^{149}\) Texas could be headed for a similar disaster in the future, especially since state water planners are already cautioning that the agricultural sector could be short 8 million acre-feet of water, roughly 2.6 trillion gallons, by 2050.\(^{150}\) The *New York Times* reported that available water for the state could decrease by 19 percent as soon as 2050.\(^{151}\) These incidents provoked the Texas Chamber of Commerce to declare electricity and water a “double dilemma” for the state in 2012.\(^{152}\)

The economic and social impacts of water shortages will not be limited to the agricultural sector. Based on these regional reports, the Texas Water Development Board has estimated that if the state does not ensure it has enough water to meet projected need, the state will have 7.4 million fewer jobs, 13.8 million fewer people, and 38 percent less income by 2050.\(^{153}\) As one recent study blithely put it, “[t]he free lunches of the original Texas water endowment have been consumed.”\(^{154}\)

\(^{146}\) Sovacool & Sovacool, supra note 1, at 2767.  
\(^{147}\) Id.  
\(^{148}\) Id.  
\(^{149}\) Id.  
\(^{154}\) RONALD C. GRIFFIN, *WATER POLICY IN TEXAS: RESPONDING TO THE RISE*
III. ELECTRICITY-WATER NEXUS SOLUTIONS

Despite the seriousness of the electricity-water nexus challenges confronting China, France, India, and Texas, regulators and electric utilities are well-positioned to respond, as local, state, provincial, and national actors have a long history of policy intervention on environmental and energy issues.155 This final section argues that while a cornucopia of different technologies and mechanisms are available to regulators and utilities, the following combination of six solutions would be most effective at avoiding future water shortages: (1) improving data collection and monitoring; (2) increasing research and development funding to minimize water use by thermoelectric power plants; (3) changing permitting and licensing requirements to better consider water use; (4) placing a moratorium on thermoelectric power generation; (5) promoting energy efficiency and water-efficient renewable electricity sources; and (6) changing electricity pricing and giving customers more feedback and information.

A. Improve Data Collection and Monitoring

The existing quality and availability of data limit policy responses to the electricity-water nexus, even in the United States, which arguably has some of the best freely available data related to energy (published by the U.S. Energy Information Administration) and water (published by the U.S. Geological Survey) in the world. However, in the United States, § 979 of the Energy Policy Act of 2005 only mentions the importance of water and energy, but provides no funding for the matter.156 Sections 316(a) and 316(b) of the Clean Water Act regulate the discharge of cooling water and power plant intake procedures without monitoring the effects of a water-intensive system.157 The U.S. Energy Information Administration (EIA) used to compile a national database of thermoelectric plants and their water use, using information collected through “Form EIA-767,” but the agency terminated this...
process in 2005 due to budgetary constraints. The EIA’s replacement “Form EIA-860” has only incomplete data on power plant water use. For several plants, the form either fails to include the water source or uses general terms such as “aquifer” or “municipal utility” without ever naming a particular aquifer or utility.

The Union of Concerned Scientists examined more than a decade’s worth of water data related to electricity generation in the United States. It concluded, “[c]ollisions and near-misses between energy and water needs point to the importance of accurate, up-to-date information on power plant water demand.” However, the analysis identified “a number of gaps and apparent inaccuracies in federal data.” Similarly, the National Renewable Energy Laboratory noted, “existing data [for the electricity-water nexus] collected from federal agencies are currently inconsistent and incomplete.”

A lack of accurate and reliable data in developing countries negatively affects those countries in many ways. Unlike developed countries, developing countries often lack baseline data and have weak data tracking systems. Even vital statistics, such

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162 Id. (original emphasis removed).
as demographic information, are “nonexistent or incomplete in some developing countries.”

The international community recognizes data limitations as a major challenge in achieving development goals. In order to improve the quality of data in developing countries, the United Nations, European Commission, Organization for Economic Co-operation and Development, International Monetary Fund, and the World Bank founded the Partnership in Statistics for Development in the 21st Century (PARIS21). The PARIS21 consortium created a global network of policymakers and statisticians to “promote, influence and facilitate statistical capacity development” and to improve the use of statistics. Nevertheless, major data limitations remain. Our study ran into several specific data challenges in developing countries. Basic data on water use, future electricity demand, and even projections for population growth were difficult to obtain. There is a lack of data disaggregated at state, provincial, or municipal levels. Even when this data has been gathered, it was not accessible on government websites. A lack of transparency in accounting procedures further raises questions about the quality of the data.

