OFFICE OF ENVIRONMENT & HERITAGE

Energy Efficiency Opportunities in Wastewater Treatment Facilities

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Published by:

Office of Environment and Heritage
59 Goulburn Street, Sydney NSW 2000
PO Box A290, Sydney South NSW 1232
Phone: +61 2 9995 5000 (switchboard)
Phone: 131 555 (environment information and publications requests)
Phone: 1300 361 967 (national parks, general environmental enquiries, and publications requests)
Fax: +61 2 9995 5999
TTY users: phone 133 677, then ask for 131 555
Speak and listen users: phone 1300 555 727, then ask for 131 555
Email: info@environment.nsw.gov.au
Website: www.environment.nsw.gov.au

Report pollution and environmental incidents
Environment Line: 131 555 (NSW only) or info@environment.nsw.gov.au
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Contents

Appendices

Abbreviations

BFB	bubbling fluidised bed
BOD	biochemical oxygen demand
CFB	circulating fluidised bed
DO	dissolved oxygen
DR/DSM	demand response / demand-side management
EP	equivalent person
EnMS	energy management system
EnPI	energy performance indicator
GWh	gigawatt hour/s
HVAC	heating, ventilation and air conditioning
kL	kilolitre/s
kWh	kilowatt hour/s
L	litre/s
LRET	Large-scale Renewable Energy Target
MABR	membrane aeration bioreactor
ML	megalitre/s
MLR	mixed liquor recycle
M&V	measurement and verification
NCA	network connection agreement
PDCA	Plan–Do–Check–Act
PV	photovoltaics
RAS	return activated sludge
SCADA	supervisory control and data acquisition
SRES	Small-scale Renewable Energy Scheme
TH	thermal hydrolysis
TKN	total Kjeldhal nitrogen
TN	total nitrogen
UV	ultraviolet
VSD	variable speed drive
WAS	waste activated sludge
WSAA	Water Services Association of Australia
WWTP	wastewater treatment plant

About this guide

This guide has been developed by the Office of Environment and Heritage (OEH) for wastewater treatment plant (WWTP) operators, sustainability managers and energy managers working in government and industry. The aim of the guide is to help you find, implement and maintain energy efficiency improvements in WWTP facilities.

The guide provides information to help you to reduce energy consumption and energy costs in your WWTP. It includes a list of opportunities applicable for all types and sizes of WWTPs. These opportunities can be broadly categorised into:

- **energy efficiency** e.g. variable speed drives on pumps, blower management, process improvement
- **energy generation** e.g. cogeneration using biogas
- **energy cost optimisation** e.g. power factor control, peak load reduction, contract negotiation.

How to use this guide

- Start by reading **Section 1: Reduce your electricity costs** to learn about your site energy consumption and strategies for reducing and controlling your electricity bills.
- Detailed descriptions of the most common opportunities in WWTP are presented in:

  Section 2: Optimise your aeration and blower system

  Section 3: Optimise your pumping

  Section 4: Optimise your return activated sludge (RAS) flow rate

  Section 5: Generate heat and power from biosolids.

  The guide uses a **Plan – Do – Check – Act** (PDCA) approach to present methods for understanding opportunities and implementing energy savings. **Appendix G** provides details on how to benchmark your site and how to calculate energy use and savings.
- For additional savings, see **Appendix B** for a comprehensive list of further opportunities for reducing energy consumption in WWTP.
- Finally, see **Appendix D** for an infographic of an energy management system (based on ISO 50001) which provides a snapshot of the steps required to implement the system and ensure savings are continuously achieved.

Introduction

Treating wastewater is an energy-intensive and costly process, and a large source of both direct and indirect greenhouse gas emissions through energy use and release of methane and other gases. Treatment quality standards are tightening due to regulatory and community pressures, and this is generally imposing additional processing requirements and energy costs on plant operators.

Wastewater treatment plants (WWTPs) are also custodians of a biological process that can produce renewable energy, in some cases sufficient to supply all of a plant's energy needs. With energy prices rising and the cost of electricity for WWTPs a significant portion of a plant's total operating costs (typically 25–50%),[1] it makes sense to take advantage of energy efficiency opportunities.

Wastewater treatment is energy intensive

The energy required to treat Australia's sewage is estimated to be approximately 1000 gigawatt hours (GWh)[2] a year, which is about the same power as that consumed by 170,000 households in New South Wales[3] or 0.4% of Australia's total electricity consumption.[4]

The energy required to treat sewage varies greatly from plant to plant. Based on Australian and international data,[5,6,7] and data collected privately through energy audits, the energy required to treat 1,000,000 litres (1 ML) of sewage usually ranges from 150 to 1400 kilowatt hours (kWh). The reasons for this wide range in energy intensity include treatment type, plant size, operation requirements, and level of energy-efficiency efforts.

The Water Services Association of Australia (WSAA) benchmark study[6] indicated that for each plant type, larger plants are more energy efficient due to economies of scale. However, there is still a range of efficiencies at any given plant size.

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[1] Tennessee Energy Education Initiative April 2016, TDEC Works with Water and Wastewater Treatment Plants on Energy Efficiency: Program administered by the State of Tennessee Department of Environment and Conservation (TDEC) Office of Energy Programs, accessed 24 July 2018.

Mayes A 2011, Schaumburg's Wastewater Costs, Roosevelt University, accessed 19 July 2017.

Rajkumar K et al. 2010, Novel approach for the treatment and recycle of wastewater from soya edible oil refinery industry – An economic perspective, Resources, Conservation and Recycling, Vol. 54 (10) pp. 752–758

[2] For sewage on centralised networks, extrapolated from Cook S, Hall M & Gregory A 2012, Energy use in the provision and consumption of urban water in Australia: an update, report prepared for Water Services Association of Australia by CSIRO (Water for a Healthy Country Flagship Report).

[3] Ausgrid 2017, Average Electricity Use: Data to share, accessed 22 May 2017.

[4] Office of the Chief Economist 2016, Australian Energy Statistics, accessed 22 May 2017.

[5] Tao X & Chengwen W 2012, Energy Consumption in Wastewater Treatment Plants in China, presented at World Congress on Water, Climate and Energy, Dublin, Ireland.

Mizuta K & Shimada M 2010, Benchmarking energy consumption in municipal wastewater treatment plants in Japan, in Water Science and Technology, Vol. 62 (10) pp. 2256–2262.

de Haas DW & Dancey M 2015, Wastewater Treatment Energy Efficiency, in Water, Journal of the Australian Water Association, Vol. 42 (7) pp. 53–58.

[6] de Haas DW et al. 2014, Benchmarking Wastewater Treatment Plant Energy Use in Australia, Water Services Association of Australia, accessed 18 May 2017.

[7] Pabi S et al. 2013, Electricity Use and Management in the Municipal Water Supply and Wastewater Industries, Electric Power Research Institute and Water Research Foundation, USA.

Potential energy cost savings in WWTP

Up to 90% of energy consumption in WWTPs occurs in these three processes:

- activated sludge aeration system (~40–50%)
- pumping (30–50%)
- sludge treatment and dewatering (5–20%).

Depending on the plant, tertiary treatment processes (e.g. filtration, disinfection) and service, water can also be significant energy consumers.

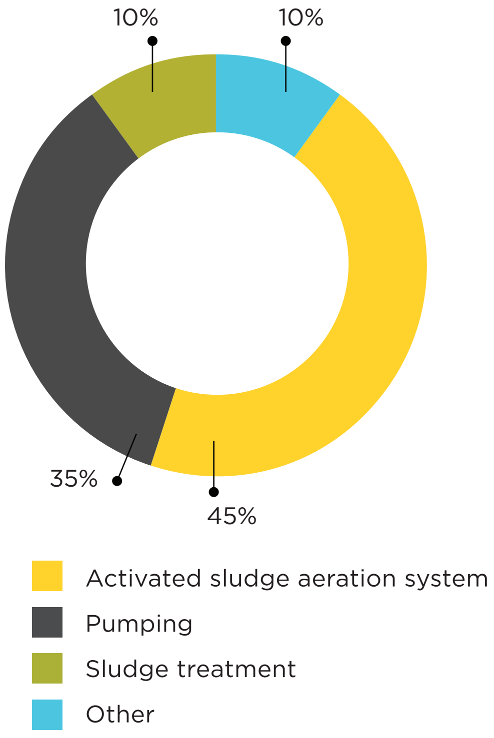

Figure 1 Typical breakdown of energy use at WWTPs (based on an analysis of the energy usage at several facilities across New South Wales)

There are three main ways to reduce energy costs at WWTPs:

1. Reduce overall energy consumption through efficiency
2. Generate power on site (e.g. using solar photovoltaics [PV] or biogas)
3. Better manage energy supply and demand (e.g. power factor correction).

Sydney Water and Hunter Water Corporations have reduced their energy costs by implementing opportunities in all three categories above.

Examples of some of their efforts to reduce energy costs include:

- process optimisation to reduce energy consumption
- blower and pump upgrades to increase their efficiency
- power generation from biogas, solar PV and solar hot water
- bill validation and peak demand management.

The results from Sydney Water's actions, as of the 2015–16 financial year, include:[8,9]

- a reduction of almost 13 GWh per year (~3%) in electricity consumption due to energy efficiency projects
- renewable generation of 86 GWh per year (21% of total energy usage) of electricity, including cogeneration from biogas, hydroelectricity, solar PV and co-digestion of food waste to increase biogas output
- over $9 million in financial benefit from onsite generation (~20% of energy costs).

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[8] Sydney Water (n.d.), *Energy management and climate change*, http://www.sydneywater.com.au/SW/water-the-environment/what-we-re-doing/energy-management/index.htm, accessed 25 October 2017.

[9] Appleby G 2017, Sydney Water's Cogeneration Experience, *Plant Energy Efficiency*.

FACT: In 2016, South Australia's Bolivar WWTP produced 87% of the site's electricity requirements by generating power from its biogas.

WWTPs in Europe have also achieved significant savings, with a comprehensive review of 23 treatment plants undertaken in Germany and Switzerland achieving average energy cost savings of 50% and 38% respectively,[10] while identified savings at one of the participating facilities was in excess of 80%.[11]

The overhaul of the Marselisborg WWTP in Denmark resulted in:

- 17% energy savings (700MWh) through process optimisation using data from SCADA (supervisory control and data acquisition)
- 7% energy savings (300MWh) through blower upgrades
- 50 MWh per year savings due to installation of a side-stream deammonification system
- overall power consumption of 3150 MWh per year for 220,000 equivalent persons (EP) (or 14 kWh/EP Year or 190 kWh/ML)[12]
- onsite combined heat and power generation exceeding requirements by more than 50%, with excess heat used in a local community heating system.

Energy management

In any energy intensive operation such as WWTP, especially with energy prices increasing, it makes good business sense to look at ways to manage energy use, and hence opportunities to save money.

There are three approaches to energy management:

1. **'Do Nothing'**: a site may undertake aggressive procurement strategies but do little in the way of managing energy performance. The net result is a decline in efficiency and a reduction of savings generated through procurement.
2. **'Conduct an audit'**: a site may decide to conduct an audit – a 'snapshot' of the process energy used over a short period of time. Usually a range of opportunities is uncovered, but for various reasons the audit may sit on a shelf or at best only 15-30% of recommendations are implemented. Some improvements are experienced, including improvements in management practices and maintenance, but some of these gains tend to fall away over time as old practices resurface.
3. **'Energy improvement process'**: a site may decide to develop an energy improvement process (as in ISO 50001 – Energy management) to deliver long-term solutions. This approach:
   - secures buy-in at all levels and includes structured plans and timelines
   - improves management practices, systems and behaviours
   - makes end-users accountable and provides the tools and processes required to enable them to meet their goals
   - encourages continuous improvement and capability development both internally and externally.

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[10] Crawford GV 2010, *Best Practices for Sustainable Wastewater Treatment*, Water Environment Research Foundation, Canada.

[11] Reference to Muller EA 1999, Handbuch – Energie in Kläranlagen, Düsseldorf: Ministerium für Umwelt, Raumordnung und Landwirtschaft, NRW, identified in the HuberTechnology website.

[12] Assuming one EP produces 200 L of sewage per day.

The following graph compares the benefits over time of the three approaches.

