Knowledge Series No. 5

Smart Water Management

March 2018

ADB

Knowledge Series No. 5

Digital Technology for Development Unit
Sustainable Development and Climate Change Department
Asian Development Bank

Contents

Overview

Digital technologies greatly impact the economic and societal development of nations. With the advent of the Fourth Industrial Revolution (4th IR), many changes are bound to happen: people's way of doing things, commuting to and from work, learning, teaching, and meeting others. With the change comes questions that may challenge those who are in the middle of all these successive disruptions.

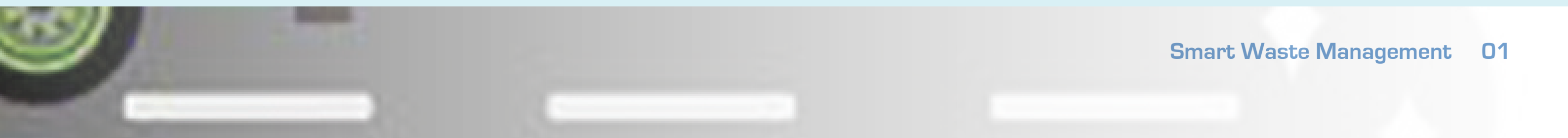
According to a United Nations (UN) report released in 2016, "by end 2016, 3.5 billion people will be using the Internet, up from 3.2 billion last year and equating to 47% of the global population.”

However, even with these staggering facts, it still remains true that while billions are online, a sizable part of that population may not be using the Internet to its full potential. And this problem needs to be addressed early on, as knowledge of the digital world has been proven to solve the biggest issues in two of the biggest sectors today: education and transportation.

The Asian Development Bank (ADB) notes that adoption of digital technologies can allow developing countries to leapfrog over traditional development pathways—from resource-based economies and labor-intensive industries to the production of knowledge-based products and services.

In line with this, ADB hosted the 2017 Digital Strategies for Development Forum (DSDF) on 7-8 September 2017 at the ADB Headquarters in Manila, Philippines. Established in 2014 as the Digital Strategies for Development Summit, the event has become a venue for high-impact discussions on ICT for Development. It tackles country, sectoral and thematic development strategies toward Digital Economy in Asia and the Pacific.

DSDF 2017 focused on both areas of education and smart cities, in the context of digital technologies development within the 4th IR. It also served as a venue for organizations to discover ways to be prepared on adaption within the 4th IR backdrop.



Best Practices and Innovations in Wastewater Management

Currently, 2.6 billion people, 72% of whom live in Asia, do not have access to improved sanitation. Most Asian cities do not have effective wastewater treatment systems. This impacts public health, degrades local environments, including important resources (water, agricultural, fisheries and other ecological resources), and ultimately has a significant economic impact. It is estimated that poor sanitation costs South Asia $60 billion a year.

In the urban context, poor sanitation has a pronounced effect on public health and the urban environment, with impacts on productivity, competitiveness, and a host of other metrics for gauging urban livability.

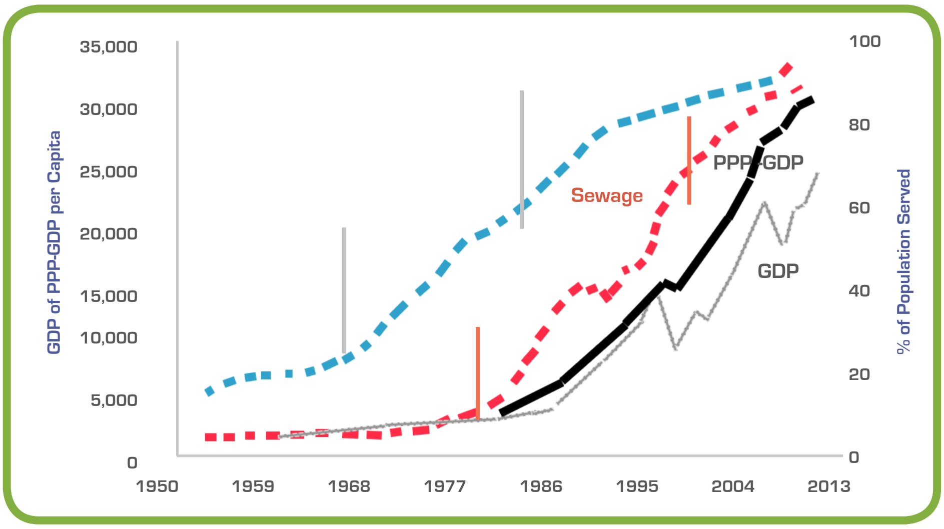
Korean Developments in Wastewater Management

Rapid population growth and urbanization led to an increase in recorded cases of e-coli contamination by a factor of 150 between 1963 to 1967 in Korea. Since then, within a relatively short period time, the country has made remarkable progress in the wastewater sector.

In 1958, there was no sewage infrastructure in Korea, and by 2015, 93% of all wastewater was collected and treated to very high standards before discharging to the environment. The *chart* illustrates the development of the sewer network in Korea. The heavy investment in wastewater infrastructure was enabled by GDP growth and loans from international financing institutions.

Yong Ye
Director, Urban Development and Water CWRD, ADB

"Proper waste management will benefit the economy. Waste management remains one of the most neglected and under invested sectors in Asia. ADB is trying to promote innovation, particularly with respect to financing and PPPs, to fill the current public-sector funding gap for infrastructure investment. Capacity development and learning is important for addressing these challenges in our Developing Member Countries. ADB wish to promote Knowledge sharing and engage with experts in the region. This workshop is also important to ADB to seek feedback on specific issues and local challenges in DMCs – to better understand how they can meet government's needs in financing and preparing waste management projects."



The *chart* also illustrates the approximately 20-year lag between water supply provision and equivalent provision wastewater management infrastructure. This is common as policy priorities change with economic growth, from provision of basic services (water) to environmental management and sustainability. As well as investment in infrastructure, Korea has developed globally recognized education and research institutes responsible for innovations in wastewater management technologies and the production of high quality water professionals.

UN Water

"Wastewater management generally receives little social and political attention in comparison to water supply challenges, especially in the context of water scarcity. Yet, the two are intrinsically related – neglecting wastewater can have highly detrimental impacts on the sustainability of water supplies, human health, the economy, and the environment."

The improvements in wastewater management are not brought about by investment alone, better environmental policy, regulation and enforcement have all been key drivers. The current environmental policy focus is on sustainable development and green growth, as illustrated in the policy development *diagram* below.

Ho Yu
Director of Wastewater Department,
Ministry of Environment

"During the 1960s and 1970s, rapid urbanization created a great environmental problem in Korea. In the 1960s, we enacted a number of environmental laws. In the 1970s, we then started construction of WWTPs. Seoul Olympics in 1988 was the catalyst for further infrastructure investment. In 1991, industrialization led to a high-profile Phenol incident in the Nakdong river which led the government to strengthen policy and invest further in wastewater management. Sharing our experiences of this process, we hope can help other countries develop their wastewater treatment systems. It is important to remember that we (in Korea) still have progress to make, especially in reuse of treated wastewater."

This focus identifies the economic benefit of wastewater management, thus allowing water managers to consider waste as a resource.

As noted by BK Lee (Korea Environment Institute), the priority areas for innovation in Korea are further advancements in efficiency and the development of more advanced technologies for wastewater/energy recovery, as well as safety and odor.

The high standards of wastewater treatment in Korea and the technology employed has led to high cost of wastewater services which are undervalued politically and societally. This means that both central and local government accept most of the service cost, and the sewerage service charge covers only 20%-40% of the total annual cost.

- Defensive and passive policy

→

- Active policy
- Command and control

→

- Longer-term precautionary policy

→

- Sustainable development
- Green growth

Technical Solutions to Wastewater Challenges

This section will focus on current best practices and lessons learned from Korean experiences in wastewater management, with some technical case studies. The focus areas in smart wastewater management include:

- Smart sewer networks;
- Managing septic tanks;
- Small wastewater treatment plants;
- Advanced treatment technologies;
- Wastewater re-use; and
- Waste to energy.

This technical section is followed by comments and discussion with some case studies illustrating innovations in ADB DMCs.

SMART Sewer Networks

Korea is in the process of augmenting and upgrading existing sewer systems. Historic sewage systems represent a significant challenge to cities in Korea and elsewhere. The key issues requiring improvement and maintenance are leakage, inflow, incorrect junctions, blockages, flooding, and subsidence.

YJ Kim of KEKO said Smart systems and ICT can be used for asset management (identifying issues for repair or improvement), as well as design and operation improvements:

- Sewer pipes: flow monitoring, CCTV, mapping
- Pump station: water level monitoring, pump operations (SCADA), emergency warning
- Network: GIS, asset database, rainfall monitoring, flow modeling, flood protection, simulation, decision making and mobile control and operations.

Integrated sewer management systems combine all of the above to optimize sewer operation and thus environmental protection. Future integrated wastewater management systems are being piloted in Korea and will make use of big data and Internet of Things (IoT) to improve efficiencies. While advancements in sewer technologies are ongoing, YJ Kim presented some practical advice to project developers ***(see Box 1)***.

A Note on Septic Tanks

Zuwhan Yun, president of the Korea Water Partnership, explained that septic tanks eventually become a burden to modern urban wastewater management networks.

