SPECIAL FEATURE SEAR

ENERGY ACCESS AND THE ENERGY–WATER NEXUS

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SEAR

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INTRODUCTION

The tradeoffs between energy and water have been gaining international attention in recent years as resource demand grows, climate change impacts manifest, and governments struggle to ensure reliable supply. Today, about 663 million people still lack access to improved sources of drinking water, and 2.4 billion people remain without access to improved sanitation (WHO/UNICEF, 2015). Water insecurity affects every continent. Additionally, 1.1 billion people lack access to electricity (IEA/World Bank 2015).

Water and energy resources are inextricably linked. Significant amounts of water are needed in almost all energy generation processes, including electricity generation and fossil fuel extraction and processing (figure 1). Conversely, the water sector needs energy to extract, treat, and transport water. Energy and water are also both required to produce crops, including those used to generate energy through biofu-els. This relationship is what is known as the water-energy nexus, and it exists within the larger water-energy-food nexus (US DOE, 2014; WWAP, 2014; Bazilian et al 2011; Stillwell et.al, 2011).

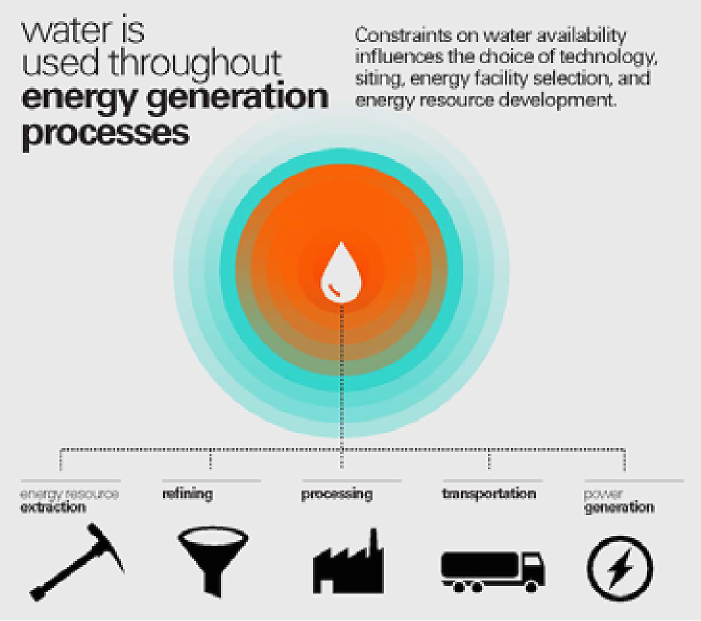
The impacts and tradeoffs of the energy-water nexus are being felt today:

- In the United States, power plant operations are being affected by water variability, such as low water flows or high water temperatures (US DOE, 2013).
- In India, a thermal power plant has been shut down due to a severe water shortage (Rajput, 2013).
- In France, nuclear power plants have been forced to reduce or halt energy production due to high water temperatures that threaten cooling processes during heat waves (WEF, 2011).
- In Sri Lanka, China, and Brazil, recurring and prolonged droughts are threatening hydropower capacity (Barrucho 2013; Sirilal 2012; Stanway 2011).
- In China and India, expansion plans for coal power plants could become unfeasible due to water scarcity (Adelman, 2012).
- In the Middle East and North Africa, desalinating water is substantially increasing energy demand, and pushing water utilities to explore ways to reduce energy demand or produce energy on site (World Bank, 2012; Siddiqi and Anadon, 2011)—in 2010, energy requirements for desalination in the United Arab Emirates were about 23.9 percent of total energy needs (World Bank, 2012).

Such resource interdependencies could complicate possible solutions and make a compelling case to improve integrated water and energy planning to avoid unwanted future scenarios.

The international community recognizes the magnitude of the tension between energy and water resources. In 2014, the water and energy nexus was the subject of the World Water Development Report (WWDR), the UN's World Water Day, and Stockholm International Water Institute's World Water Week. These efforts helped catapult the nexus onto global policy agendas, and coordinate ongoing work to consolidate indicators and data in initiatives. Such efforts must be developed and enforced

FIGURE 1 Water is used throughout energy generation process



Source: Thirsty Energy, World Bank, 2014 because water constraints challenge the reliability of existing energy operations, require costly adaptive measures, and threaten the viability of proposed projects (IASS 2015; IEA/WEO 2012).

Despite the interconnectedness of water and energy resources, energy planners and governments often make decisions without accounting for existing and future water constraints. Planners in both sectors often remain ill-informed about the drivers of these challenges, how to address them, and the merits of different technical, political, management, and governance options. To tackle the energy and water challenges in the context of each country's needs, data gaps must be addressed, and indicators that reveal resource use and cascading effects across sectors are needed. Integrated water and energy planning enhances sustainable development, national security, and economic stability. Such planning is especially needed in regions where climate change, urbanization, and population and economic growth are going to exacerbate water scarcity (Rodriguez et al 2013; Hadian and Madani 2013).

As policies are implemented to ensure that affordable, reliable, and sustainable energy is available to all, it is critical to consider the surface water and groundwater impacts that may result from them. There will be tradeoffs in all cases, but in analyzing and quantifying the impacts, the international community can ensure long-lived and sustainable successes.

