Towards a better Water-Energy-Carbon nexus in Asian Cities

Shobhakar Dhakal, Ph.D.
Head, Department of Energy, Environment & Climate Change,
School of Environment, Resources and Development
Asian Institute of Technology

SCIENCE POLICY DIALOGUE

06-08 FEBRUARY 2017
BANGKOK, THAILAND

APN ASIA-PACIFIC NETWORK FOR GLOBAL CHANGE RESEARCH

LoCARNet

Climate Change Asia

Water-Energy-Carbon Nexus

- Mostly Water & Energy are managed as separate entities
- Water and Energy management are fundamental to many other sectors (Agriculture, energy, cities, wastewater treatment etc.)
- Global water withdrawals for energy production - 583 bn m^3, or some 15% of the world's total water withdrawals in 2010 (IEA, 2012)
- Need a coupled understanding of Water-energy-carbon comprehensively and quantitatively for multiple objectives

1. Energy use in water sector is growing to meet increasing water demand

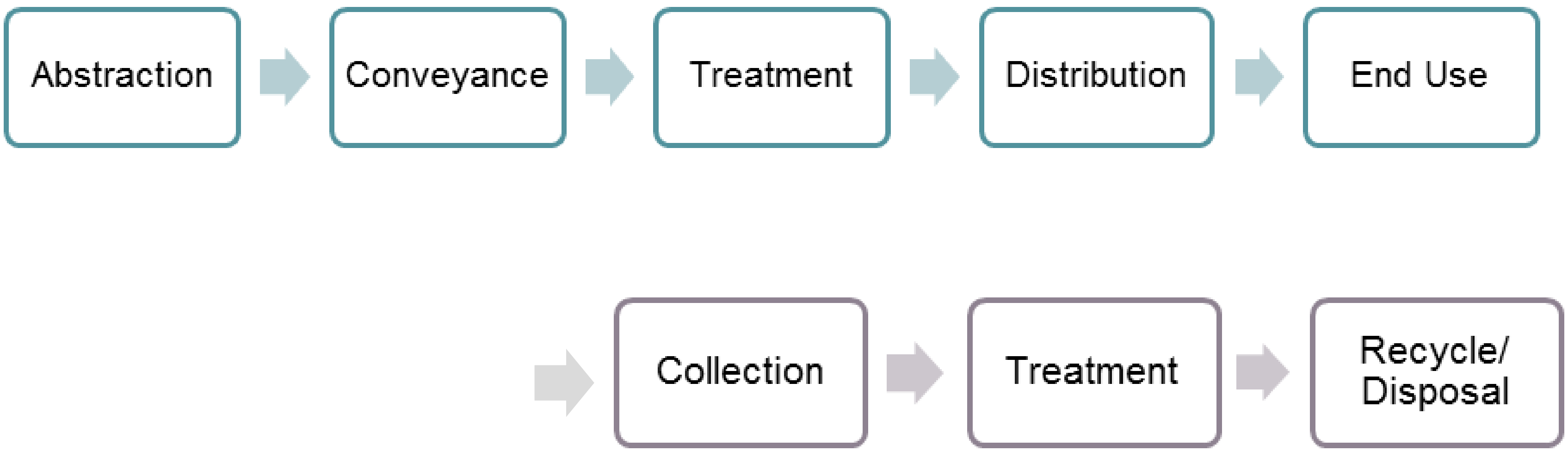
2. Energy sectors are growing which needs more water.

3. This nexus contribute to the emission of GHGs

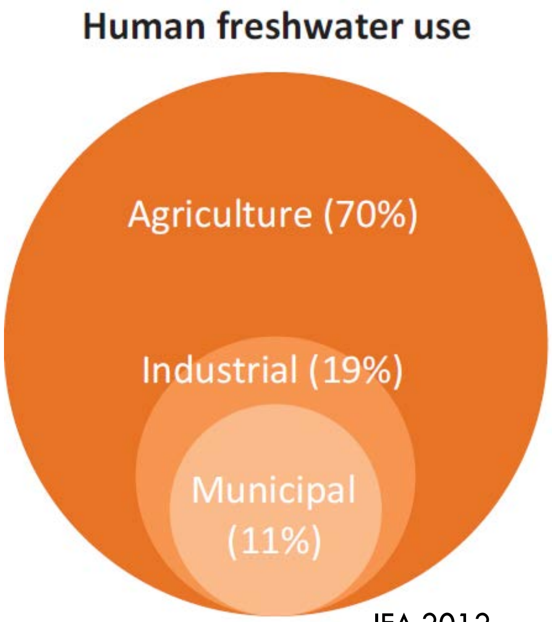
Where water in needed in energy sector?

