CASE STUDY

Case Study

Water Management

Case 38 Qingdao, Shandong Province: Water-Energy Nexus in Qingdao

Problem to resolve: Water supply for large cities imply huge embedded energy demands

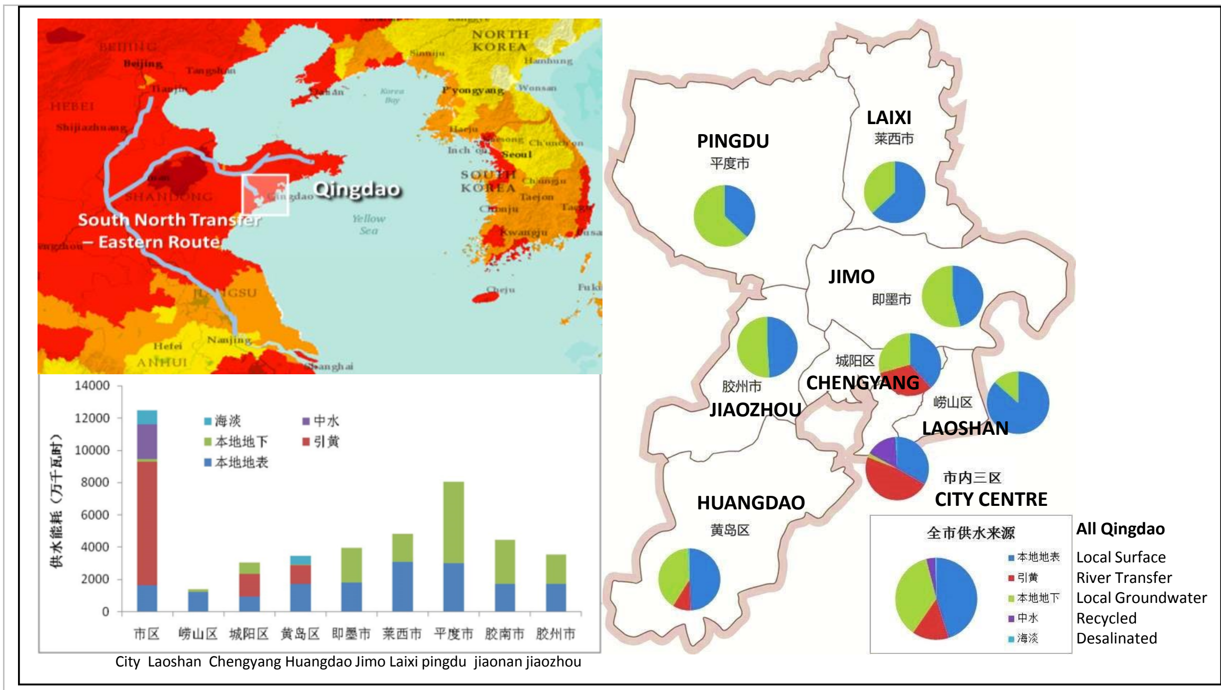
Response: Different calculation models for estimating energy demand related to alternative options to upscale Qingdao's drinking water supply

Background.[1]

Water and energy are inextricably interlinked and both have emerged as critical constraints for cities' sustainable development. Energy production requires large amount of water, while alternative water sources (e.g. long distance water transfer and seawater desalination) often have significant embedded energy requirements. Choices in urban water supply can potentially increase a city's greenhouse gas (GHG) emissions. However, as water and energy systems have historically been treated as separate realms, energy consumptions in the water system are often underestimated or ignored.

Qingdao serves as an example, where the available water resource per capita at 313 m^3/h/year is only 12 percent of China's average, even lower than the Middle East country of Tunisia. Increased water supply from long distance transfer projects or desalination have been developed to accommodate surging urban population and economic development, but either tactic would raise energy intensity of the urban water system, undermining Qingdao's low carbon development strategy. The city authority must find ways to ensure sufficient water supply without increasing the urban water system's carbon footprint.

Supported by the UK Foreign Commonwealth Office (FCO)´s Strategic Prosperity Fund and the Caterpillar Foundation, the World Resources Institute (WRI) and Atkins In collaboration with the Qingdao Development and Reform Commission, the Qingdao Water Supply Division, and the Qingdao Water Resources Bureau undertook a study to help Chinese decision makers better understand the impact of water resources policy options on energy and GHG emissions and ultimately incorporate energy considerations into water resources planning[2]. Qingdao is an excellent case study for the demonstration of this.



***Qingdao location and water scarcity*[3]**
Note: based on WRI Aqueduct model, river transfer routes and water consumption by source and district.

Introduction to Qingdao. Qingdao is a coastal city located on the southern shores of the Shandong peninsula built around Jiazhou Bay and facing the Yellow Sea. It has a Population of about 8.7 million of whom 4.1 million live in the 6 districts of the main City region about 2.4 Million are in the city centres of the 4 outlying counties and 2.2 million are rural residents distributed mostly in the counties.