HOW THE ENERGY SECTOR USES WATER

Most thermoelectric power plants require large amounts of water, mainly for cooling purposes. About 80 percent of the world's electricity is generated in thermal power plants (such as fossil fueled, nuclear, and concentrated solar power plants) (IEA 2013). In the United States and Europe, these plants account for about 40 percent of the freshwater withdrawn[1] each year, as much as is withdrawn by the agriculture sector (Maupin et al 2014; Rubbelke and Vogele 2011). Yet unlike agriculture, the power sector does not account for a large share of water consumed, given that many power plants return most of the water withdrawn back to the environment.

Most thermal power plants heat water to produce steam to drive the turbines to produce electricity.[2] The water is heated using various energy sources (coal, oil, natural gas, uranium, solar energy, biomass, and geothermal energy) depending on the type of power plant. After passing through the turbine, the steam is cooled, usually with water drawn from a river, lake, or ocean, and condensed to start the cycle again (figure 2). The amount of water withdrawn and consumed by the power plant depends chiefly on the type of cooling[3] system used (Rodriguez et.al. 2013; Macknick et.al. 2012; NETL 2009; Averyt et al 2008).

- *Once through cooling* requires large amounts of water, but consumes a very small fraction of it.
- *Closed loop cooling* systems (the most common are cooling towers) withdraw much less water, but consume most of it as water is evaporated.
- *Dry cooling* systems use air instead of water to cool down the steam, meaning that no water is used or consumed in the process.
- *Hybrid cooling* systems combine wet and dry cooling approaches. Although there are different types of systems, they still fall between wet and dry in terms of cost, performance, and water use.

The cooling system employed by the power plant affects power plant efficiency, capital and operating costs, water con-sumption, water withdrawal, and environmental impacts. Those tradeoffs must be evaluated case-by-case, taking into consideration regional and ambient conditions and existing regulations. Figure 3 illustrates the tradeoffs between various systems. Among plants with the same type of cooling system, the amount of cooling water withdrawn and consumed is mainly determined by the plants' efficiency (Delgado 2012).

In the case of hydropower, it can be generated only if water is available in reservoirs or rivers, given that hydropower plants depend on the energy of moving water to turn turbines and generate electricity. Water may be lost during hydropower operations due to evaporation from dammed water upstream from the plant; the scale of losses depends on site location, design, and operation. Run-of-river hydropower plants store no water and have water evaporative losses near zero, but they are less likely to be used for generation of peak loads or during dry seasons when there is no or limited river flows.

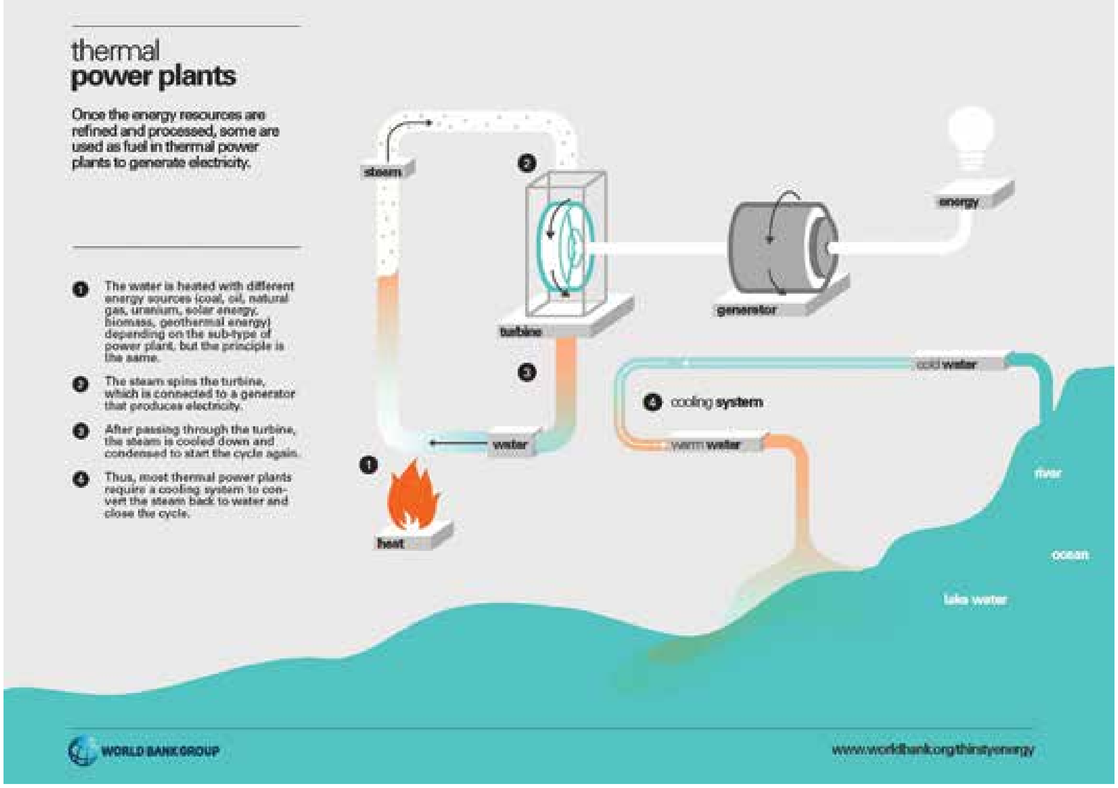
As for wind turbines, they do not require water for their operation to generate electricity, and solar PV systems require only minimal quantities of water for washing the solar panels (Macknick et al 2014; Turchi et al 2010). However, because most PV systems are located in arid places, obtaining the needed water can be challenging.

