Delivering Sustainable Water Infrastructure

Brace H. Boyden*
Hendrik Van Rhijn
Barry Sharah

NSW Public Works Advisory
66 Harrington Street
The Rocks NSW Australia 2000

*Corresponding Author: brace.boyden@finance.nsw.gov.au

ABSTRACT

The UN sustainability Goals 6 (water) and 7 (energy) are inexorably linked; energy is required for water extraction and treatment and water is required for conventional energy production. Australia is on track to meet Goal 6 by 2030 but Goal 7 seems more elusive due to the country’s dependence on fossil fuels. The Australian Government’s Renewable Energy Target and state–based actions are now driving substantial investment in renewable electricity generation and renewables are likely to account for 23% of electricity generated by 2020.

Thirty-five per cent (35%, close to 9 million) of the Australian population resides in the state of New South Wales (NSW). Public Works Advisory (PWA) is a division of the NSW Department of Planning, Industry and Environment and assists regional local governments with water infrastructure programs and the lifecycle management of assets. Delivering water and wastewater services are energy-intensive activities. Water and wastewater service providers are large consumers of energy, often accounting for 30 to 40% of total energy consumed. Delivering sustainable water infrastructure is generally about keeping the services affordable and efficient and using renewable power sources whenever practical. Energy consumption in the water sector can be reduced by an estimated 15% by 2040 if the economically available energy efficiency and energy recovery potentials in the water sector are exploited, particularly for sewage treatment, desalination and water supply.

PV power systems (solar cells and inverters) have experienced major reductions in capital costs and have good operating load factors with water infrastructure in that the maximum power demand is very nearly at midday, when PV power generation is maximum. Experience by the PWA has shown that including photovoltaic energy in the mix with new infrastructure (water and sewage treatment and pumping) lowers operating costs with reasonable payout periods and high Internal Rate of Returns (IRRs). PV electricity not utilised and exported to the grid is best minimised and used when generated. This means matching pump motor and aeration energy demands with the varying output of PV solar systems that will change throughout the day as well as potentially disappearing altogether due to cloud cover. This process can include the use of sophisticated control algorithms and/or on-site battery storage.

A number of PWA case studies are given.

INTRODUCTION

Australia is a land rich country, the 6th largest in area, with a 2019 population of over 25 million, 55% of which live within 50 km (31 miles) of a coast. Australia contributed towards and eventually adopted the United Nations Sustainable Development Goals (SDGs) in 2015 with the other UN member states (DFAT report 2019, pp 13). Reporting on the SDG goals nationally has been allocated to specific Australian Government agencies. Goals 6 is led at the national level by Agriculture and Water Resources & Environment and Energy and Goal 7 by Environment and Energy & Industry, Innovation and Science. It can be reported that sixty-three per cent (63%) of Australian companies in the recent
past have referenced the SDGs in their corporate reporting, with 39% with plans on how to achieve specific goals (Amey and Whooley 2018).

Ensuring sustainable water management in cities and rural areas is critical to meeting Goal 6. Over the past two decades, water and sewerage service charges have more than doubled with reduced consumption to meet supply in the face of drought, which has become particularly acute for many communities by late 2019. This has worsened affordability by those who now spend more than 3% of their income on water services. Irrigation efficiency and water-saving techniques have led to a reduction in agricultural water consumption accompanied by increased productivity (Australia’s Progress Towards Goal 6).

Australia seems unlikely to meet the national target of a 40% improvement in energy productivity by 2030 due to being highly dependent on fossil fuels. The country has some of the world’s highest per capita carbon emissions in the world (Thwaites and Kestin 2015). Renewable energy makes up just 14% of the total final energy mix, 60% of that coming from hydropower (Origin Energy 2014). However, the Australian Government’s Renewable Energy Target and state–based actions are now driving substantial investment in renewable electricity generation and renewables are likely to account for 23% of electricity generated by 2020 (Australia’s Progress Towards Goal 7). The Australian Government has actively partnered with some civil society organisations on the SDGs (Parliamentary Report 2019) for Goal 17 “Partnership for the Goals”, which encourages governments to engage with non-government sectors to implement the SDGs.