- Oil and gas- Drilling, hydraulic fracturing, reservoir injection enhanced oil recovery, oil sands mining etc.
- Coal – cutting and dust suppression, washing, coal slurry transport, etc.
- Biofuels- irrigation, washing etc.
- Thermal power generation- boiler feed, cooling, pollutants scrubbing
- Concentration solar power and geothermal – steam generation, cooling etc.
- Hydropower – electricity generation, storage

Where energy is needed in water sector?



Significance to cities



IEA,2012
UNFAO, 2012

- Cities are the major consumer of water and energy, along with other materials or resources.
- Per capita carbon footprints of cities, especially in developing countries, are much higher compared to peri-urban and rural, with large contribution to national emissions.
- Low carbon cities need to optimize many low carbon opportunities in the urban systems across all sectors.

Better WEC Nexus

Three pressing urban policy Issues

- **Climate change mitigation**
- **Energy security**
- **Water security**

APN- Project

Understanding and Quantifying the Water-Energy-Carbon Nexus for Low Carbon Development in Asian Cities

Project Reference Number: LCI2013-02CMY(R)-Dhakal

http://www.wec-nexus.ait.asia

Dr. Shobhakar Dhakal, AIT

Dr. Sangam Shrestha, AIT

Mr. Ashish Shrestha, AIT

Prof. Shinji Kaneko, Hiroshima University

Prof. Arun Kansal, TERI University

Our project framework

- ❑ Energy for water is more significant than water for energy in city-context.
- ❑ Energy footprint has implications on carbon footprint.
- ❑ Quantification of footprints to clarify the avenues and extent to optimize systems.
- ❑ Focus on urban water and waste water sector

Case Studies

Bangkok Metropolitan Region

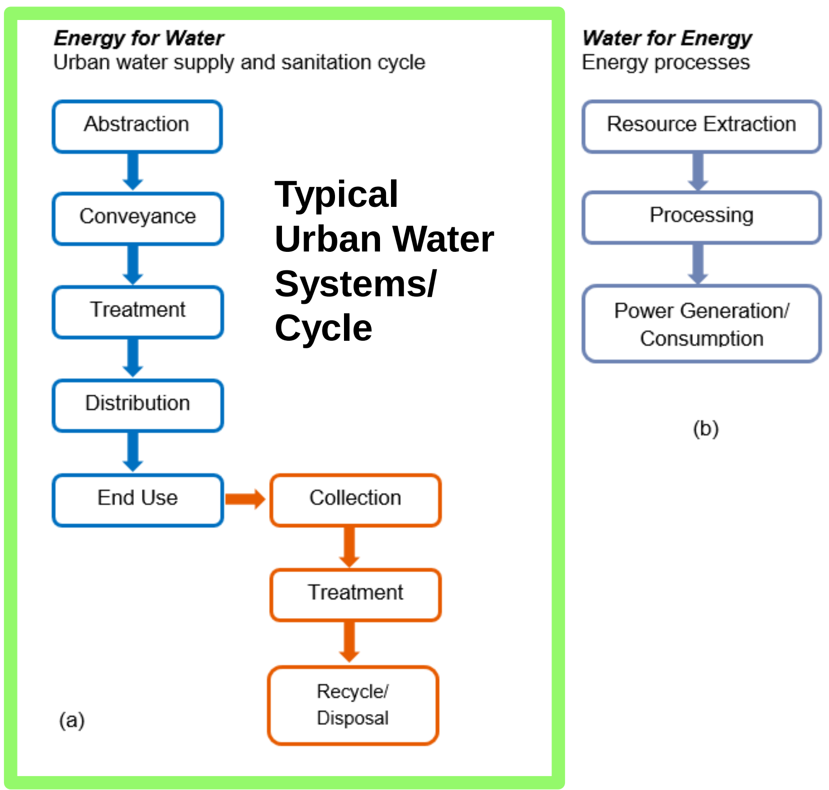
- Cover total area of 7,761.50 km²
- Population: 10.5 million

