The Food–Energy–Water Nexus

An Integrated Approach to Understanding China's Resource Challenges

Julian L. Wong

China's rapidly growing economy is very quickly testing the limits of its resource constraints. While China is home to a quarter of the world's population, it is endowed with disproportionately less arable land, oil and water. Such natural resources are vital to any nation's ability to be self-sufficient, but China's predicament is especially dire not only because of its large population, but also its rapid urbanization and climate change, both of which will exert more intensive demands on food, energy and water supply. Yet, other than recognizing that water is essential for agriculture, the discussion of each resource constraint is often conducted in isolation, without paying heed to the inter-linkages of food, energy and water systems. This article draws the connections among all three systems in China and makes the case for the urgent need for more integrated approaches to resource management.

The Example of the Yangtze River

China's Yangtze River is the third longest in the world and stretches over 6,000 kilometers from the Qinghai Plateau in the west towards the East China Sea at Shanghai. Throughout China's history, it has played a central role culturally, socially, and economically. It is the unofficial dividing line between China's north and south, flows through deep gorges in Yunnan Province that have been designated as a UNESCO World Heritage Site, and serves as the lifeblood upon which much of China's agricultural and industrial activity has depended on to the present day. All told, the Yangtze River system produces 40 percent of the nation's grain, a third of its cotton, 48 percent of its freshwater fish and 40 percent of its total industrial output value.[1]

The Yangtze has now become a victim of its own success. With China's rapid economic industrialization over the past three decades, the Yangtze has evolved from a source of life and prosperity to a symptom of the limits of China's unabated economic pursuits. It has become a depository for 60 percent of the country's pollution, making it the single largest source of pollution in the Pacific Ocean.[2] The Yangtze is also home to two massive and highly controversial hydraulic projects—the Three Gorges Dam, the world's largest hydro-electric power facility, and the South-North Water Diversification (SNWD) project, an unprecedented, multi-decade effort to channel water from the water-rich south to the arid north—each a symptom of a larger ill. The former project points to China's struggles to maintain energy security and desire to use cleaner sources of energy in a carbon-constrained world, while the latter points to its sheer desperation to address a gross imbalance in the distribution and use of water resources across the Chinese sub-continent.

Neither project comes on the cheap; the Three Gorges Dam bore a price tag of US$30 billion and the SNWD project is projected to cost twice that.[3] Both projects have caused, or will continue to cause, the dislocation of hundreds of thousands of citizens and the significant alteration of landscapes, including the destruction of arable land. Needless to say, both projects have required, or will require, massive inputs of concrete, steel and energy. Together, Three Gorges and SNWD point to a fragile interrelationship between energy, water and food. Beyond the Yangtze, the "food–water–energy trilemma" represents a looming and complex threat to China's economic stability and national security.

Watergy

Climate change now stands front and center of energy and environmental agendas around the world. In virtually every case, the discussion of tackling climate change is centered on our energy

Julian L. Wong is a senior policy analyst at the Center for American Progress in Washington, D.C., where he specializes in a range of international climate and energy policy issues. Julian is the author of The Green Leap Forward (www.greenleapforward.com), a leading blog on China's energy and environmental issues.

system, specifically the need to replace our reliance on fossil fuels with cleaner sources of energy. A staggering 80 percent of China's electrical power is derived from highly-polluting coal combustion. Meanwhile, the consumption of oil, half the domestic demand of which is met by imports, is rapidly increasing as vehicle ownership continues to make inroads into China's growing middle class. But aside from energy, at least two other elements must be considered when trying to crack the climate change equation. While keenly aware of the need to diversify its energy sources and reduce greenhouse gas emissions, China is starting to realize that proposed energy alternatives are running up against limits in water and food systems as well.

Let's start with water. Just about every traditional energy choice requires significant inputs of water. The reality is that the state of China's water supply is probably even more dire than its lack of energy self-sufficiency. China's per capita water resources are 2,200 cubic meters, just one third of the world average. Even more startling is the utter imbalance of water resources distribution. Southern China, with 55 percent of the population and 40 percent of the cropland, has about 84 percent of the water resources.[4] The north, by contrast, has to sustain 45 percent of the population and 60 percent of all cropland with just 16 percent of the water.

