Watercare
An Auckland Council Organisation

INNOVATIVE ENERGY OPPORTUNITIES FOR WATER UTILITIES

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ABSTRACT

Watercare Services Ltd is a significant user of electricity from its water and wastewater treatment processes consuming 165 GWh in 2016/17. Of this, 30% is currently generated from biogas (cogeneration) and hydro leaving some 115 GWh supplied from the national grid. This represents a significant operational cost and provides opportunities for Watercare to explore alternative energy sources including enhanced cogeneration, solar PV and battery storage. Benefits are reduced costs to serve our customers, improved system resiliency and wider environmental benefits for New Zealand.

This paper highlights the challenges of reducing operational energy costs at a large water utility and the exciting possibilities presented by ever-more affordable distributed electricity generation technologies such as solar PV and battery storage, as well as next-level wastewater treatment technologies that optimise the production and use of biogas.

Starting with a new Energy Policy in 2016, several initiatives are now underway to improve energy conservation and investigate the financial benefits of self-generation, in particular photovoltaic solar panels. Starting with several pilot projects to confirm the real-world benefits including reduced electricity costs, the initiative will create new revenue streams from the export of surplus solar electricity back to the grid and pairing with battery storage.

Although in its infancy, battery storage compliments green energy technologies such as solar, hydro and biogas by storing the generated power and controlling the release of that energy. This can be optimized to maximise revenue by exporting to the grid when tariffs are high, reduce imported electricity costs by offsetting demand and avoiding high tariff peak periods, and possibly support wider community electricity infrastructure.

Water utilities require security of supply to ensure pumping and treatment processes continue during power outages. Battery storage technologies can provide this security in lieu of using traditional diesel generators that can be operationally complex. Security of supply is also a shared common interest with electricity network companies in areas where there are known power supply issues and population growth pressures. Partnerships are being formed where there is a shared interest to jointly fund, co-locate, or prioritise use of the battery storage solution by the water utility.

There is significant potential for large electricity users such as water utilities to become more energy independent using green energy and realise a sea-change in approach where electricity supply is not simply seen as an outsourced service, but becomes a fundamental part of the business that can be channelled to drive efficiency and innovation.

KEYWORDS

Operations, Resilience, Electricity, Innovation, Green energy, Utility management

PRESENTER PROFILE

Laurence Jenner works as part of the 'Green Energy' squad at Watercare that is helping transform business practice. His background is in supply chain and he has worked in financial services, health, education and conservation. He is a passionate advocate for environmental issues regarding corporate and social responsibility and improving business efficiency.

1 INTRODUCTION

Watercare Services Limited (WSL or Watercare) provides lifeline services to Auckland. Our water supply and wastewater services are critical to the economic, social and environmental health and well-being of our communities. We supply around 360 million litres of water to the people of Auckland and treat around 460 million litres of wastewater every day. We also invest in new infrastructure such as treatment plants, pipelines, pump stations and reservoirs to maintain our levels of service and provide capacity for future population growth from a capital budget of about $350 million per annum.

Operating the water and wastewater network across the large geographic area that is Auckland requires a significant level of pumping and treatment, all of which relies on electricity. In 2016/17 Watercare consumed 165 GWh of electricity, a decrease of 5.5% from the previous year due to high levels of storage at supply lakes and therefore less need to run the Waikato WTP, which is more energy-intensive. On average Watercare can generate around 30% of its total energy use from biogas cogeneration at the Mangere and Rosedale WWTPs and from turbines located at four dams in the Hunua Ranges generating hydroelectric power. That still leaves grid-based electricity consumption of 115 GWh and energy consumption costs of around $12 million per annum.