In the case of energy extraction—such as oil, gas, and coal, as well as unconventional fuels (like shale gas and tar sands)—water is required for extracting, transporting, processing, and refining the resource (Mauter et al 2014; IEA, 2012; Fry et al 2012). Operations may consume, or remove for use from the immediate water environment, large quantities of water for drilling, washing, and processing. Water use varies depending on the fuel type, the method of extraction, geology, the degree of processing required, the geography, and the climate of the site under development. As for biofuels, water is increasingly used both to grow the feedstock (like soy, sugar cane, corn, and switchgrass) and to process it into biofuels (Stone 2010; NRC 2008).

LINK BETWEEN WATER AND UNIVERSAL ENERGY ACCESS

Given that almost all energy generation processes require water, its availability is a necessary condition for reaching universal energy access worldwide. At the same time, universal energy access can contribute to better water access (by facilitating water extraction, treatment, and delivery) and water security.[4] Whereas insufficient or intermittent electricity access can limit water availability (by restricting pumping, treatment, and distribution), reliable and afford-

FIGURE 2 **Simplified Diagram of the steam cycle in thermal power plants**



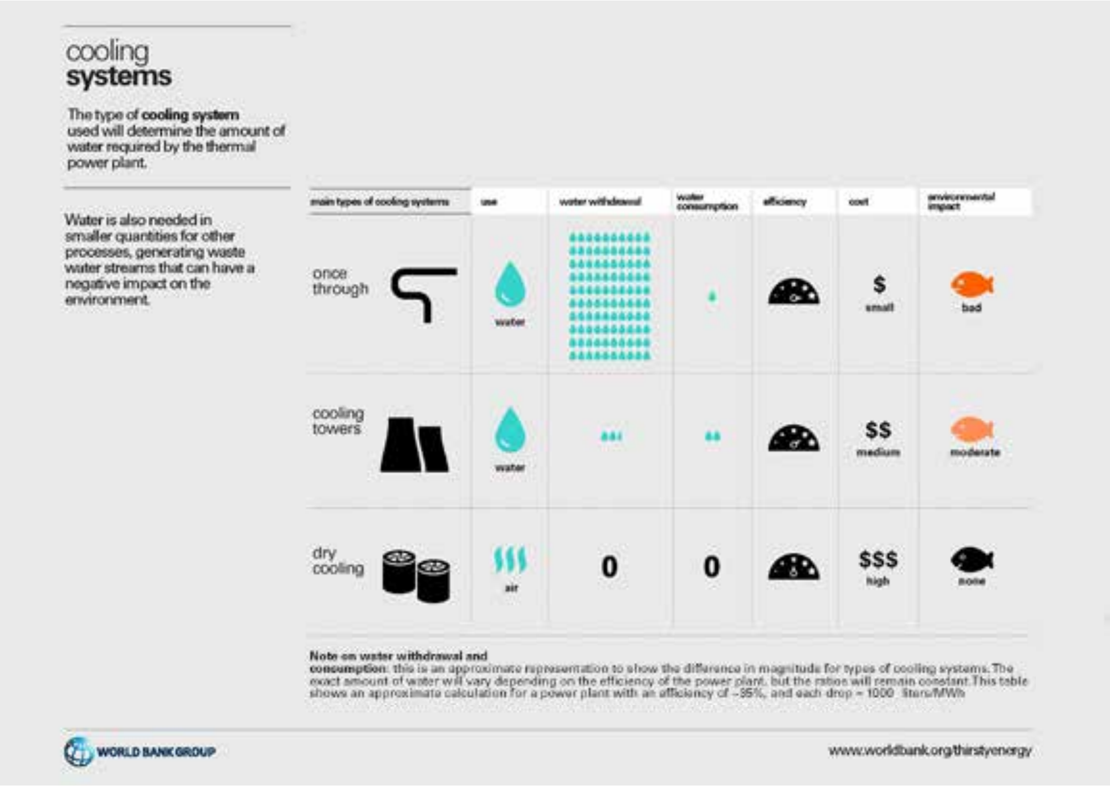
thermal
power plants

Once the energy resources are refined and processed, some are used as fuel in thermal power plants to generate electricity.

- ❶ The water is heated with different energy sources (coal, oil, natural gas, uranium, solar energy, biomass, geothermal energy) depending on the sub-type of power plant, but the principle is the same.
- ❷ The steam spins the turbine, which is connected to a generator that produces electricity.
- ❸ After passing through the turbine, the steam is cooled down and condensed to start the cycle again.
- ❹ Thus, most thermal power plants require a cooling system to convert the steam back to water and close the cycle.

Source: Thirsty Energy, World Bank 2014

FIGURE 3 **Tradeoffs among different types of cooling systems**



cooling
systems

The type of **cooling system** used will determine the amount of water required by the thermal power plant.

