Water-Energy Nexus Approach for Sustainable Development in India

Water and energy use are inextricably linked in innumerable ways. The use of water entails energy and the manner modern society produces energy consumes water. Water and energy have much in common. Each is an essential input for productive, comfortable and healthy human sociaeties. Both are also derived from natural resources, and their use by humans creates a series of impacts on the sustainability of ecosystems. The close nexus between water and energy is intertwined in two ways: (a) Water use requires energy; (b) Energy production requires water. These are briefly explained as follow.

(a)Water Use Requires Energy

The quantity of energy that goes to water use differs substantially from region to region. In the United States, about 4 percent of power generation is used for water supply and treatment, according to a report from Sandia National Laboratories to the US Congress; domestic hot water heating accounts for some 9 percent of domestic energy use.[1]

The amount of electricity utilized for some form of water delivery/extraction/purification is even higher in many partd of the globe. For example, in Northern Gujarat in India, as much as 58 percent of the electricity produced by UGVCL (the local utility that serves approximately 9 million people) is used to pump groundwater for agriculture. The case of Gujarat in India highlights another important connection in the energy-water nexus—agriculture. Globally, the agriculture sector is the largest user of water; insofar as it takes energy to pump and transport water, agriculture's water use makes it a large user of energy.

In India, increasing use of both energy and water has been associated with increased agricultural productivity and food security. Today, 60 percent of irrigated agriculture in India depends on pumped groundwater, making India the largest user of groundwater in the world.[2] This trend was not started overnight; extensive use of groundwater in India began three to four decades ago, during the Green Revolution, when water tables were much shallower.

(b) Energy production requires water

Energy production depends on water. It is used in power generation, primarily for cooling thermal power plants; in the extraction, transport and processing of fuels; and, increasingly, in irrigation to grow biomass feedstock crops. Energy is also vital to providing freshwater, needed to power systems that collect, transport, distribute and treat it. Each resource faces rising demands and constraints in many regions as a consequence of economic and population growth and climate change, which will amplify their vulnerability to one another.

For the energy sector, constraints on water can challenge the reliability of existing operations as well as the physical, economic and environmental viability of future projects. Water constraints can occur naturally, as in the case of droughts and heat waves, or be human-induced, as a result of growing competition among users or regulations that limit access to water. In the summer of 2012, for example, a delayed monsoon in India reduced hydropower output at the same time electricity demand was running high, contributing to two days of blackouts that affected an estimated 660 million people.

The role of water in energy is getting more attention than ever before. Energy production sucks up about 15 percent of the world's total water withdrawal, which could increase by about 20 percent between 2010 and 2035. Much of the increase will be driven by higher-efficiency power plants and expanding biofuels production, according to the IEA report on *World Energy Outlook 2012*, which says: "In an increasingly water-constrained world, the vulnerability of the energy sector to constraints in water availability can be expected to increase, as can issues around how the quality of water is affected by energy operations."[3]

Equally important to water-related risks confronted by the energy sector, the use of water for energy production can impact freshwater resources, affecting both their availability (the amount downstream) and quality (their physical and chemical properties).

The IEA, for the first time in its report *World Energy Outlook 2012*, has examined the water for energy relationship, reviewing water requirements for different energy sources like primary energy and electricity generation and estimating total freshwater needs by scenario, energy source and region. It amply demonstrates that the scale of water use for energy production is tremendous. Some 580 billion cubic metres of freshwater are withdrawn for energy production annually.

At about 15% of the world's total water withdrawal, the figure is second only to agriculture. To put it another way, the energy sector withdraws water at approximately the same rate that water flows down the Ganges (in India) or Mississippi (in the United States) Rivers – some of the very largest in the world.

The vast majority of water used in the energy sector is for cooling at thermal power plants, as water is the most effective medium for carrying away its huge quantities of waste heat. Though the amount used for biofuels and fossil fuels may appear minor on a global level, this must be viewed in the context of local water resources and potential risks posed to water quality. Water withdrawal by the energy sector is expected to rise by one-fifth through 2035, while the amount consumed (not returned directly to the environment) increases by a more dramatic 85%.

Water use for thermoelectric power generation is primarily used for cooling the steam that was used to the turn turbines to make electricity. While very little water is lost to the atmosphere, higher temperature discharge can lead to ecological damage. Together the water used for cooling in power plants—accounts for a stunning half of all water withdrawals in the United States, with nearly 2.5 percent never returned to the water body.[5] Most electricity comes from these steam driven turbines, whether one is using coal, natural gas, oil or nuclear fuel to heat the water.