About 35% of the Australian population live in the First State of New South Wales (NSW) on the East coast. Public Works Advisory (PWA) is a division of the NSW Department of Planning, Industry and Environment (previously Public Works, originally formed in 1856) and provides expert technical advisory and design services to Government Agency clients, including Local Government. PWA bridges the gap between the government and the private sector, helping clients with infrastructure programs and the lifecycle management of assets. PWA’s partnership with NSW Councils for delivering their water infrastructure is crucial to implementing the SDGs on a local level (DFAT report 2019, pp 83). A significant portion of PWA’s infrastructure portfolio is in water, sanitation and the environment, with consequential heavy involvement in SDGs 6 and 7.

Goal 6 of the SDGs is to ensure access to water and sanitation for all, and sets six specific targets by 2030. The targets of Goal 7 of the SDGs have five specific areas related to the expanded use of sustainable energy sources.

**WATER AND SANITATION INFRASTRUCTURE**

The linkages between water and energy (Goals 6 & 7) are increasingly recognised across businesses, governments and the public. The world demand growth for water has been double the rate of population growth over the last few decades. The next 25 years, water withdrawals are expected to increase by almost 10% from 2014 levels, whilst consumption will rise by over 20% over the same period. The energy sector is responsible for 10% of global water withdrawals, mainly for power plant operation as well as for production of fossil fuels and biofuels. Renewable energy (bioenergy, geothermal, concentrated solar, PV and wind) only requires 1% of the total water use for power (Water Energy Nexus 2016, pp 11-13).

Delivering water and wastewater services are energy-intensive activities. Water and wastewater service providers are large consumers of energy, often accounting for 30 to 40% of total energy consumed. The USEPA estimates 3 to 4 percent of the US national electricity consumption, equivalent to approximately 56 million MW (power), or $4 billion USD, is used to provide drinking water and wastewater services each year (Building Sustainable Water Infrastructure, USEPA). India uses 60% of the electricity consumed by its water sector just for groundwater extraction power (Water Energy Nexus 2016, pp 30). The amount of energy consumed globally for water treatment is difficult to estimate but the World Energy Outlook 2016 report (Water Energy Nexus 2016, pp 28) put together unit cost information from several sources as summarised in Table 1. Sourcing potable water from the sea is by far the most
expensive method. Although desalination and water re-use meet less than 1% of global water needs today, these processes account for almost a quarter of total energy consumption in the water sector.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Low</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groundwater Extraction</td>
<td>0.2</td>
<td>0.8</td>
</tr>
<tr>
<td>Surface Water Extraction</td>
<td>0.05</td>
<td>0.08</td>
</tr>
<tr>
<td>Groundwater Treatment</td>
<td>0.001</td>
<td>0.02</td>
</tr>
<tr>
<td>Surface Water Treatment</td>
<td>0.03</td>
<td>0.09</td>
</tr>
<tr>
<td>Direct Potable Reuse</td>
<td>0.9</td>
<td>1</td>
</tr>
<tr>
<td>Seawater (by Reverse Osmosis)</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Seawater (by Multi-stage Flash Distillation)</td>
<td>3.5</td>
<td>6.5</td>
</tr>
<tr>
<td>Seawater (by Multi-effect Flash Distillation)</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Brackish (by Reverse Osmosis)</td>
<td>0.9</td>
<td>3.5</td>
</tr>
<tr>
<td>Source Supply Distribution</td>
<td>0.2</td>
<td>0.7</td>
</tr>
<tr>
<td>Sewage Treatment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pumping</td>
<td>0.05</td>
<td>0.3</td>
</tr>
<tr>
<td>Primary Treatment</td>
<td>0.02</td>
<td>0.2</td>
</tr>
<tr>
<td>Secondary Treatment</td>
<td>0.09</td>
<td>1</td>
</tr>
<tr>
<td>Sludge Treatment</td>
<td>0.08</td>
<td>0.2</td>
</tr>
<tr>
<td>Tertiary Treatment</td>
<td>0.04</td>
<td>1.05</td>
</tr>
<tr>
<td>Transfer of Treated Water (highly variable)</td>
<td>0.001</td>
<td>90</td>
</tr>
</tbody>
</table>

Table 1. Estimates of energy requirements of water treatment.

Raw water is extracted from the environment, treated, pumped to homes and businesses and then often pumped to facilities to be treated again. Every year around the world additional treatment processes are required with greater power needs to extract potable water from non-traditional sources that can include seawater or to further purify water befouled by the practices of current society.

