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Initiatives for utilizing renewable energy in water supply treatment

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Abstract

Maintaining a safe and reliable public water supply uses massive amounts of energy, prompting calls for energy saving measures. The Yokohama Water Works Bureau has established the goal of building a water supply system that is environmentally friendly by implementing a variety of initiatives, starting with efforts in renewable energy. These efforts have featured installing solar power and micro hydropower generation facilities at our purification plants and distribution reservoirs. The Yokohama water treatment facilities include purification plants based on gravity systems (Nishiya and Kawai plants) and pumped systems (Kosuzume plant). As the purification plants employing gravity systems place a smaller load on the environment, we use them as effectively as we can. When it was time to refurbish the distribution pumps, we reviewed the pump control system and identified initiatives for reducing pumped system power consumption.

Key words: micro hydropower generation, reducing power consumption, solar power generation

INTRODUCTION

Municipal water supply treatment is closely related to environmental health, in that water managers must provide a stable supply of safe and high quality water from sources embedded in natural environments. Yet, water treatment has significant environmental impact because it is very energy intensive, consuming 0.8 percent of the entire annual Japanese power output.

For that reason, the Yokohama Water Works Bureau has established a ten year plan that includes the goal of building a more environmentally friendly water supply system. In accordance with this ten year plan and its long term vision statement, the Bureau has developed the Yokohama Water Works Medium-Term Management Plan (hereon referred to as the 'Medium-Term Management Plan'). This plan covers the period between FY2012 and FY2015 and establishes three pillars that underpin the direction of our work, of which one was directed to contributing to the environment in consideration of the electric power supply and demand crisis caused by the Great East Japan earthquake (2011). Thus, working within this plan, we have advanced various initiatives, including making practical use of renewable energy. This report describes the initiatives related to renewable energy and energy saving that have been established to date at the Yokohama Water Works Bureau.

ENERGY INITIATIVES OF THE YOKOHAMA WATER WORKS BUREAU

Solar power generation

Solar power generation offers the promise of using the sun to create a perpetual supply of clean energy. However, such a system requires ample space to install solar panels. Water purification facilities typically occupy substantial areas, and so can be compatible with space-intensive solar panel

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installations. Therefore, to make effective use of the top sections of purification facilities while at the same time resolve lingering problems in each facility, we started installing solar systems at the following facilities beginning in FY2000.

Kosuzume purification plant

Kosuzume Purification Plant's filtration ponds lie close to the property boundary, leading to ongoing concern about deliberate attempts to contaminate the public water supply. Therefore, from FY2000 to FY2004, we installed cover lids over 30 of the filtering ponds, and then installed solar panels on the lids (Figure 1). Taking into consideration the use of sodium hypochlorite at the plant, we chose as the lid material fiberglass reinforced plastic (FRP), which has excellent corrosion resistance qualities, and also made opening and closing feasible by using movable lids out of consideration for maintenance work.

Figure 1 | Solar power generation equipment on filtration ponds at Kosuzume Purification Plant.

From FY2004 to FY2005 and again in FY2008, we installed FRP blackout floats in four settling ponds to prevent algae outbreaks in the ponds, and we installed solar panels on those floats (Figure 2). From FY2006 to FY2008, we installed movable aluminium lids on 20 filtration ponds, and installed solar panels on them. Moreover, in FY2009, to make effective use of a vacant wastewater treatment site, we installed horizontally mounted solar generation equipment at the site. From there on, based

Figure 2 | Solar power generation equipment on settling ponds at Kosuzume Purification Plant.

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on the Medium-Term Management Plan, we installed movable aluminium lids to four filtration ponds, and installed solar panels.

The total installed area of solar power generation equipment at the Kosuzume Purification Plant is now 11,900 m^2, breaking down as follows: settling ponds have approximately 3,300 m^2 (4 ponds), filtration ponds have approximately 7,300 m^2 (54 ponds), and the vacant wastewater treatment site has approximately 1,300 m^2 of solar panel area. This change has had other benefits as well. Indeed, by shutting out sunlight through the use of lids on top of the filtration ponds and settling ponds, the plant manages to save some 7.5 million yen (approx. USD 66,000) annually by being able to cut the amount of chemical (sodium hypochlorite) used.