The climate is monsoon influenced humid sub-tropical with summer days in the upper 20's degrees C and winter temperatures rarely falling below zero. Annual rainfall is about 688mm; however, there is large annual variation and more than 70% of rain falls in the months June to September. In the past water resources were obtained from local reservoirs and groundwater from which there is a potential 2.21 bcm available each year of which some 1.5 bcm is practically exploitable. With increased population, growing industry and irrigated agriculture these have become insufficient to meet the city's needs and have been supplemented with transfers from the Yellow and Yangtze Rivers and with desalination. The following figure shows the distribution of and sources of the water resources.

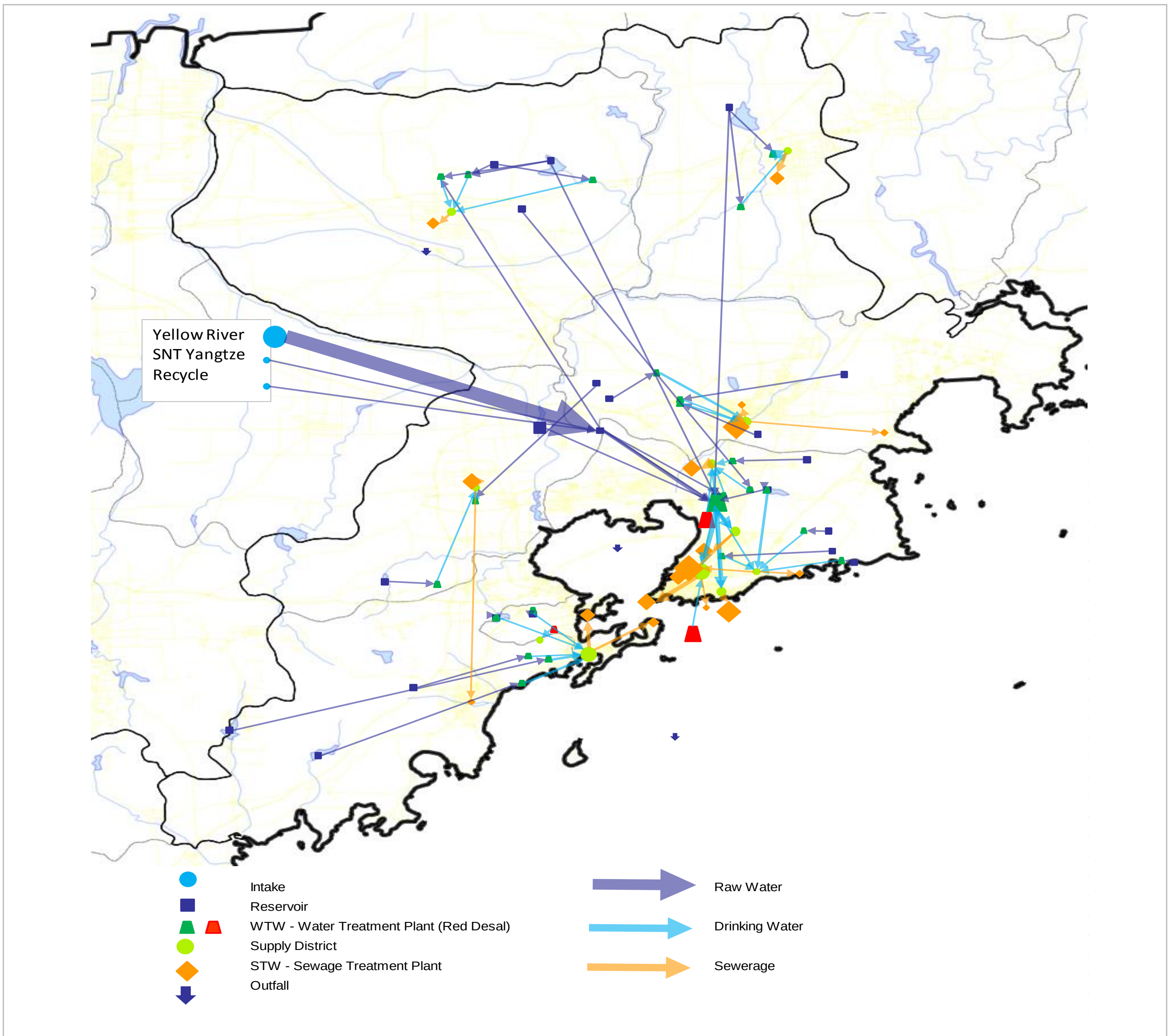
The city is projected to grow further up to 2020 such that the water resources requirement will increase by about 40%. With the local resources already fully developed and exploited, this new demand will have to be met with unconventional sources based on long distance transfers, desalination and recycling. The City Authorities face choices in which resources to develop. These decisions could be made purely on economic grounds but the different sources also have important implications for Energy use and greenhouse gas emissions.