2 OPERATIONAL CHALLENGES

2.1 INCREASED COSTS

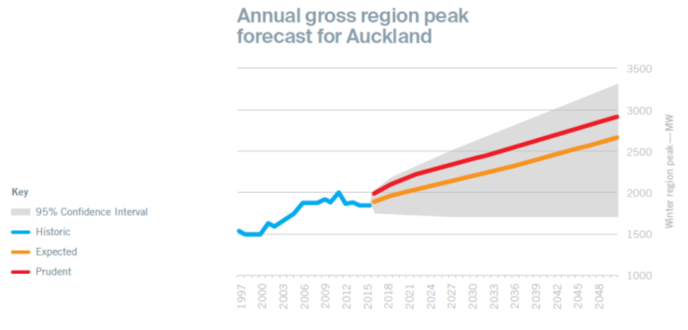
Like any business Watercare must live within its means and continually strive to seek efficiencies to deliver more with less and minimise operational expenses such as electricity. A key driver for increasing operating costs is aging infrastructure and associated maintenance costs, in particular due to facilities being expanded to meet new demand. Population increase presents a significant challenge due to the pace of growth and geographic distribution. Recent projections for Auckland indicate a population growing from 1.6 million at present to around 2.1 million in 2028 and up to 2.6 million by 2043 (Stats NZ, June 2017), necessitating increased pumping and treatment of water from the Waikato River ~30km south of the city centre, which is more energy-intensive.

New treatment plants and existing plant expansions require consenting, to enable discharges to the environment. These developments require advanced treatment approaches using UV lamp channel systems or closed reactors that consume more electricity than historically common alternatives such as treatment ponds.

Another key driver is exposure to increases in electricity market prices and demand charges. Although total national electricity consumption and electricity prices have been flat for several years the overall price trajectory is upward. Costs are forecast to increase as pressure on existing generation and transmission capacity increases due to population growth, GDP growth, the shift away from fossil fuel-based generation and the electrification of transportation.

According to Transpower's *Energy Futures* White Paper (May 2018), national electricity demand could more than double from 40 TWh per annum today to ~90 TWh by 2050 (see Figure 1 right).

Figure 1: Peak demand forecasts for Auckland to 2050
Energy Futures Te Mauri Hiko, Transpower White Paper, May 2018



With the majority of electricity generation outside of the Auckland region, it is likely that needed investments in high-voltage transmission capacity and the uncertain future of coal, gas and carbon taxes will drive up grid costs making it prudent for large consumers such as Watercare to consider all opportunities for energy conservation and cost avoidance in the design and operation of its infrastructure assets.

2.2 SECURITY OF SUPPLY & RESILIENCE

As stewards of public assets that provide lifeline services, Watercare is responsible for both the long term stability of our infrastructure as well as for ensuring resilience in the operational performance of our networks. Challenges to network resilience are both planned and unplanned. Planned service outages include routine plant maintenance by Watercare (although key sites have N-1 redundancy) as well as by key service providers such as lines companies. Changes to health and safety practices and regulations around work on live lines has resulted in more planned outages that impact operational costs, such as standby diesel generator hire and associated connection labour costs.

Service resilience and the security of supply essential services can also be tested by unplanned natural events. In early March 2017 the 'Tasman Tempest' storm dumped two months' worth of rain into the catchment that supplies most of Auckland's water supply. In addition to disruption to water treatment capability caused by large inflows of silt, downed transmission lines and the resulting electricity outages at pump stations present significant short-term challenges to sustaining levels of service throughout the wider network. It is prudent for Watercare to explore opportunities to improve service resilience and self-sufficiency for the benefit of our customers and to protect the natural environment, particularly in the face of more extreme weather events.

3 DRIVING INNOVATION

3.1 PARTNERSHIPS WITH GOVERNMENT

In 2016, EECA and Watercare entered a collaboration agreement with the Energy Efficiency & Conservation Authority (EECA) to co-fund several energy efficiency and carbon reduction activities. The purpose of the agreement is to outline how EECA can support Watercare in improving energy management and reduce emissions through knowledge-sharing and best practice. The agreement formalises the target for energy savings of 8 GWh in a new Energy Policy, representing 5% of Watercare's total electricity consumption and energy neutrality at two of our largest plants - Rosedale and Mangere WWTPs, targeting savings of 37 GWh per annum by 2025.

One of the major energy efficiency work streams to emerge from the EECA agreement is a review of the control philosophy of our pumps and pump stations. This involves reviewing the way pumps are operated as opposed to replacing the pump equipment. The aim is to reduce energy consumption and operating costs by running the pumps at their best efficiency points, as energy use is significantly increased when pumps are operated at flows greater than or less than optimum. Total energy efficiency improvements from all control systems upgrades are estimated to be 760,000 kWh per annum.