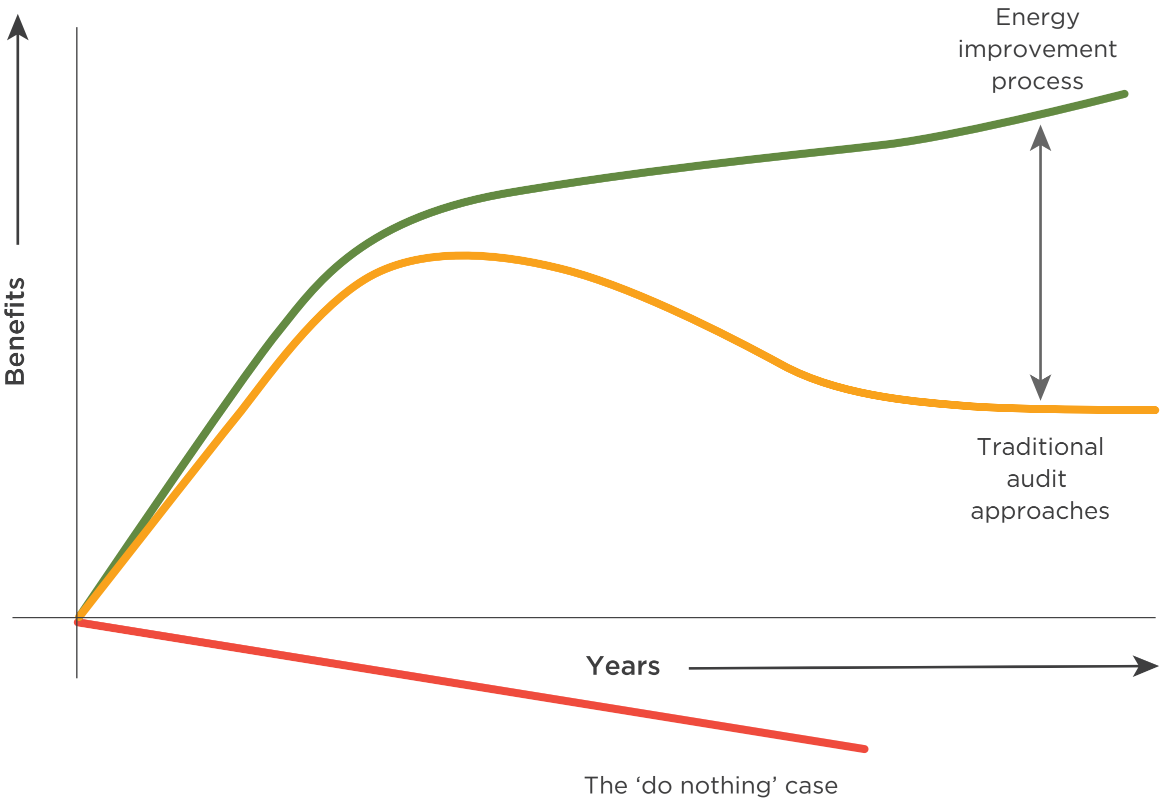


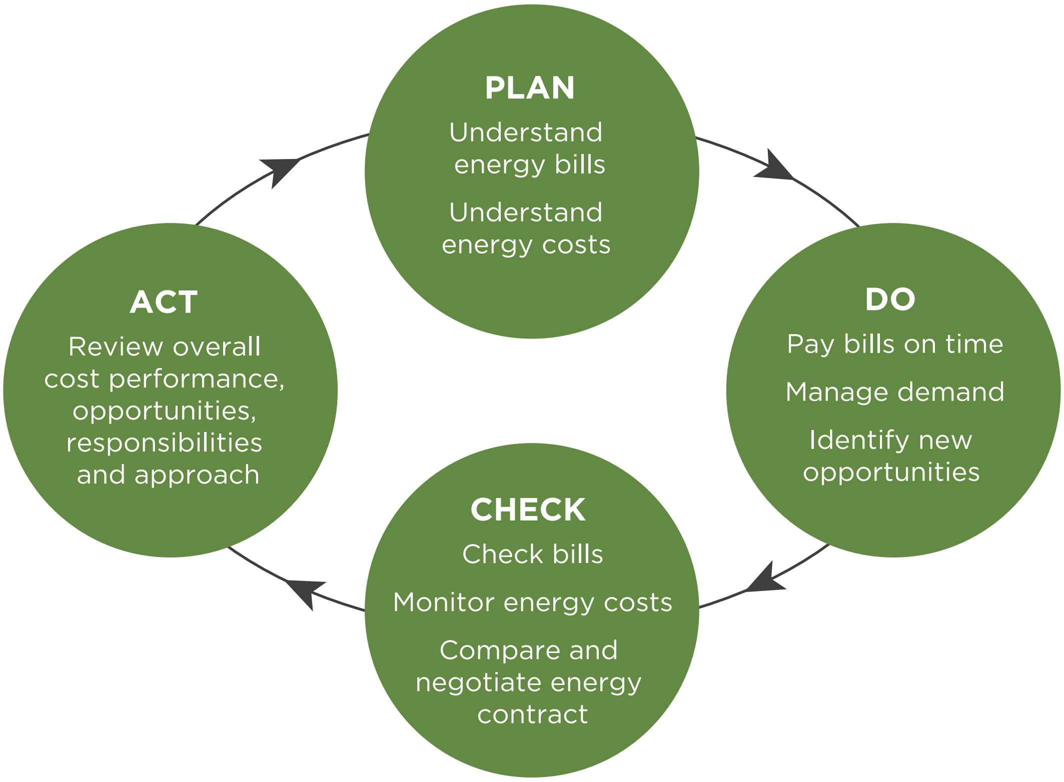
Figure 2 Energy improvement process vs energy audit and ‘do nothing’

1 Reduce your electricity costs

How to manage your electricity bills

The cost of electricity for WWTPs is usually a significant portion (15–40%)[13] of a plant's total operating costs. WWTPs typically import most of their energy needs in the form of electricity from the local utility grid. Some plants that are large enough and have been prepared to invest in biogas generation and recovery, are able to supplement their energy needs for onsite generation of electrical power and heat.

The diagram below sets out the steps involved in managing your electricity costs using the PDCA framework (as per ISO 50001):



PLAN
Understand energy bills
Understand energy costs

DO
Pay bills on time
Manage demand
Identify new opportunities

CHECK
Check bills
Monitor energy costs
Compare and negotiate energy contract

ACT
Review overall cost performance, opportunities, responsibilities and approach

Plan

Reducing your electricity costs starts with planning specific actions that will result in savings. The first step to manage costs is to understand your bills and electricity consumption.

To understand your WWTP electricity consumption, there are three important questions you need to answer:

1. How much are you paying for it?
2. How much electricity is your site currently using (kWh and kVA)?
3. When and where is the electrical energy being used?

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[13] Moore L 2012, *Energy Use at Water and Wastewater Treatment Plants*, University of Memphis.

Rajkumar K et al. 2010, Novel approach for the treatment and recycle of wastewater from soya edible oil refinery industry – An economic perspective, *Resources, Conservation and Recycling*, Vol. 54 (10) pp. 752–758.

How much are you paying for energy?

Your site energy costs are primarily defined by your consumption, time of use and network demand, which will determine your tariff structure. These, and other elements, are discussed in the table below. Note that larger facilities will have more complex tariff structures with network and demand changes whereas smaller facilities, e.g. certain pumping stations, may have a much simpler tariff structure focused primarily on consumption charges.

Understanding how much you pay for your energy bills can help you negotiate better contracts, or shift energy intensive processes to off-peak demand periods.

Understanding your electricity bill – key elements:

Energy charges

- Charges from the retailer for the electricity you consume
- Based on your kWh consumption
- Usually separated into different rates for peak, shoulder and off-peak times

Network charges

- Charges from the network distributor for the electricity you consume
- Based on your kWh consumption
- Usually separated into different rates for peak, shoulder and off-peak periods

Peak, shoulder, off-peak times

- A time window used for charging energy and demand at different rates
- Energy and demand charges differ depending on the time of day
- Different retailers and network distributors will have different peak, shoulder and off-peak times
- Retail and network peak, shoulder and off-peak times may not coincide with each other

Network demand

- Charges from the network distributor for capacity of the wires and poles needed to supply your system
- Usually based on the maximum kVA in a 15- or 30-minute interval in the past 12 months
- Can be 20–40% of an electricity bill
- Can be separated into different rates for peak, shoulder and off-peak periods

Metering charges

- May also be labelled as 'meter provider' charge: cost for providing the meter and data collection, and may include contract brokerage charges

Value added service charge

- Some retailers provide additional services, e.g. a web portal service to help you monitor your usage. The cost for this service is passed on through a per-bill or per-month basis; you may be able to opt out of this service if it does not provide value to your site

See www.yourenergy.nsw.gov.au for tips on how to reduce your energy bill.

How much electricity is your site currently using? (monthly kWh usage and kW or kVA demands)

The monthly kWh used by your WWTP can usually be found on your energy bill. A site's demand charge is usually based on the maximum kVA in a 15- or 30-minute interval in the past 12 months (rolling). If this is not on your bill, talk to your electricity retailer to find out how demand is charged for your site. **Figure 3** is a typical demand profile showing demand charge set at 950kVA and actual demand.

See **Appendix G** for site demand and potential savings calculations

TIP: Some energy retailers have data visualisation portals that can show you the latest power consumption data, and allow easy graphical comparison to other time periods.

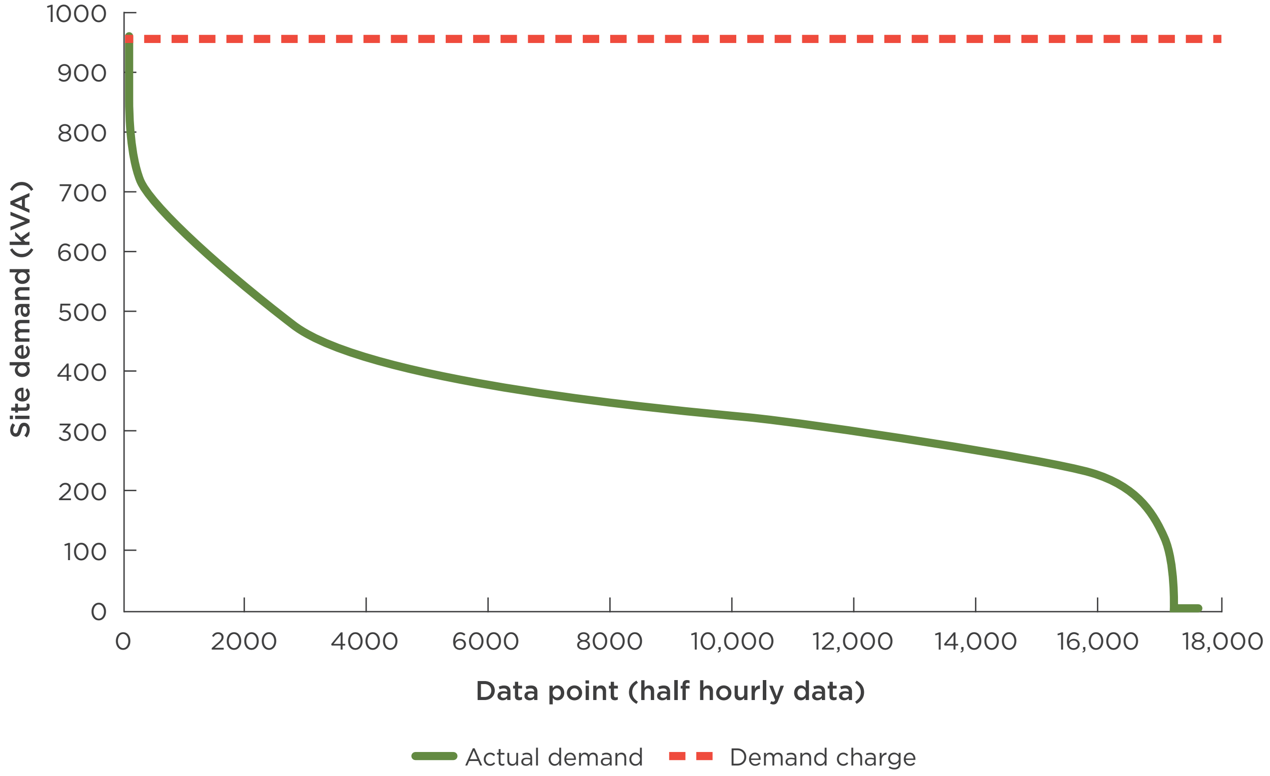

Figure 3 Sample demand profile chart for one WWTP site

When and where is the electrical energy being used?

Understanding when your site consumes more energy can help you reduce your electricity cost. Use the information from your energy bill or ask your energy retailer about your peak, shoulder and off-peak periods. The following figures provide illustrations of how the potential for demand control could be determined.

Figure 4 shows a typical demand profile for a WWTP over a period of six months. Note the axis has been adjusted to show the higher levels of electrical demand during normal operation. The extreme levels of demand are highlighted within the box. This shows short-duration excursions in high demand and indicates that demand control may be able to be successfully applied.

This graph could also be represented in a load duration curve, similar to that illustrated in **Figure 3**. By cross-referencing the load duration curve and the actual load profile, the user can be sure that the optimum balance between load management and plant performance can be achieved.

Figure 5 shows the average demand across the day and clearly points to opportunities for shifting non-essential loads into the early morning.

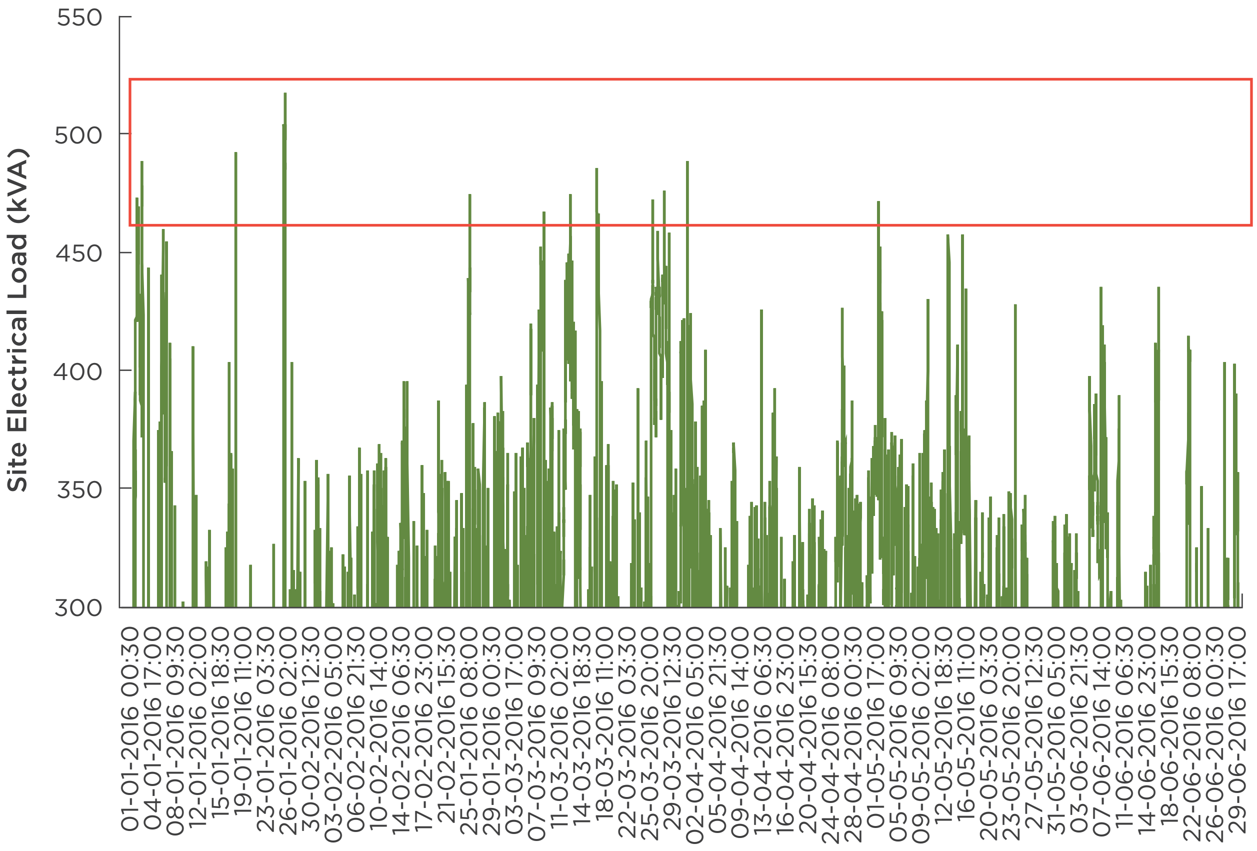

Figure 4 Typical load profile for a NSW-based WWTP showing the profusion of high peaks with short duration