Tokyo

- Cover total area of total area of 1,235 km²
- Population: 13 million

National Capital Territory, Delhi

- Cover total area of total area of 1,486 km²
- Population: 16.7 million



Energy Use: Typical Figures from Literature Survey

Countries	Energy requirements	Energy Intensity (kWh/m^3)	
		Range	Average
Australia	Energy: Water Utilities	0.09 – 1.84	0.72
	Energy Wastewater Utilities	0.47 – 1.13	0.77
United States	Production & distribution of potable water in Western US	1.32 – 3.96	-
	Production & distribution of potable water in Eastern US	0.48 – 0.66	-
	Range for water supply utilities	0.08 – 1.00	
	Range for wastewater utilities	0.20 – 0.90	
	California – Water conveyance	0.00 – 1.06	-
	California – Water Treatment	0.03 – 4.23	-
	California – Water Distribution	0.18 – 0.32	-
	California – Wastewater collection & treatment	0.29 – 1.22	-
Germany	Water conveyance & treatment	0.12 – 1.13	-
	Water Distribution	0.03 – 0.58	-
	Wastewater collection & treatment	0.39 – 0.83	-
Singapore	NEWater for uses such as industry	0.7–1.2	0.95
	Seawater desalination	3.9–4.3	4.1
	Wastewater treatment	0.52 - 0.89	
Norway (Oslo)	Electricity use in Water treatment and supply (2000- 2006)	0.38 – 0.44	0.40
	Electricity use in Wastewater collection and treatment (2000-2006)	0.67 – 0.87	0.80

Abstraction and conveyance energy intensity- what matters?

Ground water withdrawal

Surface water withdrawal

Distance of transport

Storage or dams

Loss – piped network or open canal

Case Studies – Findings

Abstraction → Conveyance → Treatment → Distribution → End Use → Collection → Treatment → Recycle/ Disposal

- Source: **Surface Water** from Chao Phraya river and Mae Klong river.
- Ground water extraction is prohibited since 1983.
- **Energy Intensity** = **0.10 kWh/m³**
- **Carbon Footprint** = **0.49 kg CO_2/m^3**

Bangkok (BMR)

- Source of water: **Surface Water** from Yamuna and Ganga River; & **Ground water**.
- **Energy Intensity** = **0.58 kWh/m³**
- **Carbon Footprint** = **0.47 kg CO_2/m^3**
- (Only abstraction)

Delhi

- Source : **Surface Water** from Edogawa, Tonegawa, Tamagawa, Sagamigawa rivers.
- Small portion from confined groundwater aquifers.
- **Energy Intensity** = **1.78 kWh/m³**
- **Carbon Footprint** = **0.90 kg CO_2/m^3**

Long distance hauling, pressure and piped network

Tokyo

Technology, water quality

Case Studies – Findings

Abstraction → Conveyance → **Treatment** → Distribution → End Use → Collection → Treatment → Recycle/ Disposal

- **4 WTPs**: Bangkhen, Samsen, Thonburi & Mahasawat

- **Energy Footprint = 1.10 kWh/m^3**
- **Carbon Footprint** = **5.28 kg CO_2/m^3**

- **10 WTPs**: Wazirabad (I, II & III), Hayderpur, Sonia Vihar, Bhagirathi (North Shahdara), Nangloi, Chandrawal (I & II), Bawana

- **Energy Footprint = 0.16 kWh/m^3**
- **Carbon Footprint** = **0.13 kg CO_2/m^3**

- **11 WTPs**: Kanamachi, Misato, Asaka, Misono, Higashi-Murayama, Ozaku, Sakai, Kinuta, Kinuta-shimo, Nagasawa, Suginami.

