Effective Utilization of Unused and Renewable Energy for Greenhouse Gas Emissions Reduction: Aiming at Sustainable and Environmentally Compatible Waterworks Services

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Abstract: Utilizing unused energy and renewable energy will greatly contribute not only to reduction of CO2 emissions but also to economic benefit. To keep a balance between capital expenditure for energy saving and water rate will achieve social responsibility as a public enterprise, and realize sustainable and environmentally friendly waterworks services.

Keywords: unused energy; renewable energy ratio; capacity factor; feed-in tariff system

1. Introduction

The Paris Agreement set the long-term goals of holding the increase in the global average temperature to well below 2℃ above pre-Industrial levels and pursuing efforts to limit the temperature increase to 1.5℃ above pre-Industrial levels. This means that we aim at achieving a balance between anthropogenic emissions by sources and removals by carbon sinks of greenhouse gases in the second half of this century. The Sustainable Development Goals (SDGs) also included targets such as mitigating climate change and improving energy efficiency. The reduction of greenhouse gas (GHG) emissions to prevent global warming and to mitigate climate change is now a common challenge all over the world. Unless countries urgently work to control GHG emissions, it will be impossible to satisfy the goals of the Paris Agreement or the SDGs.

Tokyo Metropolitan Waterworks Bureau (hereinafter, referred to as "TMWB") is the fundamental lifeline supporting Tokyo, capital of Japan. TMWB is responsible for supplying the best quality water stably. However, the waterworks services have no small impact on the global environment through its activities such as intake, purification, and distribution of water, a vital resource for humankind.

Under this situation, TMWB has been taking effort to reduce GHG emissions in order to contribute to the mitigation of climate change, with its sound and steady business operation. In 2015, TMWB formulated the "Ten-Year Plan for Energy Efficiency"[1], which aims to achieve energy conservation through the use of highly efficient machinery while maintaining a stable supply of tap water with good quality. This plan also aims for the installation of 10,000 kW of photovoltaic (PV) power generation by 2024, and the expansion of renewable energy ratio of TMWB's energy mix.

This paper provides effective ways of utilizing unused energy and renewable energy to tackle reduction of CO2 emissions in waterworks services.

2. State of TMWB energy usage and energy-saving measures

Large amounts of energy are required to provide waterworks services. In 2016, the amount of energy consumption was approximately 8.2 PJ, which is equivalent to CO2 emissions of 406 thousand ton, and 96% was due to the emission by the use of electricity (Figure 1). TMWB consumes approximately 800 GWh of electricity annually, which accounts for approximately 1% of the total amount of power use in Tokyo. More than 90% of electricity usage is to operate the facilities for water purification, transmission, and distribution (Figure 2). Therefore, cut-down on electricity usage in these processes is inevitable to reduce CO2 emissions.

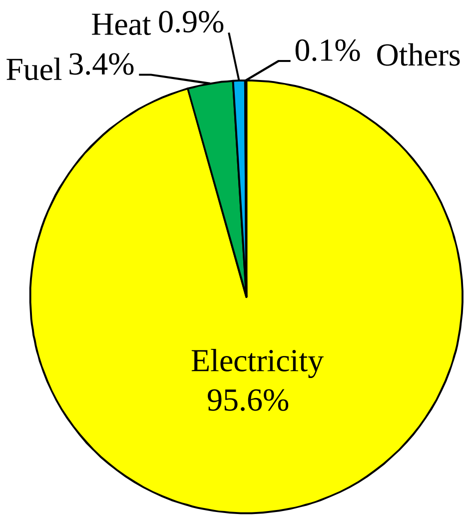

Figure 1: CO2 emission factors

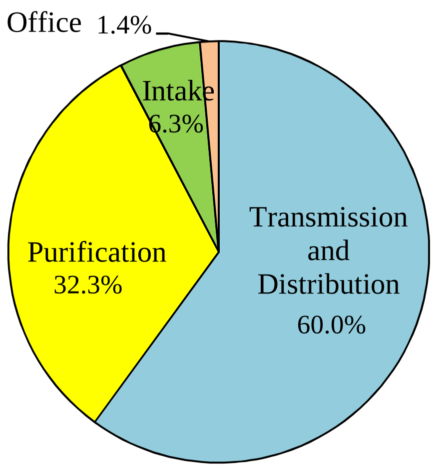

Figure 2: Sources of electricity usage

There are two unique characteristics in water purification, transmission and distribution in Tokyo. One is that we have adopted an advanced water purification method, which combines ozone contact and biological activated carbon absorption to remove musty odor in the river water. The other is that pumping to transmit drinking water is indispensable in Tokyo because of the differences in elevation between purification plants and water supply stations (Figure 3). Ozone generators (Figure 4) necessary for the advanced water purification and motors for pumps require a significant amount of electricity.