3.2 ENERGY POLICY

Effective policy development provides clear strategic direction and impetus for change. In 2016, with guidance from EECA, Watercare introduced an energy policy centred on improving energy efficiency including the key sites of Mangere and Rosedale WWTPs. The policy has since been updated to align with several United Nations Sustainable Development Goals and reaffirms our commitment to demonstrate leadership in energy efficiency and contribute to a 30% reduction in New Zealand's CO_2 emissions by 2030.

Alongside the Energy Policy a new energy team has been established tasked with monitoring and managing energy demand. This team oversees Watercare's electricity supply contracts and reverse auctions, gathers data on electricity consumption patterns and efficiency opportunities, and works with key market players to identify joint opportunities for infrastructure improvements and cost-sharing. The profile of energy as a key business input has been raised with total electricity consumption and energy efficiency initiatives now included in Watercare's Annual Report as an action area.

3.3 GREEN ENERGY TECHNOLOGIES

Green energy technologies offer exciting opportunities to realise energy efficiency improvements and operational cost savings, particularly in the area of distributed generation where end-users seek to generate and store electricity to augment the traditional centralised supply model. This includes solar photovoltaic (PV), battery energy storage systems, enhanced cogeneration using biogas (thermal hydrolysis), hydro-electric generation, real-time monitoring and control and selecting more efficient wastewater treatment equipment such as UV, blowers and diffusers. Future opportunities for Watercare and other water utilities could also include in-line hydro and wind generation.

4 OPPORTUNITIES FOR WATER UTILITIES

4.1 REDUCE RELIANCE ON GRID

The use of green energy technologies guided by a solid policy framework are enablers for innovation that allow water utilities to reduce costs, maximise asset performance and improve service delivery.

One of the biggest potential gains is to reduce reliance on the grid from using commercial-scale on-site generation. Distributed generation has numerous benefits ranging from improved resilience, lower operational costs, better return on investment from land and other assets, as well as environmental and public perception gains. Solar PV is rapidly becoming an attractive and affordable option in this space.

Once solely the preserve of NASA and space satellites, solar PV is increasingly accessible for commercial users such as Watercare and residential home owners. Advances in panel efficiency and mass production techniques over the last five years (especially out of China) has seen a dramatic fall in the cost per Watt, so that prices are now 100x less than in the 1970s (Source: www.cleantechnica.com from Bloomberg New Energy Finance 2014).

Recent supply market information obtained by Watercare shows that even in New Zealand, where long supply chains can weaken cost reductions enjoyed overseas, shows the cost per Watt for PV panels is now around 70 cents. This means that a 200 kW solar PV system delivering 275 MWh output per annum and occupying 1,700m^2 can be procured for ~$150,000 (excluding installation costs).

When combined with battery energy storage systems (BESS) solar PV can be used to power infrastructure assets during the night as well as during the day, and opens up further opportunities to shift loads and costs to off-peak times that can deliver material gains for Watercare's bottom line.

Watercare has recently initiated three pilot projects to test the real world benefits of solar PV and battery storage. A total of 370 kW of solar PV and ~230 kWh of battery storage will be deployed at Redoubt Road Treated Water Reservoir, Pukekohe WWTP and Wellsford WWTP that will help inform any future investment decisions by Watercare in these technologies.

Figure 2: Annual solar harvest (kWh)

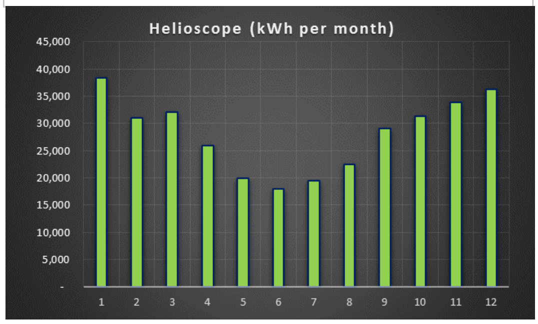
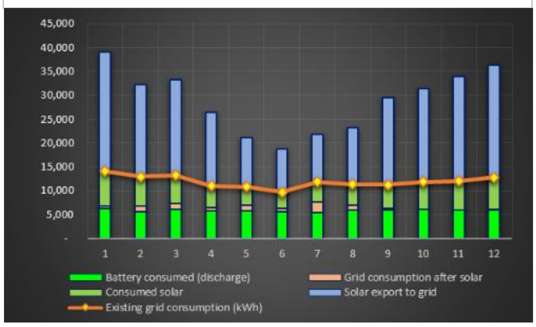