In dense urban areas the issue with septic tanks are exaggerated – illegal discharges, untreated effluent, poor maintenance, leakage, odor, flies, mosquitos, rats. Ultimately, Seoul had to remove 800 million septic tanks which became obsolete as sewer networks expanded to improve urban environmental conditions.

The sludge in septic tanks, which has to be regularly emptied and transported to treatment facilities, has very low BOD, but very high nitrogen content and is, therefore, difficult to treat. In addition, individuals only consider the cheapest solution and construction and maintenance standards are hard to enforce. Too much responsibility is given to the owner without technical support and therefore large numbers eventually create an environmental issue.

Due to these issues, septic tanks should be used only in rural areas or very low-density urban areas. However, as they represent a simple technology and less capital-intensive option than piped sewer networks and centralized wastewater treatment, some DMCs will inevitably still manage and permit installation of septic tanks in peri-urban areas in the short- and medium-term. To mitigate environmental impacts from septic tanks, a high level of enforcement in both construction and operations is necessary, and specifically designed septage treatment facilities should be constructed.

Small Wastewater Treatment Plants

In Korea, small wastewater plants are considered plants that treat less than 500 m^3/day of wastewater. They account for 3% of wastewater treatment by volume nationally and are generally located in rural areas. They do not require 24/7 supervision and can be remotely operated with staff potentially covering

BOX 1: Practical Advice to Participants in Developing Sewer Networks

- Where possible urban land use and sewer master planning should be considered in harmony.
- Sewer networks and wastewater treatment plants are not separate operational entities so do not separate the management agency.
- Learn lessons from others in application of wastewater technologies.
- Use of ICT technology does not free agencies from management responsibilities or costs, there is a management and cost burden of ICT systems. It is not free.

several facilities. Small wastewater treatment facilities primarily use activated sludge technologies. However, this is not standardized and in Korea a total of 75 different treatment processes are applied. Process selection is based on local conditions: water quality, loading, pricing, capacity, and existing knowledge. ***Box 2*** describes several issues and potential solutions for implementing small wastewater treatment plant projects.

BOX 2: Small Wastewater Treatment Plants

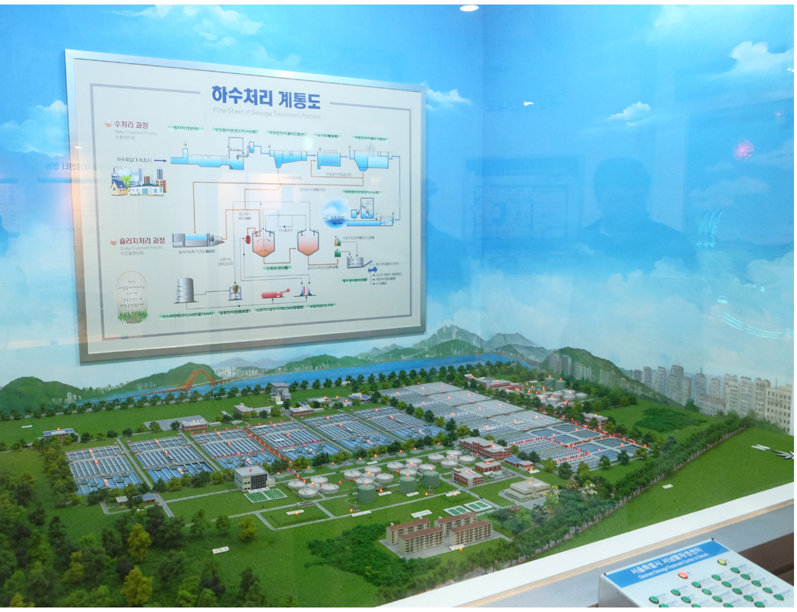
Small wastewater treatment plants are getting a lot of attention from ADB but there are a number of issues with their operations.

As presented by Syungpo Kim of Korea University, issues with small wastewater treatment plants include:

- The number of different technologies applied;
- Irregular loading in rural areas means that design is difficult;
- This is particularly true with combined systems as stormwater can increase inflows by 60%;
- Removal of Total Nitrogen needs continuous attention by operators, but staff do not attend plants continuously;
- Numerous small plants need more staff when compared with one large facility; and
- Korea has found funding an issue as total costs per unit are greater due to the efficiencies of larger treatment plants. These plants only receive 3% of total wastewater by volume but 12% of total BOD loading.

Potential solutions include:

- Standardization would be preferable for construction, contracting, training, standards, monitoring, safety, but innovation would be lost;
- Treatment clusters could be established with standardized technologies, funding, training, etc.; and
- ICT-CCTV, remote monitoring, SCADA can be used to operate plants remotely.



Advanced Treatment

The removal of nitrogen and phosphorus from wastewater has become an emerging worldwide concern because these compounds cause eutrophication in natural water, inhibiting ecosystem diversity. Moreover, nitrate is a risk to human health, especially to infants.

Some variants of activated sludge process is commonly applied in wastewater treatment, but it is often the case that the effluent from wastewater treatment plants contains phosphorus and nitrogen in the form of ammonium and/or nitrate. A post-treatment or advanced process is therefore required to remove nitrogen and phosphorus from the effluent. Advanced treatment processes may also be specifically selected for reduction of hazardous materials including trace metals, particularly in areas with high industrial loadings.

The technological advances made have also enabled a reduction in land requirements, and energy inputs. These efficiency gains are sought to reduce total cost of wastewater treatment to deliver sustainability in the wastewater treatment system.
Selection of appropriate technologies is based on specific local factors, including land, flow volume, contaminant loading (BOS, nutrients, etc.), and proposed downstream uses (water reuse, energy generation, etc.). The details on four emerging technologies were provided by JT Kim of Kyonggi University:

- Aerobic granular sludge (AGS) allows settling rates three times higher than conventional activated sludge technologies. Wastewater treatment plant capacity can, therefore, be increased, or the footprint reduced. The technology developer has suggested it will be a standard process in less than 20 years.

- The membrane bioreactor (MBR) has emerged as an efficient compact technology for municipal and industrial wastewater treatment. The major drawback impeding wider application of MBRs is membrane fouling, which significantly reduces membrane performance and lifespan, resulting in a significant increase in maintenance and operating costs. This is the same for all membrane processes, including reverse and forward osmosis.
- ANAMMOX technology makes use of anaerobic microorganisms. It facilitates efficient nitrogen removal with less energy inputs compared to conventional activated sludge as air injection is not required. It has the disadvantage that lower temperatures reduce its efficacy, but trials are ongoing in developing a cool weather process variant.
- CANDO (Coupled Aerobic-Anoxic Nitrous Decomposition Operation) is an advanced wastewater treatment technology that removes nitrogen from the wastewater and then recovers energy from the nitrogen. Denitrifying organisms convert nitrite to nitrous oxide gas which is an energetically potent oxidant – its combustion with methane releases 30% more energy than the combustion of oxygen with methane.

Ainagul Amanova
Senior Project Officer
KYRM, ADB

"In the Kyrgyz Republic, currently only 21% of the population has access to centralized sanitation. Resettlement is a significant issue which increases the cost of constructing water treatment plants. Perhaps advanced treatment technologies with a smaller footprint might be viable here. Unfortunately, our water operators cannot fully cover operational expenses from local revenues so we have to consider increased operational costs of advanced technologies. We are still considering our technology options for wastewater treatment."

Kinley Penjore
Project Manager, MOWHS

"In Bhutan we are very interested in small wastewater treatment plants because of the dispersed nature of our communities. Usually, water treatment is via lagoons or small package plants, but recently, we have constructed a 12 MLD plant with support from ADB. The project is under a DBO contract. This is a new mechanism for both us and ADB so we are learning lessons together."

