center for
ENERGY STUDIES
Rice University's Baker Institute for Public Policy

FROM THE 'WHAT?' TO THE 'HOW?' IN THE WATER-ENERGY NEXUS: CHALLENGES, OPPORTUNITIES AND LESSONS LEARNED

Regina M. Buono, J.D., M.Sc.
Baker Botts Fellow in Energy and Environmental Regulatory Affairs, Center for Energy Studies

Anna Mikulska, Ph.D.
Nonresident Scholar, Center for Energy Studies

Elsie Hung, M.Sc.
Research Associate, Center for Energy Studies

Kenneth B. Medlock III, Ph.D.
James A. Baker, III, and Susan G. Baker Fellow in Energy and Resource Economics
Senior Director, Center for Energy Studies

July 2016

Regina M. Buono, J.D., M.Sc.
Anna Mikulska, Ph.D.
Elsie Hung, M.Sc.
Kenneth B. Medlock III, Ph.D.

“From the ‘What?’ to the ‘How?’ in the Water-Energy Nexus: Challenges, Opportunities and Lessons Learned”

Introduction

On April 20, 2016, the Center for Energy Studies (CES) at Rice University's Baker Institute for Public Policy hosted a lecture by Diego Rodriguez, titled "From the 'What?' to the 'How?' in the Water-Energy Nexus: Challenges, Opportunities and Lessons Learned." Rodriguez is a senior economist at the World Bank and serves as the team task leader for the bank's Thirsty Energy program, the objective of which is to help countries integrate water constraints into the energy sector and better address water and energy challenges. Regina M. Buono, Baker Botts Fellow in Energy and Environmental Regulatory Affairs, opened the event by welcoming the audience and introducing the speaker. The event continues the CES' efforts to explore policy issues at the intersection of energy and the environment.

Lecture Summary

Rodriguez's talk addressed his experiences in contributing to the global debate on the water-energy nexus and the meaning of the nexus in practice. He particularly focused on the challenges of water resource management in developing countries, often characterized by very low government capacity and limited institutional frameworks.

Rodriguez opened his lecture by noting the complexity of water issues, which involve technical, institutional, financial, and social aspects. He argued that to achieve sustainability, the world can no longer afford business-as-usual, linear thinking that takes a sector-by-sector approach. Instead, we need to acknowledge that sectors are interlinked and that we need to understand and quantify the trade-offs that naturally occur between those sectors. For example, the water-energy nexus is particularly crucial when it comes to the Intended Nationally Determined Contributions (INDCs) submitted by more than 190 countries at the Conference of the Parties (COP21) meeting in Paris in December 2015. Rodriguez stressed that sustainability may be compromised if one focuses solely on emissions reduction without considering the trade-offs with water.

A recent World Economic Forum report on global risks lists water crises as the greatest concern in the next decade. Other top concerns include the failure of climate change mitigation and adaptation, extreme weather events, food crises, and social instability. Rodriguez pointed out the interlinkages between those issues and the need to take them into account within a nexus-driven policy. With this in mind, the World Bank Group has committed itself to two interrelated goals:

[1] to reduce extreme poverty worldwide to 3 percent by 2030, and
[2] to boost shared prosperity by improving the income growth of the bottom 40 percent in every country.

To achieve the 3 percent poverty target by 2030, all developing countries need to grow at a rate of 4 percent or higher. Increasing growth requires significant investment and, if it is to be done in a sustainable manner, an understanding of the trade-offs mentioned previously.

Rodriguez's Water Global Practice[1] at the World Bank addresses these issues with an integrated approach by planning and designing infrastructure. To accomplish these goals, global investment in energy and water infrastructure must be increased considerably. He argued that humanity needs to overcome challenges in political, institutional, policy, regulatory, financial, economic, social, and environmental dimensions.

Rodriguez stressed the strong interdependence and interlinkages between the water and energy sectors. These connections are certainly true for hydropower, but all energy production requires water, including thermoelectric cooling, power plant operations, and fuel extraction and refining. Different types of cooling systems in thermal power plants have different water intensities, levels of efficiency, costs, and environmental impacts. Rodriguez noted that cost in particular—both investment cost and operation and maintenance costs—must be taken into consideration in the planning process. He pointed out that while renewables such as wind and solar photovoltaic have negligible impact on water resources, they are not yet the answer to all our energy needs due to their intermittency and a resulting lack of reliability as a baseload power source. But the water sector, too, needs energy. The entire water supply chain—from production to processing to distribution and end-use—requires energy, typically in the form of electricity. Rodriguez noted that up to 40 percent of total electricity consumption is used by the water sector. According to a UN forecast, by 2035, energy consumption will increase by 35 percent, water consumption by 85 percent, and water withdrawal by 20 percent.