As a result, the energy consumption inevitably increases in order to provide high-quality drinking water stably. A way out of this dilemma is to improve energy efficiency by facilities development. From 1950s to 1960s, during the period of rapid economic growth, TMWB constructed purification plants one after another so as to meet increasing water demand. These plants are now aging and approaching a renewal period. TMWB plans to replace and rearrange these plants in order to take maximum advantage of potential energy (Figure 5) that has been unused, such as small-scale hydroelectric power that utilizes differences in elevation between reservoirs and purification plants (Figure 6), and gravity flows through water purification, transmission or distribution processes (Figure 7). This arrangement will result in reducing energy consumption effectively and efficiently.

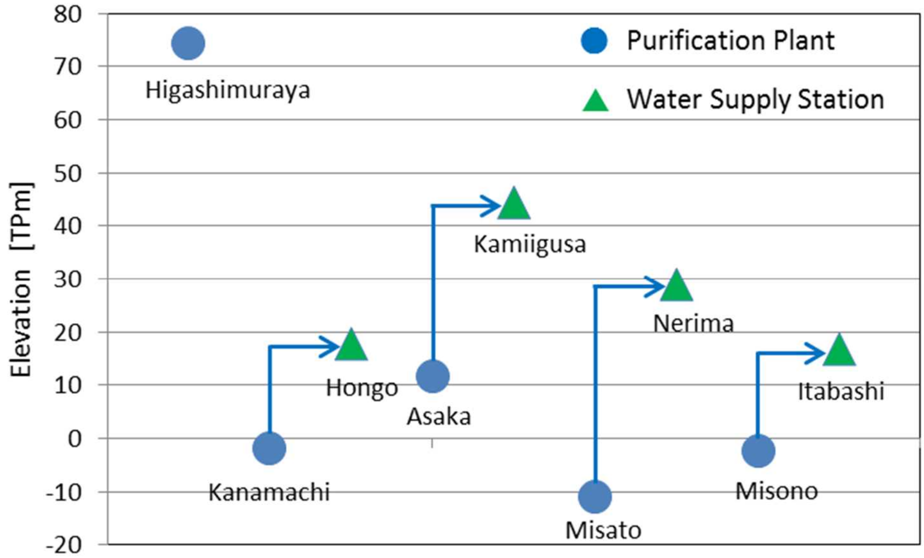

Figure 3: Differences in elevation between water purification plants and water supply stations

Figure 4: Ozone generator

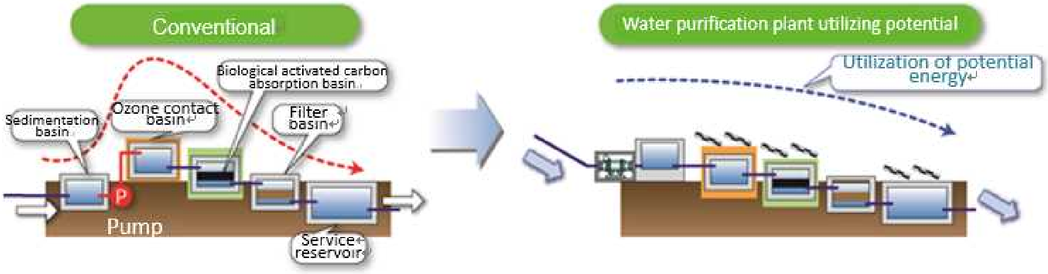

Figure 5: Water purification plant utilizing potential energy

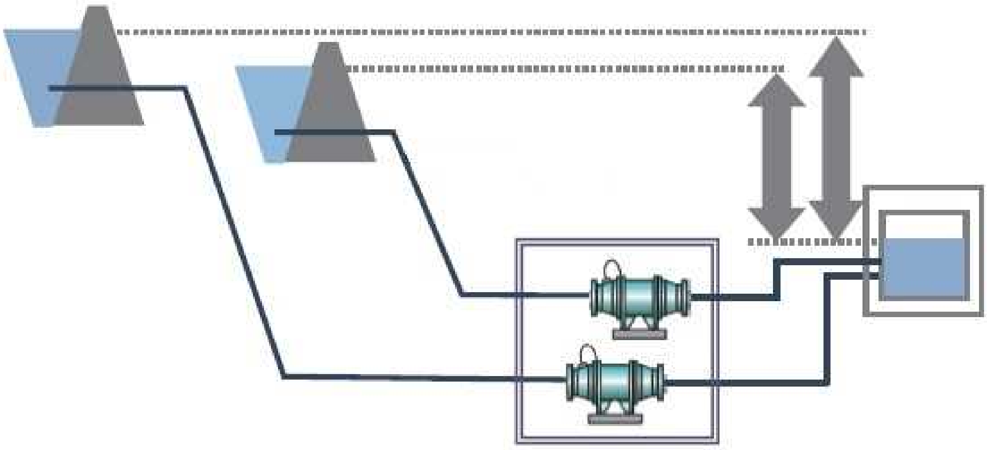

Figure 6: Small-scale hydroelectric power generation utilizing altitude differences