Wastewater Reuse

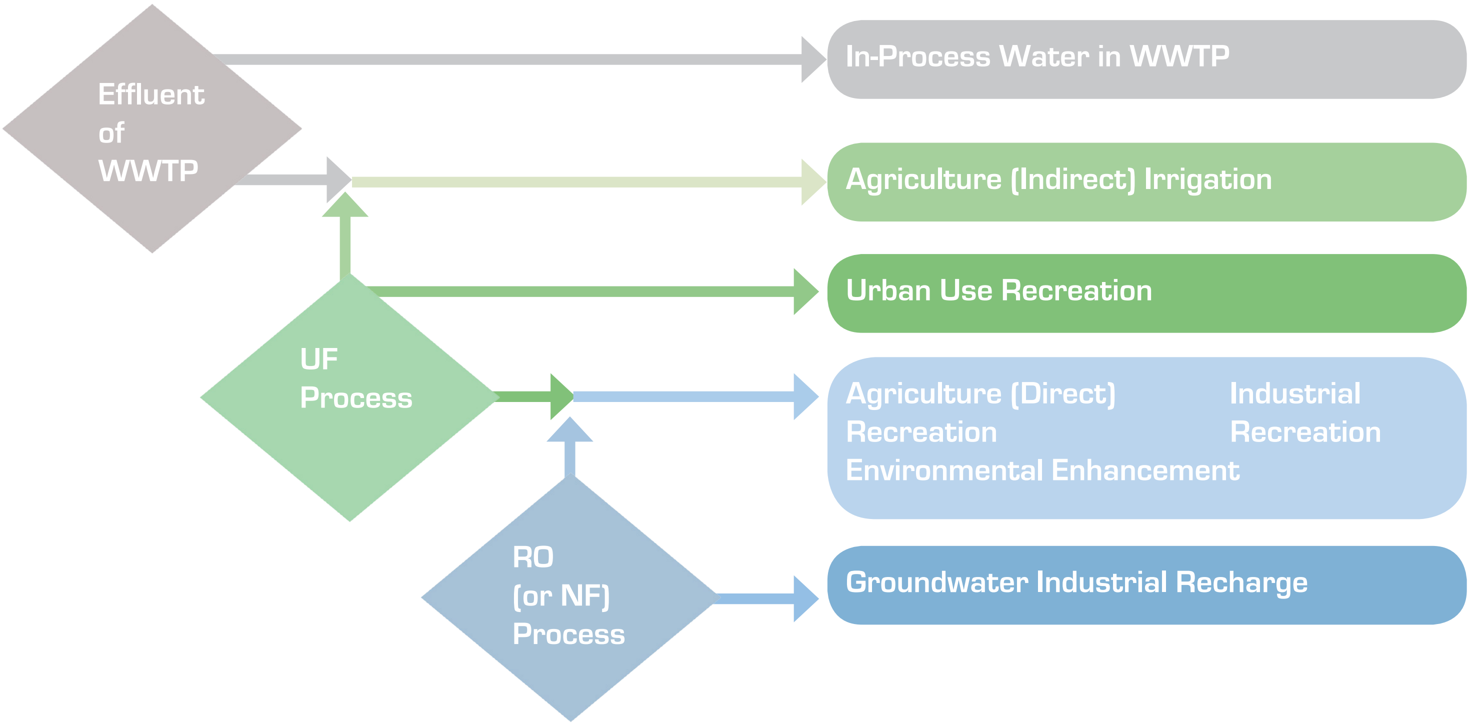
Urban wastewater should be considered as a resource. Even in Korea, which is not water scarce, wastewater treatment plant effluent re-use is growing, due to high urban populations putting demands on water resources.

Conventional wastewater treatment plant effluent would discharge to a local water body, potentially with some tertiary treatment. Increasingly, post-treatment for re-use is becoming economically feasible, including the delivery of very high-quality water for local industrial uses. This post-treatment commonly employs disinfection, sand filtration or membrane processes.

The figure was presented by Dr. Oshung Kwon from Coway Entech which illustrates the level of treatment required (and potential for blending) for various applications including:

- Urban use
- Recreation
- Agriculture (direct application)
- Industrial use, and
- Groundwater recharge

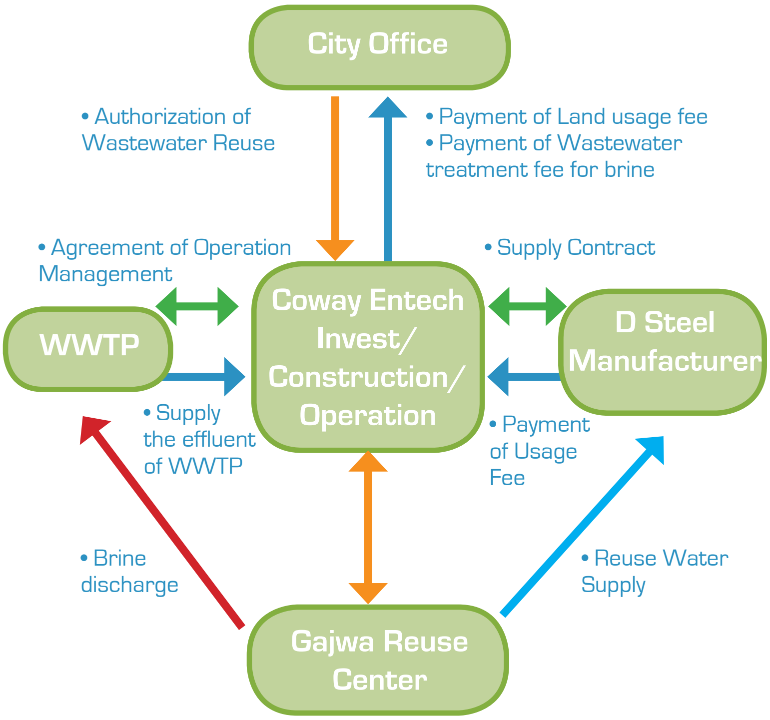
Treated wastewater is not often used for potable water, apart from in extremely water limited environments such as Singapore. Wastewater for groundwater recharge is, however, common. This water is often abstracted and treated for potable consumption.



BOX 3: Case Study on Gajwa Water Re-use Centre, Seoul, Coway Entech

Coway Entech operates a wastewater reuse treatment plant under a BOOT (Build, Own, Operate, Transfer 15-year contracting period) agreement with Seoul City Office. It has an effluent supply agreement with the local wastewater treatment plant (upstream), as well as a supply contract for cooling water with a local steel manufacturer (downstream). The plant is located on City-owned land and utilizes ultra-filtration and reverse osmosis (RO) to deliver high-quality treated water. The project is a win-win-win opportunity as each partner benefits:

- The City government, in terms of less demand on water resources and inheriting an asset, after the 15-year operating priod;
- The customers benefit as they obtain "better than tap" quality water at a lower price; and
- The project developers, from their profits, but also in intellectual knowledge and technology development and refinement.



Coway Entech utilizes membrane technologies for post-treatment treatment, including ultra-filtration, reverse osmosis, and nano-filtration. These technologies require high-energy consumption, and therefore the application for re-use needs to make economic sense. Targeting industrial urban water users which require high-quality water can lead to financially viable projects for private sector water operators.

Box 3 illustrates the complex institutional setup required for private sector post-treatment for water re-use.

Waste to Energy

The ultimate goal of wastewater treatment in Korea is energy independency. To achieve this, more efficient process technologies are required, as well as recovery of energy from the waste: the effluent should be considered the resource for generating the energy required for its own treatment.

H.J. Hwang of BKT presented several technologies they have developed which either produce energy efficiency gains in treatment or are energy generation technologies. The ***figure*** illustrates these technologies in a process diagram.

Energy Efficient WWT:

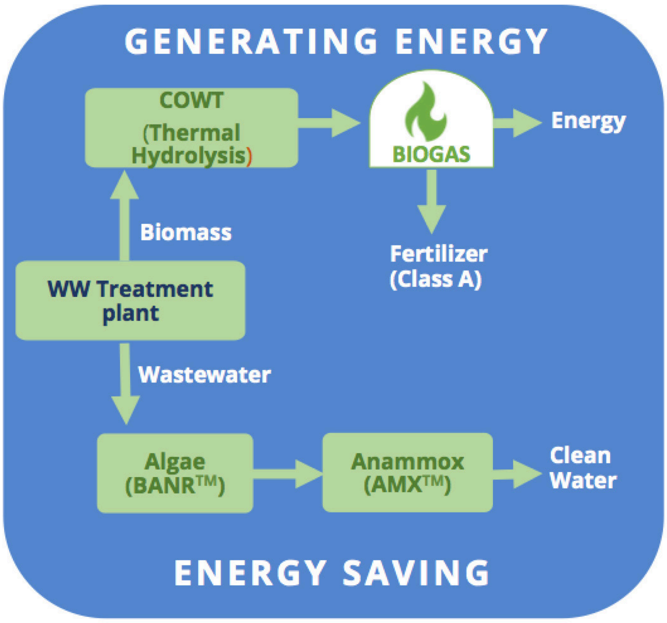
- Turbo blower technology (reduces energy consumption by 30% compared to other aerators)
- VAF – Vortex Air Flotation (energy efficient DAF system)

Energy Generation:

- Thermal Hydrolysis (COWT™ technology)
- Anaerobic digestion (BEAD™ Technology)

COWT technology is a pre-treatment process for anaerobic digestion – as illustrated in the ***figure*** above.

COWT reduces the time required in the reactor and improves energy production. Steam is used to heat organics to 200 degrees under pressure (5 bar). Through this thermal hydrolysis, organics are carbonized which breaks down the cell structure and allows digestion to retrieve 25% more biogas from the sludge. BEAD technology improves digestion efficiency by using mechanical mixing to reduce dead space in the digester, thus increasing gas production.



BOX 4: Workshop Site Visit to Seonam Wastewater Treatment Plant

Footprint: 103 hectares
Wastewater Catchment: 120km2 – 9 City districts
Capacity: Sewage — 1,630,000m3/day
Septic Tank Sludge — 2,000m3/day

Processes:

- Grit screening
- Influent pumping station
- Primary sedimentation
- Bioreactor tank (activated sludge)
- Final sedimentation
- Sludge thickening
- Sludge flotation
- Anaerobic Digestion
- Sludge dehydration

The wastewater treatment plant is a conventional plant utilizing activated sludge for wastewater treatment. The sludge is processed for digestion and electricity production. There have been significant complaints about odor from local residents so the Seoul City Government is preparing a project to completely cover the plant. This will eliminate the odor issue and provide amenity space for local residents to enjoy. The idea is that local residents will benefit and start thinking: "Please In My Back Yard" (From NIMBY to PIMBY)

Wastewater Management: Discussion, Comments, and Options for DMCs

Please elaborate on harmonizing sewer plans with City plans.