Water is also needed in smaller quantities for other processes, generating waste water streams that can have a negative impact on the environment.

main types of cooling systems	use	water withdrawal	water consumption	efficiency	cost	environmental impact
once through	water	💧💧	💧		$ small	bad
cooling towers	water	💧💧💧	💧💧		$$ medium	moderate
dry cooling	air	0	0		$$$ high	none

Note on water withdrawal and consumption: this is an approximate representation to show the difference in magnitude for types of cooling systems. The exact amount of water will vary depending on the efficiency of the power plant, but the ratios will remain constant. This table shows an approximate calculation for a power plant with an efficiency of ~35%, and each drop = 1000 liters/MWh

Source: Thirsty Energy, World Bank 2014 able access can ensure a continuous supply of the required quantities of safe water as well as wastewater treatment services. Improved energy access can also support the use of energy-intensive technologies (such as desalination or more powerful groundwater pumps), which are expected to expand rapidly as easily accessible freshwater resources are depleted.

But if present planning continues to neglect energy's impact on water, universal access to modern energy services could have a negative impact on water resources, as almost all energy production processes require water. In 2030, almost half of the world population will be living in areas of high water stress if no new policies are introduced (WWAP 2012), and greater demand for energy could put additional pressure on already constrained water resources.

Universal access to energy may also increase the contamination risk of water resources due to energy extraction and transformation processes. The energy sector not only withdraws and consumes water—thus altering water flow patterns and water quantity—it also generates large amounts of wastewater. Energy operations can greatly impact water resources through post-production water discharged and possible contamination of aquifers during drilling (IRENA, 2015). Sustainable water management practices are needed to prevent energy companies from significantly impacting the surrounding environment's water quality through spills, leaks, inefficient treatment of wastewater, or other contamination events.

Water-related risks can affect the energy sector and slow or hinder the progress toward universal energy access. Changing water supply patterns due to unanticipated weather activity, reallocation of water resources into other sectors, or new regulations, may constrain opportunities for power generation or energy extraction. Climate change is further intensifying energy insecurity through changing rainfall and surface runoff averages, increased water temperatures, and increased probability of extreme weather conditions (Cohen et.al, 2014; US DOE, 2013; van Vliet, 2012; Rubbelke and Vogele, 2011). Water scarcity, variability, and water quality can constrain or raise the cost of thermal power generation and energy extraction. Yet, in most cases the cost of accessing water is small in comparison to the revenue generated.

A role for renewable energy

Can fostering renewable energy to achieve universal energy access improve the picture? The reality is that it can either improve or deteriorate water availability and quality depending on the energy source and technology used. Raising the share of water-intensive renewable energy sources (like irrigated biofuels and some thermal power sources) can increase demand for water, and thus potentially exacerbate competition with other sectors and create social tensions among different users. However, when looking at the whole life cycle of power generation, renewable energy generally requires less water than fossil fuels. If renewable energy sources that require small quantities or no water (like photovoltaic and wind energy) are developed, the energy sector's water needs could be reduced (IRENA, 2015; Liu et.al, 2014; Arent et.al, 2014; Rogers et.al, 2013; Macknick et al. 2012; Munish et.al, 2011). In the arid state of Texas, which has installed over 12 GW of wind energy due to water pressures on the energy sector, the power sector is now more resilient to drought (US DOE 2014).

More hydropower capacity may help other sectors access water if the multipurpose benefits of the reservoirs are developed. For example, reservoir water not only provides power generation but can also be used for irrigation, water supply, flood control, and recreation. Plus hydropower dams may control water availability for downstream users, providing water in times of drought and limiting water flow during inundating rains, despite the potential losses of water from reservoirs due to evaporation. However, hydropower projects may also materially impact the quality of downstream flows (the timing, route, and duration), thus imposing burdens on fish and other aquatic life (IRENA, 2015). In a world of energy shortages and increasing water variability, multipurpose hydropower dams can provide clean energy and help allocate scarce water resources to major economic sectors. Therefore, joint planning of sustainable power and water infrastructure in river basins is key to addressing the energy-water nexus challenge.

The impact of biofuels and biodiesel on water use varies substantially, depending on where the biofuel crop is planted, whether it required land conversion and needs irrigation, and if it replaces a more or less water-intensive crop (Gerbens-Leenes, 2011; Stone et al, 2010). In China and India, ambitious plans to boost domestic production of biofuels could place additional pressure on scarce water supplies if traditionally irrigated food crops are used to meet bioenergy production targets. Yet, if biofuels are grown in rainfed regions, they will have less of an impact on existing water allocations. In Brazil, producing a liter of ethanol from sugarcane requires only 90 liters of irrigation water to supplement the rainwater, but in India, a liter of ethanol can require 3,500 liters (IWMI, 2008). Water needs and impacts should therefore be carefully assessed during the development of bioenergy programs.

Solar-based solutions can offer an alternative to grid- or diesel-based electricity in many areas. Solar water pumping can support access to water and irrigation or reduce dependence on grid electricity or fossil fuels, while mitigating environmental impacts and reducing energy subsidy burdens. India plans to replace 26 million groundwater pumps with solar pumps, despite high capital costs and a lack of established solar pump markets. But if solar initiatives are not implemented correctly, the use of solar water pumps can result in excessive and unsustainable water withdrawal, given negligible operational costs. Solar water heaters are generally price competitive with electricity and gas-based heating and are making their way in emerging markets (IRENA, 2015). Although desalination based on solar energy may still be expensive, technology advances will continue to drive cost reductions. Saudi Arabia's Solar Water Desalination initiative highlights how sustained investment and research will make solar energy a competitive energy resource in the long term (IRENA 2015).