- **Energy Footprint** = **3.21 kWh/m^3**
- **Carbon Footprint** = **1.67 kg CO_2/m^3**

Bangkok Delhi Tokyo

Tokyo Energy Intensity is high as treatment standards are higher and technologies are energy intensive. Low treatment quality increases treatment needs at end use which is more energy intensive

Gravity, pressure, loss, system layout

Case Studies – Findings

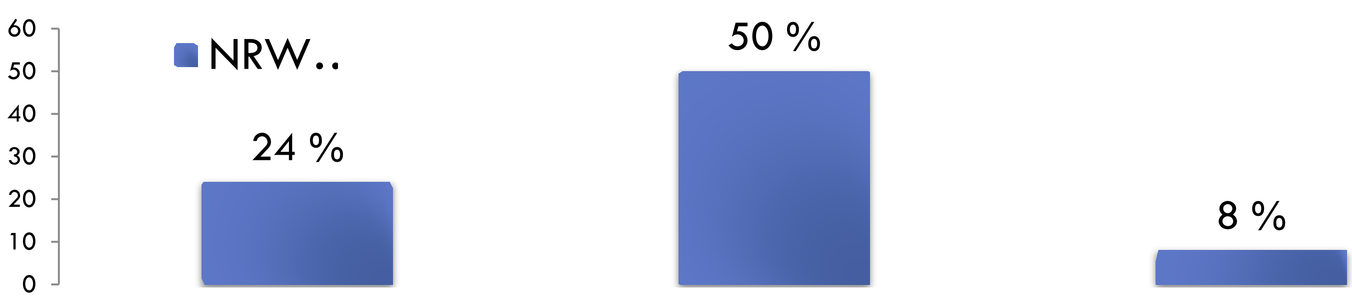
Abstraction → Conveyance → Treatment → **Distribution** → End Use → Collection → Treatment → Recycle/ Disposal

- **Piped** Network
- **Energy Footprint = 0.39 kWh/m^3**
- **Carbon Footprint** = **1.86 kg CO_2/m^3**

- **Piped** networks + **Tankers**
- **Energy Footprint** = **0.10 kWh/m^3** for Piped networks
- **Carbon Footprint** = **0.005 kg CO_2/m^3** for Piped networks

- **Piped** networks
- **Energy Footprint = 1.27 kWh/m^3**
- **Carbon Footprint** = **0.66 kg CO_2/m^3**

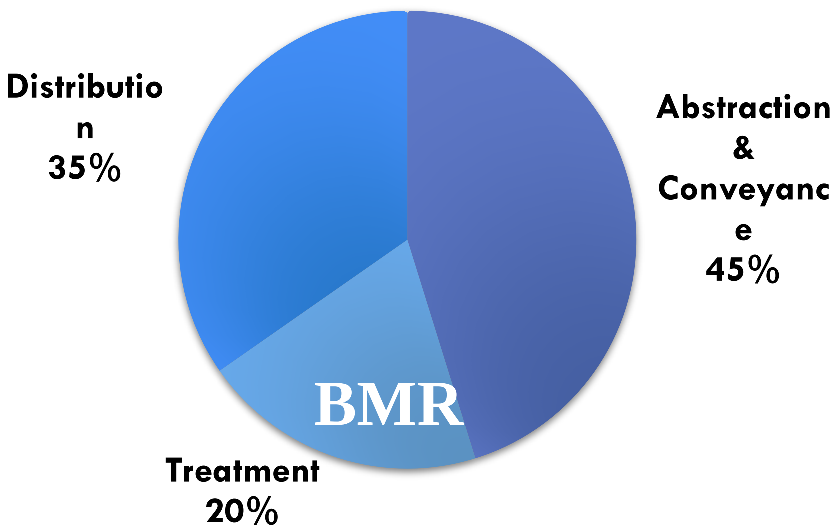
- Bangkok and Tokyo have efficient network system for water distribution
- Coverage within Delhi is less and tankers supply water to different parts of cities. Water loss is higher in Delhi