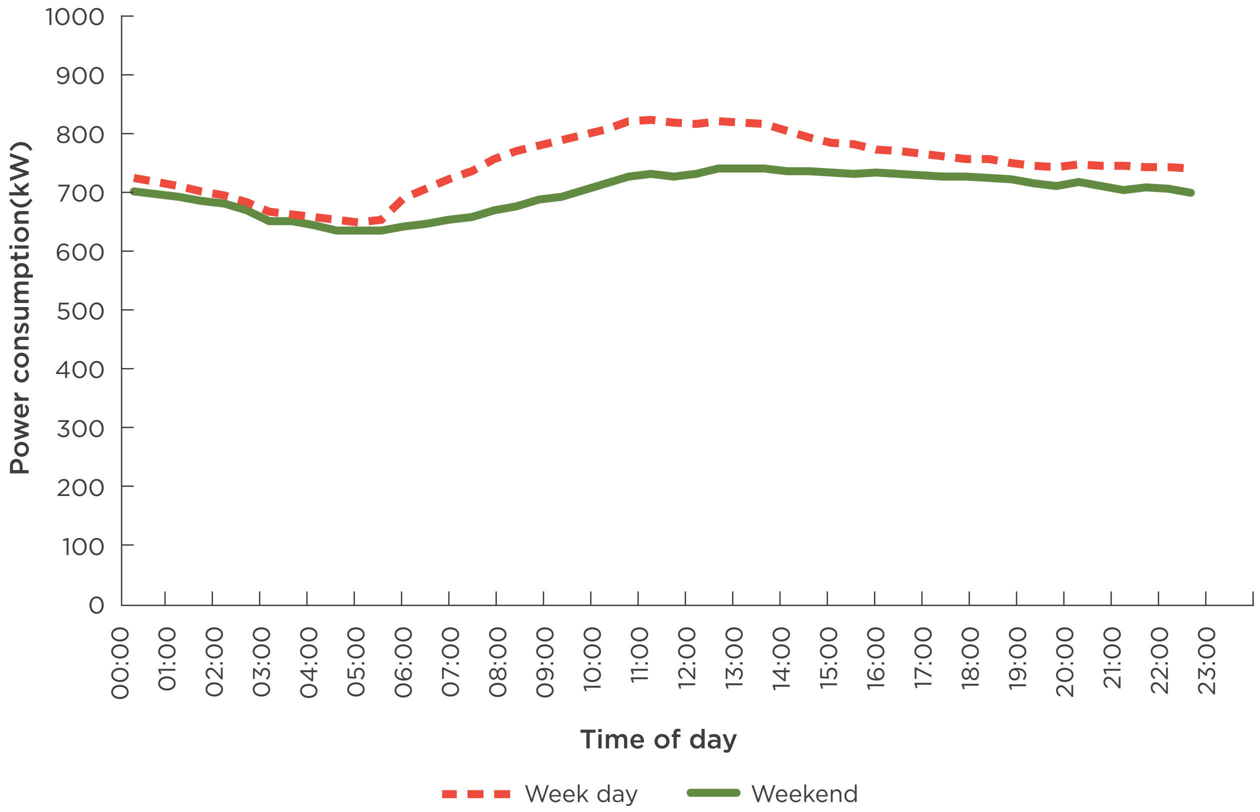

Figure 5 Average demand profile for weekdays and weekends for a WWTP in NSW with a throughput of – 30 ML/day

Analyse your operation and identify options to move energy intensive processes to off-peak or shoulder periods.

When understanding your energy profile, it is also important to know **where** the energy is being consumed. Aerators and pumps will likely be responsible for most of your site's energy consumption, but consider other equipment or processes that could be demanding significant amounts of energy e.g. motors, mixers, etc.

To estimate plant equipment energy usage:

For equipment with power metering: record energy consumption (usually in kWh), for a day, week or month.

For equipment with variable speed drives (VSDs) and advanced controllers: many VSDs or advanced controllers measure or estimate power consumption; these values can usually be exported to an onsite SCADA (or similar) system.

For other equipment:

1. Take the nameplate rating (kW)
2. Determine usage per day (hours per day)
3. Apply load factor (0.7)[14]: energy consumption (kWh/day) = nameplate rating (kW) × usage (hours per day) × load factor.

If you estimate energy usage for all equipment on site, and the total is similar to invoiced amounts, you can be confident in your calculations.

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[14] Load factor is the ratio of actual energy consumption to maximum possible by the equipment; as a general rule of thumb, the average load factor for a WWTP is in the range of 0.6–0.8.

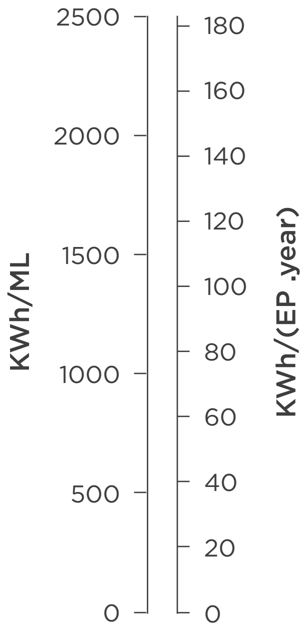
Benchmark your site

Energy efficiency improvements implemented at your site will be better monitored if they are correlated to business outputs i.e. treated water in WWTP.

The most common benchmarking internationally is energy consumed per volume of sewage treated, i.e. kWh/ML. In Europe and Australia, however, there is a recognition that energy demand on a WWTP is also affected by the nitrogen load and amount of organic matter that needs to be destroyed.

The benchmarking unit adopted in the WSAA 2013–14 benchmark study is energy consumed per equivalent person per year, kWh/EP Year, where one equivalent person is expected to produce 200 L[15] and 60 g of biochemical oxygen demand (BOD) per day[16] – see **Figure 7**.

The approximate correlation between the two benchmarking units is shown in **Figure 6.**[17] (Use the table **or** the figure.) The WSAA benchmark study has the advantage of being based on BOD which has a more direct impact on energy than flow, which can vary with BOD concentration.



kWh/ML	kWh/EP Year
2000	146.0
1500	109.5
1000	73.0
800	58.4
600	43.8
400	29.2
200	14.6
150	11.0

Figure 6 Correlation between benchmarking units

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[15] DPI 2016, *Developer Charges Guidelines for Water Supply*, Sewerage and Stormwater, Department of Primary Industries, NSW Government.

[16] de Haas DW et al. 2014, *Benchmarking Wastewater Treatment Plant Energy Use in Australia*, Water Services Association of Australia, http://www.ozwater.org/sites/all/files/ozwater/026%20DdeHaas.pdf; accessed 18 May 2017.

[17] Assuming one EP produces 200 L of sewage per day.

To benchmark your site:

- **Classify your plant:** refer to the WSSA classification in **Appendix A** and identify your plant type.
- **Calculate your benchmark figure:** to calculate your benchmark use the Australian benchmarks agreed by the wastewater industry which were collated and published by WSAA in 2014.[18] The unit for the benchmark is energy consumption (kWh) per equivalent person per year (EP Year).
  - Energy consumption (kWh) is the total consumption from the grid and from any onsite generation.
  - Equivalent person (EP) is identical to the 'persons equivalent' in European literature.

You can use the chart below to compare your plant against the benchmarks (best practice and average). You can also benchmark your historical performance to see trends in energy consumption.

See **Appendix G** for EP and benchmark calculations.

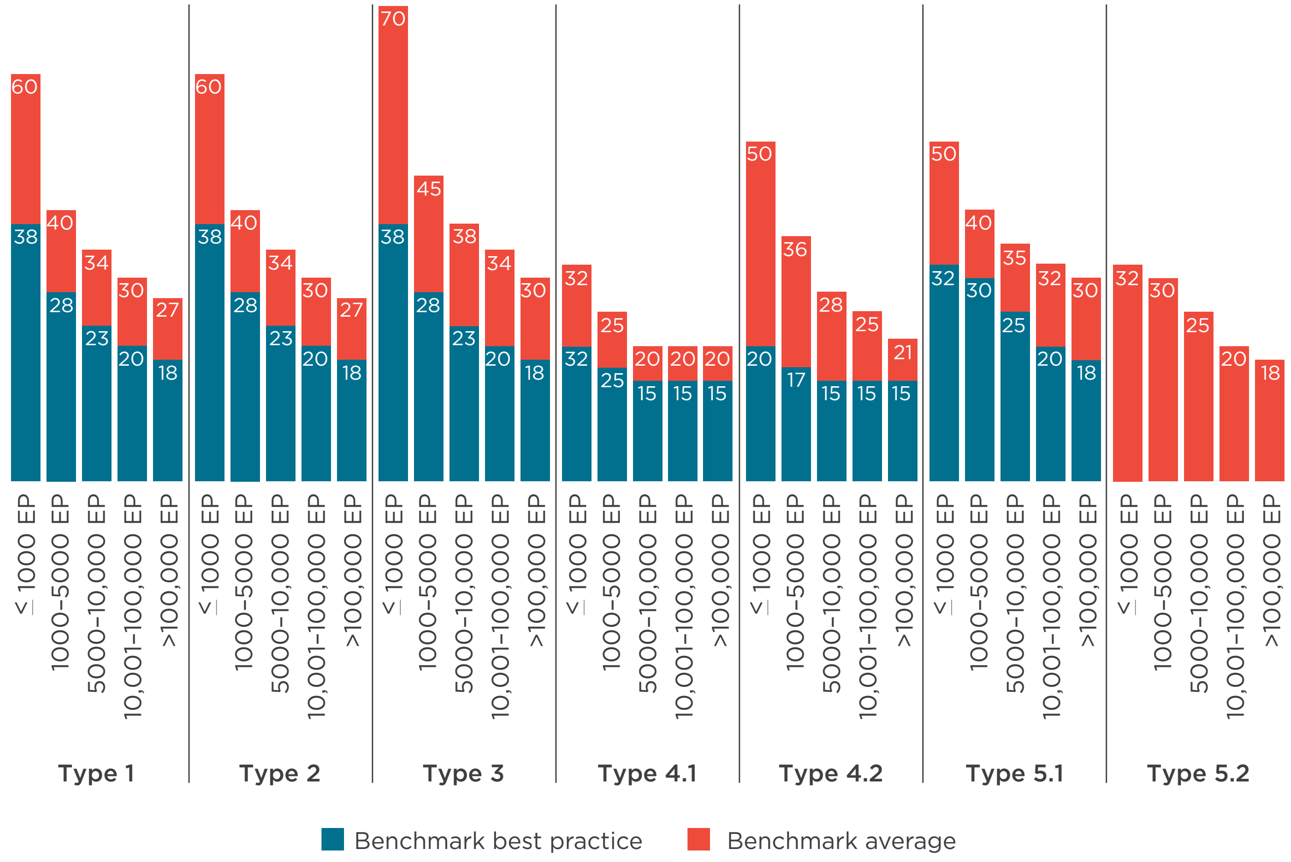

Figure 7 Industry agreed benchmarks set by WSAA (2013–14) for Types 1 – 5 of WWTP [18]: kWh/(EP year)

(See **Appendix A** for plant types.)

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[18] Revised target and guide values may be obtainable from WSAA for the most recent benchmarking round (e.g. 2015-16) for municipal WWTPs in Australia.

Do

Based on the information collected in the planning stage, you can now identify and implement actions to manage your electricity cost. Prior to implementation, allocate resources (people and budget) for energy cost management. If required, prioritise your sites, e.g. focus on largest sites and largest energy user first.

There are different ways to reduce your site electricity costs. Once you understand your energy profile, consider the options set out below. Note the savings are indicative only and not cumulative.

Options for saving energy

Reduce maximum demand

Potential savings: up to 10%

Likely payback: < 1 year (in one year's time)

Reducing your maximum demand, and keeping it controlled, will reduce your electricity costs. To reduce demand:

- set the demand energy performance indicator (EnPI) – by bringing awareness and transparency to demand charges, operators can actively change operations to reduce maximum demand
- shift your load – run non-essential services outside peak times, e.g. consider operating a recycled water pump at minimum throughput during peak periods and 'catch-up' pumping during off-peak periods
- shed your load – turn off or ramp down non-essential services, e.g. reduce effluent pump flow when site demand is elevated, by storing effluent on site.

Bill checking

Potential savings: up to 20%

Likely payback: < 1 year

Your electricity bills can have errors.

For larger sites, the bill checking process could be automated using an energy intelligence software platform.

To check your bill in-house:

1. Obtain one-month's electricity interval data from your retailer
2. Using the interval data, create a spreadsheet that will calculate the expected electricity bill using your network and energy tariffs
3. Turn your spreadsheet into a template for future months and significantly reduce process time in the future
4. Check your bill monthly, and immediately alert your retailer if you find any discrepancies.

Compare and negotiate a better contract

Potential savings: up to 25%

Likely payback: < 1 year

Shopping around and negotiating what works best for your site will result in the best deal for your electricity costs.

When comparing retail contract offers, take into account:

- the site's energy consumption (and time of use)
- energy rates (and time-of-use variations)
- pay-on-time discounts (and your ability to pay on time)
- contract length.

If you are considering using the services of a broker to negotiate your contract, ask upfront how their fees will be paid.

WWTPs are in an excellent position to negotiate better tariffs due to their relatively steady, predictable load profile that does not have significant seasonal fluctuations.

In general, greater electricity consumption will provide greater negotiation power with the retailer. Consider bundling multiple sites to increase your negotiation potential.