Concentrations of antibiotics for instance have been found above safe limits in the rivers of 47 countries across six continents that are often exploited for drinking water (Antibiotics in Water Online 2019). Polyfluorinated chemicals (PFCs), used as surfactants in a variety of industries, fire fighting foams as well as in Teflon cookware, are now known to be endocrine disruptors that bioaccumulate in humans and wildlife (Jensen and Leffers 2008). PFCs have been found in our water supplies, including 162 water systems in the USA (Trager 2017). The largest sea water reverse osmosis (SWRO) in the world has started construction to treat 909 MLD (909,000 m³/d) for the city of Abu Dhabi in the UAE and includes an accompanying 40 MW (power) PV solar field (Abengoa 2019). This challenge will be especially acute in developing countries where energy demand is rising quickly and water sources are the most polluted.

**DEFINING SUSTAINABILITY**

Conventional thinking by utilities and service deliverers concentrate on technical performance or a water quality discharge standard and the cost to meet that discharge standard. Included in their analyses are often full life-cycle costs and assessment of reliability, maintainability and accessibility. Potential innovations are varied that consider improvement to sustainability. Some are more easily implemented than others, depending on the location and existing infrastructure. Drinking water suppliers need to adopt best industry practices for water efficiency and as well as new strategies that adjust for changes in water quantity and quality.

Historically, investment has been insufficient to meet the ongoing need to maintain and renew these systems. Over the coming decades, this pattern of under investment needs to change and practices put in place to sustain the water services provided by water infrastructure and utilities. Doing so is vital to public, economic, and environmental health (Building Sustainable Water Infrastructure, USEPA).
FINANCING OF SUSTAINABLE WATER INFRASTRUCTURE

The water industry is extremely capital intensive and highly regulated, with varying water quality standards. Maintaining affordable rates is an ever pressing challenge for service providers, particularly as regulatory burdens, operational costs, and customer expectations continue to rise.

The Need

The UN High Level Panel on Water (Water Infrastructure and Investment 2016) estimated that meeting the SDG Goal 6 by 2030 will require USD1.7 trillion, such that the current capital investment will need to triple. The Business and Sustainable Development Commission (BSDC) has advised that companies should align their core strategies to the SDGs, not only because it is the right thing to do but because it is economically sensible, potentially unlocking USD$12 trillion in new business opportunities by 2030 (Better Business, Better World 2017, pp 12). Investments are needed not only in new infrastructure but also in the maintenance and operations of the existing stock to improve their efficiency and reduce water losses.

Partnerships

Water system partnerships can address a range of challenges, from water supply shortages to aging infrastructure to affordability and financial insecurity (Building Sustainable Water Infrastructure). Many different benefits achieved through collaboration were identified in this report. The most commonly cited benefits were: saving money; enhanced stature for advocacy with regulatory agencies and legislative bodies; information sharing and communication; better management of water resources across basins, sharing arrangements, and/or resulting water supply reliability; and shared operational procedures and/or models (Bielefeldt et al. 2012).

Financing Arrangements

A discussion paper from the Australian Water Association (Alternative Models 2017) considered several financing models for water infrastructure. Australian government entities own and operate approximately $100 billion in urban water infrastructure assets but in 2015 only invested 8.7% of the total national infrastructure investments on water and sanitation infrastructure. The report goes on to conclude that “Innovative funding models balance the needs of investors, governments and the community, ensuring new, sustainable water infrastructure into the future.”

WORK IN NSW AUSTRALIA

PWA projects in water and sewage/sewerage in recent years have included delivery of not only the key infrastructure for expanding populations but also components that make for more sustainable solutions. It is estimated that energy consumption in the water sector can be reduced by 15% by 2040 if the economically available energy efficiency and energy recovery potentials in the water sector are exploited, particularly for sewage treatment, desalination and water supply (Water Energy Nexus 2016, pp 6). Sewage itself has significant embedded energy that typically goes unused. The economics of extracting this embedded energy are only favourable for larger plants, usually above 50,000 EP (equivalent population). PWA have found that smaller treatment plants can benefit greatly by reducing power use from the grid through the use of renewables. NSW, like many other Australian states, is blessed with between 6 and 10+ average hours per day of sunshine (varies with geographical area, longer times away from the coast), making photovoltaic (PV) electrical generation attractive.

PV power systems (solar cells and inverters) have experienced major reductions in capital costs where payback periods can be as low as five (5) years. Treatment plants (both water and sewage) have good operating load factors to utilise PV generation on site, with the daytime operating patterns being similar to the PV generation profiles, i.e., the maximum power demand for instance is very nearly at midday. Almost all country and regional treatment plant sites are located on larger tracts of land ideal for ground mounted PV power systems. The immediate economic and environmental benefits make it easier for a Local Council to install an accompanying PV power system with new infrastructure. PWA have been
contributing to a growing trend by Local Government to capture the benefits of PV power systems. The main driver for Local Government is the simple economics of using renewable energy sources.