Nishiya purification plant

At the Nishiya Purification Plant, the wastewater treatment facilities are adjacent to a residential area; therefore, we installed lids on the wastewater ponds to prevent the spread of odours when they occur. Then we installed solar panels on the lids. This work on the wastewater treatment facilities (thickener tanks and sludge ponds) extended from FY2006 to FY2007 (Figure 3). A total of 1,700 m^2 of solar power generation equipment has now been installed at the Nishiya Purification Plant.

Figure 3 | Solar power generation equipment at the Nishiya Purification Plant.

Kawai purification plant, 'Cerarokka'

The Kawai Purification Plant, 'Cerarokka', was the first plant in Japan to be renewed, operated, and managed under a private finance initiative (PFI). At this plant we installed solar power generation equipment on the distributing reservoir and on the roof of the membrane filtration building, and started generating power in August 2014. The installed area of solar power generation equipment at the Kawai Purification Plant, 'Cerarokka', is approximately 2,300 m^2.

Thanks to the solar equipment, the plant can meet all its daytime power needs by solar power generation during clear weather.

Table 1 shows power generation results for solar power equipment used by the Yokohama Water Works Bureau.

Micro hydropower generation

Micro hydropower generation involves making use of the energy in water flow in pipelines to generate electricity. This type of power generation is not affected by the weather, and works day and night to

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Table 1 | Solar power generation results

Purification Plant	Installation Site	Generation Capacity (kW)	Annual Output (kWh)	Installation Area (Number of Sites)
Kosuzume	Settling pond	200	228,251	3,300 m^2 (4 ponds)
	Filtration pond	522	312,195	7,300 m^2 (54 ponds)
	Vacant wastewater treatment site	270	340,572	1,300 m^2
Nishiya	Wastewater treatment facilities	180	141,628	1,700 m^2
Kawai, 'Cerarokka'		336	436,077*	2,300 m^2
Total		1,508	1,458,723	–

(From Yokohama Water Works Bureau's annual power report for FY2013 [installation areas are added as reference]).
*Results from August 2014 to July 2015.

provide stable power generation all year round. Therefore, in order to effectively use the surplus energy available at Kohoku distributing reservoir, we installed a micro hydropower generation system using a PFI in FY2006, thus making use of private-sector finance and business knowhow. This system was installed on the inflow pipe side of the Kohoku distributing reservoir, using the water supply pressure from the Kosuzume Purification Plant to generate 300 kW of electric power, with an annual energy output of approximately 1.6 million kilowatt-hours.

Following on from this, we installed micro hydropower systems at the Kawai Purification Plant in FY2009 and at the Aoyama intake station in FY2011. The micro hydropower generation system at Kawai was installed on the inflow pipes of the junction wells, making use of the difference in elevation between the Sagamihara settling reservoir and the Kawai plant to generate 270 kW of electric power. This installation is capable of supplying approximately 1.4 million kilowatt-hours annually.

The micro hydropower generation system at Aoyama source station was installed on the outflow section of the settling reservoir, making use of outflow water pressure to generate electricity. Power generation capacity is 49 kW, with an annual energy output of approximately 65 thousand kilowatt-hours.

Based on the Bureau's Medium-Term Management Plan, we installed a micro hydropower generation system at the Mine distributing reservoir in FY2014. The system generates electricity using the water pressure of the supply water moving between the Kosuzume Purification Plant and the Mine distributing reservoir. The generation capacity is 37 kW, which is expected to provide approximately 320 thousand kilowatt-hours annually. In addition, micro hydropower generation systems are scheduled to be installed at the Imai distributing reservoir in FY2015 and at the Onda distributing reservoir in FY2016.

Figure 4 shows an image of the micro hydropower generation system at the Kawai Purification Plant. Table 2 shows the rated capacities and energy outputs of the micro hydropower generation systems.