B. Fund Research to Minimize Water Use By Thermoelectric Power Plants

New technologies can reduce thermoelectric power plant water vulnerabilities. As shown in Table 3, there are several types of technological solutions, each with a set of specific strengths and weaknesses: alternative cooling systems, untraditional sources of water, power plant water production, and increased water efficiency through plant design. Alternative cooling systems reduce water use by adapting cooling systems to local water constraints. Nontraditional water sources include municipal wastewater, treated coalmine drainage, and water recycled from plant processes. Power plants can produce water by capturing

(last visited Apr. 15, 2013).

166 Id.
168 Id.
water in flue gas, desalinating seawater using waste thermal heat, and transforming water intensive procedures to dry processes. Improved plant design reduces water use by increasing overall plant efficiency. Table 3 also demonstrates that alternative technologies face unique constraints. There is no proverbial silver bullet; technology effectiveness varies depending on local geographies, plant economies, and technological maturity.

Table 3: Advantages and Disadvantages of Advanced Cooling Cycles

<table>
<thead>
<tr>
<th>Technology</th>
<th>Type</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
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<tbody>
<tr>
<td>Cooling Systems</td>
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<tr>
<td>Oolong through cooling</td>
<td>Lower water consumption</td>
<td>Higher water withdrawals</td>
<td>More sensitive to steam quality</td>
</tr>
<tr>
<td>Wet cooling</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Dry cooling</td>
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<tr>
<td>Hybrid systems</td>
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<tr>
<td>Unconventional</td>
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<tr>
<td>Different sources</td>
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<td></td>
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<tr>
<td>Power Plant Water</td>
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<td></td>
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<tr>
<td>Production</td>
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</tbody>
</table>

Source: Compiled by the authors

C. Change Permitting and Licensing

Another solution would be altering the permitting and licensing requirements for power plants so that they better incorporate water needs. In China, the National Reform and Development Council or the provincial and municipal governments can decline to issue permits based on any criteria that they select. They could, for instance, refuse to license a power plant unless water is expressly accounted for in Environmental Impact Assessments. In France, the Commission de régulation de l’énergie (CRE) is in charge of the power supply for the entire country, and it has the authority for licensing and re-licensing power plants. India’s electricity market is regulated by the Central Electricity Regulatory Commission (CERC), a national agency under the umbrella of the Ministry of Power. CERC is the entity responsible for the development of the nation’s grid and is vested with licensing and permitting power for new intrastate generation projects. Unlike the other cases, “the United States has a highly fragmented electric utility industry, which is composed of three federal agencies, over seventy investor-owned power companies and numerous municipal and rural power cooperative organizations.” In the United States, licensing for power plant facilities generally falls to the state public utility commissions, except for hydropower facilities, which are

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174 Id.


overseen by the Federal Energy Regulatory Commission. In Texas specifically, the Texas Commission on Environmental Quality (TCEQ) can require a statement of environmental, social, and economic impacts (covered under the category of “any other information”) for any proposals for new sources of electricity generation.

D. Place a Moratorium on New Thermoelectric Power Generation

Perhaps the simplest response electric utilities can take is to stop building new thermoelectric generation in areas where water shortages are expected to occur or where water prices are anticipated to rise rapidly. The addition of new conventional power plants has two inherent water-related risks that suggest electric utilities should think carefully before constructing them: they are unable to withdraw water needed for normal operation in times of scarcity, and new plants can increase water demands, worsening existing shortages.

China’s rapid economic growth has led to the construction of many new coal-fired power plants to meet rising electricity demand. While the government has not issued any moratoriums based on water shortages, recent actions indicate the central government recognizes impending water limitations. The Twelfth Five-Year Plan contains ambitious goals to reduce energy and water intensities. Reducing overall energy consumption and growth will limit new freshwater withdrawals. During the 11th Five-Year Plan, water saving measures checked consumption growth, which only increased by one percent annually over the five-year period. However, the central government’s goal of reducing energy intensity is dependent on provincial governments acting to limit new capacity installations.

180 Id.
In France, no serious proposals for a moratorium on thermoelectric power plants have yet arisen because the country is so dependent on nuclear power; yet, in June 2011, likely motivated both by a desire to protect the incumbent nuclear industry and water scarcity concerns, the French parliament did vote to ban the hydraulic fracturing of unconventional shale gas (a process known as “fracking”).\(^{181}\)