Energy requirements and costs associated with each water source in Qingdao. The energy associated with different sources relates mostly to the amount of pumping required. Groundwater requires pumping out of aquifers and even for surface water, which may be supplied by gravity, pumping is required in the treatment. The poorer the quality of water the greater is the energy requirements for treatment. Long distant transfers also tend to require many pumping stages. For desalination the Reverse Osmosis process is based on high pressure pumping through membranes. The higher the salinity of the source the greater the energy required to produce fresh water. The result is that desalination as a source requires 10 times as much energy for treatment plant operation as surface water.

When estimating the costs of sources the calculation also includes the costs of building and maintaining the infrastructure as well as cost of buying energy. Thus the long distance transfer water has higher costs in proportion to its energy use. The energy and cost associated with different sources in Qingdao are compared considering that the total resource required will rise from around 970 million m^3 per year in 2011 to about 1500 million m^3 per year by 2020.

Scenario Development.

Applying internationally introduced calculation models, the maximum water supply potential of all available water resources, and not including desalination, is 2.285 billion m3 in Quingdao. Of this, the maximum available from local surface water and groundwater resources is 1.463 billion m3. The utilization rate for surface water must not exceed 40% if Qingdao wants to maintain its water use at a sustainable level, while for groundwater it must not exceed 50%. In that case, the local water supply potential will be 1.104 billion m3 (640 million m3 from surface water and 464 million m3 from groundwater). Therefore, for Qingdao to satisfy its 2020 demand for water, it must resort to water diversion, reclaimed water, and/ or seawater desalination.



WEN Tool map showing the water resources, water supply and waste water network of Qingdao Scaled by Energy use for 2010[4]

A range of scenarios were developed to explore how Qingdao might achieve these objectives based on prerequisites of (i) meet water use target (1.473 billion cubic meters by 2020 under the "3 redlines" water allocation policy); (ii) prioritize the exploitation of local water resources; and (iii) when considering water diversion, it is preferable to divert from the yellow river. The findings say that by 2020, if Qingdao keeps the current surface water utilization rate of 35%, total energy use will see a significant increase. The desalination sub-scenario has the highest growth in energy requirement (110% increase - more than double current Energy Use) while the reclamation sub-scenario appears to be the lowest of three. Accordingly, greenhouse gas emissions from the water sector showed a similar upward trend, with the reclamation sub-scenario bringing the lowest emissions, or 40% lower than the desalination sub-scenario.

If Qingdao were to increase its surface water utilization rate to 55%, local surface water and groundwater were expected to provide 1.43 billion cubic meters of water, only 50 million m^3/year short from the total water demand. The scheme prioritizing water diversion will lead to a 34% increase in energy consumption compared to 2011 baseline level, while the reclamation sub-scenario and desalination sub-scenario show potential increase of 34.3 and 41%, respectively. The desalination sub-scenario is still the most carbon intensive solution, causing 5% higher greenhouse gas emissions than the water diversion sub-scenario or the reclaimed water scenario.

To compare the energy consumption of above three scenarios, we find the more local surface water is used, the lower energy requirement of the water supply system. Given Qingdao's elastic inter-annual variability, it's critical to close the demand-supply gap by choosing the least carbon intensive type of unconventional water and balancing this against achieving sustainable water resource exploitation and meeting regulatory obligations.

Credentials:

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Editors: Kosta Mathey and Florian Steinberg.

Sources:

[1] Source: https://restorerivers.eu/wiki/index.php?title=Case_study%3ARiver_Cole-_Life_Project

[2] World Resources Institute. 2014. Water Energy Nexus in the Urban Water Source Selection: A Case Study from Qingdao, Zhong Lijin, William Wen, Fu Xiaotian, S Spooner, WRI, 2014. http://www.wri.org.cn/en/publication/water-energy-nexus-urban-water-source-selection-case-study-qingdao . See also a similar case: World Resources Institute. 2015. Environmental Energy-Economic Benefit Assessment for Sludge-to-energy: A case Study of Capturing Methane from Sludge in Xiangyang, Hubei Province. http://www.wri.org.cn/sites/default/files/_%E6%B1%A1%E6%B3%A5%E8%B5%84%E6%BA%90%E5%8C%96%E7%9A%84%E7%8E%AF%E5%A2%83%E2%80%94%E8%83%BD%E6%BA%90%E2%80%94%E7%BB%8F%E6%B5%8E%E6%95%88%E7%9B%8A%E8%AF%84%E4%BC%B0_S.pdf

[3] Source: World Resources Institute. 2014. Water Energy Nexus in the Urban Water Source Selection: A Case Study from Qingdao, Zhong Lijin, William Wen, Fu Xiaotian, S Spooner, WRI, 2014. http://www.wri.org.cn/en/publication/water-energy-nexus-urban-water-source-selection-case-study-qingdao

[4] Source: World Resources Institute. 2014. Water Energy Nexus in the Urban Water Source Selection: A Case Study from Qingdao, Zhong Lijin, William Wen, Fu Xiaotian, S Spooner, WRI, 2014. http://www.wri.org.cn/en/publication/water-energy-nexus-urban-water-source-selection-case-study-qingdao