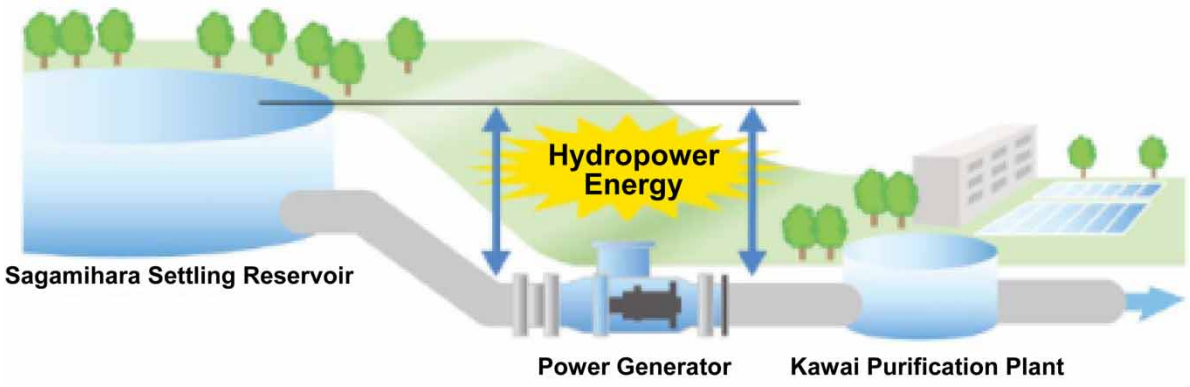

Figure 4 | An image of the micro hydropower generation system at the Kawai Purification Plant.

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Table 2 | Micro hydropower system generation results (FY2013)

Facility	Generation Capacity (kW)	Annual Energy Output (kWh)
Kohoku Distributing Reservoir	300	1,524,840*
Aoyama Source Station	49	64,946
Kawai Purification Plant	270	1,402,250
Total	619	2,992,036

(From Yokohama Water Works Bureau's annual power report for FY2013).
*From FY2013 Kohoku power plant periodic monitoring report (TEG).

Reducing power consumption

Making effective use of purification plants with gravity systems

The water supply resources of Yokohama comprise the Doshigawa River system, the Lake Sagamiko system and the Banyugawa River system. Of these, the Doshigawa River and Lake Sagamiko systems use gravity systems while the Banyugawa River system uses pumps.

The Doshigawa River system draws water from the intake dam at Abiko on the Doshigawa River, which is a tributary of the Sagamigawa upstream basin, with that drawn water going via the Aoyama settling reservoir before being conveyed to the Kawai Purification Plant. The Lake Sagamiko system draws water from the Sagamigawa upstream basin, with that drawn water then going via the Tsukui diversion reservoir, Sagamihara settling reservoir, and the junction well of Kawai Purification Plant before being conveyed to the Nishiya Purification Plant. The Banyugawa River system draws water from the intake dam at Samukawa some seven kilometres upstream from the river mouth. The water is then conveyed to the Kosuzume Purification Plant's pumping well by the Samukawa intake pump, and then pumped onto the Kosuzume Purification Plant's receiving well by the Kosuzume pump.

The purification plants employing the gravity system are being used efficiently in energy terms thanks to the differences in elevation, and considering the power consumption of the conventional pumped systems they are less of a burden on the environment. Therefore, to make optimal use of the purification plants employing gravity systems and convey water efficiently in terms of energy, we built up the facilities at the Kawai Purification Plant (running for some 50 years since start-up) in FY2013 to enable it to treat the entire volume of water that comes under the water rights for the Doshigawa River System. As the area served by plants employing gravity systems expands, we have decided to close the similarly aging Tsurugamine Purification Plant, downsize the water supply area of the Kosuzume Purification Plant (part of the pumped system), and move that water supply area to the Kawai Purification Plant. Figure 5 shows facility elevations by individual water source and Figure 6 shows the water supply area of Kawai Purification Plant.

Review of pump control system

Yokohama's topography undulates immensely with many hills and valleys, making the use of pumps a necessity in water supply. Among systems that control pump pressure, the inverter control system is extremely energy efficient in operation, so that is the system we use at the Yokohama Water Works Bureau.

Before we introduced the inverter control system, we used a pressure control system using regulating valves and a rotor resistance control system using resistors. In 2004 we adopted our current energy saving plans, and so when the pump house was due for major service and renovation, we took the opportunity to introduce a new low power-consuming inverter control system.