**Renewable Energy Target Schemes**

The Renewable Energy Target is an Australian Government scheme designed to reduce emissions of greenhouse gases in the electricity sector and encourage the additional generation of electricity from sustainable and renewable sources. It works by allowing both large-scale power stations and the owners of small-scale power systems to create large-scale generation certificates (LGCs) and small-scale technology certificates (STCs, <100kW) for every MWh (power) they generate. For small scale PV generators, an incentive/rebate scheme operated by the Federal Government allows the summation of the PV output STCs up to 2030, then sold at the time of the system’s installation to reduce the initial capital outlay. Large scale generators accumulate their LGCs over a 12 month period, then are able to sell their LGCs into the market. This creates a market that provides financial incentives to both large-scale renewable energy power stations and the owners of small-scale renewable energy systems. Certificates can be purchased by any CO₂ emitter to meet their legal obligations under the Renewable Energy Target.

Many PWA designs over the past 3 years are now moving into the operational phase following construction and others are in various stages of construction. Data is still being gathered but preliminary results are encouraging whilst also identifying additional technical components needed to capture the full benefit of PV systems for modern Sewage Treatment Plant operating practices. A series of PWA case studies are presented below.

**Case Study No. 1: Hay Sewage Treatment Plant (STP)**

Hay Shire Council is generally regarded as one of the best merino wool growing regions in Australia on the Riverine Plains. A wide variety of crops (including rice) are irrigated from the Murrumbidgee River. The Council operates the recently upgraded 3,500 EP Hay STP. A feasibility study identified that a ground-mounted grid-connected photovoltaic power system was practical and could be connected directly to the electricity grid without battery storage. The STP was estimated to have a diversified average demand of 40 kW. A 61 kW peak PV system was installed as part of the STP upgrade, comprising 192 panels at 320 W per panel. There are two arrays (Figure 1), with each array having two panels high in portrait configuration. The inverter system to convert the 48 VDC panel outputs to 230 VAC is comprised of 2 x 25 kW and 1 x 15 kW units. This installation was modelled as generating 99 MWh/year. The PV system cost was estimated at ca. $129,000 (AUD), with the STC rebate reducing this capital cost to ca. $81,000. With an average electrical cost of $0.17/kWh (AUD), the PV system would provide a saving over grid electricity of $12,700 (AUD) in the first year alone as well as reduce greenhouse gas (GHG) generation by an estimated 105 tonnes per annum. Overall the payback period was calculated at about 6 years with an Internal Rate of Return (IRR) of 15 years of 15.7%.

![Figure 1. Picture of a Hay STP PV array installation at dusk.](image-url)
The operating installation performance identified several issues. A modern day STP uses a SCADA control system that allows the operator to select different operating time sequences for the sewage treatment processes. For the Hay STP, aeration is provided by seven (7) aeration sequences per day, with the duration of each sequence controlled by the dissolved oxygen level. The aeration units are the major electrical demand for any STP, with only small pumps being used for the other operating processes, resulting in a small base electrical demand. Historical plant demand pattern has tended to be ON/OFF, resulting in periods where the PV generation is exported to the electricity grid. Exported electricity is worth approximately one third of the value compared with using the electricity at the STP.

![Figure 2](image2.png)

**Figure 2. Typical daily energy use at the Hay STP.**

*Figure 2* records energy usage and production from September 25th, 2019. The load demand over twenty-four hours is represented by the running power-demand curve that peaks when aeration is commenced. The shaded area is energy provided by the PV system. The dark grey shaded areas under the running power demand curve are those portions taken up by the PV system. The green shading between the peaks is PV electricity produced outside of the STP power demand curve that has to be exported to the grid. The PV system output does not follow a simple, smooth bell curve but has periods where the PV output suddenly falls and then recovers in response to passing clouds occluding the sun.

The PV generation will change throughout the year, reaching a peak output around January and dropping to a lower output around June each year. The STP is using about 60% of the PV generation.

A potential solution being considered to use more of the PV electricity is to add battery storage so that the stored energy is used outside daylight hours. A 600 AH battery storage system (lead acid, deep cycle) would lengthen payback period to around 7.5 years and reduce the IRR (15 years) to 10.8%.