The water-intensity of thermoelectric production means that that water needs could easily collide with energy demands in coming years. In a 2009 article for the Columbia Journal of Environmental Law, Benjamin K. Sovacool and Kelly E. Sovacool made the case that the convergence of population growth, rising electricity demand and drought in some areas "could threaten to cause massive shortages of water, while forced shutdowns could occur due to lack of water in others." Yet, "despite the seriousness of water concerns associated with electricity use, most electric utilities continue to propose water-intensive power plants as the best way to meet demand projections."[6]

The other major source of electrical energy that is threatened by water shortages is hydroelectric. Some 20 percent of the world's electricity comes from large-scale hydroelectric dams—dams that require steady, large flows of water. But as the world climate and water cycles are disrupted, energy from large hydroelectric plants is threatened. For example, low water levels at Lake Mead threatens to shut down power generation at the Hoover Dam, a major source of electricity for Las Vegas and Southern California—electricity that is used, in part, to pump water from the lake to meet thirsty Southern California's water needs.[7]

The risk to electricity from diminishing water is a global problem. In the summer of 2010, drought in the Philippines caused the National Grid Corp there to cut electricity provision in half in some areas as reservoir levels fell to unprecedented lows.[8]

The scramble for new sources of cheap, abundant energy threatens existing water sources. It is a known fact that reckless coal mining can contaminate ground and surface water. Until recently, however, natural gas drilling was considered relatively clean. Recent advances in hydraulic fracturing (hydrofracking) technology, however, have created the potential for industry to exploit vast, previously untapped reserves of natural gas across the United States and the world.

An increasing body of research as well as other available evidence suggests, however, that hydrofracking unless well managed and regulated can present a serious risk to local water quality, as the millions of gallons of water, sand and toxic chemicals it takes to frack a well seep to the surface, potentially poisoning the ground and surface water of surrounding communities.[9] Oil shale, frequently touted as another vast, non-conventional oil resource of the future, would also require staggering amounts of water (and energy) to produce.

Even solar power (which otherwise is one of the most ecologically benign ways to produce electricity) is also dependent on water. Solar thermal plants, for example, work by using mirrors to heat water to drive a turbine that generates electricity. As in a conventional fossil fuel plant, the water must then be cooled for reuse, a process that results in significant water loss. Even solar photovoltaic power plants need to be washed down periodically to maintain efficiency – especially in dusty, sunny, water-stressed areas.

Water Situation in India

Water and energy are two most significant components of sustainable development. However, India is faced with deficit in both these sectors. The demand for water in India's domestic, agricultural, and industrial sectors is currently to the tune of approximately 900 billion cubic meters of water every year and by 2050 demand is expected to double and consequently exceed the 1.8 trillion cubic meters of supply.

Keeping in view the finite water resources, which are already under stress, demand for water in India has already exceeded the available supply capability thereby giving rise to water crisis. Given the fact that India's climate is not particularly dry, nor is it lacking in rivers and groundwater, the water crisis in India is predominantly a manmade problem. Exceedingly poor management, unclear laws, malpractices, and industrial and human waste have caused this water supply crunch and rendered what water is available practically useless due to the huge quantity of pollution. There is a need for balancing competing demands between urban and rural, rich and poor, the economy and the environment**.**

Energy Sceneraio in India

India has been the fourth or fifth largest energy consumer in the world. Despite a slowing global economy, India's energy demand continues to rise. While India's domestic energy resource base is substantial, the country relies on imports for a considerable amount of its energy use. Hydrocarbons account for the majority of India's energy use. Together, coal and oil represent about two-thirds of total energy use.

Combustible renewables and waste constitute about one forth of Indian energy use. This share includes traditional biomass sources such as firewood and dengue, which are used by more than 800 million Indian households for cooking. Other renewables such as wind, geothermal, solar, and hydroelectricity represent a 2 percent share of the Indian fuel mix. Nuclear power holds one percent share. India is the world's fifth largest net importer of oil and bulk of India's foreign exchange is spent on oil imports.

In order to have a full gamut of issues involved in India's energy scenario, it deems appropriate here to briefly appraise different sources of energy in India.

OIL

Broad estimates put India's proven oil reserves approximately at 5.7 billion barrels, the second-largest amount in the Asia-Pacific region after China. India's crude oil reserves tend to be light and sweet. India produced roughly 950 thousand barrels per day (bbl/d) of total liquids in 2010, of which 750 bbl/d was crude oil. The country consumed 3.2 million barrels per day (bbl/d) in 2010.

The combination of rising oil consumption and relatively flat production has left India increasingly dependent on imports to meet its petroleum demand. In 2010, India was the world's fifth largest net importer of oil, importing more than 2.2 million bbl/d, or about 70 percent of consumption. A majority of India's crude oil imports come from the Middle East, with Saudi Arabia and Iran supplying the largest shares. Iranian oil's share of Indian imports has decreased in recent years, largely due to issues with processing payments.