Figure 3: Consumption after solar + battery



Figures 2 and 3 (right) illustrate the forecast outputs of the 246 kW solar PV array paired with a 221 kWh Tesla Powerpack 2 at Redoubt Road Reservoir. Solar harvest is 338 MWh per annum saving up to $30,000 per annum, making the site almost 95% self-sufficient year-round and with up to five hours endurance in 'island' mode. Redoubt Road Reservoir handles up to two-thirds of Auckland's treated water each day. The pilot projects are expected to be implemented within the next six months.

By utilising the available space provided by under-utilised land, lake surfaces, disused UV treatment ponds and roof tops there is potential for Watercare to deploy up to 88 MW of solar PV covering 100ha, generating up to 130 GWh of electricity per annum and enabling us to become 79% self-sufficient in electricity.

4.2 MANAGING ELECTRICITY CHARGES

In addition to self-generation, water utilities can seek to better manage their electricity consumption profile and charges. Watercare's usage profile is made up of sites that have the following supply types:

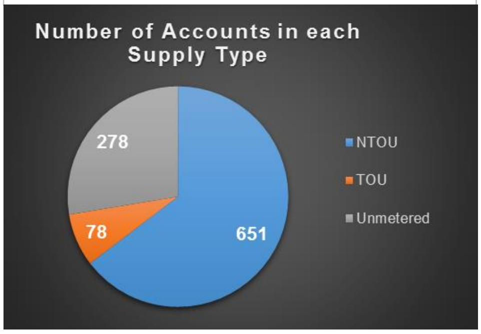
a) Time Of Use (TOU) – electricity tariff monitored half hourly with tariffs based on four hour blocks where annual usage is typically larger than 200,000 kWh;

b) Non Time of Use (NTOU) – electricity usage traditionally read monthly where annual usage is between 3,000 kWh and 200,000 kWh; and

c) Unmetered sites – sites such as water quality monitoring sites which have low usage and are charged on a fixed monthly fee where annual usage is less than 3,000 kWh.

TOU sites are typically the larger sites, production facilities and large pump stations and account for approximately 88% of Watercare's electricity expenditure. NTOU and unmetered sites are smaller sites, and although they only account for 12% of expenditure they comprise the largest volume of bill handling effort (see Figure 4 left).

Figure 4: Breakdown of accounts by type



There are ways to reduce the electricity charges and it begins with understanding the TOU pricing. Fixed price variable volume TOU tariffs typically range from 5 cents per kWh from 0000-0800 hours to 11 cents per kWh from 0800-2400 hours. Shifting energy use to partial-peak and off-peak hours could save up to 6 cents per kWh.

There is limited flexibility around changing the operation of the wastewater network due to limited storage capacity in the network and the amount of storm water infiltration. Solar and BESS can be used to reduce electricity imported from the grid during the daytime.

4.3 REDUCE PEAK DEMAND CHARGES

TOU sites are subject to demand charges imposed by the electricity network companies to cover the costs of providing enough energy to their customers. Network companies have to maintain enough generation plants "just in case" they need to supply all that energy at once. This requires them to keep and maintain a large range of expensive equipment on constant standby, including wires, transformers, and substations. Demand charges encourage customers to

a) Size the equipment appropriately to do the job – electricity demand can increase unnecessarily when equipment is larger than is required;

b) Reduce power usage during peak hours; and

c) Shift energy intensive loads from peak to non-peak hours if possible.

In the Vector network, this is calculated as the average of the 10 highest kVA demands (twice the kVAh half-hourly reading) between 0800-2000 hours (8am to 8pm) on weekdays including public holidays in any one month. The lines company demand charge is about $0.30 per kVA per day so users can end up paying for that peak demand every day of that month!