This is not good news, especially for northern China, considering the various water demands of available energy options. The trade-offs between water and energy use has been dubbed the "water-energy nexus" or "watergy" for short. Any energy source that requires extraction, such as coal, oil, natural gas, and uranium often entails significant contamination of water tables and depletion of groundwater. Power generation involving any of these fuel types also relies heavily on water inputs at various steps of the process, such as steam generation and systems cooling. The operation of nuclear plants, in particular, are as water-intensive, if not more water-intensive, than the operation of its coal or renewable counterparts because of their increased cooling requirements.[5] Nonetheless, nuclear power is being favored as a major alternative energy strategy by the Chinese government.

Hydropower displays the most obvious link between energy and water. Although hydropower dams do not actually consume or alter the physical chemistry of the water, they do temporally disrupt their natural flows. With little in the way of effective water rights management along rivers, the under-pricing of water is leading to its overuse, especially by agriculture, which accounts for roughly 70 percent of all water consumption. Such over-exploitation threatens to deplete riparian water levels causing major rivers to run dry. In 1997, the Yellow River, failed to reach the Bohai sea for most of the year, severely stunting the agricultural productivity of the coastal province of Shandong.[6] The diversion of water by the SNWD project and the increasing frequency of droughts will create uncertainty in water availability and threaten to undermine the long-term plan to increase current hydropower capacity by more than 50 percent to 300 gigawatts by 2020. In the extended drought that afflicted southwest China last fall through this spring, many hydropower stations grinded to a halt due to distressed water levels.[7] In the medium term, climate change could ironically have a countervailing effect--as the Himalayan snow frost melts due to climate change induced by the combustion of carbon-rich fossil fuels, water flows in southwestern China may actually get a boost before a long-term drought-induced decline. This complicated relationship of hydropower to water use and climate change speaks to the complexity of the water cycle which scientists are still trying to better understand.

China relies on imports to satisfy half of its current oil consumption. This reliance on foreign oil is only likely to continue increasing with its rapidly expanding market for automobiles. Policymakers are not oblivious to the oil challenge and have been seeking petroleum substitutes, but alternative transportation fuels such as biofuels and fuels derived from the liquefaction of coal also face serious limitations. The food-versus-fuel debate has given grain-based biofuels a black eye in the realm of public opinion, while coal liquefaction emits large volumes of greenhouse gases. Both also require large volumes of water. As a result, China has sensibly halted the production of biofuels derived from grain-based feedstock[8] and most (but not all) of its originally proposed coal liquefaction projects.[9]

On the flip side of the watergy coin, the extraction, transportation, purification, and distribution of water, as well as the treatment of wastewater, are energy-intensive processes. For instance, large-scale hydraulic infrastructure projects such as SNWD or any other large canals or dams (Three Gorges and others) for that matter, incorporate significant amounts of energy-intensive concrete and steel. The Chinese are also experimenting with desalination, the conversion of saltwater to fresh water fit for human consumption. Desalination can be considered the Holy Grail of water scarcity solutions, but if and only if its high costs and massive energy demands can be significantly lowered. The construction of power plants that provide the electricity to operate water treatment facilities similarly require energy embodied in material inputs, such as concrete to build cooling towers, that are seldom considered when analyzing the water supply sector's consumption of energy.

The End of Food?

Agriculture accounts for 70 percent of all water use while contributing to just 15 percent of China's GDP.[10] While the relative profligacy of water resources of the agricultural sector is often attributed to distorted water pricing policies—the agricultural sector benefits from grossly underpriced water (less than US$0.01 per cubic meter) compared to the industrial and residential sectors—some research indicates that a raising of agricultural water prices alone may have the unintended consequences of farmers reducing crop output or overexploiting groundwater in response to rising surface water prices.[11] Instead, it is clear that any sort of integrated policy should also involve strategies to improve surface water utilization efficiency. One way is to upgrade irrigation technology; current irrigation practices are so inefficient that less than half of the water applied ever reaches crops.[12] The widespread use of modern drip irrigation technologies in Israel is a model to look at. Water distribution in urban areas register similar inefficiencies; public investments in upgrading leaky pipes and taps in cities are sorely needed.