Note

Contract negotiations with your retailer will exclude the network and demand charges. Network and demand charges are set by the network provider at your location. Your retailer is only passing on the charges.

You can apply to your network provider, via your retailer, to be on a different network tariff, though you will need to provide justification.

High-voltage network tariffs may be significantly cheaper for sites with high demand, but you will then be responsible for the ownership and maintenance of the step-down transformer.

Other factors to consider before you sign your contract are:

- **Metering charge** – consider entering a direct metering agreement (DMA) with a meter data agency. The advantages of a DMA include:
    - avoiding the metering charge
    - transparency of metering costs (extra fees can be hidden under 'metering charge')
    - direct access to the metering company for obtaining service improvements (e.g. access to a real-time data or visualisation service).
- **Value added service charge** – the retailer may charge you for a visualisation and monitoring service for your site; make the most of it or opt out.
- **Take or pay clause** – some contracts require a constant minimum consumption, or payment for that consumption even if not used; this clause is significant if you are looking at onsite generation.

See **Section 5: Generate Heat and Power from Biosolids** for additional considerations when generating your own electricity.

Use the previous 12-months' interval data to predict future consumption, and speak to an energy broker or your financial controller for a forecast of retail energy prices.

Tip

If you are considering using the services of a broker to negotiate your contract, ask upfront how their fees will be paid.

Pay bills on time (or early)

Potential savings: up to 5%

Likely payback: immediate

Some energy retailers will charge interest if you pay your bills after the due date. Pay bills by the due date to avoid interest charges.

Some energy retailers will also provide discounts if you pay your bills early. The discount provided by one retailer is equivalent to 5% per year interest rate, which is higher than the rate of most interest earning accounts, but potentially lower than a corporate bank loan account.

Other strategies to reduce electricity costs include: power storage, power factor correction and voltage optimisation. See **Appendix B: Summary of further opportunities** for more details.

Check

To sustain any energy savings, and identify energy efficiency opportunities, you need to monitor your energy consumption. Here are some of the actions you can take to check your electricity costs.

Monitor energy consumption

Potential savings:
up to 20%

Likely payback:
< 1 year

You can monitor your energy consumption by:

- Using the total monthly cost or consumption (kWh) available from your bill, update the energy efficiency benchmark for the site (e.g. kWh per EP Year or volume of effluent treated)
- Develop a submetering strategy by:
  - create a submetering register and diagram if there are existing submeters on site
  - determine if additional submeters are required to measure key energy performance indicators (EnPIs); if so:
    - prioritise areas and/or equipment for additional submetering; focus first on the largest energy consumers (e.g. largest pumps and blowers)
    - install and commission new electrical submeters as operation and budget permits
  - confirm connection of submeter to onsite SCADA (or similar) system
  - confirm correct data conversion (e.g. kWh recorded as kWh and not MWh), and storage of data to allow long-term trending
  - implement a monitoring system (or procedure) to regularly (e.g. daily or weekly) assess the power data collected, and update the EnPI for each area and/or item of equipment.

For all benchmarks and EnPIs, determine if the benchmark value is slowly creeping up, or changes significantly in a short amount of time and cannot be explained by changes in processes. If so, investigate further.

Act

- Use the information from the checking stage to make informed decisions about your plant electrical energy use, electricity bills and contract.
- Review the list of opportunities in **Appendix B** and assess which ones apply to your site. Apply those that can be implemented easily and immediately.
- Investigate financing options before implementing energy-efficiency projects. Support for eligible projects may be available through the NSW Energy Savings Scheme (ESS), the Large-Scale Renewable Energy Target (LRET), Small-scale Renewable Energy Scheme (SRES) or other relevant government programs.
- Talk to other plant managers and operators to gain knowledge and insight into their operating experiences. WSAA, the NSW Water Directorate and the Australian Water Association provide opportunities to share experiences in the water sector.
- Consider establishing an energy management system (EnMS) at the corporate or council level to drive action, and ensure savings are continuously achieved. See **Appendix E** for guidance on an energy management system for WWTPs.
- For councils, operationalise savings in Operations Plan and/or delivery Program and ensure it is captured in Community Strategic Plan.

Case study: East Wagga Wagga Water Bore No.2 – Tariff and Power Factor Analysis

> **‘The potential increase in our network costs associated with a compulsory tariff change from Time-of-Use (ToU) to Demand-based tariff was the incentive we needed to investigate power factor correction measures to manage our energy demand.’**
>
> **Jason Ip**
> Manager Operations, Riverina Water County Council

Although not a wastewater treatment plant (WWTP), the water pumping system at this bore, operated by Riverina Water County Council (RWCC) is similar to pumping systems in WWTPS. Therefore, the learnings from this case study are readily transferable to a WWTP situation.

Our situation

East Wagga Wagga Bore No.2 is one of ten bores supplying water to the city of Wagga Wagga. It comprises a 75 kilowatt (kW) 2-pole motor and stainless-steel pump, approximately 45 metres from ground surface, which discharge 100 litres per second into a nearby aeration water treatment plant.

Our motivation for adopting energy cost saving measures

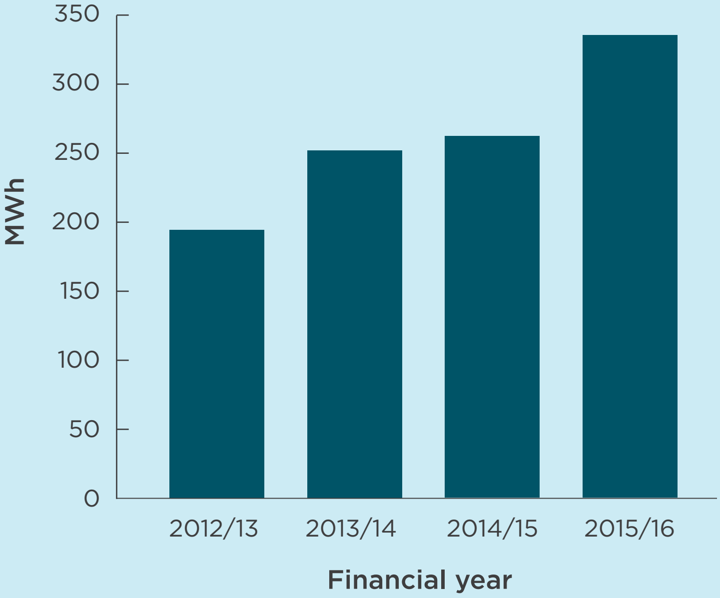
Our analysis of 2015–16 usage data (see graph below) showed that this site uses more than 160MWh per year, which justified it to move from Time-of-Use (ToU) tariff to demand-based tariff. The analysis also showed that our network costs were projected to increase from $27,603 per year to $34,483. This increase was mostly attributed to our peak power use charges (kilo Volt Amperes, kVA) and the site’s poor power factor of 0.84. As a result, we chose to investigate how we could manage power factor and kVA charges.

East Wagga Wagga bore No 2. Photo: RWCC

What we did

Our analysis highlighted the need to consider power factor correction (PFC) systems to improve our power factor and reduce our monthly peak kVA demands thus minimising the costs associated with the switch to demand-based charges.

We installed an advanced Insulated Gate Bipolar Transistor (IGBT) intelligent control switching PFC system which has a relatively small footprint and was cheaper than other systems.



East Wagga Wagga bore No 3. Photo: RWCC

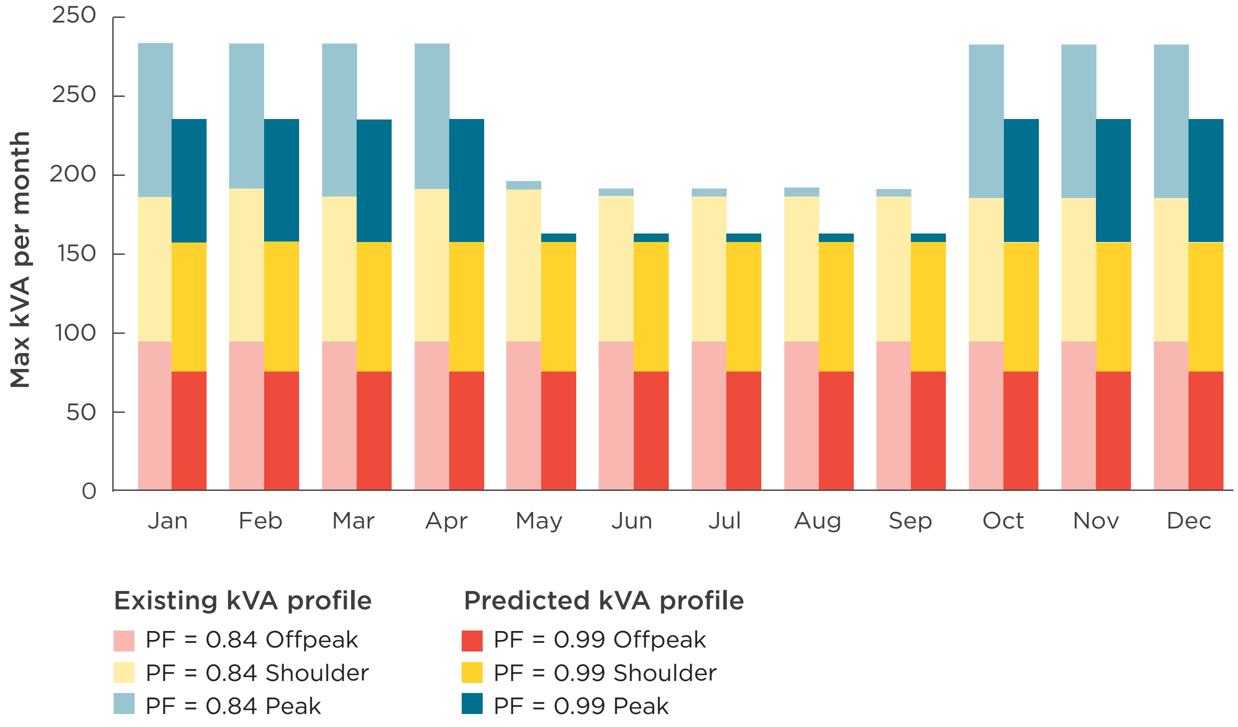
Our results

The PFC reduced the kVA by 15% at a cost to us of about $6000 installed, which resulted in an annual saving of around $6800, offsetting the cost burden associated with the compulsory change from a ToU Tariff to a Demand-based tariff.

Implementation costs: $6000

Cost savings: $6880

Simple payback: 0.9 years



Case study: Melbourne Water – Eastern Treatment Plant

The energy reduction project has helped to drive an energy efficiency culture at Melbourne Water.

Our situation

The Eastern Treatment Plant, in Melbourne's south-eastern suburbs, currently treats about 330 million litres of sewage or approximately 50% of Melbourne's total sewage to tertiary stage.

What we did

To reduce our energy costs, we looked at our peak demand management options, i.e. load reduction and implemented peak demand management, focussing on reducing our maximum demand set point, which was set at 14 mega volt amperes (mVAs).

We assessed our operational capability for long term load management, analysed our program controls and implemented the demand management practices.

Our results

Measurement and Verification of our project determined that our energy costs were reduced by an estimated $100,000 to $200,000 per year with no capital outlay. The project will also help to drive a culture of energy efficiency and energy cost improvement at Melbourne Water.

Melbourne Water's Eastern Treatment Plant. Photo: Melbourne Water

2 Optimise your aeration and blower system

About aeration and blowers

Aeration is the process that typically consumes the most energy, sometimes accounting for more than 50% of energy consumption in conventional activated sludge plants. The main purpose of aeration is to provide oxygen to biological processes in activated sludge systems. Aeration also assists with mixing treatment tanks and keeping solids in suspension.

Aeration systems have three components: airflow generation by blowers, airflow distribution, and aeration tanks (see **Figure 8**). This section of the guide is relevant to all these components, as well as the control of the system.

Aeration methods are broadly categorised as surface or sub-surface systems. The sub-surface systems include coarse-bubble and fine-bubble diffusion or jet aeration. Surface systems include fixed or floating surface aerators and a range of paddle-type (e.g. ‘brush’) aerators. Sub-surface fine-bubble diffusion aeration is the more common approach in modern, larger WWTPs and is the main focus of this section of the guide.