A role for energy efficiency

Besides weighing energy sources, policy makers should also focus on boosting energy efficiency. On the supply side, old and inefficient power plants can be replaced by plants that save energy and water and decrease GHG emissions. For example, an old coal power plant with an efficiency of 25 percent can require nearly twice the amount of water as a new coal power plant with the same type of cooling system but have an efficiency of 36 percent. Combined-cycle gas turbines (CCGTs) have higher thermal efficiencies, requiring less water for cooling (IEA, 2012). Moreover, as most energy generation processes require water, energy efficiency gains on the demand-side can decrease demand for energy and save water through initiatives such as energy efficient appliances and improved insulation.

However, using less water- intense cooling technologies may decrease energy efficiency. Thermal power plants can improve water use efficiency by using dry cooling[5] systems—cutting the amount of water needed by up to 90 percent (US DOE, 2014). Nevertheless, these systems negatively affect the power plant's efficiency, particularly in hot and dry climates. Dry-cooled systems also increase operational costs by 2-16 percent, making them more expensive than closed loop wet cooling systems (Maulbetsch and DiFilippo 2006). It is, however, acknowledged that all options carry a series of tradeoffs that must be identified and quantified.

In the water sector, greater energy efficiency may reduce the cost of delivering water and save water. Electricity costs are usually 5–30 percent of total operating costs among Water and Wastewater Utilities (WWUs)—and the share is typically higher in developing countries, reaching 40 percent or more. Such energy costs often contribute to high and unsustainable operating costs that directly affect the financial health of WWUs (ESMAP 2012). Since treating and distributing water is energy intensive, leakage reduction is a cost-effective way to save water and energy, and is largely implemented in unison with more energy efficient pumps (Barry 2007).

MOVING FORWARD

Sustainable energy for all will be achieved if water and energy interactions are taken into account and their associated impacts on one another are considered in planning. Due to the complicated nature of energy and water resource management and incomplete knowledge of systems, there is a need to create consistent frameworks for analysis, definitions of terms, and datasets that enable the water and energy sectors to understand each other and communicate effectively. Fostering collaboration among energy and water stakeholders for more sustainable solutions will be crucial in achieving universal energy access.

Reliable and comprehensive data on the energy-water nexus is scarce, inhibiting informed decisions on operations and investments, and making it challenging to monitor long-term planning efforts. Data on energy consumption and production by country is usually available with greater accuracy and abundance than data on water. When energy data is collected in detail, there is often no information on water requirements or water risks in operations. Monitoring availability and use of water resources represents an ongoing challenge, especially given variable distribution of water over time and space, and the difference in data availability of surface water versus ground water by country. Lack of data constrains water resource management and makes it difficult to prioritize water in decision-making because there is less evidence on the importance of water to economic growth. As a result, policies to improve energy access and efficiency are implemented without considering impacts on water resources and the importance of water to socio-economic development.

BOX 3

Climate Change Should Not be Left Out of the Conversation

Climate change is intensifying energy and water insecurity due to extreme weather conditions – like prolonged drought periods, powerful storms, and floods – which put populations, livelihoods, and assets in danger. A recent report by the U.S. Department of Energy (US DOE, 2013) highlights energy sector vulnerabilities to climate change and extreme weather, noting that most risks are water-related.

The effects and intensity of climate change will vary regionally, as populations' experience variable precipitation, surface runoff, stream flow, deviation from rainfall averages, and increased probability of extreme events. Altered precipitation and evapotranspiration patterns are predicted to reduce runoff in southern Africa, the Mediterranean basin, Central America, the southwestern United States and Australia, among other places (FAO 2008). This will likely increase competition for water among sectors (like agriculture, energy, municipal supply, and the environment).

The combined effects of population growth, climate change, and increasing hydrological variability will result in a heightened reliance on energy-intensive water supply options (like water transport or desalination plants) to supplement urban water supply as freshwater supplies diminish. Moreover, as temperatures rise, more water will be needed by the energy sector for cooling water per unit of energy produced, and for cooling houses, offices, and factories. Climate change will further impact the energy sector through changes in energy demand, and the need to transition to energy supply options involving low or zero greenhouse gas emissions. Some options, such as carbon capture and storage or irrigated biofuels, could further increase pressure on water resources (WWDR 2014).

In most countries, it is difficult to obtain water-related data from the energy sector. There is a lack of data from power plant operators and mining and extraction companies on: (i) water withdrawal and discharge rates by the energy sector; (ii) the use of alternative water sources in the energy sector (like saline water and wastewater); and (iii) the type of cooling system used in power plants. This shortfall makes it difficult to suggest credible assumptions on the energy sector's water needs (Madani and Khatami, 2015). Plus the environmental impacts of the energy sector on water resources are rarely documented. Governments must work to ensure all energy production facilities report water-related information in the same manner that energy operators report on GHGs emissions.

Most existing global estimates on the water needs of the energy sector are derived from assumptions. Some sources use an average number of m3/GJ for each energy source, multiplied by the future energy demand, but this is misleading, given that water requirements vary significantly even within the same energy process or energy source. Water requirements vary at all stages of energy operations, and depend on several factors—like technology employed in energy generation and production, regional variable conditions (such as climate), and efficiency of the process. Thus, there is no single "water factor," or water requirement per unit of energy produced, for a specific energy process (Madani and Khatami, 2015).