**Case Study No. 2: Junee STP**

Junee is a medium sized town (2015 population of 6,230) in the Riverina area of NSW, about 450 km southwest of Sydney. The local economy is based on agriculture, rail transport, light industry and governmental correctional services. Junee Shire Council operates a 7,000 EP STP that was recently upgraded. The STP was estimated to have a diversified average demand of 800 kW and the area has on average 8 hours of sunlight per day. Solar panels are presently being installed in two tiers of 400 m² each (*Figure 3*). The approximate supply and installation costs to establish 97 kW peak power of solar panels was $204,000 (AUD). A government rebate brought this down to $128,000 (AUD). The PV system is expected to generate up to 60% of the STP’s electricity consumption. The PV system will shave $20k (AUD) from the first year’s electricity expenditure while delivering an IRR (15 years) of 15.9% with a projected reduction in greenhouse gas generation of an estimated 167 tonnes per year.
Based on the performance of the Hay STP, it is now anticipated that battery storage would also be useful for the Junee STP, particularly because it is a water reclamation facility with a larger operating base load demand.

**Case Study No. 3: Gundagai STP**

Gundagai is a small town of around 2,000 people 390 km southwest of Sydney. Gundagai is a popular topic for writers and has become a representative icon of a typical Australian country town. The town is administered by the Cootamundra-Gundagai Regional Council (CGRC). The STP is being upgraded to 3,000 EP from an old trickling filter plant for discharge into the Murrumbidgee River in addition to being reused for irrigation. The STP was estimated to have a diversified maximum demand of 50 kW, including the use of UV disinfection system. The installation of solar panels is being considered for this facility to help offset the power costs that a new activated sludge plant will require to meet a river discharge quality.

**Case Study No. 4: Kew STP**

Kew is a small town in the Mid North Coast region of New South Wales, Australia in the Port Macquarie-Hastings Council (PMHC) local government area. It is one of the communities that make up the Camden Haven district of Port Macquarie-Hastings. The existing STP discharges treated effluent to a neighbouring golf course and to water a tree plantation. This avoids the need to discharge into the environmentally sensitive Camden Haven River [that drains into oyster leases], except under exceptional storm flows (essentially 90% reuse). The STP is to be upgraded to 6,000 EP from population growth and the inclusion of additional drainage areas. Maintaining 90% reuse may require the addition of more irrigation area and/or the inclusion of an advanced tertiary treatment system. Regardless, allowance has been made on site for PV panels to help with the additional energy requirements of the larger STP and reuse system. PMHC has been very active with renewable energy, having installed PV systems on many of their buildings, libraries, community centres and treatment plants.

**Case Study No. 5: Wentworth to Broken Hill Pipeline – Broken Hill Pump Station**

Broken Hill is an inland mining city in the far west of outback New South Wales, Australia. It is near the border with South Australia (1,100 km west of Sydney) with a hot desert climate and an annual rainfall of just 235 mm (9"). A $467 million (AUD) long-term water supply project has recently been completed that provides water from the Murray River (433 L/s or 37.4 MLD) to the Mica Street Water Treatment Plant in Broken Hill some 270 km away. Water shortages during drought conditions caused mounting salinity and other water quality problems that this project has now alleviated. While three large, ground-mounted grid-connected 1.1 MW – 1.4 MW photovoltaic power systems (PVPS) were
originally proposed for the transfer Water Pump Stations Nos. 1, 2 & 3, the project was sourced as a Turn Key contract and the PV systems were not delivered by the proponent.

However, a fourth transfer Water Pump Station was added by Essential Water to pump from a bulk storage facility outside of Broken Hill to their Mica Street WTP in Broken Hill. This Broken Hill Water Pump Station (BHWPS) did include a large PV system of 624 kW peak from 1581 SunPower 395 W PV modules (Figure 4). The DC output is converted to AC electricity by 7 x 75 kW and 1 x 60 kW SMA Inverters. Its AC output is 510 kW.

The BHWPS commenced the commissioning process in February 2019. The operation of the pumping system is still being fine-tuned to maximise operation efficiency. Essential Energy made available the BHWPS performance energy data to assist with the learning processes of how to match the operational requirements of pumping water with the generation of a large PV system during daylight hours.

Figure 4. Aerial photograph of the extent of the 624 kW PV arrays and water storage.