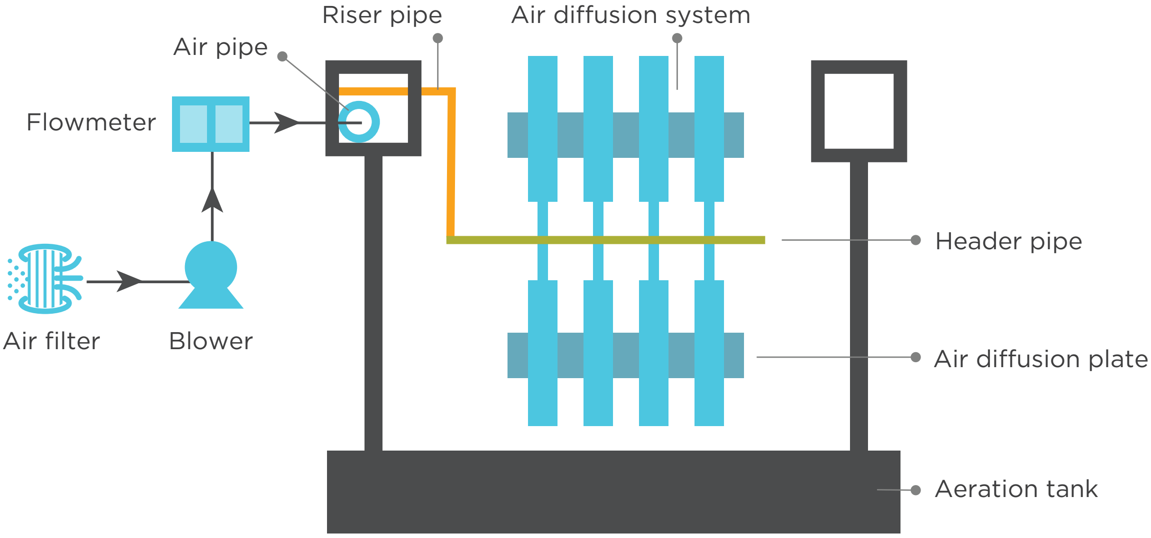


Figure 8 Example of a typical blower and aeration system[19]

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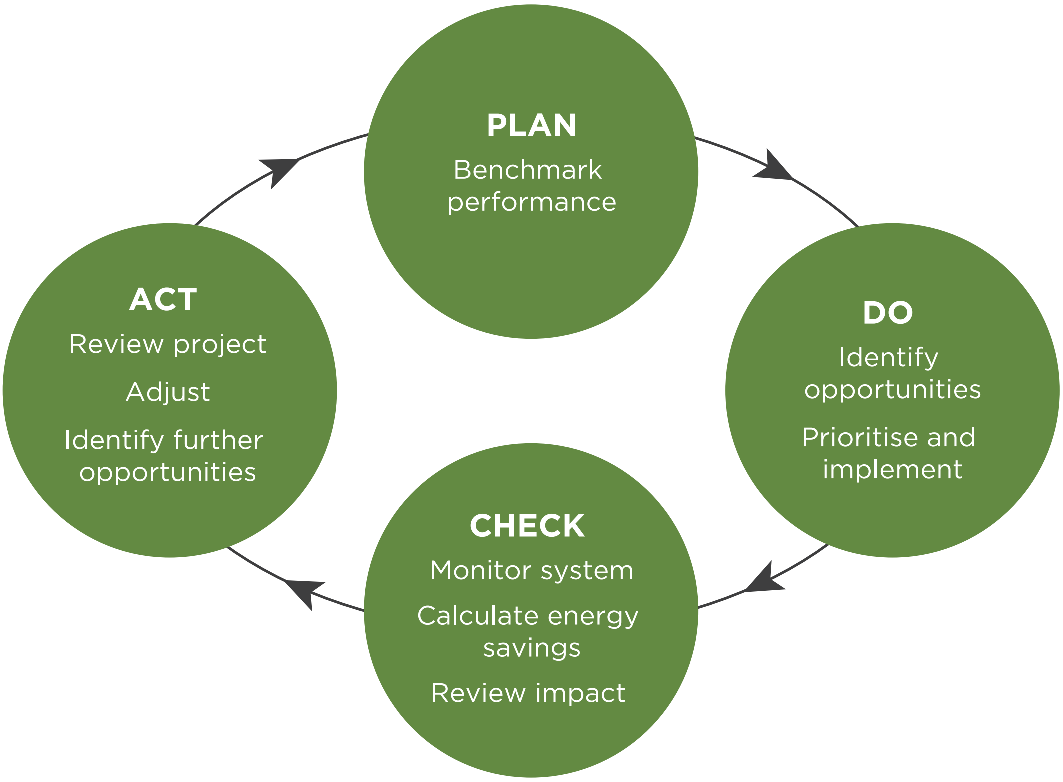
[19] Diagram extracted from the MetaWater Co. Ltd, Japan website.

Optimising your system

The diagram below sets out the steps involved in optimising your aeration and blower system using the PDCA framework:



Plan

Benchmark your aeration system performance

1. Set EnPIs for your aeration systems. Suggested EnPIs are:
   - aeration energy efficiency e.g. kWh/(EP Year)
   - aeration demand e.g. air m^3/(EP Year)
   - blower-specific power e.g. kW/(m^3/min), where m^3/min refers to the free air delivery – see **Figure 9** below for sample blower power chart.
2. Gather existing operational data for calculating these EnPIs. If required, log additional data, e.g. blower energy consumption, over a representative period (normal operation in wet and dry weather and peak load events)
3. Calculate your chosen EnPIs
4. Compare them to available benchmarks. Suggested comparisons include:
   - historical plant performance; if no historical data is available, start tracking your selected EnPIs
   - for blower-specific power, compare with manufacturer's data
   - plant design specifications.

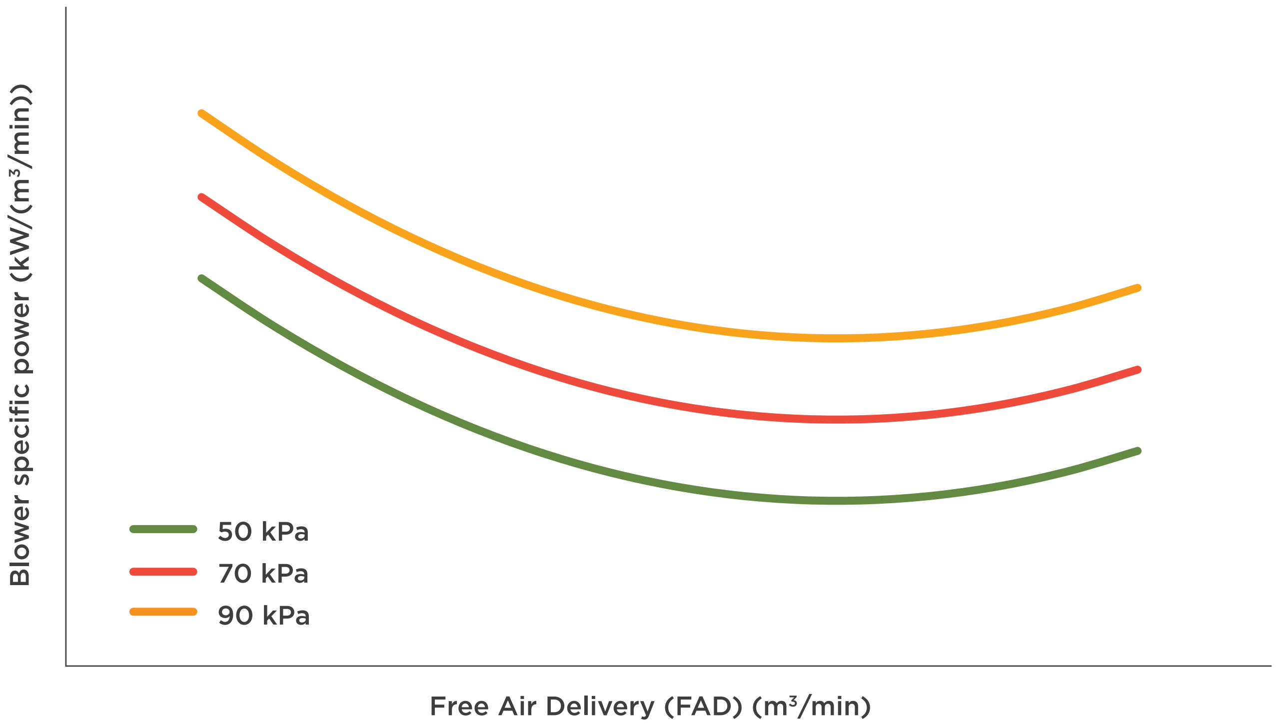


Figure 9 Typical blower-specific power chart

Do

Identify and list efficiency opportunities for your aeration system

Energy efficiency opportunities for aeration systems typically fall into four categories:

- reduce aeration demand
- reduce system pressure
- improve blower system efficiency
- replace or upgrade equipment to more energy-efficient technology.

The opportunities with the most significant savings and/or lowest payback are described below. See **Appendix B** for a summary of further potential opportunities.

Reduce aeration demand

Opportunity: Control aeration flow rates to each zone based on residual dissolved oxygen online monitoring

Potential savings: up to 20%

Likely payback: 1–6 years

Using online dissolved oxygen (DO) monitoring to control blower output can better match the rate of aeration to the requirement of the process, avoiding excessive aeration which increases energy costs.

Install DO sensors, or calibrate existing sensors.

Modulate air flow to maintain required residual DO levels according to requirements in each zone.

Further improvements can be made by using ammonia and nitrate sensors to adjust DO set point and fine-tune nitrification/denitrification processes.

Reduce system pressure

Opportunity: Control blower output pressure based on most-open-valve logic

Potential savings: up to 15%

Likely payback: 1–3 years

In centralised blower systems, the control system must calculate the required flow rate to different areas of the plant. The flow rates are achieved by modulating a control valve on the supply line to each zone. Blower controls respond by varying blower output to maintain outlet, or header pressure, according to a pressure set point.

Most-open-valve (MOV) logic, instead of maintaining a constant pressure, will control blower output to deliver the required air flow to all aeration zones. If air flow to individual zones exceeds the target flow rate to that zone, flow will be restricted by the control valve. The system pressure is now the minimum pressure required to deliver the target flow rate to the zone with the most open control valve.

Use control valves to modulate air flow to each zone to deliver the required flow rate to that zone.

Modulate blower output to total flow rate required, instead of maintaining a set outlet pressure.

The system overall will have minimal pressure losses while ensuring the right amount of air is delivered to all zones.

See publications by Water World[20] and Compressed Air Best Practices.[21]

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[20] Jenkins T 2009, New Aeration Control System Offers Energy Savings.

[21] Gray M & Kestel S 2012, Improved Aeration Efficiency through Design and Control, Compressed Air Best Practices.

Improve blower system efficiency

Opportunity: Optimise blower sequencing and control

Potential savings: 10–40%

Likely payback:
1–2 years

Regardless of the number, size and type of blowers in your aeration system, there will be an optimum configuration where air is delivered to the aeration tank for the minimum energy spend. A specialist or aeration supplier could help you identify the best configuration for your aeration system.

1. Measure the specific power of individual blowers across a full range of output conditions
2. Create a compiled specific power curve, overlaying the specific power of each blower across its full capacity range
3. For each level of aeration demand, identify the blower, or combination of blowers, that can deliver the required flow rate with the lowest power consumption
4. Implement control logic to govern the blower system, calling on the most efficient combination of available blowers based on the present aeration demand for the process. Consider how to ensure stable transitions as blower output ramps up and down, and individual machines become unavailable e.g. in case of fault or downtime for servicing.

Replace or upgrade equipment to more energy-efficient technology

Opportunity: Replace aging, inefficient or unsuitably sized blowers

Potential savings: up to 40%

Likely payback:
2–5 years

Most blowers for a site are selected based on maximum site capacity, with backup for when the largest blower fails. Yet most WWTP systems operate at less than full capacity for the majority of their useful lives.

Depending on the size of the blowers and the aeration requirement, acquisition of a smaller blower, with less power consumption, may be more economic.

For example, at one WWTP, the minimum required aeration is 15 m^3/min. The minimum air flow from one of the existing blowers is 45 m^3/min. Thus, three times the required air is delivered. This excess air delivery results in air being ‘blown off’, resulting in poor efficiency, heating of the blower room, and excessive noise.

If required, seek external expertise for a major upgrade or reconfiguration of your blowers or aeration system.

Consider the following if the equipment selection is done in-house:

1. Create a compiled specific power curve for the blower system, as outlined in previous opportunity
2. Compare the specific power observed in the blower system to best efficiency available using current technology (refer to manufacturer’s published data or consult various equipment suppliers directly)
3. Estimate the energy savings that could be achieved by upgrading equipment. (Consider packaged blowers where the motor, VSD and blower are specified for best overall efficiency)
4. Aim for best efficiency in the range of aeration demand that is most frequently observed in your process. If your plant aeration system comprises multiple blowers, it may be more economic to have one very efficient blower to cover normal operations while maintaining the older machines for the conditions that are less frequent.

Prioritise and implement your opportunities

Determine which opportunities are applicable to your site, or consult a WWTP energy efficiency expert to identify opportunities for your site.

For a list of accredited suppliers see Find an energy expert on the Office of Environment and Heritage website.

Prioritise the opportunities you have identified based on your energy savings targets, financial criteria (costs, payback period, etc.), and ease of implementation. In organisations with energy management systems in place, a procedure to prioritise energy savings opportunities should already be in place.

Before implementing energy savings opportunities, remember to consider:

- in-house skill set and availability of resources
- operational conditions and process control benefits
- forecast energy demand increases e.g. due to projected population increases
- project complexity
- impact on plant stability and reliability
- impact on peak demand (and associated electricity cost changes)
- energy performance outcomes
- energy savings certificates to help reduce payback
- links with the site's continuous improvement and asset maintenance programs or sustainability goals
- reduction in greenhouse gas emissions
- external expertise in aeration or process control.

Total Cost of Ownership (TCO)

Equipment purchasing and system design decisions should always be based on TCO, especially in blowers where energy costs can exceed the purchase price within the first few years. TCO includes:

- initial cost – purchase, installation and commissioning
- energy cost – including demand and environmental charges
- maintenance cost – including planned and unplanned downtime
- disposal – residual or scrap value, or disposal and recycling costs at the end of service life.

Check

Monitor your aeration system

In conjunction with benchmarking efforts and asset maintenance programs, efficiency and performance of blower systems should be monitored over time to determine specific maintenance requirements that are over and above the regular maintenance practices.

Make sure blowers and the aeration system are well-maintained, as they all contribute to overall system efficiency:

- ensure adherence to maintenance schedules
- change filters when required
- fix air leaks
- clean intake air filters
- fix sticking check valves
- open or eliminate throttling valves
- clean diffusers regularly (e.g. in-situ chemical cleaning)
- check, clean and calibrate DO sensors regularly according to the manufacturers' instructions.

Calculate energy savings

Measure post-implementation energy consumption over a suitably representative period to determine the new average energy consumption, e.g. kWh/(EP Year).

One month is sufficient for plants with moderately consistent influent loads; six to nine months may be required for plants with more varied influent loads.

To calculate annual energy savings:

Energy before (kWh/[EP Year]) – energy after (kWh/[EP Year]) × total influent volume per year.

Compare the calculated energy savings to expected energy savings.

Measurement and Verification (M&V)

Energy savings cannot be directly measured, but can be determined using M&V. Refer to the International Performance Measurement and Verification Protocol (IPMVP) or consult a Certified M&V Professional (CMVP).

Evaluate the impact of your project

- Were the energy savings and implementation costs consistent with project expectations?
- What are the key lessons to be shared internally or externally?
- Prepare a case study or project summary to share the results.

Continue the monitoring plan

Continue to monitor performance to ensure savings are maintained.

Act

- Use the key learnings to inform the next planning phase, identify new opportunities, review priorities and continue to drive further savings.
- Adjust operations based on the results achieved.
- Identify energy saving opportunities in other areas or processes of your WWTP.