As is the case with water resources, China is also short on arable land. With 20 percent of the world's population, China has to feed itself with just 7 percent of the world's farmland. At current rates of growth, China will add 125 million to its population by 2025. In this scenario, China will have to expand its agricultural output by 25 percent to sustain this growth, yet this will have to be realized in the face of the pressures of increased urban and sub-urban development, which is encroaching on arable land. Food security will not only be threatened by increased urbanization and existing water scarcity, but by ongoing climate change induced by the ever growing dependencies on fossil fuels. Climate change will lead to increased temperatures, water scarcity, and desertification, with a recent study projecting a 23 percent decrease in Chinese agricultural production by 2050 from 2000 levels.[13] This downward trend is hard to square with the aforementioned needs to increase food output to match population growth.

Another overpowering demographic trend accelerating China's head-on charge toward the limits of its food-water-energy systems is the rapid pace of urbanization. In 1990, 26 percent of Chinese population lived in cities. This proportion has now risen to 46 percent. By 2030, it is projected that 350 million people will be added to urban centers.[14] This largest rural-to-urban migration in human history is not simply a spontaneous demographic phenomenon, but a product of purposeful policies based on the premise that urban centers are engines of GDP growth. This trend reflects both the increasing economic outputs of cities, which produce three quarters of the nation's GDP with less than half of its population, and declining economic contributions of agriculture as arable land becomes scarcer due to development and unsustainable farming practices.

In the wake of the recent global financial crisis, however, the assumptions of the limitless growth potential of urban centers are called into question. In early 2009, as a direct consequence of the global economic downturn and collapse of China's export market, 20 million migrant workers were repatriated from cities back to their rural hometowns, unable to find work. This occurred at the same time that northern and central China was experiencing one of the worst droughts in recent memory, affecting 10 million hectares of wheat crop and the drinking supply of 2.3 million people. Given the social importance of the countryside in China's modern political history, rural development has, at least on paper, always been an economic development priority of the central government. Yet in recent decades, it is clear that industrialization has been the currency of progress. However, when urban center economic opportunities at least momentarily hit a "great wall," rural development policies started to retake center stage in the immediate thinking and rhetoric of the Chinese government. It may indeed be time to question the wisdom of policies promoting unabated urbanization and to reconsider the role of agriculture in China's economic and environmental future. Regenerative agriculture represents a promising platform to rejuvenate the natural, social, and economic systems of rural areas, while enhancing national climate, water, and food security.

The Way Forward

As China seeks a cleaner, softer path of development, renewable energy sources such as wind, solar, and geothermal are attractive not only because of their lower carbon emissions profiles, but because they use far less water than their fossil fuel counterparts. However, while displacing all fossil fuel power plants with solar and wind farms is necessary in curbing the flow of additional greenhouse gases into our atmosphere, it does nothing to capture the prevailing stock of greenhouse gases that has already accumulated.

While efforts are being made to devise technical means to capture and sequester carbon dioxide emissions from power plants and other industrial processes, a natural solution which has been proven for hundreds of millions of years of evolutionary history lays before us: soils. Soil is a vast carbon sink, containing more carbon than all terrestrial vegetation and the atmosphere combined. Regenerative farming techniques, such as nutrient management, manure and sludge application, no-till agriculture, use of cover crops, and crop rotations, can rehabilitate degraded or desertified soils, which span a massive 3.57 million square kilometers in China,[15] and correspondingly increase soil carbon sequestration. Such regenerative farming methods also address another crucial link between agriculture and energy, by reducing petroleum-based fertilizer and pesticide inputs. Reliance on such fossil-fuel inputs not only sustains oil dependency but also represents a major water pollution problem when they run off into rivers.

A second important way in which proper management of the food and agriculture systems can reduce its impacts on climate change and water use is a reduction in meat consumption. Livestock activities release significant amounts of methane, carbon dioxide, and other greenhouse gases. Cattle manure, flatulence, and belching, for instance, contribute a massive 30 to 40 percent of human-induced methane emissions. Moreover, meat, especially from cattle, represents one of the most inefficient ways to gain calories—it takes as much as 20 kilograms of grain feedstock and 15,000 liters of water to create one kilogram of boneless, edible beef.[16] While pork and chicken fair with better ratios, their reduction in grain and water impact is still significant. To the extent livestock is not grain-fed but instead grazes on pasture, such land use comes at the expense of arable land. Growing meat consumption patterns in China will thus exacerbate grain and water security. While some may consider controlling individuals' diets as an overreach of government functions, there is certainly a role for policy to influence individual behavior by reflecting the true environmental costs of meat production into the price of meat.