The BHWPS comprises 4 identical 355 kW pumps that can operate up to 3 pumps simultaneously at full load, with the fourth pump as a standby unit. All four pumps use Variable Speed Drives (VSD) to match the water delivery demand. The grid electricity supply is taken from a 22 kV Feeder that has a 1500 kVA substation that steps down the voltage to 433V AC. A 715 kVA emergency generator is also installed that can operate in parallel with the PV system during any daytime grid outage.

Figure 5. Electricity performance of BHWPS (March 2019) when just commencing operation.
Figure 5 is energy performance for March 2019 and is intended to convey the challenges of how to fully utilise the PV output when the pumping needs may not justify pumping water during the peak period, as well as being aware that time-of-use tariffs are used in Australia. A time-of-use tariff comprises Peak periods (weekdays 7am-9am, 5pm-8pm), Shoulder periods (weekdays 9am-5pm, 8pm-10pm) and Off-Peak periods (weekdays midnight-7am, 10pm-midnight; all weekend and public holidays). While this tariff discourages operating large electrical plant during peak periods, daylight hours are when the most valuable contribution from the PV systems are available, and when the best financial offset is achievable. Further, the BHWPS can operate for up to 22 hours per day during peak water demand periods.

The graph colours are consistent for all the graphs presented for the BHWPS, the line colours representing:

- Blue (the most consistently positive demand curve) – this is the kilowatt (kW) demand of the pumps.
- Light Orange (the most negative demand curve) – this is the output of the 624 kW PV system. It is shown as negative to indicate that it is on-site generation or negative demand.
- Grey – this is the power drawn from the electricity grid.
- Dark Orange (curve that runs at zero net demand) – this is result of the Grid power minus PV power. When this line is negative, it means that the PV system is exporting electricity to the Grid.

The information being presented Figure 5 can be summarised as follows.

1. The PV system generation (this is a negative demand) follows the expected output of a bell curve. The efficiency of the PV panels are dependent on the angle of the sun in relation to the fixed PV panels. The sun’s angle towards the fixed solar arrays changes throughout the day while the sun’s changing solar altitude throughout the year has a direct effect on the PV system generation. The loss of the PV generation around 8:15am to 9:10am in Figure 5 was the result of a grid outage, where the PV system is automatically disconnected from the grid which is near to where the metering is located.

2. Only one pump is operating at this time, with pump demand being less than the PV generation, resulting in 100kW being exported to the grid.

![Water Pumping kW 14-09-2019](image_url)

**Figure 6. Electricity performance of BHWPS during September 2019.**

The energy performance for BHWPS six months later is shown in Figure 6 and is summarised below.

1. The PV system generation (light orange, most negative curve) follows the expected output of a bell curve, but interestingly the maximum output of the PV system is similar to the March peak.
2. Only one pump is operating at this time, with the VSD setting the pump speed lower than during March, resulting in a lower kW demand. It is also noticeable that the pump speed (blue line) is changing during the day. It is not known why the VSD was oscillating prior to it being switched off at 8:15am.

3. The pump demand is less than the PV generation, resulting in a major part of the PV generation (dark orange) being exported to the grid.

![Water Pumping kW 16-09-2019](image)

**Figure 7. The BHWPS electricity performance only two days later Figure 6.**

The information in Figure 7 is just two days later from Figure 6. It is apparent that the PV system generation (light orange) started with the expected smooth output of a bell curve that became irregular due to intermittent cloud cover. The draw from the grid also became irregular (grey line) to make up the required power required by the pumps (blue line). Two pumps are operating during the day, with pump demand for the period prior to 6:40am being at maximum load.

The lessons learnt from Figure 5 to Figure 7 illustrate the need for sophisticated control algorithms in lieu of battery storage to maximise the use of the PV output for its intended purpose.

**Case Study No. 6: Mid North Coast Council STP**

This Case Study presents a large PV system that can be matched to the operating demands of a larger STP of 60,000 EP. This STP has dual 1,000 kVA substations, with a split Main Switchboard that includes a bus-tie to be able to take supply from one substation during an emergency event. For this dual supply Main Switchboard, each side is separately metered. The STP also has two different generation sewage treatment plants in use, with each treatment generation connected to separate sides of the split Main Switchboard.