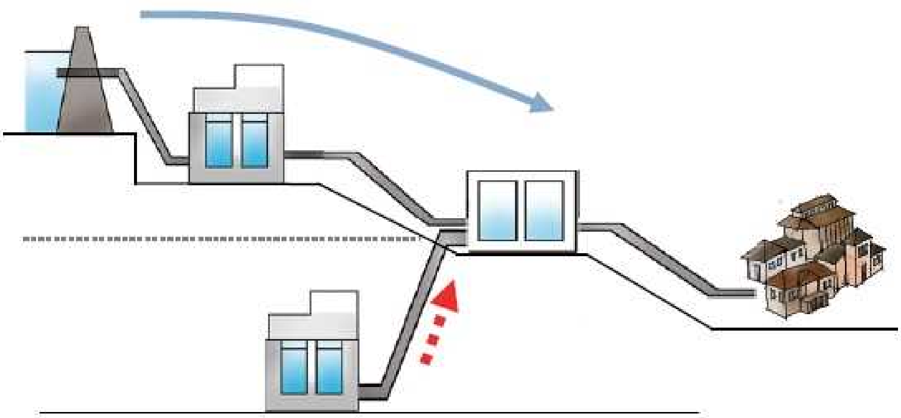

Figure 7: Water transmission utilizing gravity flows

3. Challenges and solutions in renewable energy use

In order to cut down CO_2 emissions, TMWB has been positively adopting renewable energies (Figure 4). The annual amount of power generation was 14 GWh in FY 2016, and this was almost equivalent to the amount of the reduction of CO_2 emissions of approximately 7,000 ton. However, this accounts for only 1.8% of the total amount of CO_2 emissions from our activities. TMWB purchases almost all electricity from electric power companies, and therefore, amount of CO_2 emissions greatly depends on power generation conditions of the electric power companies. Power companies' CO_2 emission factors drastically increased after nuclear power plants were shut down due to damage from the Great East Japan Earthquake in 2011. Under the cap-and-trade system which is employed by Tokyo Metropolitan Government, emission factors are revised every five years. In 2015, after nuclear power plants' accidents, the emission factor rose by approximately 30%. As a result, the amount of CO_2 emissions of TMWB increased by 30%, while electricity consumption remained flat (Figure 8). In order to avoid such uncontrollable CO_2 emissions, it is necessary to lower reliance on purchased electricity. This indicates that it is effective for reduction of CO_2 emissions to avoid such uncontrollable CO_2 emissions and eliminate external factors by increasing Renewable Energy Ratio, the usage of energy from renewable energy sources as a percentage of total energy usage. However, as capital source of waterworks services depends on the revenue from water rate, it is difficult to value only advantageous aspects of environmental efforts without ample concern for cost-effectiveness. We must recover investments so as not to make an impact on water rates.

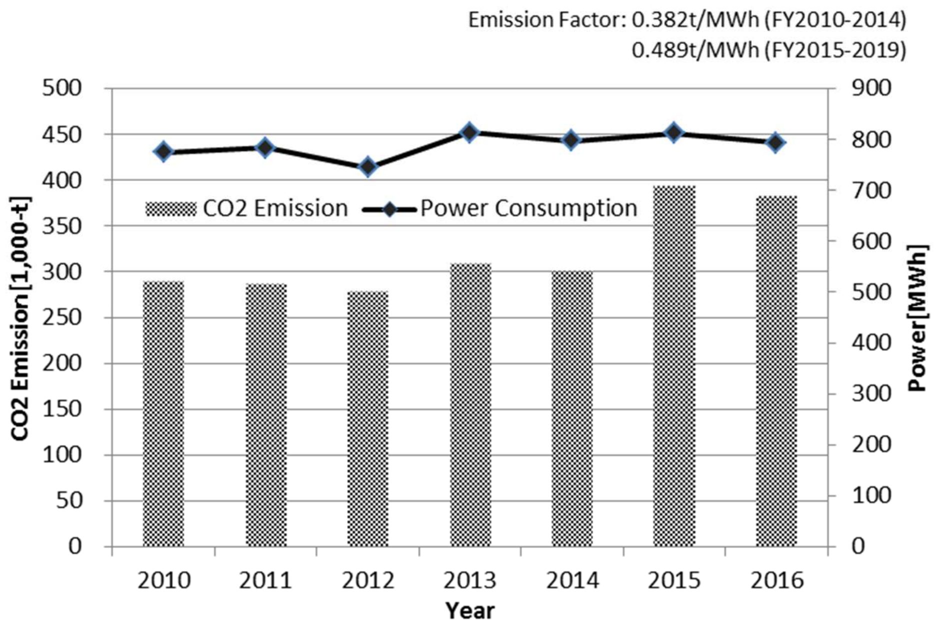

Figure 8: CO_2 emissions and power consumption

PV power has great potential because it can be set up anywhere there is space. TMWB has installed PV generators at filter basins, distribution reservoirs, and other open spaces at purification plants and water supply stations (Figures 9, 10). However, TMWB is now faced with three tough challenges.