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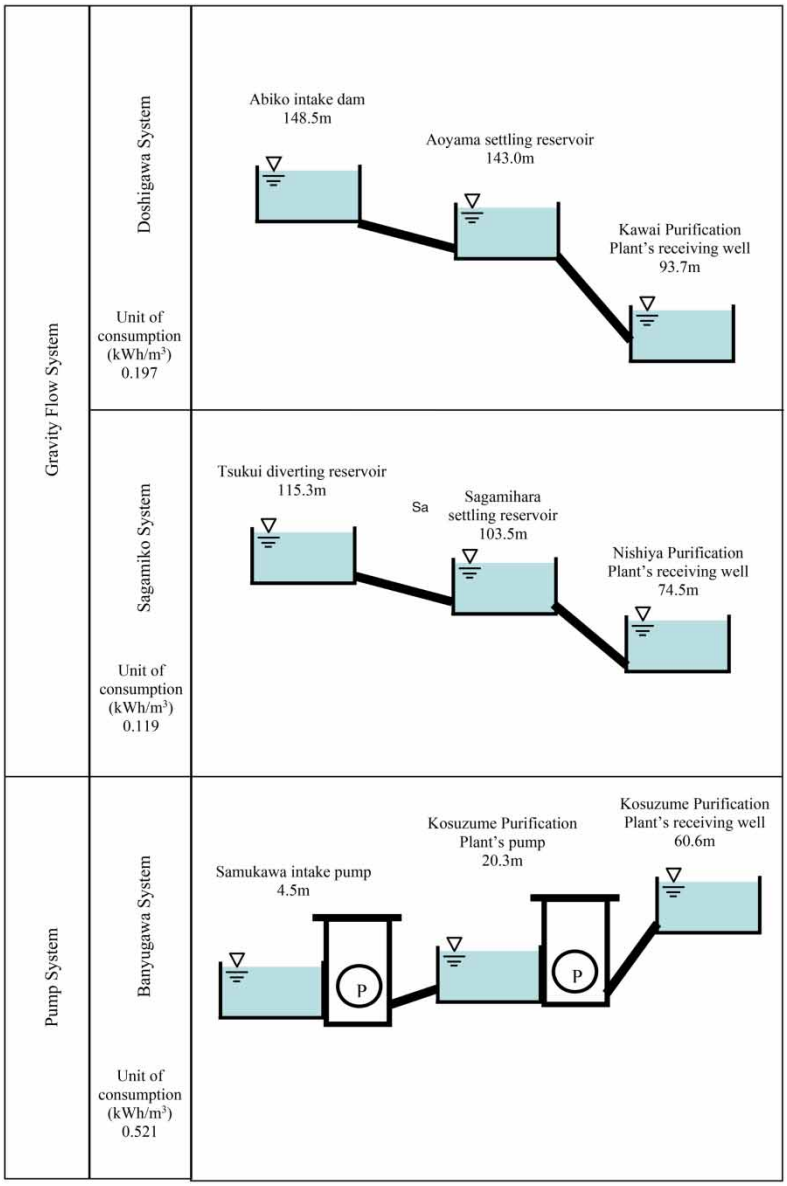

Figure 5 | Elevation and units of consumption of facilities by individual water source system (Units of consumption from Yokohama Water Works Bureau's annual power report of FY2013).

The power consumption of the pump house employing the inverter control system has been reduced by between six and 30 percent. Nevertheless, there are some issues because the inverter control system is expensive and it requires a large space for motor panels to control the many devices in the setup, while it also requires air conditioning to counter the inverter-generated heat. Yet, the system does offer the best energy efficiency.

Table 3 shows the power consumption reductions achieved due to the system renovation.

CONCLUSION

Overall, the Yokohama Water Works Bureau realized to reduce annual power consumption by approximately 6.6 million kilowatt-hours through the introduction of solar power and micro hydropower generation systems, and the new inverter control system. This amount is equivalent to reduction of 3,460 tons of carbon dioxide (CO_2) emission.

