Concept and Indicators of Eco-Efficient Water Infrastructure for Asia and the Pacific

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ABSTRACT: This research aims to evaluate the concept of eco-efficient water infrastructure and provides a list of case studies in order to help understand the applicability of eco-efficient water infrastructure to Asia and the Pacific. A set of indicators have been explored to assess eco-efficiency in water infrastructure for the region on a micro and macro scale. The core idea of eco-efficiency, 'more value with less impact (on the environment)', has proven to be applicable in management of water infrastructure. The fundamental elements in eco-efficient water infrastructure should encompass physical infrastructure and non-physical infrastructure, which is more needed particularly in Asian countries.

The case studies have demonstrated the applicability of the concept of eco-efficient water infrastructure. The Republic of Korea has provided the case of the eco-friendly approaches to enhance dam management and its innovative solutions how to use water more efficiently through state-of-art technologies. The experiences of Singapore are some of the best evidence to establish eco-efficient water infrastructure, for instance, the NEWater project via application of cutting edge technologies (recycled water) and institutional reform in water tariff systems to conserve water as well as enhance water quality.

A list of indicators to assess eco-efficiency in water infrastructure have been discussed, and the research presents a myriad of project cases which are good to represent eco-efficiency in water infrastructure, including multipurpose small dams, customized flood defense systems, eco-efficient ground water use, and eco-efficient desalination plants. The study has presented numerous indicators in five different categories: 1) the status of water availability and infrastructure; 2) production and consumption patterns of freshwater; 3) agricultural products and sources of environmental loads; 4) damages from water-caused natural disaster; and 5) urban water supply and sanitation. There are challenges as well as benefits in such indicators, since the indicators should be applied very carefully in accordance with specific socio-economic, political and policy contexts in different countries in Asia and the Pacific Region.

The key to success of establishment of eco-efficient water infrastructure in Asia primarily depends on the extent to which each country is committed to balancing its development of physical as well as non-physical water infrastructure. Particularly, it is imperative for Asian countries to transform its policy focus from physical infrastructure to non-physical infrastructure. Such shift will help lead to implementation of sustainable in Asian countries.

1 INTRODUCTION

The aim of this research is to explore the concept of eco-efficient water infrastructure and its applicability to Asia and the Pacific. The research conceptualizes the eco-efficient water infrastructure by discussing eco-efficiency and the significance of water infrastructure in socio-economic development. A myriad of case studies with reference to the Republic of Korea, Japan, Singapore, and Australia provide good practices in which some innovative approaches to eco-efficient water infrastructure have been adopted and implemented. In addition, the study aims to help assess the degree of eco-efficiency in water infrastructure in the region through provision of a set of indicators.

The paper consists of the three major parts. The first section of this research evaluates the concept of eco-efficiency and water infrastructure. The section not only discusses the definition of eco-efficiency but also provides the definition of eco-efficient water infrastructure with an emphasis on the duality of physical and non-physical infrastructures. The second section illustrates particular cases in relation to application of eco-efficient water infrastructure. The countries shown in the case studies are the Republic of Korea, Japan, Singapore and Australia. The third section pays special attention to the development of a set of indicators to assess eco-efficient water infrastructure.

2 CONCEPTUALIZATION OF ECO-EFFICIENT WATER INFRASTRUCTURE AND GOOD PRACTICES

2.1 Conceptualization of Eco-efficient Water Infrastructure

In terms of the concept, although the idea of eco-efficiency has been developed mostly in industrial processes, the concept is useful as one of the supplementary approaches to implement sustainable development in society. The term, 'eco-efficiency' was devised in 1991 by the Business Council on Sustainable Development (now the World Business Council on Sustainable Development – WBCSD) (Bohne, 2007; WBCSD, 2000). The new idea was the response of the business sector to discourses on sustainable development in the early 1990s, prompted by the Earth Summit in 1992. According to WBCSD, eco-efficiency can be defined as 'the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impact and resource intensity throughout the life cycle to a level at least in line with the earth's carrying capacity' (WBCSD, 2000). The term, 'eco' means both economy and ecology. Industrial entities can maximize their productivity and commercial benefits through innovations whilst such activities do not result in degrading natural resources.

Eco-efficiency has not been limited to the business sector's boundaries. The approach, 'creating more value with less environmental impacts' has been hailed not only by the private sector but also the public sector, particularly by political leaders and decision makers. A myriad of institutions in developed countries adopted such innovative approach in the 1990s, including the US Presidential Commission on Sustainable Development (US PCSD), the Organization for Economic Cooperation and Development (OECD), and the European Environment Agency (EEA) (WBCSD, 2000).

The core idea of eco-efficiency, 'more value with less impact (on the environment)', has proven to be also applicable in management of water infrastructure. The eco-efficient water infrastructure indicates physical infrastructure in water and sanitation services that adopt the sustainable processes of design, construction, operation and maintenance with less environmental impacts. The eco-efficient water infrastructure also includes institutional arrangements and policy measures that support water supply and sanitation services to entail an optimal level of water utilization and a less burden to limited water resources. This idea focuses on the life cycle of planning, design, construction, operation and maintenance of water services facilities but also of institutional measures including relevant legal, economic and regulatory instruments to manage water resources in a sustainable manner.