Currently, India imports 80 percent of its crude oil requirements which accounts for $120 billion of the country's wealth. If oil prices increase, the import bill increases and will impact India's economic growth. By 2030, India's oil import is expected to increase to 90 percent. India imported 186.7 million tons of crude oil and fuel products in fiscal year 2012, according to the Indian Oil Ministry data. In 2011, the amount was 148 million tons.

Keeping in view the importance of the strategy and economics of energy security, demand for energy is escalating in India but sources of energy are depleting at the same pace. Going forward, if [demand continues] to grow at 8 percent to 9 percent, import dependence is likely to increase and India would be importing 35 percent to 57 percent of coal, 90 percent to 94 percent of oil, and 20 percent to 57 percent of gas by 2031-32.[10]

Natural Gas

Despite major new natural gas discoveries in recent years, India continues to plan on gas imports to meet its future needs. According to *Oil and Gas Journal*, India had approximately 38 trillion cubic feet (Tcf) of proven natural gas reserves as of January 2011. EIA estimates that India produced approximately 1.8 Tcf of natural gas in 2010, a 63 percent increase over 2008 production levels. The bulk of India's natural gas production comes from the western offshore regions, especially the Mumbai High complex, though fields in the Krishna-Godavari (KG) are increasingly important.

In 2010, India consumed roughly 2.3 Tcf of natural gas, more than 750 billion cubic feet (Bcf) more than in 2008, according to EIA estimates. Natural gas demand is expected to grow considerably, largely driven by demand in the power sector. The power and fertilizer sectors account for nearly three-quarters of natural gas consumption in India. Natural gas is expected to be an increasingly important component of energy consumption as the country pursues energy resource diversification and overall energy security.

Despite the steady increase in India's natural gas production, demand has outstripped supply and the country has been a net importer of natural gas since 2004. India's net imports reached an estimated 429 billion cubic feet (Bcf) in 2010.

According to one report, the whole natural gas value chain including domestic production, LNG imports and pipeline transportation and gas pricing are key focus areas and Government of India is taking measures to increase the share of natural gas in the energy basket from the current 9 percent towards the global ratio 23 percent. This will require collective action by the government, industry and consumers.[11]

Electricity

India suffers from a severe shortage of electric capacity. According to the World Bank, roughly 40 percent of residences in India are without electricity. In addition, blackouts are a common occurrence throughout the country’s main cities. The World Bank also reports that one-third of Indian businesses believe that unreliable electricity is one of their primary impediments to doing business. Further compounding the situation is that total demand for electricity in the country continues to rise and is outpacing increases in capacity. Adequate additional capacity has failed to materialize in India in light of market regulations, insufficient investment in the sector, and difficulty in obtaining environmental approval and funding for hydropower projects. In addition, coal shortages are further straining power generation capabilities.

Electricity generation by power utilities, during 2012—13, was targeted to go up by 6.05 per cent to 930 billion units. The growth in power generation during April to December, 2012 was 4.55 per cent as compared to about 9.33 per cent during April—December, 2011. The estimated hydro potential is about 1,45,000 MW. The total potential for renewable power generation from various sources other than large hydro projects stood at 89,760 MW.[12]

Peak power shortage is shortfall in generation capacity when electricity consumption is maximum. During the 11th Five Year Plan (2007—12), nearly 55,000 MW of new generation capacity was created. Yet, there continues to be a peak shortage of 9 per cent.

Coal

Coal has been a mainstay of India's electricity-generating sector. It accounted for 53 percent of India's energy consumption in 2007 and by late 2012 it increased to 56.65 percent, and demand is set to grow dramatically over the coming decades. Coal use for electricity generation is projected to grow 2 percent every year, almost doubling its share of India's generating capacity by 2030. This will increase not only domestic production but also imports: Over the next two decades, coal imports are projected to triple compared with the 2007 level.

Coal is used mainly for generating electricity, and currently 44 percent of rural households (amounting to 400 million people) do not yet have access to electricity. The government and its coal ministry plan to ramp up production by 65 percent in less than a decade to meet the growing demand for rural electrification.

Because coal is both cheap and abundant domestically, it may seem like the perfect solution to India's energy and electricity woes. However, using coal has severe health, environmental, and economic effects. As quality of life improves for most Indians, many will protest against this dirty pollutant. As the world moves closer to a consensus on climate change, using coal at this growing rate may become untenable. To work around these problems, India will need to address market inefficiencies. Developing alternatives to coal will also be essential. India's coal reserves are not as large as previously thought. At the current usage rate, India's reserves would be depleted in 80 years. At the projected rate of growth in production, that number becomes 40. Transporting coal is cumbersome and inefficient. Most of the domestic reserves are concentrated in India's eastern and central states, far from the urban centers most in need of increased energy.