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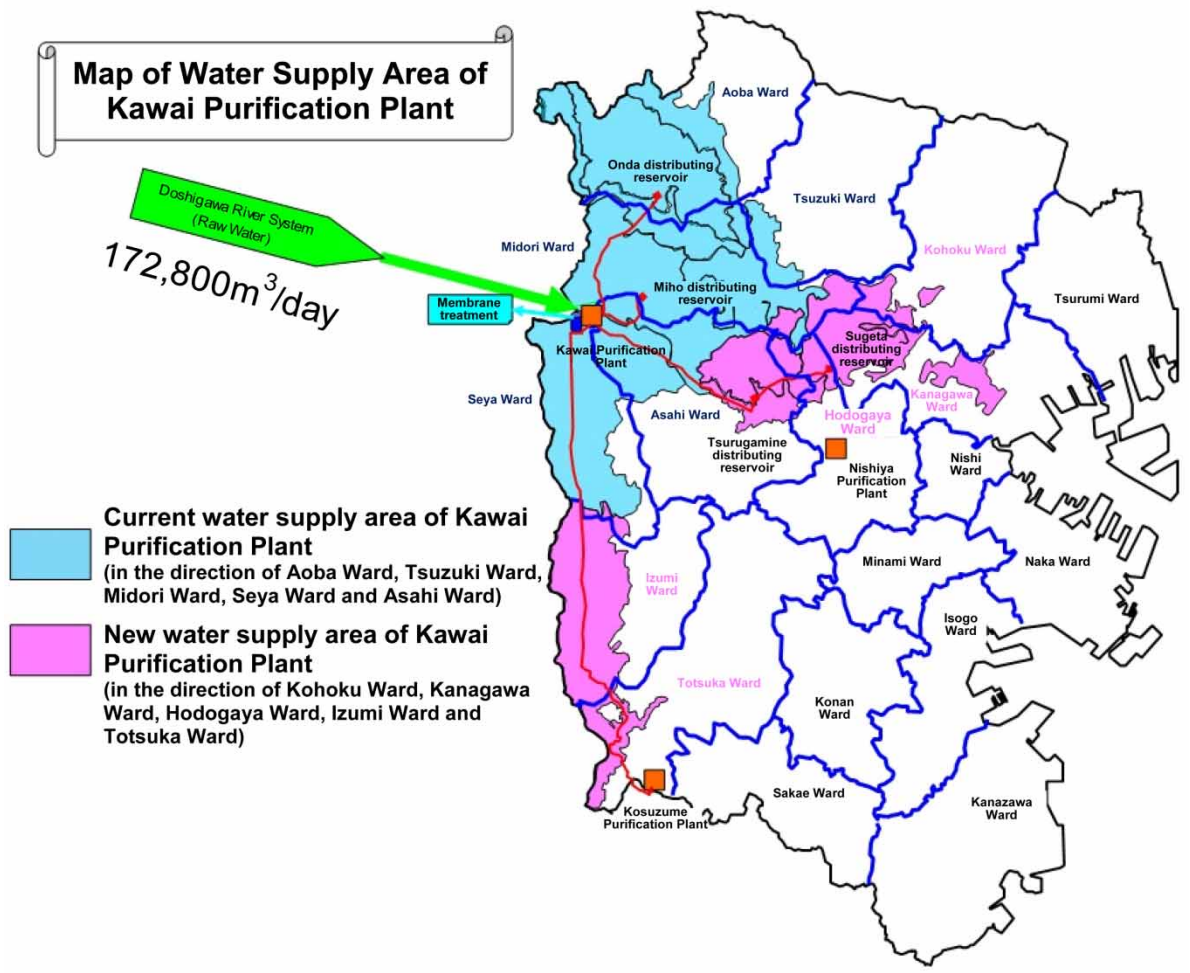

Figure 6 | Water supply area of the Kawai Purification Plant (blue denotes the area prior to build-up, and pink denotes the added area after build-up).

Table 3 | Power consumption reductions achieved by changing to inverter control system

Pump Facility		Sugeta Pump	Nishiya Pump	Kawai Pump
Fiscal Year of Renewal		FY2009	FY2011	FY2009
Energy Consumption (Annual)	Before Renewal	1,753,000 kWh (FY2008)	1,853,000 kWh (FY2010)	1,856,000 kWh (FY2008)
	After Renewal	1,213,000 kWh (FY2010)	1,542,000 kWh (FY2012)	1,749,000 kWh (FY2010)
Control System Before Renewal		Regulating valve control	Rotor resistance control	Rotor resistance control
Reduction Benefits		30%	17%	6%

This paper has summarized the progress made by the Yokohama Water Works Bureau in the introduction of renewable energy systems, and described our initiatives for reducing power consumption. While saving energy and implementing renewable energy schemes is an important goal, the highest priority of water managers must be providing a stable and safe supply of water. In addition, consideration must be given to economic efficiency, because large outlays are required for the installation of renewable energy facilities.

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We at the Yokohama Water Works Bureau will continue to promote the establishment of a water supply system that is environmentally friendly in order to achieve the goal of maintaining and developing the water supply in Yokohama. We will also work enthusiastically to contribute to solving issues in the water supply industry both at home and abroad.