2.2 Good Practices

The case studies have demonstrated the applicability of the concept of eco-efficient water infrastructure. The case of the Republic of Korea shows eco-friendly approaches to enhancing dam construction and management with innovative solutions on how to use water more efficiently through state-of-art technologies and consideration of socio-economic elements. The high population density and the high seasonal variability in precipitation have pushed forward the government to opt for engineering solutions, such as small and large dams, including 16 multi-purpose dams in 2007 (Ministry of Construction and Transportation, 2007). Another technological innovation case is the reuse of treated sewerage water thanks to cutting-edge sewerage treatment technologies and a list of laws since 2001 (Ministry of Environment, 2007). In terms of non-physical dimension, the central government in Korea introduced a cascade of new institutions, including the 'Guidelines for Environmentally Friendly Dam Construction' in 2003 and the 'Environmentally Sound and Sustainable Development Guidelines for Dam Construction', in 2006. These guidelines accommodate voices from various stakeholders in water policy-making, reflect socio-economic variables and encourage local residents to set up resident councils for submitting their opinions to concerned authorities (Ministry of Construction and Transportation, 2007; Ministry of Environment, 2007).

The experiences of Singapore are some of the best evidence related to establishment of eco-efficient water infrastructure, for instance, the NEWater project via application of cutting edge technologies (recycled water) and institutional reform in water tariff systems to conserve water as well as enhance water quality. Confronted with the extreme water shortage, the government in Singapore embarked on the NEWater Study in 1998 to supplement water supply (Tortajada, 2006; Evans, 2008; Madslien, 2008). 'NEWater' is referred to as 'treated water that has undergone stringent purification and treatment process using advanced dual-membrane (microfiltration and reverse osmosis) and ultraviolet technologies.' So far four plants have been built and the water produced through the NEWater plants now accounts for about 15% (about 90 million m^3/day) and will provide 30% of the total water supply in Singapore by 2010 when the fifth plant is completed (Evans, 2008).

The rationale in institutional reform in water tariff systems is linked to adoption of demand management for optimization of water saving. Domestic and non-domestic users have to pay S$ 1.17/m^3 9US$ 0.72) at the consumption up to 40 m^3/month, and domestic users will be charged S$140 (US$0.86) at the consumption over 40 m^3/month, which is higher than the level to non-domestic users. The government has no intention to subsidize tap water supply and levies equal prices to domestic and non-domestic users. This implies the strong political willingness of the government to encourage the public to use water wisely and economically (Tortajada, 2006).

3 INDICATORS FOR ECO-EFFICIENT WATER INFRASTRUCTURE

3.1 Development of Indicators

A list of indicators to assess eco-efficiency in water infrastructure have been discussed on the basis of the previous research focusing on sustainability assessment, developed by different institutions, such as Yale University and Columbia University's Environmental Sustainability Index (ESI), and the United Nations Environmental Program's Environmental Vulnerability Index (EVI). The ESI serves as a tool to assess a society's natural resource endowments, environmental history, pollution stocks and flows, and resources extraction rates as well as institutional mechanisms and abilities to change future pollution and resource use trajectories. The ESI provides a policy-related gauge for national environmental conditions and a policy trajectory over the next several decades. Also the index can evaluate impacts and human vulnerability to environmental change and society's capacity to cope with environmental stresses (Esty et al., 2008). The Environmental Vulnerability Index (EVI) is a measurement to characterize the relative severity of various types of environmental problems suffered by individual nations. The results of the EVI are useful in devising planned solutions against negative pressures on the environment (SOPAC and UNEP, 2005).

The research presents a myriad of project cases which can be referred to as eco-efficient water infrastructure ones. These are four cases. The first case is multipurpose small dams such as the sabo dam and small hydropower plants, and the second case is customized flood defense systems including a use of structural and non-structural measures – flood storage reservoirs, diversion to adjacent watersheds, underground reservoirs, advanced flood warning and preparedness system. The third case is linked to eco-efficient ground water use, i.e. the repeated cycling framework of groundwater pumping-groundwater depletion-aquifer recharge, and the fourth example is eco-efficient desalination plants such as the plants using reverse-osmosis technology and solar power.

The term, eco-efficiency, encompasses a vision for the production of economically valuable goods and services while reducing the ecological impacts of production. Eco-efficiency can be measured with the following equation (WBCSD, 2000):

$$\textit{Eco-Efficiency} = \frac{\textit{Product or Service Value}}{\textit{Environmental Influence}} = \frac{\textit{Net Sales}}{\textit{Environmental Impacts}}$$

The environmental impact is measured through both resource use and emissions to air, soil and water (the sink side) per produced unit or activity. The reduction in ecological impacts is translated into an increase in resource productivity, which in turn can create a competitive advantage. Some examples for the elements to construct the numerator and denominator related to the equation are (Fet, 2000):

- Product or service value, including quantity of product/service produced or sold and net sales
- Environmental influence, including energy, water, material consumption and greenhouse gas and ozone depleting substance emissions

In order to assess eco-efficient water infrastructure, a list of indicators are suggested as below:

- Water related products or service values
  - Hydropower energy product
  - Water supply from desalination plants
  - Groundwater pumping
  - Wastewater treatment
  - Decrease in potential water related disaster from flood and drought
  - Net sales or investment related to the above products or services

- Environmental influence
  - Land occupancy
  - Groundwater depletion
  - Energy consumption
  - Greenhouse gas emissions
  - Potential damage to organism habitat

The assessment of eco-efficient water infrastructure is closely related to policy-making and implementation processes at the national level. In order to collect the data for the evaluation, there are five categories as follows:

- Status of water availability and water infrastructure
- Production and consumption patterns of freshwater
- Agricultural products and sources of environmental loads
- Damages from water-caused natural disaster
- Urban water supply and sanitation

Each category has a number of indicators to assess the degree of eco-efficiency in water infrastructure. It is crucial to note that there are challenges as well as benefits in such indicators, since the indicators should be applied very carefully in accordance with specific socio-economic, political and policy contexts in different countries in Asia and the Pacific Region.

3.2 Eco-Efficiency Indicators

The variables of the eco-efficiency indicators are classified into 5 categories as following based on products/services and environmental influences related to water sector; 1) status of water availability and water infrastructure; 2) production and consumption patterns of freshwater; 3) agricultural products and sources of environmental loads; 4) damages from water-caused natural disaster; and 5) urban water supply and sanitation.

The indicators associated with each category are listed up in Table 1.

Table 1. Eco-Efficiency Indicators by Categories

Category	Indicators
Status of water availability and water infrastructure	- Population - Precipitation - Evapotranspiration - Streamflow - Runoff ratio - Available water resources - Hydropower per capita - River reaches (length) managed by central government - River reaches (length) managed by local governments - Percentage of the river segments that have improved channel cross-section and embankments - Water supply and wastewater treatment plants (location, capacity, treatment type, etc) - Water use by sectors (agricultural, municipal, industrial, and in-stream flow sectors)

Production and consumption patterns of freshwater	- Regional freshwater consumption by sectors - Regional groundwater consumption by sectors - Natural mineral water consumption - Domestic product by sectors (agriculture, mining, manufacturing industry) - Hydropower energy production (MWh)
Agricultural products and sources of environmental loads	- Area of cultivated land - Farm population - Livestock (heads) - Agricultural products - Land use area - Wastewater discharge by industry - Night soil generation and treatment - Livestock wastewater - Consumption of chemical fertilizers - Consumption of pesticides - River and reservoir water quality by components (temperature, pH, DO, COD, BOD, SS, T-N, T-P, E-COLI)
Damages from water-caused natural disaster	- Flood damage (persons suffered, total damaged property and casualties, flooded area, damaged farm area) from storms and floods - Drought damage (persons suffered, total damaged property, drought area)
Urban water supply and sanitation	- Serviced population - Water supply capacity - lpcd (liters per capita per day) - Sewage treatment serviced population - Polluted water treatment serviced population - Annual water for charging and charges - Water production cost (dollar) - Sewage water for charging and charges (dollar) - Treatment cost (dollar)

4 CONCLUSION

This research has evaluated the concept of eco-efficient water infrastructure and provided a list of case studies in order to help understand the applicability of eco-efficient water infrastructure to Asia and the Pacific. A set of indicators have been explored and suggested to evaluate eco-efficiency in water infrastructure for the region on a micro and macro scale. The core idea of eco-efficiency, ‘more value with less impact (on the environment)’, has proven to be also applicable in management of water infrastructure. The fundamental elements in eco-efficient water infrastructure should encompass physical infrastructure and non-physical infrastructure, which is more needed particularly in Asian countries.

The case studies have demonstrated the applicability of the concept of eco-efficient water infrastructure. The Republic of Korea has provided the case of the eco-friendly approaches in dam management and sewage treatment services. The experiences of Singapore are some of the best evidence to establish eco-efficient water infrastructure, for instance, the NEWater project via application of cutting edge technologies (recycled water) and institutional reform in water tariff systems to conserve water as well as enhance water quality.

A list of indicators to assess eco-efficiency in water infrastructure have been discussed, and the research presents a myriad of project cases which can be referred to as eco-efficient water infrastructure ones. These are good project cases to represent eco-efficiency in water infrastructure, including multipurpose small dams, customized flood defense systems, eco-efficient ground water use, and eco-efficient desalination plants. The study has presented a number of indicators in five different categories. These are: 1) the status of water availability and infrastructure; 2) production and consumption patterns of freshwater; 3) agricultural products and sources of environmental loads; 4) damages from water-caused natural disaster; and 5) urban water supply and sanitation. There are challenges and benefits in such indicators, since the indicators should be applied very carefully in different countries in the region.

The key to success of establishment of eco-efficient water infrastructure in Asia primarily depends on the extent to which each country is committed to more emphasis on improvement of non-physical water infrastructure, such as institutions, organizations, regulatory programs, and empowerment of civil society. It is imperative for Asian countries to transform its policy focus from physical infrastructure to non-physical infrastructure. Such shift will help lead to implementation of sustainable in Asian countries.

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