Water *quantity* is not the only issue. Rodriguez stressed that water *quality* can also be problematic if not managed properly. Developing countries often lack necessary regulations to prevent and address water pollution. Examples that highlight the lack of appropriate oversight include drainage from abandoned coal mines, thermal pollution from once-through cooling systems that have adverse effects on ecosystem, and wastewater generated from hydraulic fracturing activities.

The World Bank's ultimate concern with regard to water policy is to provide poor people with access to water services. Out of the more than 7.4 billion people on Earth today, 2.5 billion lack reliable access to electricity, 2.8 billion live in areas with high water stress, and 2.4 billion lack sanitation services. Rodriguez argued that this is truly a social poverty issue. Increasing water scarcity is a trigger for conflict, and climate change is exacerbating the challenges present today in the developing world. The World Bank addresses the energy-food-water nexus issues by looking at incapacities in energy systems caused by potential water constraints, such as decreased water availability, increased water temperatures, regulatory uncertainty, sea level rise, and decreased water quality. These constraints can result in reduced output of electricity, increased operating costs for utilities, damage to coastal energy infrastructure, and even social and political instability. Meanwhile, noted Rodriguez, the energy-poor population is often also water poor, further enforcing the need for an integrated and coordinated approach to address both energy and water issues.

[1] http://blogs.worldbank.org/team/diego-juan-rodriguez.

Rodriguez argued that after recognizing the physical challenges, it is important to understand the three "I"s: infrastructure, institutions, and information. According to the World Economic Forum, the investment needed merely to maintain existing water infrastructure is estimated at $1.3 trillion per year. The additional investment required in a green growth scenario[2] is $700 billion more per year. He observed that the numbers are outrageous, as they far exceed any government's fiscal budget, especially in developing countries.

Rodriguez highlighted the nature of water infrastructure in terms of public finance, noting that water infrastructure is usually held by a natural monopoly and characterized by long-lived, large, sunk-cost facilities without much flexibility to adapt. Typically, operating and maintenance costs for a municipal-scale water system are very high and can exceed the initial fixed cost of development. This "lock-in effect" creates path dependency in the sector. Planning infrastructure from within a silo also can cause inefficiency in investment. Very little private investment is involved in water infrastructure due to water's nature as a public good and natural monopoly. These characteristics underscore the need to develop, operate, and maintain a sustainable system. Rodriguez argued that in order to develop a sustainable system, regulations and policies need to encourage technological innovation, integration across sectors, flexible investment, and a combination of green and grey infrastructure.[3]

Rodriguez observed that information asymmetries are a major constraint in the water-energy discussion. Lack of shared, transparent information across sectors creates difficulty in analysis and planning as well as infrastructure design. In some cases, information is even used as a political tool. At the same time, there are very few protocols and incentives across agencies for data sharing, which makes joint, integrated planning even more challenging. When it comes to numbers used for research purposes, global averages can be grossly misinforming, effectively leading to a significant aggregation bias. Rodriguez stated that the indicators used in global studies do not capture the magnitude of resource use or the depth of local pressures. For infrastructure planning, it is crucial to understand the actual water stress in a particular region. Misleading information about the nexus gives the public wrong ideas, such as the idea that water use by different power plants depends on the type of cooling system rather than fuel type.

Existing institutions are often yet another major challenge in development. Rodriguez argued that while infrastructure can be planned and designed, institutional frameworks are difficult to alter. He noted that in developing countries, institutions usually have low enforcement capacity and are affected by political cycles, which can be disruptive to project execution. Rodriguez stressed that governments need to understand the numerous entry points to the nexus discussions, whereby different sectors including energy, water, and agriculture are discussed at the same level. However, he noted that the energy sector

[2] See https://www.weforum.org/reports/financing-green-growth-resource-constrained-world/.
[3] Green infrastructure uses vegetation, soils, and other elements and practices to restore some of the natural processes required to manage water. Grey infrastructure uses concrete, steel and other traditional materials.

typically is the most influential voice in the discussion, which poses a challenge to initiating balanced institutional arrangements.