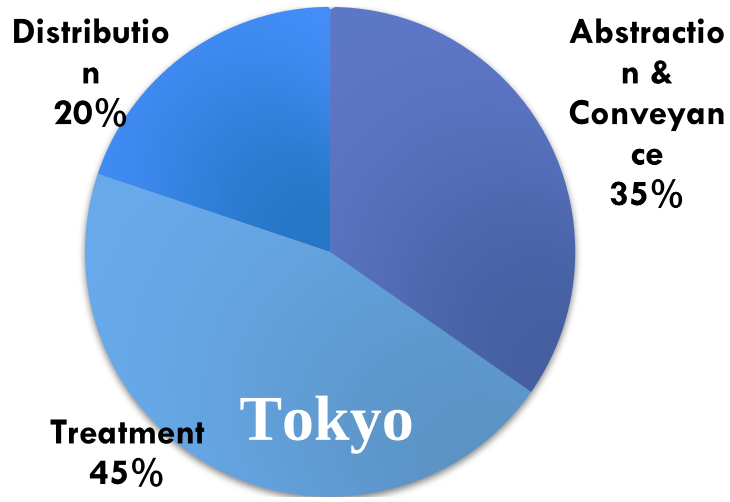


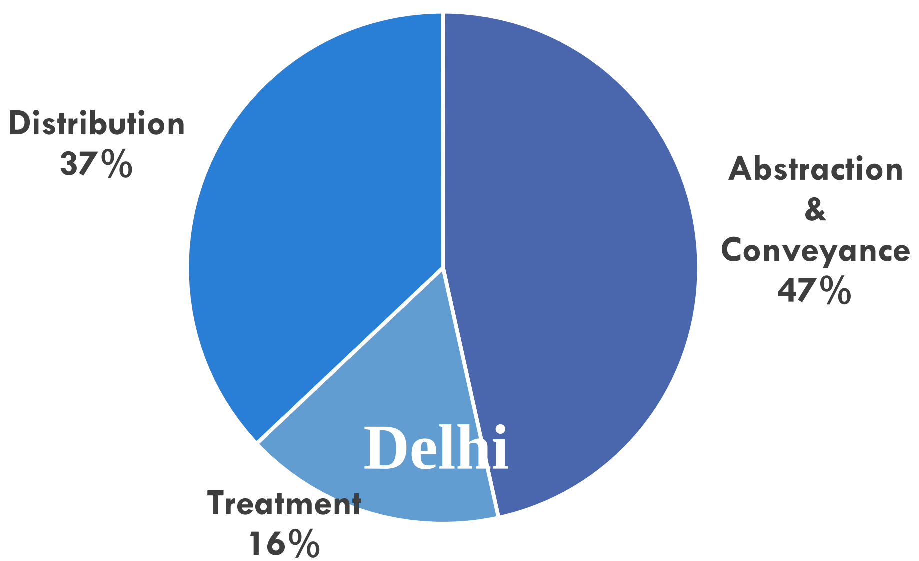
Non Revenue Water Losses in three cities

Bangkok Delhi Tokyo

Case Studies – Findings







Comparative Energy use in Water Supply Sectors

Case Studies – Findings

Abstraction → Conveyance → Treatment → Distribution → End Use → **Collection** → **Treatment** → **Recycle/ Disposal**

Bangkok

- **7 WWTPs**: Si Phraya, Rattanakosin, Dindaeng, Chong Nonsi, Nong Khaem, Thung Khru, Chatuchak
- **Energy Footprint** = **2.16 kWh/m^3**
- **Carbon Footprint** = **10.35 $kg\ CO_2/m^3$**

Bangkok has higher footprint as massive pumps are used for collection of waste water

Delhi

- **12 WWTPs**: Rithala, Coronation Pillar, Okhla, Kondali, Pappankalan, Najafgarh, Yamuna Vihar, Vasant Kunj, Sen Nursing Home, Delhi Gate, Nilothi
- **Energy Footprint** = **0.45 kWh/m^3**
- **Carbon Footprint** = **3.0 $kg\ CO_2/m^3$**