In India, the nongovernmental organization Greenpeace has called for a moratorium on granting environmental clearances to inland coal-fired thermal plants until their impact on water resources has been taken into account.\(^{182}\) Greenpeace also suggested placing a moratorium on allocating water to power generation in Vidarbha District in Maharashtra State.\(^{183}\) The Prayas Energy Group, a nonpartisan energy think tank, has also argued that “[t]here should be an immediate moratorium on any further grant of environmental clearances to [thermal power plants].”\(^{184}\) However, unlike in China, France, and Texas (see below), Indian policymakers seem reluctant to act on these sorts of recommendations. One recent study noted that India “is tugged backwards by inefficiency and corruption in its operating and governing practices” and that “India’s insistence on managing its energy, food, and water sectors as a social policy program needed an urgent update.”\(^{185}\)

In Texas, no moratoriums have been proposed as a response to water scarcity. However, there was a concerted effort to enact a moratorium on coal-fired plants due to worries over air pollution. In 2007, a coalition of over thirty groups supported a bill that called for a “time out” for building new coal-fired power plants.\(^{186}\)


\(^{182}\) GRACE BOYLE ET AL., supra note 31, at 65.


\(^{184}\) PRAYAS ENERGY GROUP, supra note 121, at 17.


\(^{186}\) STATE CAPITOL REPORT, LONE STAR CHAPTER, SIERRA CLUB 1 (2007).
The bill was primarily aimed at halting the construction of nineteen new coal plants that would have worsened air quality.\textsuperscript{187} It called for, among other things, a greater role for renewable energy in the Texas energy mix.\textsuperscript{188}

There have been many calls for moratoriums on new thermal coal-fired power plants in the past. In the United States, groups as diverse as the League of Women Voters,\textsuperscript{189} the Union of Concerned Scientists,\textsuperscript{190} and Trillium Asset Management\textsuperscript{191} have called for halting new coal plants because of their carbon emissions or other environmental problems. In 2006, California passed SB-1368 that stipulates that all new coal plants must have the same carbon emissions as combined cycle natural gas plants.\textsuperscript{192} While not a direct moratorium, SB-1368 is often called a de-facto ban on building new coal plants, as no conventional coal plant can meet this standard.\textsuperscript{193} The U.S. EPA’s proposed New Source Performance Standards for carbon dioxide were similarly designed such that no existing coal plants can meet the standard, effectively banning the use of coal in new power generation.\textsuperscript{194}

Other states have enacted moratoriums when faced with water scarcity issues. In an effort to address environmental and water concerns, the Idaho House Committee adopted a two-year moratorium on construction of new coal plants in 2006.\textsuperscript{195} Around

\begin{thebibliography}{9}
\bibitem{} Id.
\bibitem{} Id.
\bibitem{} Moratorium on New Coal-Fired Electric Power Plants is Imperative to Address Global Warming, League of Women Voters, http://www.lwv.org/content/moratorium-new-coal-fired-electric-power-plants-imperative-address-global-warming (last visited Apr. 15, 2013).
\bibitem{} Id.
\end{thebibliography}
the same time, Arizona also rejected a permit for a coal-fired plant based on water issues. In addition, in 2007, the Kansas State Assembly considered but ultimately voted down a moratorium on coal plants in the state. One of the principle concerns was the effect that new plants would have on groundwater supplies.

One possible objection to a moratorium would be that future increases in electricity demand can only be reliably met by fossil-fueled and nuclear base-load power plants. While this concern is a legitimate one, the next two sections show that the promotion of energy efficiency and renewable energies, demand-side management (DSM), and improved feedback to electricity customers could offset the need to build any new thermoelectric capacity.

E. Promote Energy Efficiency and Renewable Electricity

To offset the risks associated with placing a moratorium on future thermoelectric generators, electric utilities should rigorously implement energy efficiency and DSM programs. Such actions would not only address impending electricity-related water shortages, but would also improve energy security, lower electricity and water prices, and enhance reliability. Evidence suggests that energy efficiency, DSM, and load management practices represent the most feasible way of responding to increases in electricity demand. Increasing energy efficiency, one study concluded, “is generally the largest, least expensive, most benign, most quickly deployable, least visible, least understood, and most neglected way to provide energy services.” As Jon Wellinghoff, the Commissioner of the FERC, put it, “these potential benefits from the incorporation of demand response into wholesale markets indicate that a considerable margin of gain is

196 Id.
200 AMORY B. LOVINS, ROCKY MOUNTAIN INST., ENERGY END-USE EFFICIENCY 1 (2005).
possible from accelerating such activity.

The DOE recently calculated the benefits of DSM and found that it lowers wholesale electricity prices as costly power plants are displaced and total demand on the system decreases. Generating peak electricity is extremely expensive, often exceeding $5,000 to $10,000 per installed kW (meaning a 100 MW plant can cost $750 million to build and require seventy-five million dollars per year to operate); therefore, it is likely that DSM would be profitable for all utilities.