Figure 9: PV systems installed at a distribution reservoir

Figure 10: PV modules installed over filter basins

One challenge is that the PV power generation cost is still high in Japan. It is approximately twice that of other countries.[2] Japanese power producers tend to choose modules made by Japanese manufacturers even though they are expensive than those made in other countries. This is because Japanese power producers find that Japan-made products have high-added value from the perspective of quality assurance, parts procurement, and other long-term maintenance advantages. Although quality is important to a public utility service, it can also be a cause of high costs.

A second challenge is that the capacity factor of PV modules installed at filter basins is low. TMWB has installed covers over filter basins to prevent contamination by foreign substances or poisons due to terrorism or other causes. The PV modules were mounted on these covers, so that most of them is not necessarily optimum angle to the incident sunbeam. Therefore, the capacity factor is low at approximately 7%, while that of modules installed on the top of distribution reservoirs achieve around 14%.

A third challenge is that the purchase price in feed-in tariff system has been declining. TMWB has sold electricity produced by its own PV generators. In 2012, when the system was launched, the price was USD 0.36/kWh, however the price was lowered to USD 0.16/kWh in 2018. If the price drops any lower than this, it becomes less than the electricity rates charged for purchased power, which makes it quite difficult to recover investments.

In order to resolve these challenges and earn a return on our investment, we analyzed how to lower lifecycle costs by extending the usable lifetimes of PV systems. As a result, we determined the renewal period of modules and power conditioners that makes it possible to recover the investment. In this case, it was found that PV modules should be used for 35 years and a power conditioner for around 12 years to get cost effectiveness (Table 1). As there are actual solar panels that have been in use in Japan for around 35 years, and the TMWB itself had used power conditioners for a 12-year period, these could be called realistic figures. However, low capacity factors such as modules installed on the covers of filter basins make it difficult to expect a good return on the investment. Therefore, it is essential that we extend the lifetimes of PV systems as well as improve capacity factors.

Renewal Period [Year]		Expenditure and Income [USD/kW]	
PV Module	Power Conditioner	Distribution Reservoir	Filter Basin
		Capacity Factor 14%	Capacity Factor 7%
20	10	-2,050	-3,934
30	10	-674	-3,499
35	12	554	-2,755
40	20	1,564	-2,204

Table 1: Cost effectiveness based on the renewal period of the PV system

In order to continue implementing PV power generation systems in the future, it is essential that TMWB, as a public utility, should choose a viable method to improve cost effectiveness. TMWB will pursue lower power generation costs by adopting competitively priced foreign-made modules while focusing on quality of them. TMWB will also improve capacity factors and lower lifecycle costs by extending lifetimes and lengthening maintenance cycles. In addition, it should be considered to privately consume electricity generated in TMWB’s plants instead of selling it.

4. Conclusion

Effective usage of unused energy and renewable energy will greatly contribute not only to the reduction of CO2 emissions, but also to economic benefit, such as decrease in electricity costs. It is the social responsibility for a public enterprise to strive on reduction of GHG emissions, which has been a global issue. Improving energy efficiency is a target of the SDGs. Meanwhile, another important target of the SDGs is universal access to safe, affordable drinking water for all. Our mission at TMWB is to continue providing a stable supply of tap water to sustain the lifestyles of 13 million city residents and maintain Tokyo's functionality as the capital city of Japan. As energy-saving measures require corresponding capital expenditure, we must consider cost-effectiveness in order not to have significant impact on water rate. The key to a good balance of business management and environment conservation is how to expand the utilization of unused energy and renewable energy. Reconstruction of old facilities is the golden opportunity to utilize unused energy for energy saving. PV systems should be used as long as possible to reduce the lifecycle cost, and improved in their capacity factors as well. These well designed projects make it possible to expand introduction of unused energy and renewable energy.

TMWB will continue to positively work to mitigate climate change and contribute to the achievement of the SDGs through energy conservation and energy creation. Moreover, we will continue maintaining a balance between investment and costs to achieve a sound and solid business foundation. Finally, these continuous efforts will realize sustainable and environmentally compatible waterworks services.

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