Nuclear Energy

Because India's coal production at the current level is sustainable for only a few more decades, viable alternatives must be developed and brought to the market. Nuclear power is a low-carbon energy source. That means that the pollution problems stemming from generation are minimal; instead, its environmental costs show up at the back end of the production chain in the storage of nuclear waste, a testy political issue.

At present, nuclear power accounts for only 2.3 percent of electricity generation in India. The Indian government plans to raise nuclear energy's contribution to about 5 percent by 2020 and hopes to derive 25 percent of total energy from nuclear power by 2050. These goals are ambitious, especially in an industry that has generally run behind the government's planning targets. The U.S.-India agreement on civil nuclear cooperation makes reaching these goals more likely. Realistically, however, a significant increase in nuclear power is a long-term, not a short-term, option.

Following the completion of the U.S.-India civil nuclear agreement, France and Russia have been the first to sign nuclear power deals with India. Nonetheless, moving from designation to production will be slow. The U.S. suppliers are reluctant to jump in until India has put in place liability legislation.

The resources currently allocated to energy supply are not sufficient for narrowing the gap between energy needs and energy availability. One of the key challenges remains resolving the energy bottlenecks. Further, the country's excessive reliance on imported crude oil makes it imperative to have an optimal energy mix that will allow it to achieve its long—run goal of sustainable development.

Conclusion

There exists an intertwining relationship between water and energy. Water is often regarded as an input for generating power in case of thermal and hydro-electric power stations. However, when it comes to usage the situation is reversed, particularly when it is used for extracting and distributing water. Urban and rural water supply systems need power to distribute water through pipe networks and farmers need power to run pump sets and irrigate their fields. Therefore, the hydrological and power cycles are combined together at multiple points.

While the power sector uses only a small amount of water as most of it is released downstream for other purposes; it cannot be said to 'use' water in the sense that agriculture does. While, on the other hand, extracting ground water, distributing and treating it including wastewater treatment uses a considerable amount of power, though the percentages are unclear, since there are no research work that examines the multiple linkages between water and energy.

Given that agriculture is the largest user of water (86% in India), it is imperative that it is one of the focus areas of research in order to fully unravel the water-energy nexus. Some research studies on energy policies and their impact on groundwater already exist based on Indian conditions.

These studies make it discernible that small and marginal farmers are adversely impacted when power supply to tubewells is regulated, assured and charged, even though such a scheme helps improve the groundwater table. As observed in the case of groundwater depletion, the effects of water-energy nexus are cumulative and therefore, research needs to be undertaken on this crucial aspect as well.

Energy efficiency could help address the adverse impact on small farmers due to increase in power tariff. For example, a programme by the United Nations Development Programme aims to promote energy-efficient electric motors to reduce power consumption for irrigation and the possible burden on farmers due to increased tariffs. Innovative approaches are called for to better understand the water-energy nexus particularly from the farmer's perspective.

Further research is needed to understand the linkages between the water-energy cycles at the local, regional and national levels. Such research would help in scenario planning and take into account drivers such as demographics, consumption and production patterns, technology, globalization and environmental issues.

Another area, where water and energy are most visibly connected is the hydroelectric sector. Further in-depth research and analysis could help identify the potential sites for hydroelectric projects taking into consideration resettlement and rehabilitation, submergence, social and cultural losses. There is a need to curtail the methane emissions from decaying submerged plants and risks of reservoir overtopping due to exceptionally heavy rains (as could happen due to climate variability) through research and innovation.

There are multiple networks working on energy, water and climate change in India that could act as conduits for outreach and dissemination of knowledge. However, the objective needs to be more inclusive than just knowledge dissemination to include inputs for policy formulation and programmes that address the water and energy cycles. Informed decision-making in both the water and energy sector is crucial and needs to be undertaken at all levels.

Capacity building is required to bridge knowledge gaps, particularly at the local level. Awareness regarding the efficient use of energy and water is also crucial. School and college curricula need to include these aspects which are a glaring gap that needs to be filled by developing suitable courses for the youth and training modules for teachers.

Some observers feel that in addition to the knowledge gap and paucity of research, there is no single source where information on water and energy is readily available in India. There are now several knowledge platforms on water, energy and climate change but they view these themes in isolation. It may be possible for some of these knowledge platforms to find common sub-sets and present it to the public in a more coherent manner.

Notes

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