ASIA-PACIFIC NETWORK FOR GLOBAL CHANGE RESEARCH

POLICY BRIEF LCD-01

APN Global Change Perspectives

Low Carbon Development

October 2015

Towards a Better Water-Energy-Carbon Nexus in Cities

Shobhakar Dhakal, Sangam Shrestha, Ashish Shrestha, Arun Kansal and Shinji Kaneko

KEY MESSAGE

- Water-energy-carbon nexus directly influences three key contemporary policy issues in cities: climate change mitigation, water security and energy security.
- Water and energy are generally managed as separate entities, but integrated knowledge as well as considerations to up-stream implications are immensely useful.
- Improving water-energy-carbon nexus in cities will greatly aid sustainability efforts of city governments through reducing GHG emissions and ensuring energy and water security.

Box 1. Key message.

As water and energy are becoming limited resources, water footprints in the energy sector and energy footprints in the water sector are increasingly concerning in development and planning processes. In the context of cities, energy is of primary importance for urban water system management. From source abstraction, conveyance, treatment, distribution, waste water collection and treatment to recycle and disposal, every element of urban water system relies on energy. Typically, fossil fuels are the primary sources of energy, which produce considerable amounts of carbon dioxide and other greenhouse gases (GHGs) in the atmosphere. The relevance of an energy-carbon footprint lies not only at the operational stage of water management but also at the construction of infrastructure in the form of embodied energy. This gives rise to the concept of a "nexus," where water, energy and carbon can be managed under the same domain. Cities are a significant place to study this nexus because of high population density, complex agglomeration of infrastructure, economy, industry, technology and their overall dynamics. The high energy demand for water utilities is one of the issues in sustainable management of water and sanitation services in developing and developed countries. There is limited research in Asia, and few efforts have been made in development and planning to address the water-energy-carbon nexus.

Drivers that Influence Water-Energy-Carbon Nexus in Cities

The geophysical, climatic, technological, social and economic environments in cities affect their water-energy development. As a result, the energy-carbon footprint per person with respect to per unit of water used will differ within cities and between countries. It is vital for water sector planners to understand the drivers that influence the water-energy nexus in order to formulate policies for optimising energy-carbon footprint. Urban settlements support more than half the global population and 2.8 billion more will be added by 2050. Energy use in the water

Recommended Citation:

Dhakal, S., Shrestha, S., Shrestha, A., Kansal, A., & Kaneko, S. (2015). *Towards a better water-energy-carbon nexus in cities* (APN Global Change Perspectives Policy Brief No. LCD-01). Kobe: Asia-Pacific Network for Global Change Research.

APN Secretariat, 4th Floor, East Building
1-5-2 Wakinohama Kaigan Dori, Chuo-ku, Kobe 651-0073, JAPAN.

Tel: +81-78-230-8017;
Fax: +81-78-230-8018;
Email: info@apn-gcr.org;
Website: www.apn-gcr.org

ASIA-PACIFIC NETWORK FOR GLOBAL CHANGE RESEARCH

Implications on energy-carbon footprint must be considered in the planning, design and operation of urban water infrastructure.

sector will continue growing to meet the increasing water demand. Climate change will influence water availability, water quality, salt water intrusion, water and energy demand, and may impact built infrastructure, which have further implications on energy. Technological change, innovation and other factors affect the adoption of new water treatment technologies. This might have positive or negative implications on energy. However, newer technologies, which are less energy intensive, could be emphasised. For example, most households in New Delhi have been purchasing reverse osmosis water purification units in recent years, which will eventually increase the energy footprint of water. Further, water consumption patterns, physical loss of water in distribution networks, ageing infrastructure and inevitable maintenance will have more energy implications. 45–88 million m^3 of water is lost every day due to leakages in water supplies worldwide, half of which are in developing countries. This amount is sufficient to serve 200–400 million people (Olsson, 2012).

Various factors determine the design and construction of water infrastructures. Among them are water sources, quality, future water demand, water/waste water standards, environmental regulations, natural hazards, feasible technologies and budgets, etc. Any new water infrastructure design and construction should be assessed and regulated by responsible institutions. The energy footprint of water infrastructure depends not only on its design but also on the embodied energy of construction materials in those systems. Therefore, different scenarios should be studied and planned—for example, selection of lined canal versus natural conduits for drinking water transport, or open drainage versus closed pipes for waste water systems. There is a need to assess or model every element of an urban water system to foresee its possible energy-carbon implications.