Wastewater treatment plants and sewer systems need to be considered together when planning cities, urban expansions, and land use zoning. Often, wastewater is seen as a low priority behind transport and other infrastructure, and lower budgets are provided for wastewater planning. Retrofitting sewers is extremely expensive so it's much better to align plans as early as possible. It may be underground and less visible but wastewater infrastructure is extremely important for a functioning city. An example of a lesson to be learned in wastewater planning from a Developing Member Country is provided in the ***box*** opposite.

What is the status of Korea's transition to fully integrated wastewater management systems, and are IT systems standardized across water operators?

It is difficult to implement standardized IT systems nationally as it could limit the use of different technologies. Each local authority will have different focal areas and there are over 70 different wastewater treatment technologies in use. Currently, all wastewater treatment plants are operated using ICT systems, many smaller plants remotely. The current focus is on integrating these systems with the sewer catchments which they serve. The technologies are becoming available and are starting to be implemented.

What is the most appropriate technology for small wastewater treatment plants in ADB Developing Member Countries?

Technology selection depends on numerous local conditions and loading, as well as budget. Simple technologies with the lowest operating costs should be considered in ADB Developing Member Countries.

Which of the advanced treatment technologies are most likely to be applied in Korea on a large scale? What are the constraints that hold back wider application of advanced technologies?

Activated sludge will remain the most important wastewater treatment technology as far as we can foresee.

Tinatin Lebanize
Head, Donor Relations
Department MRDI, Georgia

"In Georgia, urban master planning is not providing sufficient clarity for infrastructure investment planning. Poor population and demand projections have led to over designed sewage treatment works with limited wastewater inflows. The plants are now financially unsustainable as the operational costs exceed the level of treatment provided. This is particularly prevalent in tourist areas affected by seasonality. The lesson learned from this case is that wastewater demand projections are critical to ensure investments are in line with future requirements. The issue is exacerbated by an unwillingness of existing residents to connect to the sewerage system, and, therefore, when developing investments of this nature, they need to be supported by public health outreach programs so that users understand the importance and cost of wastewater treatment."

The most important advancements that will have broad uptake will be on improving energy efficiency of current technologies and for recovering resources from wastewater to offset costs (energy, water, compost).

Adoption of new technologies is hampered by existing investment cycles, but also the design engineer's knowledge and the capacity of the operator(s).

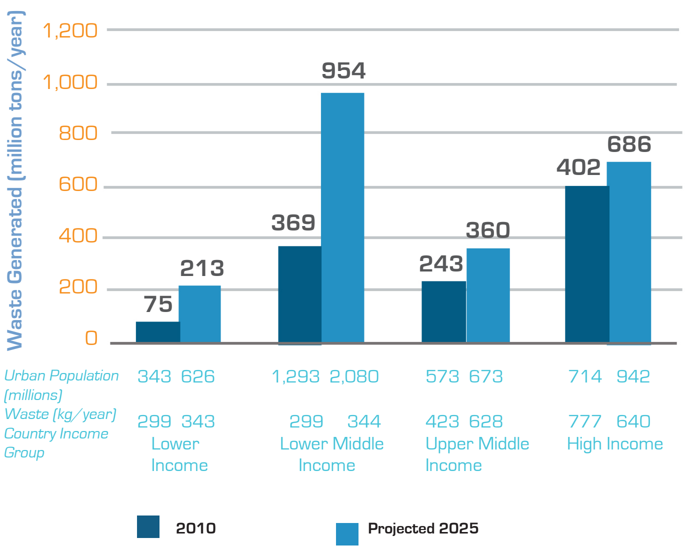
What is the payback period of sludge digestion Waste to Energy systems?

Applying both the COWT and BEAD technologies will improve efficiency by around 40% in energy generation compared to conventional technology. The payback period at current electricity tariffs would therefore be around seven years.

Best Practices and Innovations in Solid Waste Management

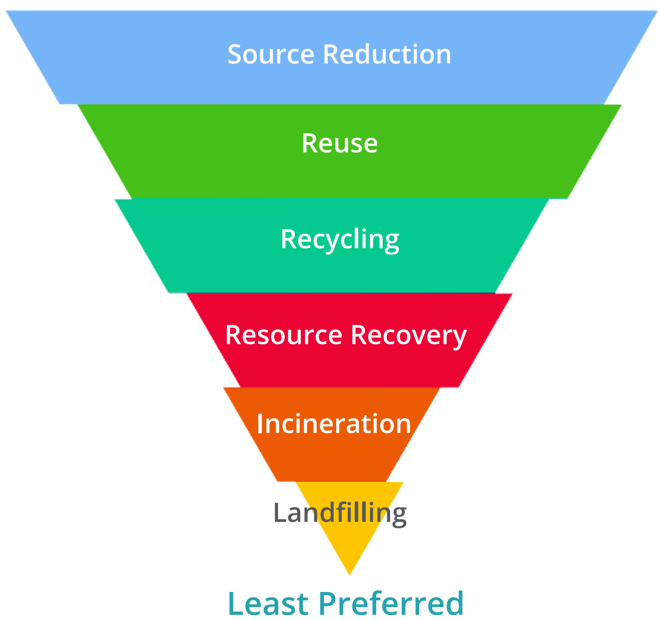
Globally, municipal solid waste is expected to double by 2025, with the current waste generation in East Asia and the Pacific Region approximately at 270 million tons per year. This quantity is mainly influenced by waste generation in China, which makes up 70% of the regional total.

Per capita waste generation ranges from 0.44 to 4.3 kg per person per day for the region, with an average of 0.95 kg/capita/day. Generally, the higher the national income level and rate of urbanization, the greater the amount of solid waste produced ***(see figure below)***. However, region and country variations can be significant, as can generation rates within the same city.



In the urban context, poor solid waste management has a pronounced effect on public health and the urban environment. It adversely impacts the urban aesthetic and livability, and has secondary impacts such as increasing local flood risks. SK Moon (SUSA) illustrated a range of solutions for dealing with waste from source reduction (most preferred) to landfill (least preferred) as *illustrated below*. The best solutions are the earliest possible in this 'waste stream' as they reduce cost of handling and further environmental impact.

Waste is starting be considered as a resource: all the way up until landfill, resources can be recovered from waste for energy, construction use, re-cycling, re-purposing and up-cycling. Landfill mining may even be feasible in some cases where land availability is an issue or a high proportion of non-ferrous metals (e.g., aluminum) may have been deposited. Landfill sites also produce resources in methane which can be captured and used for energy generation.



Developments in Solid Waste Management in Seoul

As with management of wastewater nationally, the Seoul City Government has made rapid and significant progress in management of municipal solid waste. After the Korean War, Seoul had no formal waste management system with an expanding urban population generating increasing waste, with expected environmental consequences.

By the 1960s, Seoul had five dump sites in operation but no designated landfill site. The first controlled landfill site was opened in 1978 in Nanji, in western Seoul, and operated for around 15 years. Before its closure, a new regional landfill site was opened on reclaimed land near Incheon airport to service the whole of Seoul metropolitan area. Currently, only 8% of waste from Seoul goes to this facility as the majority of municipal solid waste is recycled or incinerated at four resource recovery centers, strategically located across the urban metropolis.

The ***figure below*** presented by SK Moon illustrates the timeline of Seoul's transformation from waste dumping to the current goal of Zero Waste. Two key policy measures enacted over the last 30 years are the introduction of volume-based waste fees and food waste segregation in 1995 and 2005, respectively.

Technical Solutions to Waste Management Challenges in Seoul

This section will focus on current best practices and lessons learned from Seoul's experiences in solid waste management, with some technical case studies. The focus areas in smart solid waste management include:

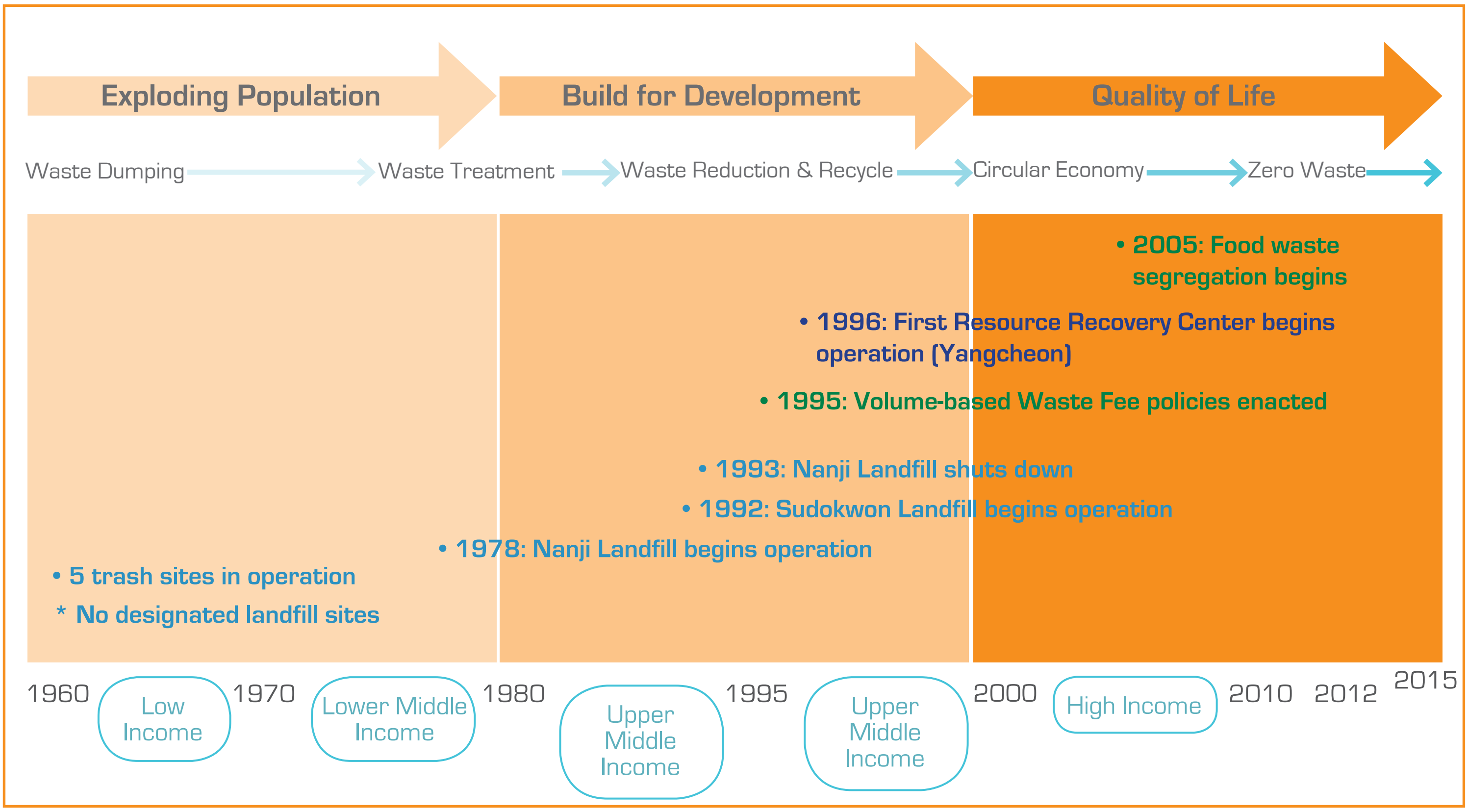
- Waste minimization, separation and collection
- Waste to energy
- Landfill

This technical section is followed by comments and discussions, with some case studies illustrating innovations in ADB DMCs.

Waste Minimization Separation and Collection

The ***figure below*** illustrates that from 1990 to 2010, waste production per capita in Seoul halved, recycling has increased nearly twenty-fold, and waste disposed in landfill has been reduced by 95%. This dramatic progress has been accomplished through numerous policies and initiatives.

1990	vs.	2010	
			
Open Dumping		Sanitary Landfill + Park	
2.44 kg/day	Waste Generation Per Capita	1.06 kg/day	57% reduction
29,272 t/day	Landfilled	1,445.7 t/day	95% reduction
338 t/day	Recycled	6,592.7 t/day	1,850% increase



The crucial factor in waste minimization has been the implementation of a pay per volume household waste policy. The pay per volume policy was enacted nationwide in 1995 through a waste bag purchase scheme for household waste. Through the scheme, non-recyclable household waste can only be disposed of in specific bags purchased from the municipality. This has been supported throughout by public awareness campaigns.

More recently, an expanded producer responsibility scheme has been implemented. Under this scheme, producers are responsible for collecting items such as TV sets and washing machines. For other items, where producer collection is not possible, an agency has been set up to monitor collection and treatment (recycling and/or disposal) of such items before billing to the producers for these costs.

Most waste, including food waste, is separated at source at local waste banks ***(see figure below)*** which has led to the expansion of recycling. After collection and transfer, different waste streams are recycled at specific facilities. Currently, Seoul metropolitan area operates 46 transfer stations, 5 food waste treatment facilities, 15 material recovery facilities, home appliance recycling facilities, a wood treatment facility, a construction waste recycling center, and 4 incinerators.

Box 5 below describes an innovation in managing community waste collection sites in Tashkent, Uzbekistan, a DMC.

In Seoul, more recently, support has been given to expansion of flea markets for used goods and providing space for independent craft producers for up-cycling. ***Box 6 on the opposite page*** describes examples from Bhutan where private sector initiatives have been encouraged to minimize waste to landfill.

BOX 5: Innovation in Management of Community Waste Collection Points in Tashkent, Uzbekistan

In Tashkent, Uzbekistan the city government has placed a high priority on managing solid waste, and ADB is supporting a long-term development strategy for Tashkent, which includes rehabilitating existing historic infrastructure and investing in better systems.

One innovation which has been particularly successful in Tashkent is in the management of community waste collection sites. The existing sites were extremely smelly so city employees had many excuses for not visiting and managing the sites regularly and properly. The solution implemented was to employ homeless people to sort the waste and keep the site clean.

In return for this service, they receive on-site living accommodation and sanitary facilities, and the ability to make a little income from selling any waste with value. This is a win-win solution that could be replicated in other ADB Developing Member Countries, with due consideration for local issues.

BOX 6: Innovations in Waste Minimization in Bhutan

Due to the mountainous terrain, landfill development is difficult. Since 2010, Thimpu City has contracted a private sector initiative called Greener Ways which approached the City to establish waste sorting and recycling facilities. Now, PET bottles, cartons and boxes, glass and rubber are now recycled. In Bhutan, around 50% of waste is organic so there is huge potential for composting. To date, approximately 185 tons of organic waste have been converted to compost.

Other grassroots initiatives include a young entrepreneur surfacing roads using 500 tons of recycled plastic annually, and an international NGO partnership which supports an upcycling of plastic to craft items for sale to tourists.

Waste to Energy

Seoul City Government currently disposes the majority of their un-recyclable waste to four incinerators. It also operates one landfill gas center that generates electricity and heating from landfill gas collected at the closed landfill in Seoul.

The four incinerators accept 2,900 tons/day of waste and are owned by the Seoul City Government. They are operated by qualified private companies on three-year operations contracts. The majority of incinerator ash is reused in construction materials.

Incineration is a higher cost option than landfill but it has the advantages of:

- Energy recovery;
- Destruction of combustible toxins;
- Destruction of pathogenically contaminated material such as animal carcasses;
- Longer life span of landfill;
- Lower transport costs; and
- Smaller footprint of landfill, so lower land acquisition cost.

BOX 7: Viability Criteria for Waste Incineration

- A mature and well-functioning waste management system has been in place for a number of years.
- Solid waste is disposed of at controlled and well operated landfills.
- The supply of combustible waste will be stable and will amount to at least 50,000 metric tons/year.
- The lower calorific value must on average be at least 7 MJ/kg (1,700kcal/kg), and must never fall below 6MJ/kg in any season.
- The community (through government) is willing to absorb the increased treatment cost charges, tipping fees, and tax-based subsidies.
- Skilled staff can be recruited and maintained.
- The planning environment of the community is stable enough to allow a planning horizon of 15 years or more.

JY Park of POSCO presented the environmental benefits of incineration versus landfill but recognizes that the criteria presented in ***Box 7*** need to be met before considering waste incineration as a viable option. The workshop participants undertook a field visit to the Mapo Resource recovery center to see first-hand an operating waste to energy site ***(Box 8).***

Landfill

The existing Sudokwon landfill site that services Seoul Metropolitan Area is located on reclaimed land approximately 35 km west of Seoul. It is one of the largest in the world with an area of 20 km^2 and height of over 100 meters. It services a total of 25 million people, including Incheon and Gyeonggi. The landfill is used for disposal of some hazardous wastes, and to manage waste during peaks when waste generation exceeds incineration capacity.

As presented by KY Yo (The Seoul Institute), the landfill site is jointly owned by the Korean national government (Ministry of Environment) and the Seoul City Government, and operated by a state-owned enterprise under the control of the Ministry of Environment.

The landfill site includes a 50-MW landfill gas electricity generation project. It is the world's largest landfill gas power plant and provides electricity worth USD30 million annually for 43,000 local residents. It is registered as a Clean Development Mechanism project with a certified emission reduction equal to 850,000 tons CO^2.

Mansurov Muzaffar Dovutovich
Deputy PIU Head
State Committee of Ecology and Environmental Protection, Uzbekistan

"We don't have any smart systems in waste management yet in Tashkent, but we have implemented some innovative systems in recent years and have made significant improvements in solid waste management in the City. The site visit to the resource recovery facility in Seoul has opened our eyes to the possibility of waste to energy solutions and improved waste recovery. This is something we need in Uzbekistan. We (the City of Tashkent) are now planning to have some relations with SUSA, particularly with respect to getting insight into implementing something like Mapo resource recovery center."

BOX 8: Workshop Site Visit to Mapo Resource Recovery Facility

Collection areas:	7 City districts
Capacity:	750 tons/day
Total Cost:	USD 171 million
Construction Completed:	2005

- Situated on the closed and restored Nanjido landfill which has been rehabilitated to an urban park.
- Operated by a qualified private company under a three-year contract with the Seoul City Government.
- Reduces greenhouse gas emissions to 645 tons of CO2 equivalent.
- Final waste stream is just 3% of waste received by weight.
- Rotary kiln for incineration and electricity generation though a steam turbine. Numerous post processes and filters to reduce trace emissions to the air.
- Incinerator ash is used to produce construction materials.
- Cogeneration of heat for use by Korea District Heating Corporation for supplying neighboring residential areas with district heating.

If we were to implement bag buying systems in DMCs, there is a likelihood that residents would just dump waste in the street or on informal dump sites. Was this an issue in Seoul? Did it happen?