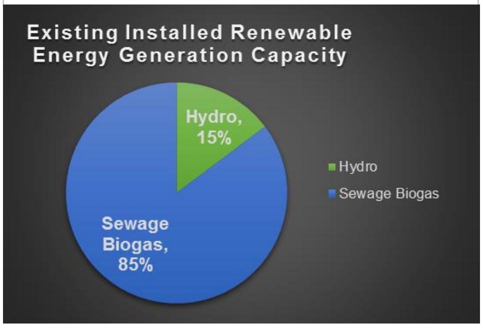
Due to limitations in the water and wastewater systems it is very difficult to move the energy intensive loads outside the 0800-2000 hour period charged by the lines company. An alternative power supply such as diesel generation, solar PV and BESS could potentially supplement the grid electricity supply for the site and therefore 'shave' the peak demand and cost. For large sites with existing installed standby diesel generators that are synchronised to the grid, running the generator during peak demand times can replace the scheduled run time that prevents the generator fuel from settling.

There is also the potential to explore capacity reductions for sites whose load reduces significantly during the night time. The capacity usually measured in kVA is the nominated demand reserved for a TOU site and is typically charged as a fixed monthly cost. BESS installed at these sites could charge at off peak times when the electricity tariff is the cheapest then power the site or supplement the grid power supply to the site during peak times reducing the required capacity and resulting in lower energy and capacity charges.

4.4 MAXIMISE GENERATION & REVENUE POTENTIAL

Watercare currently has 9.4MW renewable energy capacity installed for electricity generation at the water supply dams and wastewater treatment plants (see Figure 5 right).

Figure 5: % of existing generation capacity



The cogeneration engines at Mangere WWTP generate both electricity for the plant and heat for the digestion process and are capable of supplying up to 30% of the plant's electricity needs.

The majority of the hydro generation at two of the four dams are surplus to the site's needs. There is an opportunity to explore partnerships with local lines company to store that power in batteries to provide resilience for their customers and / or sell to an electricity retailer. There is also the opportunity to store the hydro generation in a BESS and control the timing of the release of energy to the grid to maximise revenue opportunities including during times of high spot-market electricity prices.

4.5 DEMAND RESPONSE PROGRAMME

Transpower owns and operates the national grid - the high voltage transmission network connecting areas of generation with towns and cities across New Zealand. Transpower runs a Demand Response Programme that financially incentivises an electricity consumer to reduce their electricity demand for a short period of time. This helps Transpower manage peak demand on the grid while the consumer is compensated for their involvement and will see lower charges in the long term.

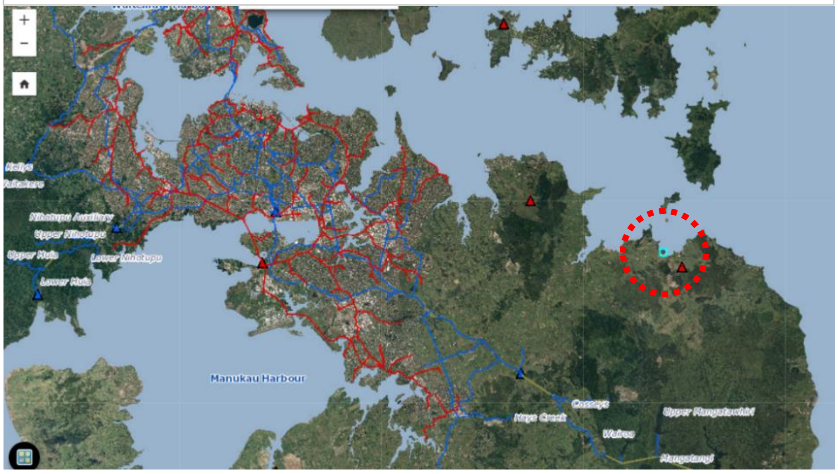
Transpower confronts similar challenges to Watercare with aging infrastructure and the pressures of increasing demand and peak demands on the system, especially in the Auckland region. The Demand Response programme is one way to manage the peaks and help defer and spread the burden of major capital upgrades. While there may be challenges in reducing demand through operational changes to our business, Watercare can still benefit financially from participating in the programme by coupling on-site solar PV generation with non-grid electricity supplies like battery storage or diesel generation to offset and shave peak demand on the grid.

There is also some potential to synchronise existing standby diesel generators to the grid as a number of them are sized for peak loads that can be more than 80% higher than the average load of the site. This presents an opportunity to generate at full capacity for demand response and receive the financial benefit of not importing from the grid and at the same time receiving a revenue for exporting more than the plant's needs. Using the generators in this way also flushes the diesel tanks, which will otherwise settle over time and require regular replacement and creates wastage.