Case study: Hornsby Heights Waste Water Treatment Plant

> **‘Although turbo blowers have limitations, they are an excellent option for reducing operating costs in wastewater treatment plants when base load air supply is an option.’**

Greg Appleby,
Senior Resource
Management Advisor
Liveable City Solutions
Sydney Water

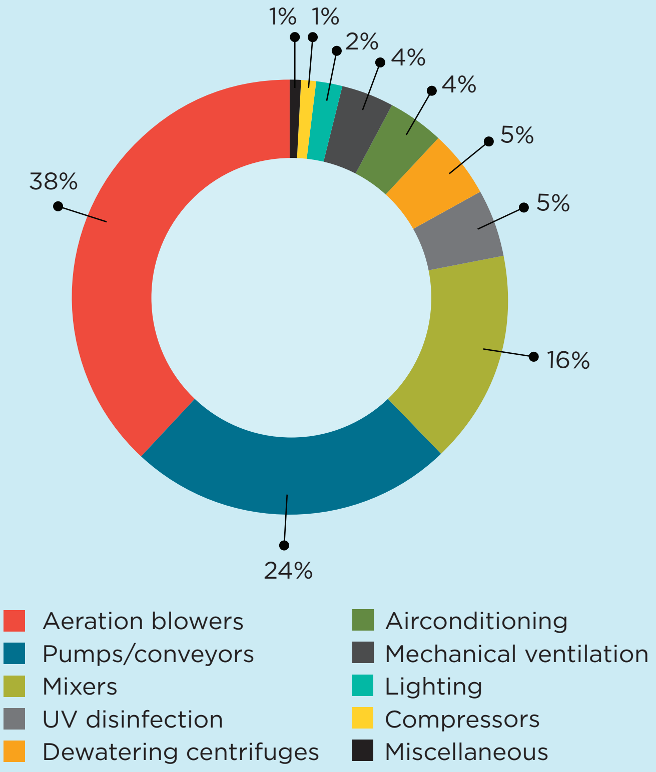
Our situation

Sydney Water owns and operates the Hornsby Heights Wastewater Treatment Plant (HHWWTP). It treats effluent to tertiary level, with sludge being bio-digested to produce biogas and biosolids, while treated wastewater is released into the nearby Calna Creek. It serves a population of about 30,000 people, treating around five megalitres a day.

The biogas produced on-site is used to heat the digesters. Our annual electricity bill at the Hornsby Heights site is approximately $200,000 with our biggest energy users being our blowers, pumping system and mixers as shown in the pie graph below.

The blowers are used to force air through diffusers into biological reactors that help remove carbon and nitrogen from the wastewater.

There were four blowers at the site. Two small 75kW blowers and two large 220kW Aerzener blowers.



HHWWTP electricity use breakdown

What we did

The blowers at Hornsby Heights WWTP were positive displacement lobe blowers which are known to be less efficient than screw, centrifugal or turbo blowers. Based on the air demand and the efficiency of the existing blowers, we determined that replacing one of the blowers with a turbo blower would provide significant savings and have a reasonable payback.

The turbo blower was a 110kW, Atlas Copco magnetic bearing blower, with a flow range of between 2500-6000m^3/hour at 20°C. It replaced one of the large blowers. Commissioning was completed in May 2015.

Our challenges

Turbo blowers are highly efficient in a very narrow range around the design point. The design point chosen for Hornsby Heights was 5,500m^3/h at 20°C. Outside of about 400m^3/h plus or minus, the efficiency drops off quickly.

We identified a trade waste issue once the turbo blower was installed, which significantly increased air demand at the plant. The turbo blower could not meet air demand during these periods.

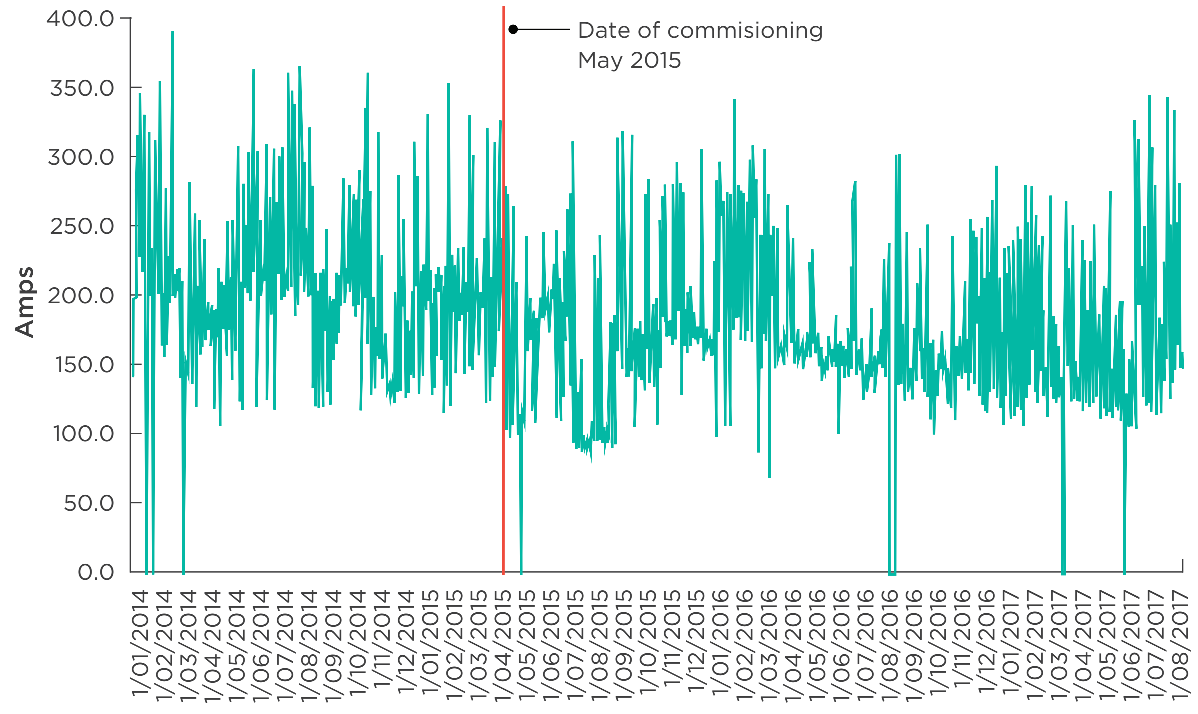
This has been resolved by allowing a positive displacement blower to operate with the turbo blower.

Our results

There was an immediate energy saving following installation and this has improved as the plant optimised control of the new blower.

Energy savings average about 21kW or 184MWh per year.

Turbo blower maintenance is significantly less than for positive displacement blowers. Energy and maintenance savings together have resulted in a total saving of about $45,000 per year.



Average of combined blower current (amps) at HHWWTP.

Case study: Belmont Waste Water Treatment Works

> **'We are applying the learning from this project to our other waste water treatment plants.'**
>
> **Daniel Livingston**
> Wastewater Treatment Planning Team Leader
> Hunter Water Corporation

Our situation

Belmont Waste Water Treatment Works (BWWTP) is owned by Hunter Water Corporation and operated by Veolia. The plant currently treats 30 megalitres of wastewater per day from a population of approximately 115,000 people. Our plant has a number of treatment processes that convert the sewage into treated effluent and treated bio-solids. The treated effluent is discharged to the ocean via an ocean outfall, and the biosolids are dewatered onsite and taken offsite.

What we did

Following a site audit, we optimised the operation of our aeration tank mixers by installing controls so they now operate intermittently instead of continuously. We also optimised several of our pumps and adjusted the aerator blower speeds. To complement these actions, we introduced a site-specific energy management plan to ensure that the entire plant is operating as efficiently as possible.

Our results

We have significantly reduced our energy use, saving around $60,000 per year, and reduced our greenhouse gas emissions by more than 500 tonnes a year. Following the success of the change to intermittent operation of our aerator mixers, we have introduced this at our other waste water treatment plants with significant energy savings being achieved at these sites.

Implementation costs: $200,000

Cost savings: $60,000 per year.

Energy savings: 590MWh per year

Simple payback: 3.3 years

BWWTP aerator tank. Photo: Hunter Water Corporation

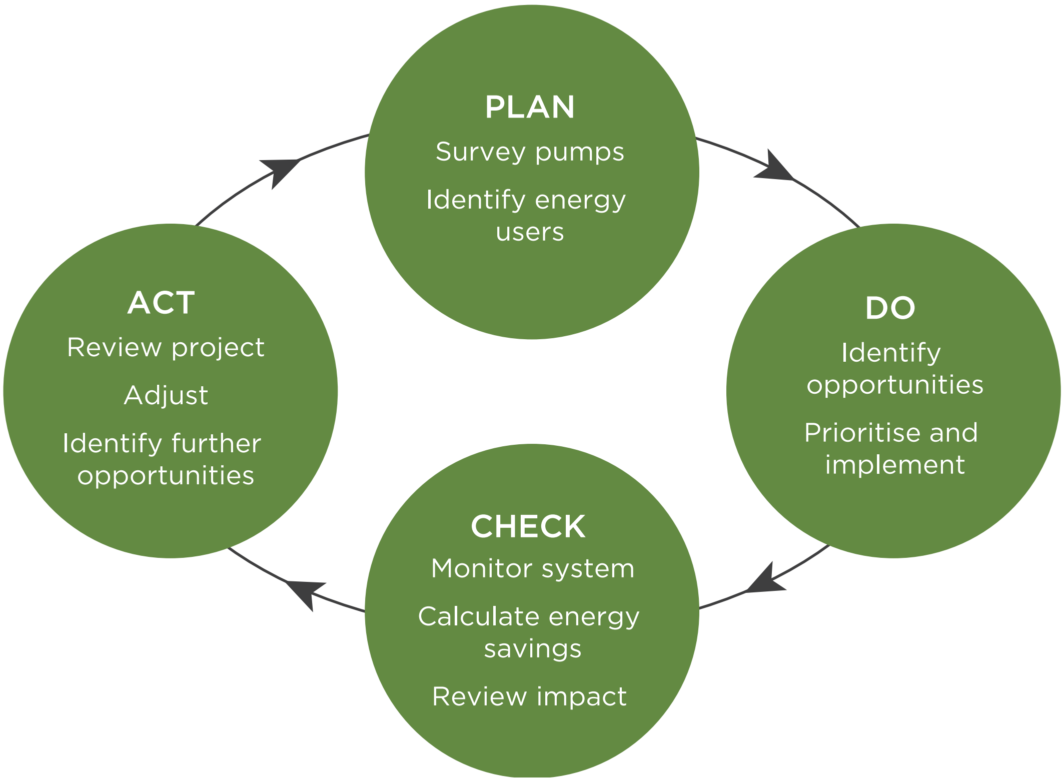
3 Optimise your pumping

About pumping systems

Pumping systems at WWTPs can typically account for 30–50% of total energy consumption. The factors that contribute to a pump's energy consumption include the difference between pump inlet and outlet pressure, flow rate, operating hours and overall efficiency.

Optimising your pumping system

The diagram below sets out the steps involved in identifying and maintaining energy savings in your pumping systems using the PDCA framework:



Plan

Survey your pumps: develop a pump register

You may already have an asset register with a list of pumps on site. Make sure to record these details for each pump:

- pump name and function
- pump type e.g. centrifugal, progressive cavity, rotary gear, screw, diaphragm
- motor details: rated power (kW); speed (RPM or no. of poles); drive e.g. direct on line (DOL), VSD or soft start
- pump supplier and model number; if this is unavailable look for a 'pump number' embossed on the pump casing, e.g. '150-250/238'
- average operating hours per day
- **optional**: mechanical drive and/or gearbox (if present): drive ratio or pump shaft speed
- end of life date (if known)
- energy consumption: measure or estimate the power consumed (in kW) and use the operating hours to determine the energy consumption (in kWh) in normal operation. Note: some VSDs will calculate power and/or energy consumption.

TIP: estimating pump energy consumption

Fixed-speed pumps: the annual energy consumption (kWh) for a fixed-speed pump can be estimated by rated power (kW) x annual operating hours x 0.75 (load factor).[22]

Variable speed drive (VSD) pumps: most VSDs, particularly new ones, calculate energy consumption in their internal computer. Check your VSD user manual to determine how to view the energy consumption or export it (once-off or continuously to your plant's SCADA system).

The part-load efficiency of a VSD will vary between manufacturers, so the associated documentation should be consulted. If this is not available, other resources can provide a reasonable estimation, e.g. the US Department of Energy Motor Efficiency Tip Sheet #11.[23]

Identify significant energy users

Investigate operation of the pumps with the highest annual energy consumption for opportunities to optimise performance.

Profile the largest pumps in detail

To determine the range of loads that dominate a pump's operating time, prepare a load duration curve (see **Figure 10** and tip below) based on logged flow or power data to illustrate the distribution of pump load over time. Any performance optimisation activity should focus on this aspect first.

Using the example shown in **Figure 10**, improving efficiency in the conditions corresponding to the 40–60 kW range would deliver the greatest energy savings as the pump operates at that range for the greatest proportion of time. Optimising the pump's operating in this range will most likely provide the greatest return on effort.

TIP: creating a load duration curve

To create a load duration curve select all pump power data points from your data logger, for data at regular intervals, then sort from largest to smallest and plot the data on a line graph.