Incentives are crucial to ensuring coordination among necessary institutions in development discussions. However, regulations, policies, and legal frameworks are often conflicting across sectors and can present disincentives to efficiency improvements. For example, energy for pumping water and irrigation in agriculture is often subsidized, which encourages overuse and waste of water. As an example, Rodriguez presented a situation in Peru and Bolivia where a retrofitted wastewater treatment plant also produces electricity for self-sufficiency purposes. However, the plant cannot sell any excess power it generates to electricity companies due to a regulatory prohibition.

The World Bank seeks to collaborate with energy stakeholders—who are generally more influential than their water counterparts—by increasing awareness of the complexity of the nexus and focusing on integrated energy and water investment planning. It is crucial to understand, identify, and evaluate the trade-offs and synergies between water and energy planning. Rather than focusing on the water regulatory agencies as an entry point, the World Bank works with the actors in the energy sector to incorporate water planning into their asset portfolio, such as in the power dispatch system. He noted that the complexity of the task is to align the water basin—a geographical unit—with national and regional grids, which are geopolitical units. With this nexus-driven thinking, the World Bank identifies trade-offs and anticipates potential issues from both the energy and water sectors.

Water is not an isolated sector; rather, it touches all parts of society and economy, including food and agriculture, energy, industrial activity, and health and the environment. Urbanization, which is highly correlated with economic growth, drives increased water demand, especially in developing countries. At the same time, maintaining a healthy ecosystem, which requires adequate quantities of good quality water, is critical to supporting essential services to increasingly urban populations. This creates greater competition for water supply, argued Rodriguez, so the challenge is to plan and design investment in water infrastructure in a sustainable way. He noted that sustainability is a critical issue, but it is discussed little on the global agenda.

Rodriguez argued that we need sustainability not only in environment but also in institutions, finance systems, infrastructure, and society. However, current challenges at the political level are impeding effective planning. In addition, current energy planning is often done without taking into consideration future changes in water availability, water quality, competing uses, and the impacts of climate change. It is also essential to understand and quantify trade-offs, because there are always winners and losers in each policy or economic decision. For example, dry cooling systems for power plants require no water for operation, but they operate less efficiently and increase greenhouse gas (GHG) emissions as well as the cost of electricity.

Rodriguez described the World Bank's current project in South Africa, which is nearing completion. South Africa is an extremely dry country, and 97 percent of the country's

water resources have already been allocated. Moreover, the driest region—the southeast—also contains a significant number of thermal power plants, exacerbating competition for water. As of 2010, coal-fired power plants accounted for 86 percent of the total power generation capacity. Rodriguez posited that the challenge is to ensure that energy demand is satisfied by increasing energy investment. The infrastructure in South Africa is very complex, as energy and water are tightly interlinked in the river basins. While energy production and use certainly benefit from well-interconnected water infrastructure, transporting water within such a system is also dependent on energy.

To address the water issue in South Africa, the World Bank utilized the South Africa TIMES Model (SATIM), a linear optimization model to represent the entire energy sector. The inquiry found that while water consumption for technology purposes was already included as a parameter in the model, there was no constraint on water consumption itself. In fact, the model assumes that water is infinitely available without constraints. Many planning frameworks do not contemplate physical constraints much less incorporate adequate costs, noted Rodriguez. In addition, he stressed the long-term nature of planning. It is not unusual to see 15-year lead times for water-related infrastructure. Thus, the energy and water sectors need to be more proactively aligned to avoid future potential costs (for example, a power plant without sufficient water supply for cooling purposes must shut down, thereby incurring stranded costs for idled capital).

Many scenarios were developed in the SATIM-water model after modifications were made to account for potential water scarcity. The World Bank divided the water basins in South Africa to match energy-producing regions with water resource areas. Rodriguez noted that it is important to spatially represent power plants and other energy facilities accurately with other infrastructures and, ultimately, demands. By assigning different power plants and energy extraction activities to appropriate locations, the amount of water available to each energy infrastructure could be better represented. The model also included the costs of supplying water to the energy facilities. Incorporating the costs of infrastructure and geographical constraints in the model allows researchers to develop a forecast of water consumption by technology through 2050 that is based on the projected energy requirements and energy conversion technologies. In particular, the work identified the potential for water use reductions facilitated by a significant shift from wet cooling to dry cooling as well as to solar technology. Rodriguez noted that the trade-offs in this situation are increased delivered energy costs in exchange for climate and water benefits. By contrast, in scenario analysis without incorporating water constraints, water consumption by the power sector increases between 2030 and 2050. Additionally, in a scenario where CO_2 emissions are capped, another trade-off is revealed—namely, water use for power generation increases due to increased use of wet cooling systems to control CO_2 emissions.