In Bangkok and Tokyo, surface water is a major water source. In Delhi, however, excessive extraction of ground water is in practice, which will eventually result in higher energy footprints of water abstraction. Moreover, in most of the East, West and South parts of Delhi, ground water depth has increased in recent years, causing more pumping energy requirements. The energy intensity in drinking water treatment is slightly higher in Tokyo than in Bangkok or Delhi due to its higher water quality standards, although this is not an accurate comparison as the value chain of energy footprints will be higher in cities like Delhi if energy intensive end-use water purification is involved.

Opportunities to Reduce Energy and Carbon Footprints in Urban Water Systems

Apart from efficient design and optimum operation in urban water system management, other options to reduce net energy-carbon footprints must be explored. The majority of energy in many cities still comes from fossil fuels. Some water and waste water treatment plants in Tokyo use solar energy to meet part of their energy demands. Similarly, the chemical energy

	Bangkok	Delhi	Tokyo
Water source	Surface water	Ground water and surface water	Surface water
Energy use for drinking water treatment	20%	16.5%	45%
Energy use for water transport and distribution	80%	83.5%	55%
Non-revenue water loss	24%	50%	8%
Remarks	Excessive pumping involved in water transportation and distribution	Higher energy use in pumping due to increasing ground water depth	Energy intensity is higher due to high water quality standards

Table 1. Summary of energy usage in Bangkok, Delhi and Tokyo in water treatment and distribution.

CASE STUDY: WASTE WATER MANAGEMENT IN DELHI

In Delhi, the total operational energy consumed for treatment of waste water is 182.97 MWh/day and the resultant carbon emission is 5.98 $GgCO_2eq$/day despite the fact that only 60% of waste water is treated. The current energy burden of the entire waste water infrastructure is 253.25 MWh/day. This burden can further increase by an additional 30% if discharge standards for centralised Sewage Treatment Plants (STPs) are revised from 30 to 10 mg/l BOD in accordance with the Yamuna Action Plan. One way to reduce this burden is to have decentralised systems that can reduce overall energy consumption by 35% when treatment standards are 10 mg/l. This would result in a 66% reduction in carbon emissions.

This study shows that conveyance systems contribute 35% to the energy footprint of a sewage system and hence are an important aspect to be considered if a centralised and decentralised system of sewage were to be conceptualised. Topography has a huge influence on electrical energy consumption for sewage conveyance and in Delhi it is found to influence energy consumption by a factor of three. The operational energy share is less than the share of embodied energy of the material in a sewer system.

Centralised Systems	Decentralised Systems
High energy burden from the system perspective and in terms of the degree of treatment.	Lower energy burden from the system perspective and in terms of the degree of treatment.
The transport of sewage consumes 45.3% of the total energy used.	The transport of sewage consumes a very small portion of total energy used.
Energy footprint in terms of BOD removal is higher, i.e., 0.8 kWh/kg BOD, with corresponding GHG emissions at 2.83 $kgCO_2e/m^3$.	Energy footprint in terms of BOD removal is lower, i.e., 0.35 kWh/kg BOD, with corresponding GHG emissions at 1.44 $kgCO_2e/m^3$.
If the objective of urban waste water infrastructure is to control pollution, then centralised systems are a better option as they offer better energy saving potential due to economies of scale.	If the objective is to recycle and reuse wastewater, then decentralised systems are better as they have less energy burden due to the absence of conveyance systems.

Open drainage systems do not contribute to energy consumption in Delhi as they are unlined and water flows under gravity. However, Delhi presents an excellent case of water-energy-carbon trade-off with environmental and health goals. Open drainage systems substantially reduce energy consumption, resulting in one-third as much carbon footprint as other systems, despite their negative impact on health and environment. Capacity utilisation of STPs are very important in terms of lowering the energy footprint of sewage systems. Wherever capacity utilisation is low, the energy footprint in the treatment system is high. Engineers in urban utilities appear to have a tendency to design STPs on the basis of forecasts of urban population in two decades, and hence create STPs that have higher capacities in the base year. This will inevitably result in high energy burden during the initial years of STP operations. It is, therefore, pertinent to rethink the design period for STPs and appropriate to construct STPs in modular format, where capacity additions take place more frequently over a smaller number of years.

Box 2. Case study: Waste water management in Delhi.

of waste water treatment by-products are utilised as a means of resource recovery. For example, in Tokyo's Tobu Sludge Plant, carbide products manufactured from sludge are being used as fuel in coal-fired power plants. A small percentage of treated waste water is also utilised in Delhi for gardening. The application of decentralised green energy systems in water/waste water systems and resource recovery from treated waste water shall be scaled up.