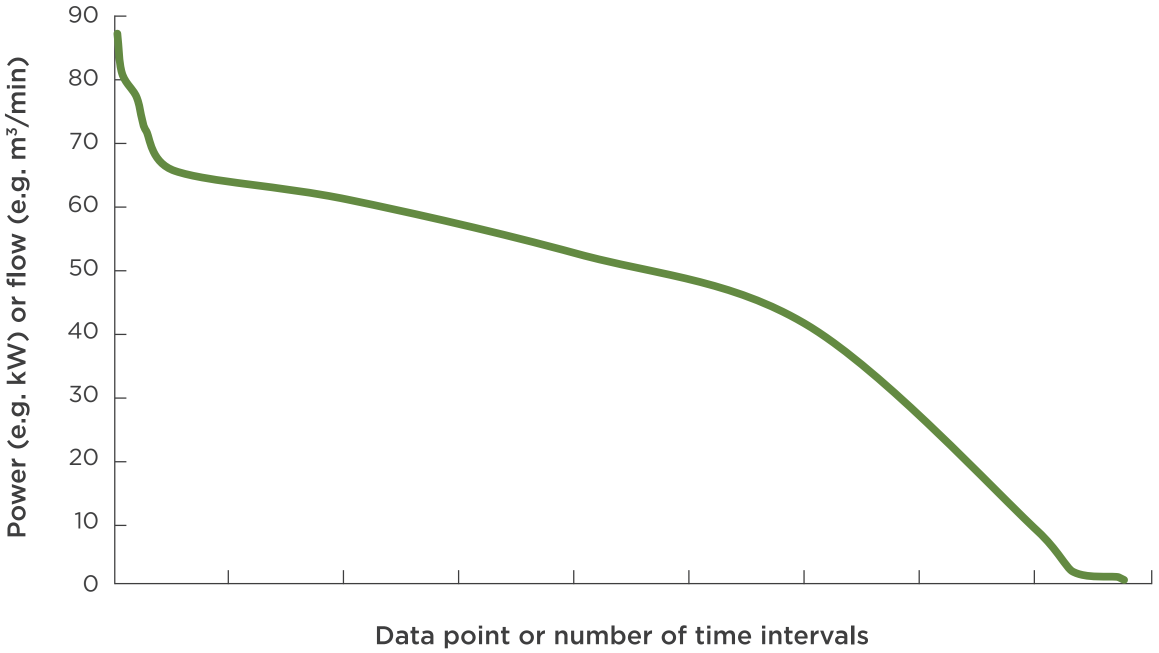


Figure 10 Sample load duration curve for a pump

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[22] Load factor is the ratio of actual energy consumption to maximum possible by the equipment. As a general rule of thumb, the load factor for fixed-speed pumps is 0.7–0.8. The estimated energy consumption should be seen as an indicative value only.

[23] US Department of Energy 2012, Motor Systems Tip Sheet #11: Adjustable Speed Drive Part-Load Efficiency, Energy Efficiency and Renewable Energy Advanced Manufacturing Office.

Do

Identify a list of efficiency opportunities for your pumps and pumping system

Energy efficiency opportunities for pumps and pumping systems typically fall into four categories:

- improve controls – to more efficiently deliver the required output
- modify pumps – to better match the required conditions
- replace or upgrade equipment – use more efficient technology or more suitable equipment
- re-design the system – to minimise friction losses, static pressure or required flow rate.

A full list of opportunities can be found in **Appendix B**.

Pump affinity laws

Pump affinity laws describe the relationship between power, flow, impeller diameter, head, and shaft speed of centrifugal pumps. Most pump suppliers have their own 'pump handbook' that describes the laws in detail.

The take-home messages from the laws is that a reduction in pump speed will result in a disproportionate reduction in power consumption.[24] For example, a 20% reduction in pump speed can result in approximately 50% reduction in power.

TIP: additional opportunity

See **Section 4: Optiminse your RAS flow rate** for further opportunities to significantly reduce your plant's pumping requirements.

Prioritise and implement your opportunities

Determine which opportunities are applicable for your site, or consult an energy efficiency expert to identify opportunities at your site.

For a list of accredited suppliers see Find an energy expert on the Office of Environment and Heritage website.

Prioritise opportunities based on your energy-saving targets, financial criteria (costs, hurdle rate, payback period, etc.), and ease of implementation. To ensure systematic energy management, consider developing a procedure to prioritise energy savings opportunities. This should include the financial and energy criteria set by your organisation. Refer to *ISO 50001:2011 Energy management systems: Requirements with guidance for use* (International Organization for Standardization) for guidance on criteria.

Before implementing energy savings opportunities, consider:

- in-house skill set and availability of resources
- operational conditions and process control benefits
- forecast energy demand increases e.g. due to projected population increases
- project complexity
- impact on plant stability and reliability
- impact on peak demand (and associated electricity cost changes)
- energy performance outcomes
- energy savings certificates to help reduce payback
- links with the site continuous improvement program or sustainability goals
- reduction in greenhouse gas emissions
- external expertise in aeration or process control.

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[24] Note: reducing pump speed may not be appropriate for systems with high lift requirement.

Total Cost of Ownership (TCO)

Equipment purchasing and system design decisions should always be based on TCO, especially in pump systems where energy costs in some cases can exceed the purchase price of the pump within the first year.
TCO includes:

- initial cost – selection, procurement, installation, potential changes in pipes, valves, etc., and commissioning
- energy cost – including demand and environmental charges
- maintenance cost – including planned and unplanned downtime
- disposal – residual or scrap value, or disposal or recycling costs at end of service life.

Maintaining savings over time

In addition to your energy savings opportunities, implement strategies to ensure savings will be sustained over time:

- Consider operational controls to maintain pumps operating at appropriate levels of efficiency (additional metering may be required e.g. flow meters, pressure transmitter, power meters). See OEH's Electricity Metering & Monitoring Guide
- Establish smart performance monitoring to track deviations from optimal conditions and maintenance needs
- Train relevant staff to understand pump system performance and efficiency
- Establish procurement controls to ensure energy efficiency specifications are considered when replacing the system or parts of it
- Carry out checks during commissioning to ensure specified efficiency is achieved, and establish benchmarks for future performance tracking and comparison.

Check

Monitor your pumps and pump system

In conjunction with benchmarking efforts, efficiency and performance of pumps and pumping systems should be monitored over time to determine specific maintenance requirements that are over and above the regular maintenance practices.

Make sure pumps and the pumping system are well-maintained according to the manufacturer's instructions or in-house procedures; this contributes to overall system efficiency.

Calculate energy savings

Measure post-implementation energy consumption over a suitably representative period to determine the new average specific energy consumption (kWh/ML, assuming head requirement is unchanged).

Keep monitoring the average energy consumption, e.g. on a monthly basis, to track pump performance, and identify when performance has a step-change or drifts.

To calculate annual energy savings:

Energy before (kWh/ML) – energy after (kWh/ML)) x volume pumped per year.

Compare the calculated energy savings to expected energy savings.

This calculation assumes the head requirement is unchanged. In most instances this would be the case, however, should the head requirements change (for example as a result of altering the piping configuration), then the calculation methodology becomes more complex. In these instances, consult an appropriate pump guide or other technical reference for assistance.

Measurement and Verification (M&V)

Energy savings cannot be directly measured, but can be calculated from measuring data using M&V methods. Refer to the International Performance Measurement and Verification Protocol (IPMVP) or consult a Certified M&V Professional (CMVP).

Evaluate your project

- Were the energy savings and implementation costs consistent with project expectations?
- What are the key lessons to be shared internally or externally?
- Prepare a case study or project summary to share the results.

Continue monitoring

Continue to monitor performance to ensure savings are maintained.

Act

- Use the key learnings to inform the next planning phase, identify new opportunities, review priorities and continue to drive further savings.
- Adjust operations based on the results achieved.
- Identify energy savings opportunities in other areas or processes of your WWTP.

Case study: Burwood Beach Waste Water Treatment Plant

> **'Not only did we achieve considerable energy cost savings, the wear-and-tear on our pumps was reduced, prolonging their service lives and reducing maintenance costs.'**
>
> **Chris Farragher**
> Senior Electrical Engineer
> Hunter Water Corporation

Our situation

Burwood Beach Wastewater Treatment Works (BBWWTW), located in Newcastle, is Hunter Water Corporation's largest capacity wastewater treatment works. It treats about 45 million litres of wastewater per day from four main Newcastle catchments and one Lake Macquarie City catchment, as well as septage delivered by tanker.

Our pumping system consists of a Primary Pump Station that pumps wastewater for preliminary treatment, and a Secondary Pump Station that pumps the treated effluent for biological treatment. The pumping control scheme was prone to wasting energy and operating pumps in ways that shorten their service life. For example, usually two pumps would be running at any one time, but one would be spinning without any flow through the pump.

The inlet lift station consists of seven variable speed lift pumps, with a full flow capacity of 5900 litres per second and generally pumps around 20 gigalitres a year.

What we did

Based on modelling of specific energy consumption curves of the various valid pump combinations at the lift station, we designed a control scheme to maximise the energy efficient use of the pumps, while maintaining optimal operating conditions for pump service life.

Implementing the new control scheme involved a cut over to the new scheme plus commissioning work. The stages in the project were: a design phase; workshopping of the design with stakeholders; a hazard and operability study (HAZOP); design revisions and approvals; implementation; and operator training. The overall cost of the upgrade was $160,000.

Aerial view of BBWWTW.
Photo: Hunter Water Corporation

Our challenges

The project generally went very smoothly. The only issue was a four-month delay in closing-off the project while we waited for a large wet weather event so we could carry out a full-flow test of the new control scheme as part of commissioning.

Our results

We reduced our energy use by 281 megawatt hours per annum, saving us around $48,600 per year, meaning the simple pay back was 3.3 years, not allowing for cost offset from Energy Saving Certificates (ESCs).

But importantly the wear-and-tear on the pumps has been reduced, resulting in fewer breakdowns, longer service intervals and hence reduced maintenance costs and higher pump availability.

The new pump controls also mean smoothed-out flows to the screen house, reducing the incidence of spillage which improves the safety of the plant. And the automatic recovery after an interruption to pumping enhances our operating licence compliance.

Our licence compliance is also enhanced by the fact that the new controls interlock with our downstream plant elements restricting plant flow in the event of a breakdown.

A third party successfully claimed ESCs for the project, resulting in payments to Hunter Water thus offsetting some of our capital cost.

Our advice to other WWTW operators

We'd recommend that all WWTW operators consider upgrading their pumping system's control scheme. Poor control of variable speed pumps is not uncommon in WWTWs and incurs extra costs both in energy and in pump health; and a well-designed control scheme can help to overcome certain shortfalls in a plant such as hydraulic limitations.

Our advice to other operators considering a similar project is to incorporate specific energy consumption analysis into the design of any variable speed pumping system. This will help maximise efficiency and avoid poor operating conditions for the pumps.

We would also advise extensive dialogue with plant operating staff to ensure the new control scheme is fit for purpose, as well as ensuring acceptance by staff.

Implementation costs: $160,000

Cost savings: $48,600 per year.

Energy savings: 281 MWh per annum

Simple payback: 3.3 years

4 Optimise your return activated sludge (RAS) flow rate

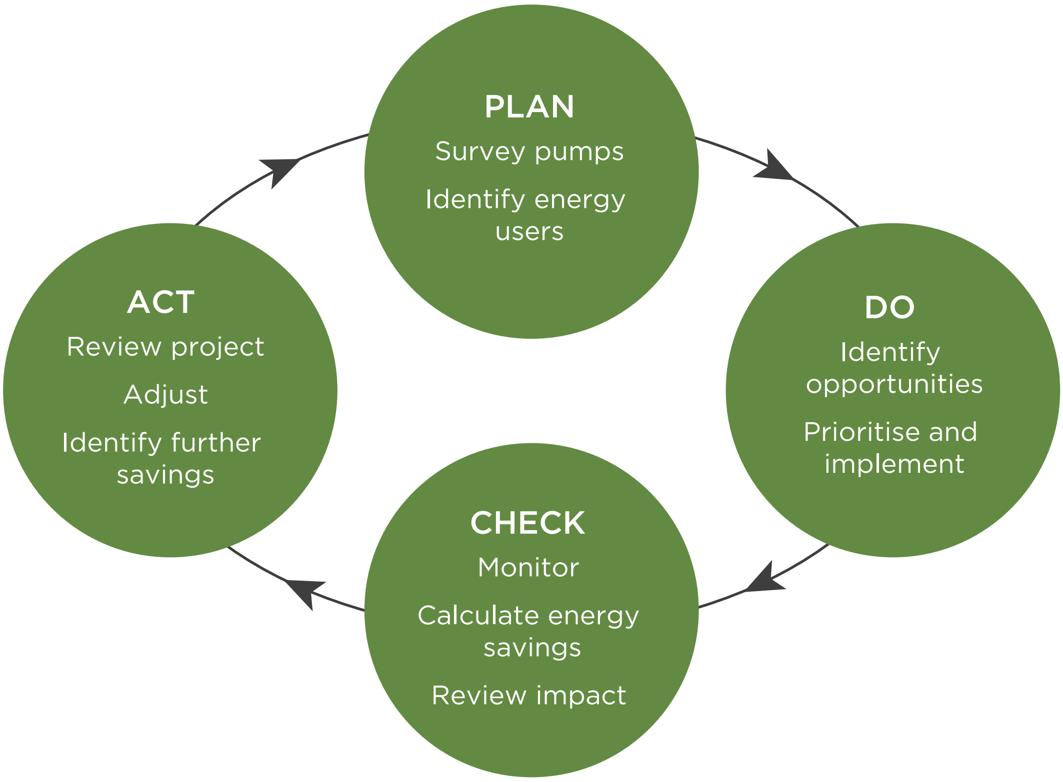
Fine-tuning a delicate process

WWTPs are carefully engineered facilities for receiving sewage and discharging treated effluent – that meets environmental requirements – into water bodies. The amount of sewage and level of treatment required can vary daily, seasonally, and due to weather events.

The aim of optimising the processes in a WWTP is to reduce energy consumption without adversely affecting the quality of the treated effluent or biosolids produced.

This section of the guide discusses optimising your return activated sludge (RAS) flow rate as an example of how to reduce energy consumption. This approach is applicable to activated sludge plants equipped with clarifiers. It can also be applied to other energy-intensive units or treatment processes.

The diagram below sets out the steps involved in optimising your RAS flow rate using the PDCA framework:



Plan

Define your objective

The objective in optimising RAS is to minimise the RAS pumping required, while maintaining plant process stability, plant flexibility, and quality of treated effluent.

TIP: understanding plant design intent

An energy efficiency engineer once found the original blueprints for a plant designed in the 1950s. These blue prints showed that the plant had been operating incorrectly for at least 20 years.

It can be worthwhile investigating how a WWTP was originally intended to be operated by referring to functional descriptions, plant manuals, design drawings and other available resources. If current operation deviates from original design, determine the reasons.