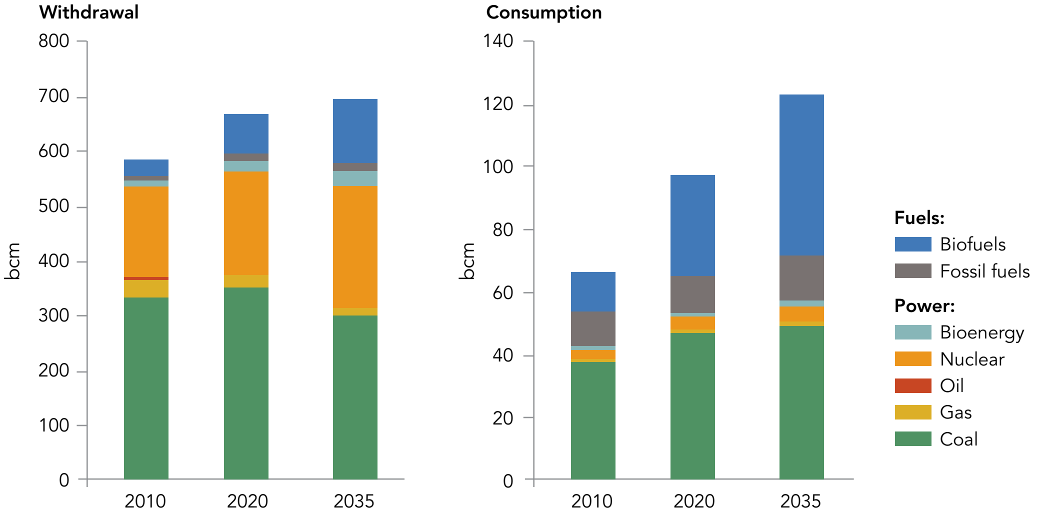
In 2012, the IEA published a series of macro-level indicators measuring global trends of global water use for energy production, which help capture upcoming global changes (although not with enough detail to represent realities at the operational and planning levels in developing countries). Between 2010 and 2035, as figure 4 shows, withdrawals by the energy sector will increase by about 20 percent, but consumption will rise by a dramatic 85 percent (under IEA's New Policies Scenario). These trends are driven by a shift toward higher efficiency power plants with more advanced cooling systems (that reduce withdrawals but increase consumption per unit of electricity produced) and by expanding biofuels production, which by 2035 consume nearly as much water as power generation.

Life cycle analysis. To fully understand the water requirements by energy sources, a life cycle analysis should be completed that accounts for water used in the production of the energy facilities. IRENA (2015) argues that renewable energy usually requires less water than fossil fuels based on a life-cycle assessment of water use in energy production. For example, a solar thermal power plant might require more water than a coal power plant that uses the same cooling system to generate electricity; however, when the water needed for coal mining is accounted for, solar thermal requires less water. The vast differences in water demand across the energy sector are challenging and critical to consider when analyzing and quantifying potential water constraints.

Water risk. Measuring companies' water risk will be important to understand how business strategies adapt to changes and heightened uncertainty. Water risk indicators aim to highlight regional differences and complement data on water uses. The Carbon Disclosure Program (CDP) report and its water questionnaire are one initiative that seeks to provide comprehensive analysis of water risk to companies and governance, and develop accounting and strategy indicators (CDP, 2014b). According to the CDP, physical water risks such as water stress and floods are the most prevalent water-related threat for utilities; other risks include deteriorating water quality and regulatory uncertainty. In 2014, 50 percent of utility companies and 41 percent of energy companies experienced water-related business impacts (CDP, 2014a).

Environmental impact. Policies and regulations that focus

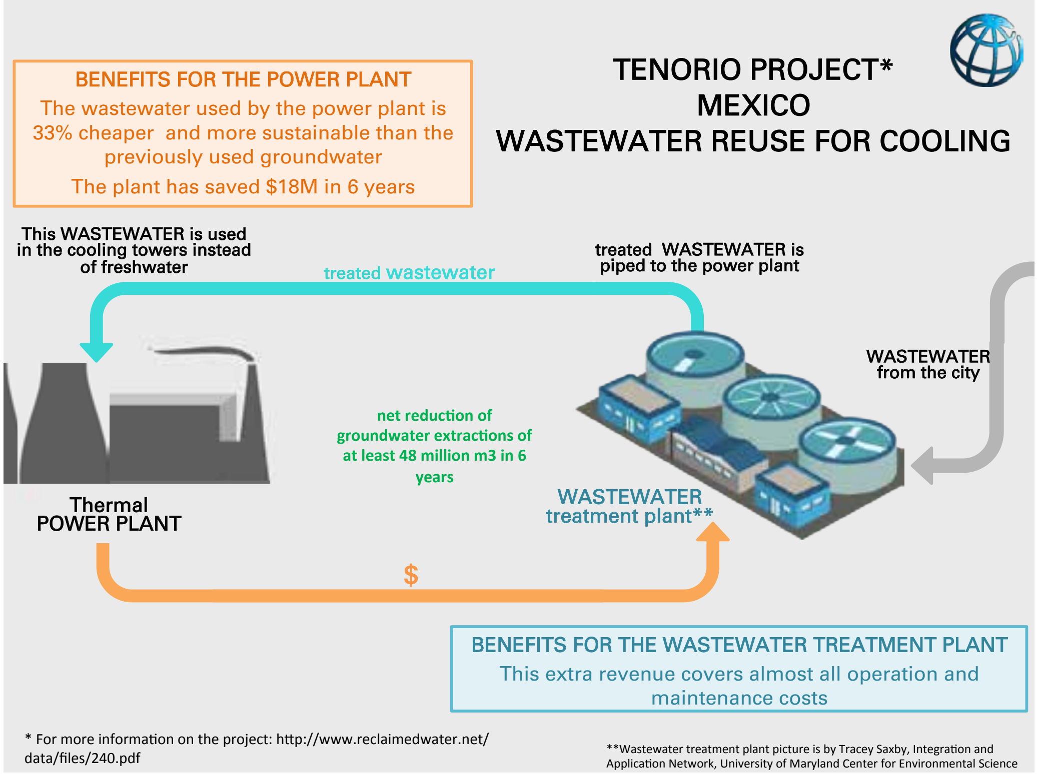
FIGURE 4 **Global water use (withdrawal and consumption) for energy production by fuel and power generation type**



