# Eco-efficient water infrastructure practices in Singapore

Singapore is the island city-state with a population of 4.4 million and has suffered from water shortage. Although the country receives a vast amount of precipitation per annum (2,400 mm), the limited size of the nation's territory cannot store such amount of rainfall. The two bilateral agreements on freshwater supply from Malaysia, which will terminate in 2011 and in 2061, have not made Singaporeans comfortable, since Malaysia has attempted to increase water prices at 15-20 times higher than the current level (Tortajada, 2006; Madslien, 2008).

Confronted with such challenge, the Singaporean government has sought to achieve self-sufficient water strategies taking advantage of cutting-edge technologies in exploitation of used water. At the moment, Singapore relies on the 'four taps' in terms of water supply – the water imported from Malaysia, the water stored in its own catchment, the recycled water acquired through NEWater, and the water produced through desalination (Gareth, 2008; Madslien, 2008). Amongst such four different water supply methods, the recycled water, NEWater, has been promoted by the government as the most viable option to secure self sufficient water resources for Singapore.

The Public Utilities Bureau (PUB), which is now in charge of all the water issues in Singapore, and the Ministry of the Environment and Water Resources embarked on the NEWater Study (the Singapore Water Reclamation Study) in 1998 to supplement water supply. 'NEWater' is referred to as 'treated used water that has undergone stringent purification and treatment process using advanced dual-membrane (microfiltration and reverse osmosis) and ultraviolet technologies. The primary purpose of the NEWater project was to provide sufficient water supply for commercial and industrial uses but the water quality through the NEWater plants is regarded as good as the one for drinking. PUB has succeeded in producing high quality drinking water from NEWater blended with reservoir water after usual water treatment.[1] So far four plants related to the NEWater project have been built, and the fifth one is now under construction. 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 the city state by 2010 when the fifth plant is completed (Gareth, 2008).

In addition to NEWater, desalination has been seriously considered as an option to augment water supply to Singapore. The first desalination plant, the SingSpring SWRO Plant, began to be in operation in September 2005 with the name of 'one of the most energy efficient in the world'. The selling price of water through the plant in the first year reached US$ 0.48/$m^3$ (as of June 2008), one of the lowest records for desalinated seawater. The plant is now taking charge of 10% of the total water supply in Singapore with a capacity of 136 million $m^3$ /day, and the contribution level via desalination will increase up to 30% by 2011 according to PUB's CEO, Khoo Teng Chye. But since the cost of the recycled water (NEWater) is half the price of desalinated seawater, the major driving force for future water supply in the country is NEWater (Gareth, 2008; Tortajada, 2006).

The self sufficiency of water supply in Singapore cannot be achieved only based on engineering and technical solutions such as NEWater and desalination. The cases of

[1] About NEWater: Overview. The webpage of Public Utilities Bureau in Singapore (accessed 10 October 2008. Http://www.pub.gov.sg/newater

NEWater and desalination are good examples in terms of accomplishing eco-efficiency in water infrastructure, particularly focusing on physical water infrastructure. However, it is necessary to pay attention to enhancement of non-physical water infrastructure to achieve eco-efficiency. Singapore pursues eco-efficiency through demand management in the water sector, i.e. water tariff reform. Water services in Singapore are now charged based on three elements – water tariff, Water Conservation Tax (WCT), Water Borne Fee (WBF) and Sanitary Appliance Fee (SAF) (Tortajada, 2006).[2] The government conducted the water tariff reform to encourage Singaporeans to use water sustainably in July 2000. Now domestic and non-domestic users have to pay S$1.17/$m^3$ (US$ 0.72) at the consumption up to 40 $m^3$ /month (a uniform rate to non-domestic consumers). Domestic users will be charged S$ 1.40/$m^3$ (US$ 0.86) at the consumption over 40 $m^3$ /month, which is higher than the level to non-domestic users. This indicates that the government has no intention to subsidize tap water supply and levies equal prices to domestic and non-domestic users (Tortajada, 2006).

Such policy can be found in the collection of the Water Conservation Tax (WCT). The level of WCT in June 2000 was increased from 15% to 30% of the tariff for the first 40 $m^3$ per month for domestic consumers and all level of consumption for non-domestic consumers. But the households which use more than 40 $m^3$ per month need to pay 45% of the tariff. Analogous to the tariff policy, the WCT policy signifies the government's will to impose sustainable water consumption through financial disincentives against overconsumption of the limited water resources. Thanks to the institutional rearrangements, the average monthly water consumption level per household in the city declined about 11 % in the period between 1995 and 2004, from 21.7 $m^3$ in 1995 to 19.3 $m^3$ in 2004. In the same period, the average monthly water bill per household doubled. This shows the evidence that demand management has had an influence on the change of consumer behavior as well as providing useful financial resources to water management authorities. The government has invested about US$ 3.5 billion in the last five years and will add the same amount to water infrastructure development and research in the next five years (Tortajada, 2006; Madslien, 2008).

To sum, the Singaporean case implies that the genuine achievement of eco-efficiency in water infrastructure requires not only the development of physical water infrastructure but also non-physical water infrastructure. The NEWater and desalination options have been adopted based on the country's strength in cutting-edge technologies and scientific innovations. Such hardware development would not have been possible without the contribution of institutional reform, such as the adoption of demand management in the new water tariff setting, i.e. removal of subsidy for domestic users. The proper water tariff system in Singapore has been, and will be a backbone to provide continuous financial support for physical infrastructure development and to encourage consumers to use water wisely. The case of Singapore can be replicated in other countries as long as those countries appreciate basic but important principles in water management – promotion of eco-efficiency in physical and non-physical water infrastructure simultaneously.

[2] Water Conservation Tax (WCT) is levied by the government to reinforce the water conservation message. Water Borne Fee (WBT) and Sanitary Appliance Fee (SAF) are statutory charges to offset the cost of treating used water and for the maintenance and extension of the public sewerage system. WBF and SAF charges are included in goods and services tax.