Rodriguez argued that we now have a “new normal” where challenges such as water scarcity and water conflicts are already occurring in many parts of the world. It is crucial to scale up the development and implementation of water infrastructure to actually make a difference, particularly in the developing world. Nexus thinking is critical in the modeling framework. Rodriguez stressed again the need for decision-makers to understand the

interconnected nature of resources and the associated trade-offs of particular development paths. As the case of South Africa demonstrates, the cost and availability of water supply are crucial in energy planning. Rodriguez concluded by underscoring the importance of thoughtful policies and well-run regulatory and industrial institutions that set appropriate guidelines.

Question and Answer

After finishing his talk, Rodriguez addressed a number of questions from the audience. In response to a question about nuclear development in South Africa, Rodriguez noted that there is an ongoing internal debate at the highest political level on the operational risk of nuclear power. Regardless of that debate, however, nuclear is still considered a long-term planning option. Meanwhile, South Africa is building more coal-fired plants and renewable capacity to address the electricity challenge in the short term.

When asked about alternative supply options for water, such as desalination and rain catchment, Rodriguez stated that such solutions depend on the scale and location. In some cases, it requires a mix of green and grey infrastructure. In addition, cost considerations and quality issues need to be taken into account in planning water supply infrastructure.

In response to a question about the World Bank's role with respect to the water-energy nexus, Rodriguez noted that there are different angles from which to approach the issue. In the case of South Africa, the Thirsty Energy group first conducted upstream planning and consulted with potential investors. The World Bank is also involved in financing infrastructure for particular projects. For example, Morocco is looking at public finance options for a desalination plant. The World Bank incorporates principles from energy financing in the design of these types of investments.

When asked about incorporating carbon pricing into the SATIM Model, Rodriguez noted that the project stopped at pure financial costs, as there are no actual prices available to estimate the cost of carbon. As such, absent a carbon price in the model, the World Bank capped CO_2 emissions as a scenario based on stated national climate goals. The scenario showed that water use increases with more stringent goals for carbon emissions.

A question was raised on collaboration with energy companies on the various possible options and policies. In response, Rodriguez discussed the Bank's private sector reference group. The World Bank has been working with a number of energy companies in global efforts in recent years to gather common definitions, indicators, and methodologies for measuring data. In fact, the data used in the model was directly from an operating power plant in South Africa.

When asked about addressing the political uncertainty in developing countries, Rodriguez replied that this issue is what World Bank seeks to address. It incorporates the political context and various constraints into a more realistic approach. Rodriguez shared as an example one experience with the SATIM Model, which had included adequate water

pricing. Due to political limitations on fixed water tariffs, the group removed water pricing from the model.

CES Reflections

For the last two years, CES has been expanding its work in the area of water and energy, hosting a number of events addressing various relevant issues and conducting research, thinking, and writing on these topics. The water-energy nexus is inescapable, and the linkages between resources must be considered in the development of good public policy. Nexus-focused thinking in practice, development, and planning can contribute to policy and projects that maximize efficiencies between sectors and sustainability for systems and institutions.

Modeling that takes multiple sectors and resources into account in a realistic manner can aid a better understanding of the otherwise unforeseen effects—the proverbial "law of unintended consequences"—of policy actions over time. Understanding these issues in the context of a specific geographic region is also important, as resources and conditions in different parts of the globe vary widely and may be disparate from global averages. This is the approach being taken at CES, and is evidenced in the work being done by the World Bank.

Institutions and regulatory frameworks are vital factors in developing and implementing policy, and these factors must be fully incorporated into nexus thinking. Having the world's best water or energy technologies will not facilitate achievement of even the most beneficial policy objectives if it is not possible to implement or install the solution because of political infighting, sector territorialism, or obstructive regulation. Understanding and navigating these contexts and legal structures can be complicated in any locale, and might be especially challenging in developing countries, particularly those with unstable political environments or that suffer from low institutional capacity. Much of the world's newest infrastructure is being and will be constructed in developing countries and will be in service for the next half-century or more. Ensuring that we get the balance right between water and energy from the beginning is a key objective.

It is very important that governments ensure consistency in stated goals and policy actions across sectors. As much as possible, efforts must be made to understand the interplay of various laws and policies and the implications they may have for resource management. Siloed decision-making can lead to expensive and counterproductive inefficiencies that can undermine even the best of intentions. Regulations for one sector should not hinder desirable objectives in other, interconnected areas, and policies need to provide adequate incentives to drive technological innovation, investment, and integration across sectors. This will help ensure that sustainable outcomes are achieved at the lowest possible cost.