In most cities, policies and practices related to water/waste water, energy and carbon management exist independently outside the framework of a water-energy-carbon nexus. Few city-level governments are taking actions to reduce the net energy-carbon footprint related to urban water sector, such as the design of energy-carbon efficient infrastructure, promoting the use of alternative energies and recovering energy from treatment by-products. Integrating water, energy and carbon policies with direct participation from different government departments will enhance their overall goals and help achieve the common objectives to meet GHG reduction targets and ensure energy and water security.

Policy Implications

» Every city has an opportunity to apply different options to reduce their energy-carbon footprint, and each city's objectives for water and waste water management will depend on the local context, such as

Apart from efficient design and optimum operation in urban water system management, other options to reduce net energy-carbon footprints must be explored.

RECOMMENDATIONS

- Water-energy-carbon nexus in cities is a key area for study both from direct and indirect perspectives as an essential part of reducing their overall GHG emissions.
- The energy and carbon footprints of the urban water cycle depend on multiple characteristics, which include the nature of water sources, transportation distances, nature/extent of infrastructure, choice of technologies, water losses and management practices. A better understanding of the drivers of the water-energy-carbon nexus would assist policy makers because energy security, climate change mitigation and water security are three key contemporary items on the policy agenda and must be integrated and optimised locally.
- City governments and water utilities should plan urban water infrastructure development in a coherent manner addressing the optimisation of overall energy use.
- Resource recovery and reuse of resources from waste water treatment helps to reduce overall energy-carbon footprints.
- Evaluation of overall urban water management should be undertaken at regular intervals based on performance assessments.

Box 3. Recommendations.

use of surface, ground or sea water as drinking source, reuse of waste water for gardening or other purposes. Thus, system designs will vary between cities. Scenario analyses, for example on whether to implement a centralised or decentralised waste water system, should be studied in the planning process.

» Proper assessment on each element of the urban water cycle on energy-carbon implications is needed. Efficient operation of water infrastructure such as capacity utilisation should be planned so that energy-carbon footprint could be reduced even under different future scenarios.

» City governments and water utilities should place emphasise on water demand management, leakage detection techniques, prompt repair of leakage and rehabilitation of old infrastructure. Decision makers should understand that "water is energy and energy is water," and the prevention of water losses will not only reduce the energy-carbon footprint but also help achieve water and energy security.

» Up-scaling of resource recovery and use of decentralised renewable sources of energy should be emphasised in order to achieve low carbon development in cities.

References

Bureau of Waterworks Tokyo Metropolitan Government (2013). Tokyo waterworks management plans.

Bureau of Waterworks Tokyo Metropolitan Government (2014). Water supply in Tokyo.

Olsson, G. (2012). Water and energy: Threats and opportunities. IWA Publishing, London.

Metropolitan Waterworks Authority (2012). MWA annual report. Bangkok.

About this publication: This policy brief is developed for APN project "Understanding and Quantifying the Water-Energy-Carbon Nexus for Low Carbon Development in Asian Cities" (LCI2012-02NMY(R)-Dhakal; LCI2013-02CMY(R)-Dhakal) under APN's Low Carbon Initiatives Framework. For full details of this project, including technical reports and other outputs, please visit the project metadata page at www.apn-gcr.org/resources/items/show/1916.

Authors: Dr. Shobhakar Dhakal, Asian Institute of Technology; Dr. Sangam Shrestha, Asian Institute of Technology; Mr. Ashish Shrestha, Asian Institute of Technology; Prof. Arun Kansal, TERI University; and Prof. Shinji Kaneko, Hiroshima University.

ASIAN INSTITUTE OF TECHNOLOGY 1959

teri university

HIROSHIMA UNIVERSITY

The Asia-Pacific Network for Global Change Research (APN) is a network of 22 governments in the Asia-Pacific region that promotes global change research in the region, increases developing country involvement in global change research, and strengthens interactions between the science community and policy makers.

"APN Global Change Perspectives" is a policy brief series started in 2015 that aims to bring latest evidence, insights, potential alternatives and recommendations on issues related to global change to the attention of the policy-making community in Asia and the Pacific.

Managing Editor: Linda Anne Stevenson;
Content Coordinator: Taniya Koswatta;
Editors: Linda Anne Stevenson, Taniya Koswatta, Xiaojun Deng;
Design: Xiaojun Deng, Huong Long Dinh.

The views presented in this policy brief are those of the author(s) and do not necessarily represent the views of APN or its member countries.

This policy brief is available online under APN E-Lib at www.apn-gcr.org/resources.

To receive email notifications of our latest news and publications, please subscribe to "APN Updates" by visiting www.apn-gcr.org/getmail or scanning the QR code below.

APN ASIA-PACIFIC NETWORK FOR GLOBAL CHANGE RESEARCH

20 YEARS Bridging Science & Policy for a Sustainable Asia-Pacific