In situations where energy efficiency and DSM programs are unable to completely offset the need to construct new generation capacity, utilities could rely on wind turbines and solar panels to produce electricity. These two technologies use almost no water to generate electricity and need only a very small amount for cleaning and maintenance. Cost is not a barrier; the marginal levelized cost of building offshore and onshore wind turbines in 2008—that is, the cost of constructing, operating, maintaining, and fueling a new facility—was between 2.6 and 5.6 cents per kilowatt hour (¢/kWh), making them two of the six cheapest sources of power. Solar photovoltaic panels (PV) are the most expensive at 39 ¢/kWh, but not far behind expensive natural gas peaking plants that cost between 32.5 and 35.6 ¢/kWh to operate. Wind, in other words, is already cheap, and solar (which is getting cheaper) is nearing parity with natural gas peaking facilities. Costs of renewable energies have continued to decrease since 2009, increasing their economic feasibility.

F. Change Electricity Prices and Improve Information Access

A moratorium on thermoelectric generation, energy efficiency and DSM programs, and wind and solar PV deployment could be
supplemented by utility efforts to alter electricity prices and provide better feedback and information to electricity customers. Though they would need to be properly incentivized, three changes would be most significant: more accurate electricity pricing, altered electricity billing practices, and a utility-wide information program to educate consumers.

Consumers are generally unaware of daily, weekly, and seasonal changes in electricity prices, and instead see only a monthly electricity bill. Therefore, many consumers presumably consume electricity without consideration of fluctuating prices. Utility programs that reflect time-of-use through “real-time,” “interval metering,” “time-of-use,” or “seasonal” rates could show customers how electricity production and consumption varies according to the time of day, week, and month. Most electricity bills combine charges into a lump sum, making it difficult for consumers to tell how much of the bill results from the individual use of appliances or technologies, how much the bill could be decreased by using more efficient models, or how much electricity use can be shifted to off-peak hours.207

Because most people remain uninformed about the electricity-water nexus, a second form of feedback could be useful: making water usage associated with electricity generation “visible” by including it in people’s electricity bills. California, for example, was the first state in the country to enact an Advance Recovery Fee on sales of some electronics.208 Whenever customers purchase new cell phones and televisions, a visible fee between six and ten dollars appears separately on receipts, showing consumers how much it will cost to collect and recycle some of the toxic elements inside their products.209 The same technique could be used in electricity billing by showing consumers a separate line estimating the number of gallons of water used (and/or its associated cost) to

produce the electricity they used within their home that day, week, or month.


CONCLUSION

Of the commodities necessary for continued economic stability, water and electricity are two of the most vital. Yet existing global reliance on thermoelectric power generation could contribute to potentially massive shortages of water in China, France, India, and the United States (and possibly everywhere else). The energy sector, predominantly electricity generation, already accounts for roughly 15 percent of water withdrawals globally.\footnote{International Energy Agency, supra note 5, at 501.} Thankfully, we have shown that the technology and policy tools needed to lower the water intensity of electricity
generation are widely available and include clean power
technologies in the form of energy efficiency, wind farms, and
solar PV panels, as well as alternate cooling technologies,
combined cycle natural gas power plants, and some shrewd
changes in pricing and policy. With this in mind, we advance three
key conclusions.

First, the electricity-water nexus makes “business as usual”
completely nonviable. Combined trends in population growth,
increasing electricity consumption, and increasing water usage
indicate that we cannot, and should not, continue to generate
electricity the way we do today. Because water is an essential part
of the cooling process for thermoelectric power plants, such
sources of electricity supply may become wholly unsuitable as the
globe enters a new era of accelerated water stress and water
scarcity.

Second, including consideration of water availability in
electricity planning fundamentally “changes the game” of how we
make future projections about power plants and capacity additions.
Accounting for water constraints in electricity planning will
become a critical component of maintaining system reliability.
Location-specific assessment of water resources can thus help
guide new generation and decrease electricity-water nexus
vulnerabilities.

Third, our study is yet another reason, on top of climate
change and energy security, to promote energy efficiency, wind
turbines, and solar panels. As we have shown, the electricity
generation technologies that are beneficial for reducing greenhouse
gas emissions correspond with those that require less water to
operate, providing crucial benefits on both ends of the scale:
reducing the inputs that contribute to the severity of climate
change, avoiding additional stresses on water resources (so-called
“mitigation”), and minimizing water use as climate change
inevitably stresses water resources (so-called “adaptation”).
Policies that promote renewables and efficiency thus provide
multiple benefits beyond technical reliability and economic cost.