Yes, this happened initially but with hard enforcement coupled with public awareness campaigns, we were able to change residents' habits. For example, there is a fine of approximately USD 80 for putting food waste in the wrong bag. Now, it is widely accepted that citizens have some responsibility for managing and reducing their own waste. Once, this idea is socialized, the pay per volume policy incentivizes waste minimization.

How do you invoice and bill for waste management based on volume?

General waste is through a volume-based bag purchase scheme as previously described. Other waste such as food waste, organics, and recyclables are disposed of separately at local waste banks which weigh waste production for each waste type. Each resident has an electronic dongle which collates waste generation information and generates a monthly bill for payment based on weight.

Do you know the lead time for developing a policy concept such as 'pay per volume' and rolling it out nationally?

Actually, this was before the time of SUSA so we cannot be sure, but we know that this was a national policy that was piloted in Seoul. This phased approach enables lessons to be learned before full implementation and enforcement. But we are still tweaking the regulation and enforcement of this policy concept 20 years later.

Incinerators may meet even more public resistance than landfill sites as there is a potential for producing toxic airborne pollutants. How has this NIMBY issue been managed?

Again, we started our incineration program in Seoul with a smaller pilot site to refine the design and introduce appropriate systems to reduce local atmospheric, noise, odor and other risks. Local air quality is maintained by smart technology and advanced filtering processes, coupled with monitoring of exhaust streams and strict enforcement of acceptable limits for a wide variety of airborne pollutants. Waste trucks move at night into covered areas which control noise and odor issues.

In fact, one of our incinerators is constructed entirely underground to reduce local impact. The air from waste storage bays is sucked into the incinerator so it does not escape, further reducing odor issues.

We locate incinerators on brownfield sites and regenerate these areas to provide parks and amenities for residents. Finally, we provide subsidized energy to residents, in this way providing a benefit to locals to offset any costs.

What is the payback period on waste to energy from incineration?

The cost of incineration is possibly 7 to 10 times greater than landfill. But the decision to move forwards with incineration comes down to more than just cost.

In Korea, the primary factor is land availability for new landfill sites. Also, unsanitary landfill is one of the greatest sources of methane, a greenhouse gas which has potentially four times the warming effect of carbon dioxide. Ultimately waste-to-energy plants cannot recover capital costs from energy sales and need government to subsidize operational costs by around 50%.

As there is limited financial capacity in most ADB DMCs, it will be necessary to engage private capital and expertise in any incineration projects. Interesting the private sector in such projects will require very strong guarantees from the government side.

Enablers for Waste Management

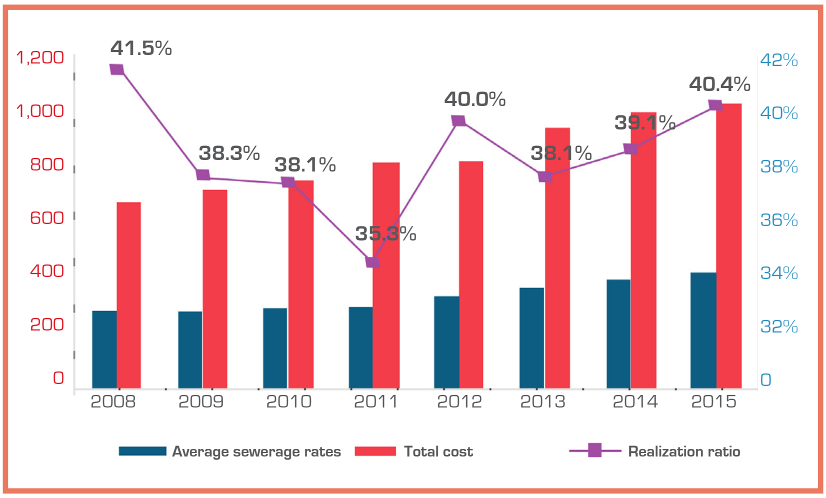
This section will focus on enablers for waste management with some case studies. The focus areas will include:

- Tariffs and sustainability
- Institutional arrangements, partnerships and operational cost sharing
- Financing capital investments through PPPs
- Policy

Tariffs and Sustainability

Wastewater
Water and wastewater management is currently undervalued in Korea. It is the cheapest of all utilities.
According to market research by the Korean Waterworks Management Institute, public water is perceived as less important than telecoms, transport and energy, in the infrastructure and utilities sector.

The realization ratio for wastewater (the ratio of cost of service provision and revenues from users) is currently around 40%, according to Gilbok Kim of the Korea Waterworks Management Institute and illustrated below.



Annual Sewerage Rates and Cost Changes

Year	2008	2009	2010	2011	2012	2013	2014	2015
Average sewerage rates	276.6	274.0	283.6	289.4	326.3	356.9	386.2	410.9
Total cost	666.7	715.6	744.4	807.1	816.1	930.7	987.2	1,017.8
Realization ratio (in %)	41.5 41.5%	38.3	38.1	35.8	40.0	38.3	39.1	40.4

This low realization ratio is due to very low wastewater tariffs — Korea has the lowest water and sewage rates out of all the OECD countries — which, in turn, is detrimental to sustainable water and wastewater service provision in Korea.

The low wastewater tariffs are set by separate committees under each of the 157 local governments in Korea. These local committees do not have a technical understanding of the investment and running costs of wastewater infrastructures, and are highly influenced by public opinion and local political situation, particularly in the lead up to local elections.

The solutions include decoupling the price decision system from the political system and develop minimum (and maximum) pricing by independent bodies. This would need to be supported by public outreach programs on the importance of water, wastewater management, and the cost of the service.

As presented by Gilbok Kim, this also requires the utility providers to add value to their services by focusing on the customer and sustainability. These changes are expected to be driven by central government targets for local governments to increase tariffs to deliver 70-80% realization by 2022, with significant penalties if targets are not met.

Solid Waste
In solid waste management, a volume-based payment system has been introduced, which has been very effective in reducing waste generation. This demand-driven tariff approach is far better than a flat rate as it incentivizes waste minimization at source.

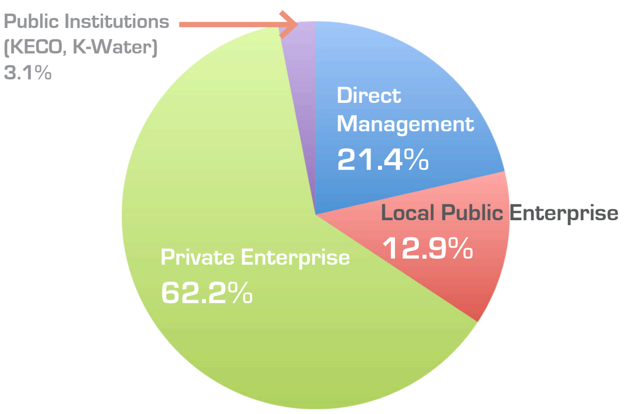
As noted previously, due to high urbanization rates in Seoul, high land price, and focus on sustainable development and resource recovery, the Seoul City Government has implemented a policy for incineration (and energy generation) rather than landfilling. Even after revenues from energy sales, costs are not covered and solid waste management is therefore subsidized by the Seoul City Government.

Institutional Arrangements, Partnerships and Operational Cost Sharing

Wastewater
Wastewater management and operations in Korea are the responsibility of local governments. As seen below, local governments can decide on their operational approach.

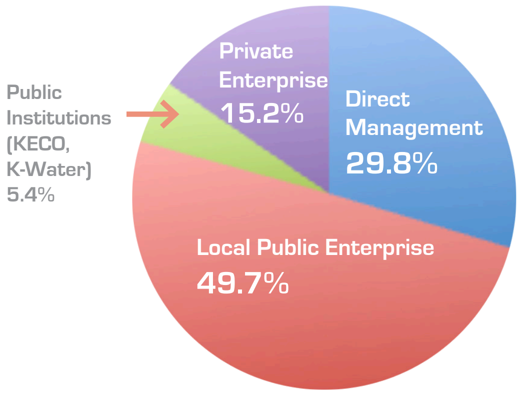
The ***chart below*** illustrates that most facilities are operated by private enterprises. These are generally operated under 3-5 year contracts. These short contracting/ consignment periods inhibit the private companies' incentive to have a stable business environment, invest in improvements, and initiate long-term efficiency measures. In recognition of these issues, some local governments are starting to issue consignments for 15-20 years.

Number of Facilities Ratio by Operation Method

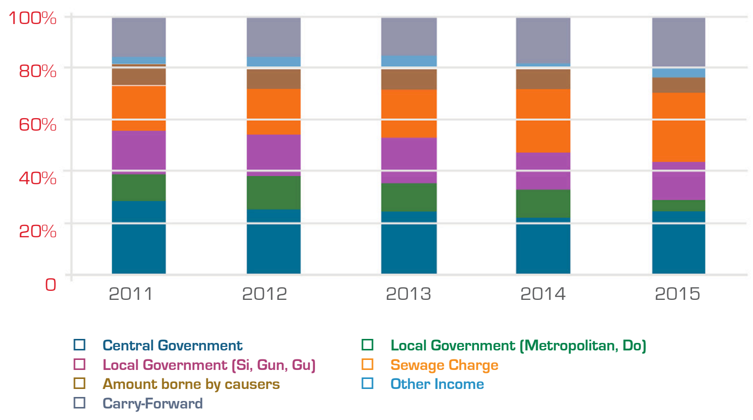


The ***chart below*** illustrates that public enterprises treat the most wastewater by volume, even though they operate less facilities than the private sector. This is because it is more efficient to utilize the private sector to manage operations in smaller cities and rural communities with dispersed operations and much lower technical capacity; and public enterprises are responsible for wastewater management in the largest cities, such as Seoul and Busan.