The PV systems planned for this site consist of a 191 kW peak ground mounted array (part of which is shown in Figure 8), whilst a 21 kW roof mounted array will be installed on a large roofed building that is also connected to the same split Main Switchboard. The system will use 340 W PV panels, with varying numbers of 25 kW inverters to transform the DC power to AC power. The system is estimated to provide saving of $47,000 for the first year, have a payback period of 6 years with an Internal Rate of Return (15 years) of 16.7% and reduce greenhouse gas emissions by an estimated 300 tonnes.
It is important in the planning stages that the system designer takes into account that there are two grid supplies on site with two baseline demands attached to each (Figure 9). The orange line (Mains 2) represents the power demands of a modern sewage treatment system with the clearly distinctive pattern of 8 aeration cycles during a 24 hour period.

The PV output needs to be distributed between the two grid supplies in order to minimise the exporting of PV power to the grid. Without the benefit of the metered consumption from smart meters that identify power usage every thirty minutes, it would be quite easy to place the 191 kW PV system on only one supply or to simply split the PV system equally over both substation supplies. A more thorough analysis (not shown) revealed that a 116 kW PV array connected to Mains 1 and a 75 kW PV array connected to Mains 2 would minimise the export of power to the grid. It is important to gather all the available demand information to correctly size PV systems for existing STPs.
CONCLUSIONS

Ensuring sustainable water management in cities and rural areas is critical to meeting SDG 6. SDG 7 is about energy efficiency and the use of renewables. The linkages between the goals are undeniable. Water is needed for energy generation and energy is needed for water extraction and treatment. Water consumption by 2039 is expected to be 20% greater than 2014 levels and the energy sector is responsible for 10% of the global water withdrawals. Renewable energy sources currently require only 1% of this water withdrawal or 0.1% of the global water withdrawal.

Delivering sustainable water infrastructure is generally about keeping the services affordable and efficient and using renewable power sources whenever practical. The innovations necessary for achieving sustainability for large and small facilities do differ as they do when applied to centralised and decentralised populations. Larger STPs for centralised populations for instance often have better economics for extracting embedded energy. Smaller STPs have to rely on selecting an efficient process and offsetting the grid power costs (and greenhouse gases) through renewables. Centralised populations with paved surfaces have plenty of issues with stormwater, whereas less decentralised populations are better able manage and exploit environmental runoff.

The case studies illustrated that for smaller STPs, the electricity demand for the newer treatment processes tends to be ON for two and a quarter hours, then OFF for one hour and a quarter hours. In order to maximise the benefits of a PV generation system, battery storage will be a necessary component of the sustainable solution. Larger STPs have larger demands that can mislead a designer into believing that a large base load exists. However, in designing the PV systems for larger STPs, an understanding of both the sewage treatment process in use together with the valuable information that is available from electricity metering and electricity accounts provides demand patterns that are critical to maximising the on-site usage of the planned PV system.

Larger water pumping stations supported with large PV systems pose difficult challenges for the designer and for operators in matching water flows with pump motor demands and with the varying output of PV solar systems that will change throughout the day as well as potentially disappearing altogether due to cloud cover.

Financing sustainable infrastructure is as varied as the potential project but can be sourced from government, banks and investor groups. The PWA assists water service providers in regional NSW with delivering their water infrastructure. Experiences to date have shown valuable benefits to the services providers when PV systems are included to reduce the demand for grid power. Payback periods of less than 7 years are common with Internal Rates of Return (IRR) greater than 13%.

REFERENCES

“Abengoa Receives the Order to Start Early Works For The Construction of the Largest Reverse Osmosis Desalination Plant of The World”, Water Online, May 13, 2019; https://www.wateronline.com/doc/abengoa-start-early-works-construction-largest-reverse-osmosis-desalination-plant-world-0001?vm_tId=2134310&user=b0391f76-4c9d-493a-b1e4-852e43936067&vm_alias=Beginning%20Work%20For%20The%20World%27s%20Largest%20Reverse%20Osmosis%20Desalination%20Plant&utm_source=mkt_WOL&utm_medium=email&utm_campaign=WOL_06-09-2019-wne&utm_term=b0391f76-4c9d-493a-b1e4-852e43936067&utm_content=Beginning%20Work%20For%20The%20World%27s%20Largest%20Reverse%20Osmosis%20Desalination%20Plant&mktt)=eyJpIjoiWVRZMFpqUTRNREJqWTJKbCIIsInQiOiJyamM1NzA2VmF1dTJRWlZ VelgybENnXXdWhSV11t0wTXtNfWxh3Nn1MbEVOeUJRUpHd2pFeUd1Y2h3WF2cJBiUlRhM2FjY0JWUnlyUlhnRk1aU3dLWGVMOWwxUEJDRu9HVVo4R3hKUGlWN0FxT1RYbkNcL3dzS0dnK2FMD08ifQ%3D%3D; accessed June, 2019.
discussion paper by Australian Water Association, 2017;