Source: IEA 2012

FIGURE 5 **A Mexican power plant uses wastewater for cooling purposes**

(Simplified diagram of Project Tenorio, an innovative solution to reduce groundwater over-extraction)



* For more information on the project: http://www.reclaimedwater.net/data/files/240.pdf

**Wastewater treatment plant picture is by Tracey Saxby, Integration and Application Network, University of Maryland Center for Environmental Science

Source: Thirsty Energy, World Bank, 2014

solely on how much water the energy sector uses—without accounting for how this use affects the environment—could encourage unsustainable practices. For example, reducing the amount of water withdrawn from a source per energy produced is not always better for the environment if the quality of discharged water prohibits its future use.

Local/regional context. Variations in water resources reflect factors as diverse as geography, population, economic growth, demand, energy mix, and climate change. These factors can combine to create "hot-spots" where the water-energy nexus is more challenging than elsewhere. Thus, it is vital to understand the regional challenges and devise context specific solutions to address the nexus in these critical hot-spots. Electricité de France (EDF) is leading the Water for Energy Framework (W4EF) initiative to help energy actors assess and report the relations between energy production activities and local water environments through a common terminology and methodology. This framework will account for quantity and quality related uses of water resources, and relate usage to local conditions (EIP 2015).

Infrastructure investments. Choices and decisions made today about which extraction facilities to develop and where, which power plants to build, which to retire, and which energy or cooling technologies to deploy and develop, are critical. Energy infrastructure is designed to last for decades and thus decisions should account for future water availability—including climate change impacts and increasing future competing water demands—across sectors. The energy sector needs to assess if that water is used sustainable now and into the future, and it is imperative account for and anticipate any future tradeoffs among different water users.

There are opportunities to jointly develop and manage water and energy infrastructure and technologies that maximize co-benefits and minimize negative trade-offs. In Mexico, new water reuse regulations and a creative project funding contract (Built Own Operate Transfer -BOOT) incentivized waste water reuse in San Luis Potosi. Instead of using fresh water, a power plant uses a treated effluent from a nearby wastewater treatment plant in its cooling towers. This wastewater is 33 percent cheaper than groundwater, which has resulted in $18 million of savings for the power utility (in 6 years) (Lazarova et.al. 2013). For the water utility, this extra revenue covers almost all operation and maintenance costs of the WWTP (figure 5). Moreover, groundwater extractions have been reduced by 48 million cubic meters in 6 years (equivalent to nearly 20,000 Olympic-sized swimming pools). Other examples include combined power and desalination plants, combined heat and power plants, and energy recovery from sewage water (biogas production in waste water treatment plants).

Besides the pursuit of new technical solutions, new political and economic frameworks need to be designed to promote cooperation and integrated planning among sectors. Integrated policies and planning efforts will help ensure sustainable and efficient use of water and energy resources. In order to plan and invest in a more integrated manner, water requirements can drive policy decision making and be prioritized in how the energy mix is selected. Water requirements and water-related impacts of project development should be considered during the planning stage. Harmonized approaches to collecting and sharing data on water and energy production will enhance a country's ability to manage water and energy resources sustainably. In the energy and water sectors, it is critical that data gaps are addressed and new tools are developed to measure water use. This would help ensure that water is being allocated and used appropriately and efficiently. The World Bank's Thirsty Energy Initiative, for example, works with countries to analyze sustainable development of their water and energy resources, and to foster cross-sectoral planning.

CONCLUSIONS

Achieving universal energy access can improve water security, but to be sustainable, it must incorporate water into the planning and implementation of energy investments. The water sector can benefit from universal energy access by improving access to reliable, affordable, and safe water supplies. Further, the energy poor and water poor are often the same people. By achieving universal energy access, we can also achieve universal access to an improved water source. However, meeting rising energy demand may have a negative impact on water resources as water is necessary for almost all energy production processes and water-related risks can affect the energy sector and hinder progress toward energy access goals.

Understanding and analyzing the inter-sectoral linkages between water and energy is necessary to optimize the management of water and energy resources. But without reliable and comprehensive data on water-energy issues—the current situation—it is difficult to make informed decisions on policies, infrastructure development, operations, development investments, and long-term planning efforts. Thus, governments should encourage energy production facilities to report on water use and energy companies to collect data on water-related risks. They should also encourage decisions to reflect social, political, and environmental contexts.