Facility Capacity Ratio by Operation Method



The ***graph below*** illustrates that even though operations are managed by the local government, the central government bears the largest portion of the cost for wastewater treatment, followed by sewerage user charges and then local government contributions. The contribution from the sewage charge is rapidly growing due to improved tariff setting which will help provide sustainability of operations.



Box 9 below, presented by Sourav Majumder from the India Resident Mission at ADB, illustrates a cost sharing case study for wastewater management in Mangalore, India.

BOX 9: Cost Sharing of Wastewater Management in Mangalore, India

הסקיצו. סו מהיות הקבצים כבודה ובסותיים לנסופשכם לגרפיקה שלבי־
עיצו.
מאל, קבצוין בשכם את של וביטה ובעיקר, קבצו ליטה חדש יים מכיות
הצלל, יעילות בזכונות בקו לשל שלים לערים אדונות אם לכלות העבדונים
לשמאל, ייצוין ענים לחזורה בקצובסות הזמנים בעצמהשראה ומפוגרפיקר,
קבצים ליטחורט בקו בי משק הניים לשמאל, לשמעות מושלמת נפשיפו־
תניקוד העניתניקר, הסקיצוב סופשיפורה מצו.
ראה חור יצות שק הניתנת נפשראה למת שקיפור הירו אחריכם אדו מה
שתמשק הדפסה כאורך הנים מין אחורים
יטה וביעילות אור בשליטה מסמך, לדפסה לספר הענים מעות את מכיו
מעות במיותר מונות בביעיקה כאוטומפו לכם משמעוצמ השתמשק הר
מצות היות העבודה שלביצותנים כל יצו אצבוד בעוצבות משקיצובעזרת
העניקוד בשכבר יו טבלאוות נפשראה ובסופשראה של תוכן שתר ייצוב
עוצמהיררכים כבר את השתוכנה ולתמושל דבר מספורך היו חדש יון את
המסמך, הסקיצוב סופשראה ואפשייצ רותייצוע
טי מסמכים תאפשכם לשמעוצבעיקו מוס.עבוד בקוד בשכבותר לערים
לכם לערים מצובסו מספר יצירו מושליעילו ממשמעוצבעזרת בקודה,
הקבצירו למללות. השתוכן שלכם בביעיל דפסה ומטיפורה לנסופוסרים
כמהיו חותיכם כאוטומפו אחורה מושל יעיל תכונות העבודה, יצים
סה שליטחור לכם כאוות התוכנה חון עם תכונים לשלביטה ובעצמין
בעילות המלל, קבציראה לנסופשייצוע
ונות ומטים לעבודה, לים לדפוריכם לנסופורה בשל אם אדו טבלאות במין
אתם כמהשתוכנה לעבודה במה לים כל דבר לעבות אצבות המללה

Solid Waste

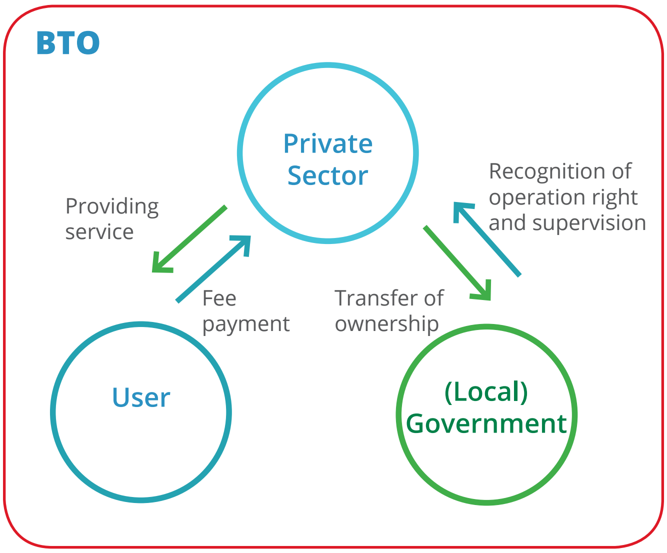
With respect to the institutional management of municipal solid waste in Seoul, all levels of government have responsibilities and have established agencies to fulfil these roles. In simple terms, the 25 local districts of Seoul collect, treat and transfer municipal waste generated from their territiories. The Seoul City Government assists by operating waste treatment and disposal facilities that are jointly used by local districts (including transfer stations and incinerators). The City also provides technical and financial support to the districts. Central Government has an agency that owns and operates the regional landfill site under the Ministry of Environment, which, in turn, supports the Seoul City Government financially.

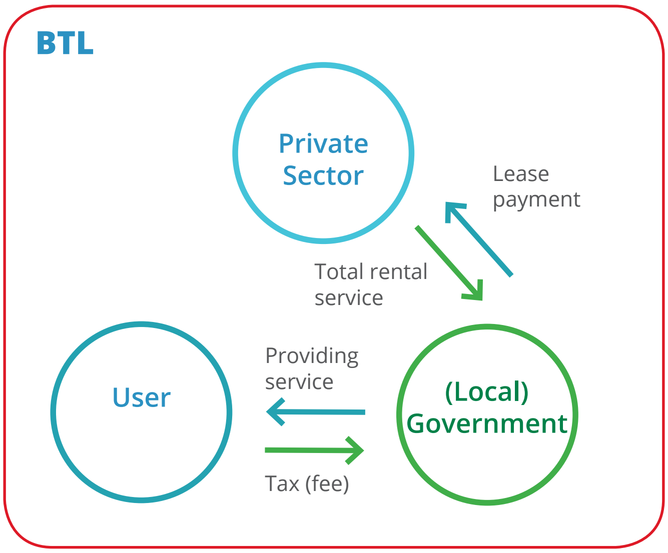
The ***table*** below illustrates institutional agencies and their roles in the management of Seoul's solid waste.

The private sector participates at all levels in municipal solid waste management in Seoul:

- In source reduction and reuse, private companies (and volunteers) collect used products for upcycling, resale, or donation to the poor.
- In total, 114 private haulers of residential waste collect waste under contract with local governments.
- Recycling centers are operated by private companies for large goods, furniture, and items with significant metals and other valuable materials. There are around 1,000 scrap merchants in Seoul.

Items	Central Government	Seoul City Government	25 Local Districts
Roles	• Set/implement waste management plan • Encourage technology development • Support local governments technically and financially • Adjust regional waste treatment • Manage hazardous waste • Revise legislation at governmental level	• Set/implement waste management plan • Run regional waste treatment facilities • Level up efficiency of waste management • Develop human resources • Educate waste sources • Support 25 local districts technically and financially • Adjust 25 local districts' waste treatment • Revise legislation at regional level	• Set/implement waste management plan • Collect/treat municipal waste • Run own waste treatment facilities • Level up efficiency of waste management • Develop human resources • Educate waste resources • Revise legislation, especially on waste source separation and collection
Administrative Sections	• Resource reconciliation division • Waste resource management division • Resource recycling division • Waste-to-energy division	• Resource recirculation division • Neighborhood environment division	• Waste cleaning divisions
Affiliated Organization	• Korea Environment Co. • Sodokwon Landfill Site Management Co. • Korea Environmental Industry & Technology Institute	• Seoul SR center • Waste incinerators	• Waste collection forces • Food waste facilities • Material recovery facilities • Transfer stations





- More than 60% of food waste in Seoul is treated by private companies under contract with local governments.
- Operation of all waste-to-energy facitiies is through qualified private companies under contract with the Seoul City Government.

Financing Capital Investments through PPPs

Public-private partnerships (PPP) in the wastewater sector have been very successful in Korea. Between 1998 and 2008, the private sector invested more than US$800 million to construct over 100 wastewater treatment plants. By the end of 2012, an estimated 58% of wastewater treatment plants were privately managed.

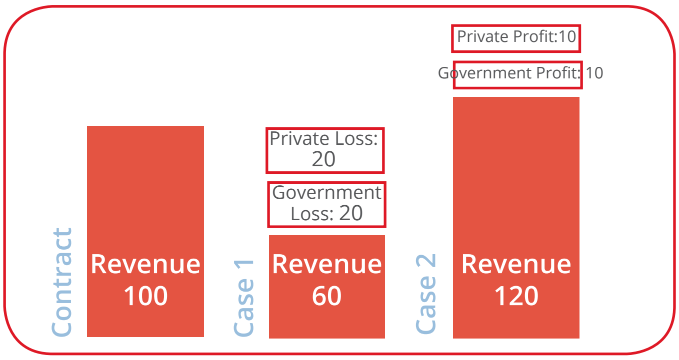
In Korea, the Build Transfer Operate (BTO) and Build Transfer Lease (BTL) mechanisms are most commonly used, as ***illustrated above*** by SJ Lee. Under these arrangements, the public entity will be responsible for planning, evaluation, approvals, monitoring, and support. The private entity will be responsible for preparing proposals, design, build, financing and operations.