Amey, M. and Whooley, N., “Corporate Reporting on the SDGs: Mapping a Sustainable Future”,

“Antibiotics Found in Some of the World’s Rivers Exceed Safe Levels, Global Study Finds”, Water Online, May 27, 2019; https://www.wateronline.com/doc/antibiotics-found-world-s-rivers-exceed-safe-levels-global-study-finds-0001?vm_tId=2134304&user=b0391f76-4c9d-493a-b1e4-852e43936067&vm_alias=Antibiotics%20Found%20In%20Many%20Of%20The%20World%26%238217;20%20Rivers%20%26%238226%3B%20Exceed%20%27Safe%27%20Levels,%20Study%20Finds&utm_source=mkt_WOL&utm_medium=email&utm_campaign=WOL_06-09-2019-wne&utm_term=b0391f76-4c9d-493a-b1e4-852e43936067&utm_content=Antibiotics%20Found%20In%20Many%20Of%20The%20World%26%238217;20%20Rivers%20%26%238226%3B%20Exceed%20%27Safe%27%20Levels,%20Study%20Finds&mkt_tok=eyJpIjoiWVRZMFpqUTRNREJqWTJkBci5nQ1oiOjyamM1nPzA2VmFlTJRWLZVe1gybENhMZXNxdWhSV1lWSGzTNTFwWXh3Nn1MbEVOeUJ0RUPd2pFeUd1Y2h3WF2cjBiU1RhM2FjY0JWUn1yU1hNRk1aU3dLWGVMOWxUXElDRU9HVVo4R3hKUGlWN0Fxt1RYbkNcL3dzS0dnK2FMD08ifQ%3D%3D; accessed June, 2019.


Department of Foreign Affairs and Trade (DFAT), Submission 60, p. 3.; Excerpted from Parliamentary Report “Foreign Affairs, Defence and Trade References Committee, United Nations Sustainable Development Goals (SDG)”, February, 2019, pp 13.


Parliamentary Report “Foreign Affairs, Defence and Trade References Committee, United Nations Sustainable Development Goals (SDG), February, 2019, pp 103.


BIOGRAPHY

Brace Harvey Boyden

Brace is a trained chemist and Ph.D. Chemical / Process engineer and Principal Process Engineer in NSW PWA. He is a chartered engineer, a fellow of Engineers Australia, an IWA fellow and a fellow with the American Institute of Chemical Engineers. He has over 35 years of experience around the world in various aspects of wastewater, trade waste and water supply infrastructure projects. This experience includes whole city master planning and strategy studies, contract management and biological process and environmental design.

Hendrik Van Rhijn

Hendrik’s field of specialisation for the past 40 years has been the development of master plans, design, contract management, construction and commissioning of water and wastewater treatment plants and related infrastructure. The majority of his career was spent with major international consultants and contractors with his experience progressing from hands on design to project management of multidisciplinary projects.

Dr Van Rhijn has been responsible for a range of assignments for both Government and private sector clients. These have included financial and risk analysis, D&C tendering, contract management, Alliancing and acting as an Independent Engineer and Expert Witness on largely water related infrastructure projects worldwide. Hendrik has a MBA as well as a DBA which suits him well in assisting Clients with financial matters.

Before joining PWA Infrastructure Services where his role is that of Director, Water & Wastewater he had been involved in tendering and executing Water Infrastructure projects in Singapore, Malaysia, Africa, North America, Australia, NZ and Peru.

Barry Sharah

Barry Sharah’s area of specialisation for over 40 years has been in the building electrical services field, encompassing master planning and scheme designs, completing design and documentation services together with project management and other engineering services, all undertaken within the NSW public services sector.

His skillset includes an extensive understanding of electrical building systems, the establishment of energy management services during the early 1990’s, the establishment of a Whole of Government electricity contract, the early design and construction supervision of several PV systems that were part of the Sydney Olympics buildings, the development of electricity network design consulting services during the early 2000’s as well as leading the building services consulting services for the NSW Government Architects Office as its Principal Engineer.

In recent years, Barry has also specialised in the off-site electricity infrastructure solutions and the photovoltaic power systems solutions for water and sewage treatment plants for PWA Infrastructure Services. Barry has also provided electrical technical services over the past 3 years for the current $3.8 Billion prison beds expansion program of NSW Correctional Centres.