Third, it goes without saying that sweeping reforms in water governance are needed. Institutional capacity must be built to manage water allocations among various regions and various uses, introduce water pricing coupled with a concerted outreach to educate end-users, especially farmers, on water conservation technologies and techniques.

The interactions among the energy, water, and food systems are complex and, in China, especially critical given the scarcities involved in all three systems. Integrated policies are essential; it is vital that a policy addressing any one of these systems pay heed to that system's linkages to the others. Thus, for instance, energy infrastructure decisions must be undertaken not only in consideration to carbon and air pollution constraints, but to the water and otherwise arable land resources that may be needed to support such choices. It means that in seeking to rationalize water pricing, consideration must be given to its effect on farmer's choices of crop output. It also means that in seeking to enhance food security, the energy, carbon, and water footprint of food supply chains must be simultaneously considered. Holistic approaches that weigh trade-offs among the three resource systems are the future of natural resource management and, indeed, any sustainable economic or national security policy.

NOTES

[1] Xinhua News, "Water schools shed light on degenerating Yangtze," April 11, 2009, available at http://english.peopledaily.com.cn/90001/90776/90882/6634777.html.

[2] Id.

[3] "South-to-North Water Diversion Project, China," Water Technology, available at http://www.water-technology.net/projects/south_north/ (accessed April 20, 2010).

[4] "Protect Precious Freshwater Resources," China Daily, December 28, 2006, available at http://www.chinadaily.com.cn/opinion/2006-12/28/content_769401.htm.

[5] *See* U.S. Department of Energy, "Energy Demands on Water Resources: Report to Congress on the Interdependency of Energy and Water," December 2006, 38 available at http://www.sandia.gov/energy-water/docs/121-RptToCongress-EWwEIAcomments-FINAL.pdf.

[6] Rena Singer, "China's yellow river, now a trickle, poses new threat," International Reporting Project," The Paul H. Nitze School of Advanced International Studies, John Hopkins University, December 31, 1998, available at http://www.internationalreportingproject.org/stories/detail/737/.

[7] "Drought paralyzes power supply," China Daily, March 24, 2010, available at http://www.chinadaily.com.cn/china/2010-03/24/content_9631695.htm.

[8] Hong Yang, Yuan Zhou & Junguo Liu, "Land and water requirements of biofuel and implications for food supply and the environment in China," Energy Policy 37 (2009), 1876-1885.

[9] Zhang Qi, "Is it the end of the line for coal-to-oil in China?" China Daily, October 9, 2008, available at http://www.chinadaily.com.cn/bizchina/2008-10/09/content_7090441.htm.

[10] "Major Agricultural Statistics 2008—Table 2.1: Share of agriculture in GDP," Food & Fertilizer Technology Center, available at http://www.agnet.org/situationer/stats/21.html, accessed April 19, 2010.

[11] Hong-yun Han & Lian-ge Zhao, "The Impact of Water Pricing Policy on Local Environment - An Analysis of Three Irrigation Districts in China," Agricultural Sciences in China, Vol 6 Issue 12, December 2007, 1472-1478

[12] Xinhua News, "China to improve irrigation efficiency," October 26, 2009.

[13] "Climate Change Threatens China's Food Security, warns Greenpeace," Greenpeace China, press release, October 15, 2008, available at http://www.greenpeace.org/china/en/press/release/food-security-climate-change .

[14] McKinsey Global Institute, "Preparing for China's Urban billion," March 2008, available at http://www.mckinsey.com/mgi/publications/china_urban_summary_of_findings.asp.

[15] Xinhua News, "China's 646 counties suffer heavy water and soil loses," January 25, 2009, available at http://english.people.com.cn/90001/90776/90882/6581089.html.

[16] Vaclav Smil, "Water News: Bad, Good and Virtual," American Scientist, Sep-Oct (2008), 399-407, 406, [also available at http://home.cc.umanitoba.ca/~vsmil/pdf_pubs/American%20Scientist%202008.pdf]