The international community should continue to raise awareness regarding the inextricable link between the world's water and energy systems. Through these efforts, water and energy's external stressors, such as population growth and climate change, will be better understood. The energy and water sectors should share data and document best practices so successes can be replicated and sustainable efforts are catalyzed. Improved information could drive technological innovation and spur adoption of more effective policies and data collection methods. These practices will increase security and access through sustainable resource use and contribute to resilient water and energy resources management.

NOTE

1. Water withdrawal is typically defined as the amount of water that is taken from a water source (lake, river, ocean, aquifer, etc.). Water consumed is the water that is not returned to the water body after use. Water discharge is the amount of water that is returned to the water source and its quality matters due to environmental reasons. These requirements for and impact on water resources can differ dramatically depending on the type of process or technology employed.
2. Open-cycle power plants (mainly used as peak power plants using gas as fuel) do not use the steam cycle to turn turbines and thus do not require water for cooling.
3. The other processes for which water is required include the steam cycle, ash handling, and flue-gas desulfurization, among others. Although these processes consume relatively little water, their effluents contain pollutants and should be treated before being returned to the water source. From a plant-level economic standpoint, therefore, such processes can incur very significant costs related to wastewater treatment.
4. Water security refers to "the capacity of a population to safeguard sustainable access to adequate quantities of and acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability" (UNU, 2013).
5. Other ways to increase water efficiency in power plants may be the use of non-fresh water resources for cooling (such as sea water or waste-water) (US DOE 2009), and the practice of recycling and reusing water in energy extraction facilities.

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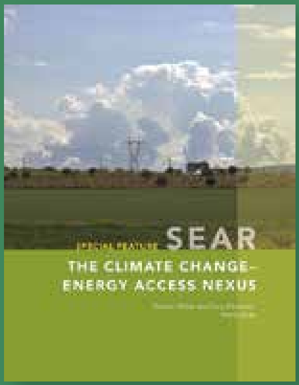
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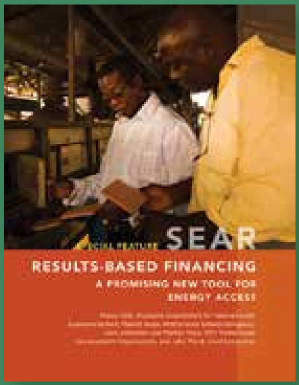
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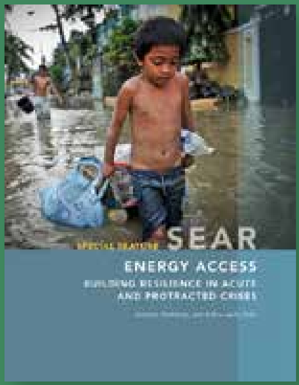
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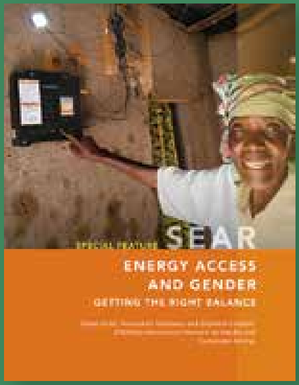
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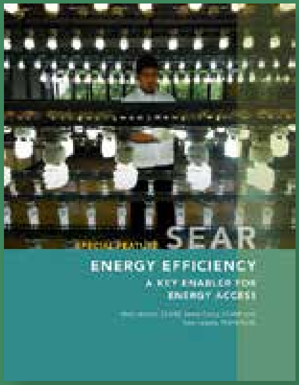
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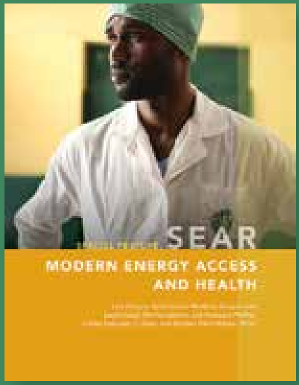
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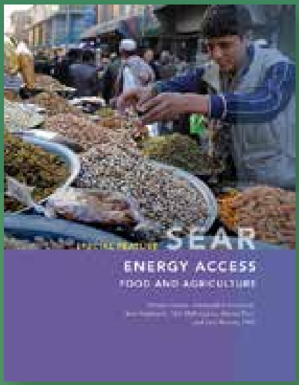
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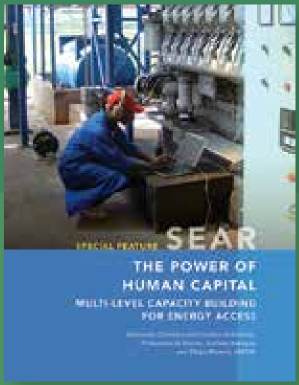
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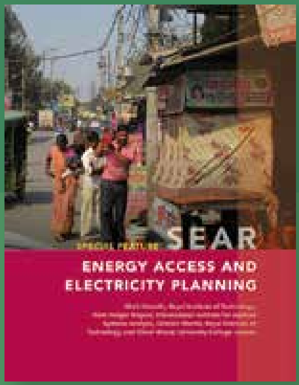
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