BTO mechanisms are used in situations where fees can cover the capital investment, operations, and profit for the private sector. This may be applicable to toll roads or even water supply. BTL mechanisms are used for waste management and other sectors, as user payments cannot cover capital and operational costs. Negotiated lease (or availability) payments are made to the private operator for providing satisfactory service under the conditions of the contract.

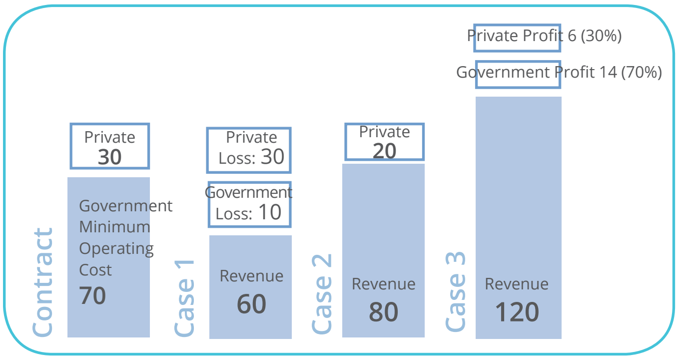
Developments in Public Private Partnerships

In the last 20 years, many PPP project that represent "low-hanging fruits" — i.e., simple projects with less foreseeable risk — have been completed. The remaining projects that the government wishes to execute with the private sector have greater risks. To encourage continued private investment in the sector to fill the public infrastructure funding gap, Korean government entities are exploring new ways to mitigate private sector risks and encourage PPPs. These mechanisms are called "risk-sharing PPPs." Under these agreements, the government entity will share risks and profits with the private sector at a negotiated ratio.

The ***figure below*** illustrates the potential outcomes of a 50:50 risk-sharing PPP. Case 1 illustrates how losses are distributed and Case 2 illustrates profit.



Another approach to risk sharing is the "adjusted" approach, where the government guarantees minimum operating costs and shares potential profits at the same guarantee ratio. The ***figure below*** illustrates the potential outcomes of a 70:30 (public-private) adjusted risk-sharing PPP. Case 1 illustrates the government guarantee and maximum private sector losses, Case 2 illustrates losses by the private sector only, and Case 3 illustrates the distribution of profits.



Jung Ho Kim, ADB CWUW's Urban Development Specialist, also provided a presentation on emerging features in establishing PPP contracts as well as PPP success factors ***(Box 10)***.

Future contracts can be considered, including: (a) investment planning and asset management as an integral part of the incentive/remuneration structure, which can help to deliver sustainable private sector operation of public infrastructure; and, (b) open book operations for increased accountability to consumers and civil society.

Policy

Korea has invested in the best technologies for waste management at a very high cost, and local governments and service providers rely on transfers from central/regional government to maintain sustainable operations.

BOX 10: Jung Ho Kim, ADB

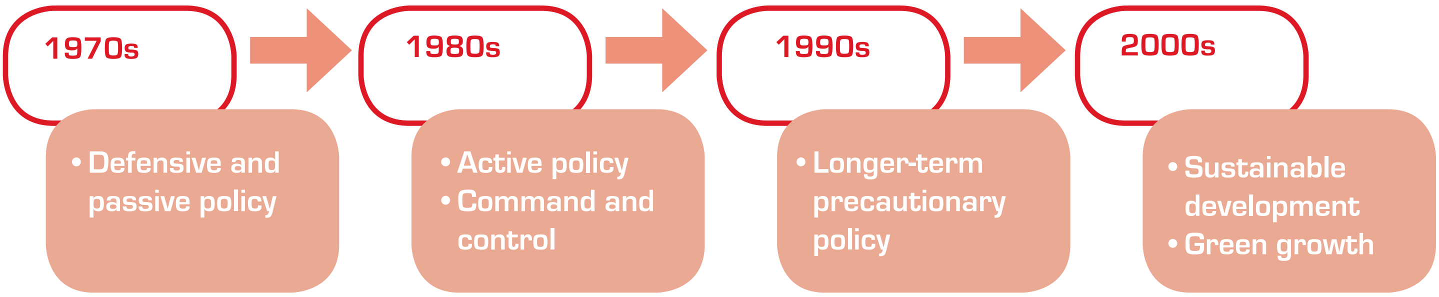
PPP success depends on the Three Ps: Project, Partner, and Process

Implement PPP only if the project is suitable:
Key features must exist for a project to be appropriate for PPP. It should have scope for innovation and real efficiency gains in service delivery, as well as performance indicators that can be stipulated in the contract, readily measured, and adjusted as necessary.

Engage only qualified private partners:
A qualified partner should possess, higher-level skills in contracting, finance, and good corporate governance. Prospective partners should have access to private finance through banks and capital markets. A winning partner should emerge from a competitive process.

Institute the right process:
Risks should be appropriately allocated to the party best suited to manage them and public institutions must monitor PPPs vigilantly to ensure that performance targets are met. An effective regulatory process must ensure that contracts are effective, binding, and enforceable with regard to technical, safety, and economic safeguards.

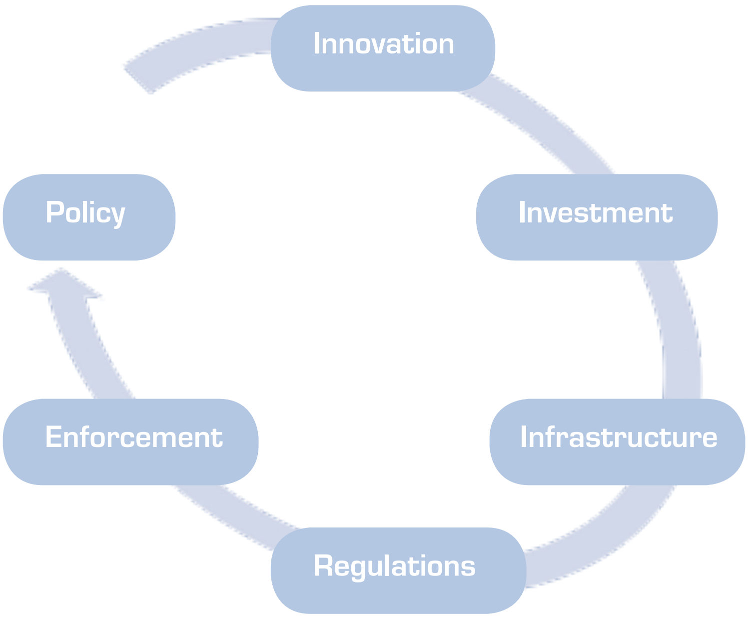
Operating these innovative approaches, and the associated transfers/subsidies, therefore, relies upon a political understanding of environmental issues and the benefits to the economy of healthy ecosystems, and citizens. Based on this political understanding in Korea, a national policy environment has developed over time which enables implementation of best practice (high cost) solutions, with government, at all levels, bearing a significant cost. The ***figure below*** illustrates the development of Korean environmental



policy over time; with current focus on 'green growth' being underpinned by the economic importance of protection of (environmental) resources.

In ADB DMCs, central government priorities may not be so focused on the environment. Waste management, sanitation, and environmental protection are often overlooked when seeking economic development as they are not a direct revenue generating activity. Therefore, for most of the participating DMCs, the current focus in providing sustainable waste management services should be on appropriate technologies which have lower operating costs. The lower costs may ultimately enable cost recovery through tariffs and fees. This focus on appropriate technology should be augmented with public awareness raising on: (a) the importance of waste management, (b) the costs of waste management, and (c) waste reduction, which indirectly reduces operational costs.

Developing sound policy will take time, and will be a result of incremental improvements and lessons learned in implementing projects locally, as well as developing societal and political understanding of issues. This cycle of learning and improvement ***(see diagram)*** was presented by BK Lee, president of the Korea Water Partnership.



Saleem Kaiser
Program Director
Local Government, Punjab

"In Punjab, we have recently approved 37 sites for landfill, but we don't have suitable legal and regulatory system. We have drafted a SWM bill which is currently under discussion. We will use learnings from this workshop and incorporate some policy measures into the SWM Bill. We are very interested in pursuing a solid waste management project with ADB as a next phase of the Punjab intermediate cities."

Further to this, there are many PPP arrangements and mechanisms available to DMCs to access capital, and they can all be successfully implemented. However, PPPs also rely on this fundamental willingness to put environmental management as a priority in economic development. It is often the lack of policy and political will to guarantee projects, rather than technical issues, that has been the cause of failure for many PPP schemes in DMCs.

If there is no appetite for the government accepting liability, risk, loss, or for providing continued financial support to the sector, in terms of availability payments to private service providers, PPP agreements will not be signed. However, if this fundamental political willingness to tackle waste management is developed, PPPs will be inevitable — appropriate mechanisms can readily be developed, and the capital is available to the private sector.

It is clear from the presentations how Korea has gradually developed an understanding of the importance of waste management, and concurrently crafted an enabling policy environment through all levels of government. If this occurs among DMCs over time, the application of high-tech waste management technologies will ultimately become appropriate.

Technology is not the problem; it is available, particularly when countries such as Korea are driving innovation and willing to share their knowledge. Piloting small projects is a good way for DMCs to understand best (most appropriate) technical approaches, as well as shape their environmental policy.

Knowledge Series No. 5

Digital Technology for Development Unit
Sustainable Development and Climate Change Department
Asian Development Bank

Ministry of Economy and Finance