4.6 PARTNERSHIPS WITH LINES COMPANIES

Watercare has facilities such as pump stations all over Auckland to service its customers and in some areas face power supply issues particularly during storm events. The Kawakawa Bay wastewater vacuum pump station was identified as having recurring power supply issues due to its remoteness (see Figure 6 below), which can greatly affect the local community because of the way the system operates.

Figure 6: Partnership with Vector – location of the Kawakawa Bay pump station



Typical pump stations will receive sewage through pumping or gravity and the station will then pump sewage away towards the treatment plant. This vacuum system uses pressure to pull sewage collected at multiple cesspits located around the community towards the station and then pump it to the treatment plant. During power outages, the cesspits can overflow necessitating a major clean-up to get the entire system operational again.

Alternative power supplies were investigated for Kawakawa Bay pump station. The site already had a diesel generator connection but due to its remoteness and sporadic inaccessibility during storms, getting a generator to site in time and refuelling proved problematic. Watercare approached the local electricity network company for a proposal regarding solar PV generation and battery storage. Vector responded with a proposal to co-locate a MWh-scale battery storage solution for the entire Kawakawa Bay community, which included reserved battery capacity for the Watercare vacuum pump station. Vector will own and maintain the batteries and Watercare will own and maintain the solar PV. This project is currently being implemented and will deliver cost-sharing and security of supply benefits for both parties.

4.7 REAL TIME MONITORING & CONTROL

Real time monitoring and control of solar PV and BESS is critical to leveraging these technologies and enables participation in schemes such as the Demand Response programme above. Online monitoring and control systems either via SCADA systems or by the vendor's web applications provide real-time consumption data, status alerts and programmed reserve capacity control. Integrated monitoring and control via Watercare's SCADA system is an important part of the three pilot projects being deployed.

4.8 ENHANCED WASTEWATER TREATMENT TECHNOLOGY

Reductions in energy demand at WWTPs can be achieved through process and technology changes as well as increase biogas yield and therefore self-generation. As part of the work with EECA, Watercare has developed five work streams to achieve energy neutrality at Mangere and Rosedale WWTPs.

4.8.1 AERATION REDUCTION

Aeration for the biological nutrient removal process is one of the largest energy users at treatment plants and this work stream includes trialling a shortcut nitrogen removal process that could reduce aeration requirements by 25%, thus reducing overall electricity consumption.

4.8.2 BIOCHEMISTRY OPTIMISATION

Anaerobic ammonium oxidation microbes (annamox) can significantly increase the efficiency of current treatment technologies and reduce plant electricity consumption. Work in this stream involves developing de-ammonification technology, re-assessing plant performance based on use of the bacteria and testing the production of microbial acids.

4.8.3 CARBON HARVEST

Carbon occurs naturally in wastewater and is a key player in both the biological nutrient removal process and in the generation of biogas. Work in this stream involves optimising the use of carbon without compromising on treated effluent quality and trialling increased settling to harvest more carbon from primary sedimentation tanks to increase biogas production.

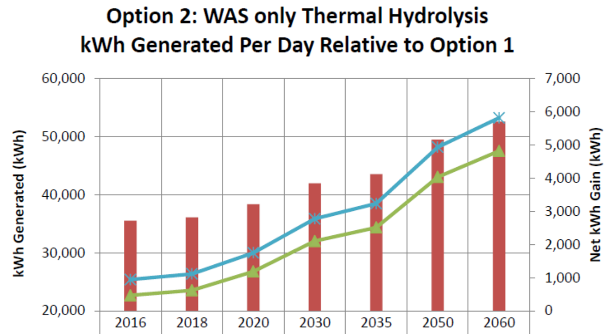
4.8.4 BIOSOLIDS & BIOGAS PRODUCTION

Biogas and biosolids are produced from digestion of solids separated during the treatment process. As well as the financial and environmental benefits, co-generation using biogas improves operational flexibility and resilience enabling the plant to function even when grid supplies may be interrupted.

Work in this stream includes increasing the biogas yield and finding new uses for biosolids through the use of thermal hydrolysis technology. The Thermal Hydrolysis Process (THP) is a wastewater treatment process that combines pressure boiling sludge followed by rapid decompression. THP supports a closed-loop approach where additional biogas production is used to improve cogeneration output and power additional wastewater treatment.