Tokyo

- **13 WWTPs**: Shibaura, Mikawashima, Sunamachi, Ariake, Nakagawa, Kosuge, Kasai, Ochiai, Nakano, Miyagi, Shingashi, Ukima, Morigasaki
- **Energy Footprint** = **6.31 kWh/m^3**
- **Carbon Footprint** = **2.61 $kg\ CO_2/m^3$**

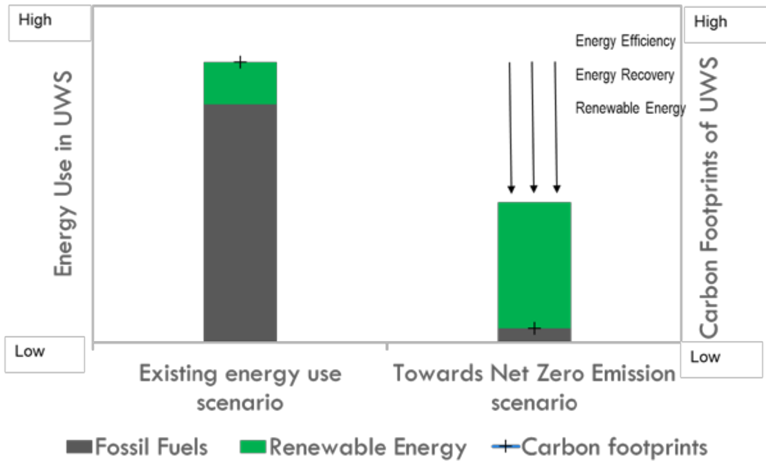
- Tokyo has highest footprint as water are treated to higher quality
- Resource and energy are recovered in some treatment facilities of Tokyo

Summary: Existing policies & practices

	Summary of Policies and Practices	Major Issues
Bangkok	• Regulatory policies for GW • Reduce pollution of canals • Reduce NRW and optimize energy use	• Pollution of canals within city due to inadequate wastewater treatment. • Increased GW table affecting underground infrastructures.
New Delhi	• Reduce water losses, rehabilitate and upgrade existing infrastructure. • Increase coverage and optimize capacity utilization.	• GW abstraction increased by 2.4 times and energy consumption by 3 times in last 10 years. • Change in treatment technology choices e.g. simple filters to Reverse Osmosis.
Tokyo	• TMG aims to reduce GHG emitted by the sewerage industry by 25% or more by 2020 and 18% or more by 2014, based on 2000 levels. • Advanced leakage prevention • Recover chemical energy for treatment byproducts	• Comparatively best practice, aims towards reducing energy-carbon footprints through use to alternative energy source.

Towards net zero GHG emission and self-sufficiency

- Shift towards cleaner energy sources.
- Improving measures for energy efficiency and energy recovery.
- Reducing water losses. In Asian countries NRW levels ranged from 5 to 56 % in 2009 (ADB, 2010).
- Compact settlements have lower footprints of water distribution and wastewater collection infrastructures that reduces embodied energy footprints.
- Operational energy depends on type of systems: decentralized versus centralized, scales of UWS utilities and their capacity utilization. The optimum operating condition have minimum water, energy and carbon footprint.



Conclusion

- Cities' water-energy-carbon nexus is a key area to look into- both from direct and indirect perspectives
- There is a growing need for cities' transition into a cleaner, healthier, sustainable and economically secured future.
- There are number of approaches that cities must adopt in water-energy systems, including investments in renewable technologies, improving efficiency of water and energy systems, reforming the necessary regulations and policies
- Cities play a significant role in determining the future of water and energy resources as well as combating climate change.

Further readings

Dhakal, S., Shrestha, S., Shrestha, A., Kansal, A., and 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. (http://www.apn-gcr.org/2015/10/26/policy-brief-towards-a-better-water-energy-carbon-nexus-in-cities-lcd-01/)

Dhakal, S. and Shrestha, A. (2017). **Optimizing Water-Energy-Carbon Nexus in Cities for Low Carbon Development**, In Creating Low Carbon Cities (Ed. Shobhakar Dhakal and Matthias Ruth), Springer International Publishing. DOI: 10.1007/978-3-319-49730-3.

Prevailing driving forces