Watercare will introduce THP as pre-treatment to the waste activated sludge stream at the Rosedale WWTP as part of wider plant upgrade work. THP can enhance sludge sterilization and realise operational cost savings through improved digestion performance and sludge de-watering.

Figure 7: Expected improvements in kWh production from THP at Rosedale WWTP



	2016	2018	2020	2030	2035	2050	2060
Net Gain	2,718	2,822	3,212	3,841	4,121	5,166	5,705
Opt 1	22,647	23,518	26,765	32,006	34,345	43,048	47,540
Opt 2	25,365	26,340	29,977	35,846	38,467	48,214	53,245

In this instance THP will help defer capital upgrade costs by improving the capacity of existing digesters and reduce the need for additional digesters and pipework. Compared with a conventional digester upgrade (Option 1 in Figure 7), introducing the THP as pre-treatment to the waste-activated sludge is expected to aid digestion capacity and enable the plant to generate an additional 12% kWh per annum (Option 2 in Figure 7 above).

4.8.5 WET WEATHER TREATMENT

Storm water can inundate the wastewater network and treatment plants during periods of heavy rainfall resulting in large volumes of diluted wastewater that require more energy to aerate and pump. The fifth work stream will investigate improving plant performance and energy efficiency by identifying options to reconfigure the plant and minimise the effects and costs of storm water inflow and infiltration.

4.9 EQUIPMENT SELECTION & EVALUATION

Equipment procurement and selection methodology is another tool water utilities can use to drive savings across the business. Whole of Life Cost assessments as part of Price-Quality Methods of evaluation should be used to identify solutions that deliver the best combination of functional effectiveness, reliability, capital acquisition cost and ongoing operational cost. This approach can realise benefits across a range of equipment such as pumps, ultrafine bubble diffusers (used in aeration), blowers and UV treatment systems. The selection of next-generation UV treatment systems at Mangere WWTP is expected to reduce electricity consumption by ~3 GWh and save up to $300,000 per annum.

5 CONCLUSIONS

There is significant potential for large electricity users such as water utilities to become much more energy-efficient and realise material reductions in grid-based electricity consumption and associated costs, benefitting customers and the natural environment alike.

Green energy technologies guided by a clear policy framework are enablers for innovation that allow water utilities to reduce costs, maximise asset performance and improve service resiliency. Where there are clear shared interests, water utilities should seek to work with local electricity retailers and lines companies to investigate opportunities for cost-sharing and project collaboration.

Efforts to improve plant efficiency through the selection of energy efficient equipment, the effective use of data from monitoring and control systems and investigating enhanced treatment technologies such as thermal hydrolysis are unlikely to go un-rewarded. Similarly, exploring the advantages offered by distributed generation such as solar PV, hydro and battery storage technologies is the key to unlocking additional value from existing infrastructure and land assets.

REFERENCES

- Auckland population estimates, Stats NZ, June 2017 http://archive.stats.govt.nz/browse_for_stats/population/estimates_and_projections/auck-pop-alt-migration-2017.aspx
- Annual gross region peak forecast for Auckland, Transpower, *Energy Futures - Te Mauri Hiko*, White Paper, May 2018.
- Solar PV costs since 1977, www.cleantechnica.com from Bloomberg New Energy Finance, 2014.

NOMENCLATURE

BESS: Battery Energy Storage System.

PV: Photovoltaic or solar cells convert sunlight (photons) directly into electricity (voltage).

GWh: Gigawatt hours, a unit of electricity consumption over time (1 GWh = 1000 MWh).

MWh: Megawatt hours, a unit of electricity consumption over time (1 MWh = 1000 kWh).

kWh: kilowatt hours, a unit of electricity consumption over time (1 kWh = 1000 Watt hours).

kVA: kilovolt amps is a unit of apparent power. The primary difference between kW (kilowatt) and kVA (kilovolt-ampere) is the Power Factor that is related to losses & resistance (kVA*PF = kW).

NTOU: Non Time of Use electricity tariff usually read monthly.

TOU: Time Of Use electricity tariff monitored half-hourly.

WSL: Watercare Services Limited.

WTP: Water Treatment Plant.

WWTP: Wastewater Treatment Plant.