Understand the process

The primary purpose of RAS is to re-seed incoming sewage with the activated sludge biomass needed for treatment. The sludge contains microorganisms that remove carbon and nitrogen. If too much is returned, higher microbial activity may result in higher air consumption leading to higher energy consumption. If microbes are not returned in sufficient volume, treatment of carbon and nitrogen may be reduced leading to poor effluent quality.

RAS is pumped from the bottom of clarifiers to the bioreactors, where mixing and aeration of the biomass with influent sewage takes place.

Critical factors for understanding the overall process include:

- the minimum ratio of RAS to inlet sewage required for treatment, particularly for stable and reliable clarifier operation under changing flow conditions
- the point at which additional RAS provides no additional treatment benefit.

Both factors can be determined by either:

- referring to the plant manuals to determine design intent, with minimum, ideal and maximum RAS flow rates as a proportion of inlet sewage flow rate
- experimentally by following the suggested approach (see ‘Do’ below), continually monitoring the selected indicators (see ‘Set baseline’ below) to identify impact on treatment quality.

Understand flow-on effects

In any WWTP, changes to one process are likely to have a follow-on effect on other areas of the system.

Understanding process interactions can ensure potential adverse or beneficial outcomes will not be overlooked.

For example, changing RAS flow rate may:

- alter the ratio of RAS to inlet sewage, impacting treatment
- change the level or stability of the sludge blanket depth in the clarifiers. At low RAS rates, process instability can arise from thickening failure at the bottom of the clarifier (i.e. sludge accumulation on or near the floor of the clarifier, potentially leading to a rising sludge blanket and/or floating sludge). The consequence can be high effluent suspended solids or, even gross loss of biomass from the process
- affect the ability of the plant to treat high influent flow rates (e.g. during wet weather events)
- affect clarifier operation, which is affected by feed flow rates, sludge settleability, RAS and waste activated sludge (WAS) removal rates
- alter the appropriate removal rate for WAS, with downstream impacts on sludge thickening, pumping and digestion processes
- affect biological nutrient (nitrogen and phosphorous) removal processes (e.g. the quantity of nitrate and oxygen recycled via RAS; or phosphorus release in the clarifiers).

In a limited number of instances, changing the RAS flow rate may:

- affect the turbulence and mixing behaviour of RAS and influent due to lower flow velocity
- contribute to fouling due to sludge settling in the RAS pipework at low flow rates.

Understanding these aspects allows them to be monitored, controlled, and balanced to find the best process outcome.

Set your baseline

Determine suitable measurements or indicators for monitoring plant performance potentially affected by RAS flow changes, for example:

- efficiency of RAS pumps (see **Section 3: Optimise your pumping** for more information)
- BOD in treated effluent
- amount of WAS
- water content in WAS
- sludge blanket depth.

TIP: Estimating RAS pump energy consumption

Fixed-speed pumps: annual energy consumption (kWh) for a fixed-speed pump can be estimated using rated power (kW) × annual operating hours × 0.75 (load factor).[25]

Variable speed drive (VSD) pumps: most VSDs, particularly new ones, calculate energy consumption in their internal computer. Check your VSD user manual to determine how to view the energy consumption or export it (once-off or continuously to your plant's SCADA system).

The part-load efficiency of a VSD will vary between manufacturers, so the associated documentation should be consulted. If this is not available, other resources can provide a reasonable estimation, e.g. the US Department of Energy Motor Efficiency Tip Sheet #11.[26]

Do

Design and execute a trial to assess the impact of changing one component of the process on overall plant operation and sewage treatment.

Suggested approach: incremental change

A suggested approach is to reduce the RAS flow rate in small increments over a week or two to avoid shocks to the system and allow adaptation time. The methodology to adjust the RAS flow rate depends on your plant's operation. For example, some RAS flow rates may be controlled by weir height rather than flow rate directly.

Note: different flow controls or settings may be required to account for dry or wet weather flow conditions.

If effluent quality is not adversely affected by the initial decrease in RAS rate, decrease the flow rate by another small increment. Continue until the minimum RAS flow rate ratio (to inlet sewage flow rate) is reached while maintaining treated effluent quality. A safety margin can be added to ensure process flexibility and stability.

Once the new process condition is confirmed, implement permanent changes where appropriate, namely, control parameters, operating procedures, equipment modifications (e.g. VSD, pump configuration, instrumentation, control valves, and other process settings as appropriate).

RAS flow rate optimisation summary

Potential savings: 20–60% of RAS pump energy consumption

Likely payback: < 3 months for control changes only

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[25] Load factor is the ratio of actual energy consumption to maximum possible by the equipment. As a general rule of thumb, the load factor for fixed-speed pumps is 0.7–0.8. The estimated energy consumption should be seen as an indicative value only.

[26] US Department of Energy 2012, *Motor Systems Tip Sheet #11: Adjustable Speed Drive Part-Load Efficiency*, Energy Efficiency and Renewable Energy Advanced Manufacturing Office.

Check

Monitor performance indicators

Monitor the performance indicators collected for the baseline to identify any delayed impacts.

Calculate energy savings

To calculate annual energy savings:

[Pump energy consumption$_{\text{Before}}$ (kWh/[ML.m]) × Head$_{\text{Before}}$ – Pump energy consumption$_{\text{After}}$ (kWh/[ML.m]) × Head$_{\text{After}}$] × annual flow (ML).

The annual flow volume can be RAS or influent flow rate, depending on data availability and reliability.

Measurement and Verification (M&V)

Energy savings cannot be directly measured, but can be calculated from measuring data using M&V methodologies. Refer to the International Performance Measurement and Verification Protocol (IPMVP) or consult a Certified M&V Professional (CMVP).

Evaluate your project

- Were the energy savings and implementation costs consistent with project expectations?
- What are the key lessons to be shared internally or externally?
- Prepare a case study or project summary to share the results.

Continue monitoring

Continue to monitor performance to ensure savings are maintained.

Act

- Use the key learnings to inform the next planning phase, identify new opportunities, review priorities and continue to drive further savings.
- A similar approach to that described here for RAS can also be applied to other opportunities for optimising processes, e.g. optimising the mixed liquor return flow rate, aeration supply, or ultraviolet disinfection.
- To ensure savings are continuously achieved:
    - assess opportunities for further fine-tuning and improvement
    - document and share benefits and key lessons
    - continue to monitor performance over time.

Case study: Shellharbour Waste Water Treatment Plant

‘Reducing the Returned Activated Sludge (RAS) flow rate reduced pump energy use by 13% and increased the life of our pumps with no adverse impacts – not bad for an action that cost us nothing.’

Greg Appleby
Senior Resource
Management Advisor
Liveable City Solutions
Sydney Water

Our situation

The Shellharbour Waste Water Treatment Plant (SWWTP) is located on the coast approximately 100km south of Sydney, and is owned and operated by Sydney Water. The plant treats approximately 17 megalitres of wastewater (sewage) each day to secondary level including disinfection. Treated effluent is discharged off Barrack Point via an outlet located about 130m offshore.

What we did

Reducing the flow-rate of recycled activated sludge (RAS) was identified as an energy efficiency opportunity in an external energy audit of the plant.

Prior to the audit, the RAS flow rate was set to a diurnal pattern with an average flow of 280 litres per second (L/s), or 124% of the inlet sewage flow rate. The audit identified the potential to reduce the RAS flow rate to 107% of the inlet sewage flow rate with an average of 250 L/s.

SWWTP bioreactor. Photo: Sydney Water Corporation

Our results

The RAS flow rate was reduced by 11%, reducing the energy used by the RAS pumps by about 13%, and saving around 45 megawatt hours (MWh) per year.

The reduction has not caused any adverse changes to the process indicators on site, e.g. biological oxygen demand (BOD)

An additional benefit is a significant reduction in spikes in pump and valve operation that controlled the RAS pumps. This reduction will increase pump life, reduce pump maintenance costs, and reduce unexpected pump failure.

A further 5% energy reduction (to achieve 18% in total) is possible by tuning of the RAS flow PID control system in order to eliminate the pump spikes entirely.

Implementation costs: $200,000

Cost savings: $60,000 per year.

Energy savings: 590MWh per year

Simple payback: 3.3 years


SWWTP Influent piping. Photo: Sydney Water Corporation

SWWTP RAS tank. Photo: Sydney Water Corporation

5 Generate heat and power from biosolids

Biosolids are a resource

Biogas, produced by anaerobic digestion of biosolids, is a valuable source of energy and is increasingly used in Australia to generate heat and electricity. Many larger WWTPs produce biogas for heat and electricity generation on site. Sydney Water has been utilising biogas to produce energy since 1999, and now generates 21% of its operational energy requirements on site.

This section of the guide focuses on combustion, gasification or pyrolysis of biosolids (digested and undigested) for the generation of heat and power. This is possible at all WWTPs where biosolids (or sludge) are generated in sufficient quantities. While this technology has been around for some time, it is not a common application in Australia, primarily due to historically low energy costs. This situation has changed in recent years with a greater emphasis on energy cost reduction and the use of renewable energy.

Example

For one WWTP in New South Wales, a pre-feasibility analysis indicated that 30,000 tonnes of wet biosolids per year (45% sourced from other WWTPs) will generate ~4000 MWh using gasification technology, with a payback period of less than six years.

Benefits

The benefits of energy from biosolids are:

- disposal of wet biosolids no longer required[27]
- onsite generation of renewable power, with significantly lower greenhouse gas emissions[28]
- reduced dependency on electrical power from the network (and exposure to retail price fluctuations)
- the biosolids 'ash' may be a valuable fertiliser – an additional revenue source
- depending on the availability and quantity of biosolids, the size of the generator, and the site energy requirements, the potential exists to export power to other nearby sites or to the grid.

Technologies

There are a range of technologies available to improve the energy performance of WWTPs. Conventional approaches like anaerobic digestion with biogas generation are common across a broad range of plant however, some alternative technologies may be more appropriate to maximise the benefits available. These alternative technologies are discussed below.

If you are considering using these technologies, you need to undertake an independent assessment of the opportunity, taking into account the specific operational aspects of your facility to verify their applicability. The technologies considered include combustion, gasification and pyrolysis.

Combustion

Overall this involves using a boiler to generate steam or hot oil. (For more information see OEH's Cogeneration Feasibility Guide)

Key considerations:

- Excess air is required (usually included in the design of combustion units)
- Drying of fuel is not required for circulating fluidised bed (CFB) or bubbling fluidised bed (BFB) boilers, but any drying of biosolids will improve system efficiency
- CFB or BFB boilers are most suitable for a range of fuels, including municipal green waste, agricultural waste, construction and demolition waste, and contaminated paper and cardboard packaging
- Electricity can be generated using a steam turbine or organic rankine cycle (ORC) turbine

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[27] Note that this benefit only applies to the generation of energy from biosolids as described in this section of the guide, however, generation of energy via other methods (e.g. anaerobic digestion) will still produce wet biosolids, albeit a lower quantity.

[28] The current protocol from the Intergovernmental Panel on Climate Change (IPCC) specifies that carbon dioxide emissions from combustion of all biofuels is zero, though there are some minor methane (CH_4) and nitrous oxide (N_2O) emissions.

- Excess heat can be used in digesters (or other processes nearby)
- Suitably skilled operators are required to ensure smooth and safe operation.

Gasification

Biomas is heated to 700°C in presence of limited oxygen to produce a synthetic gas.

Key considerations:

- Sludge drying is required. The level of drying required depends on the specific technology and fuel mixture
- Syngas can be fed into a gas engine to generate electricity
- Gas engines can be co-fired with natural gas and/or biogas for additional energy production (additional mixing train and/or controls may be required)
- Heat can be recovered from a gas engine for sludge drying and/or digester heating
- Suitably skilled operators are likely to be required to ensure smooth and safe gasifier operation.

Pyrolysis

Similar to gasification but the reaction occurs at 300–400°C with no oxygen, producing syngas and biochar.

- Sludge drying is required. The level of drying required depends on the specific technology and feed fuel mixture
- Heat and/or electricity can be generated from syngas (as gasification technology, above)
- Biochar can be sold as fertiliser or a soil additive, or combusted to generate heat and/or power (as combustion technology, above)
- Suitably skilled operators are likely to be required to ensure smooth and safe operation.

Project economics

Potential sources of revenue or cost savings for these projects include:

- reduction in electricity bills
- reduced biosolids disposal costs
- renewable energy generated on site, on-demand
- gate fees can be charged for delivery of biosolids from other WWTP and for other suitable waste e.g. municipal wastes
- revenue from sale of biosolids ash or biosolids char
- eligibility for large-scale generation certificates (LGCs) or Australian carbon credit units (ACCUs).

Project operational expenses relate mainly to characteristics of biosolid feedstock and any analysis and treatments required. Key characteristics include:

- ‘proximate analysis’ (moisture, sulphur, energy content, volatile matter, fixed carbon, ash)
- ‘ultimate analysis’ (moisture, ash, carbon, hydrogen, nitrogen, sulphur, and oxygen [by difference])
- ash composition
- ash fusion temperatures
- trace metals and other impurities (including pollutants of environmental concern).

Analysis of at least 12 monthly samples is needed to understand seasonal fluctuations in these properties over time; data over several years will improve understanding of long-term fluctuations and build confidence in your business case.

Feasibility studies required (preliminary and/or bankable) include:

- equipment costs, including: dewatering of biosolids (as required), exhaust and/or syngas treatment, gas mixing train, fuel handling system, ash handling system
- potential costs (or revenues, if helping an organisation to avoid their waste disposal costs) associated with importation of supplemental fuels and cost for disposal of additional ash from the supplemental fuels.

Note: should supplemental fuels be considered, additional equipment costs will be required for fuel storage, handling and blending:

- installation costs
- engineering costs (design, civil, commissioning)
- control systems (with or without integration into existing site systems)
- electrical connections, substation, network connection agreements
- environmental approvals and community engagement.

Additional operating expenses:

These include the costs of personnel, maintenance, ongoing management and monitoring costs, and the potential requirement for supplementary fuels. The supplementary fuels could be associated with plant start-ups and maintenance programs and some facilities may need to supplement their fuel supply to ensure stable operation of the plant, which in turn helps improve plant efficiency.

TIP: Package units

Commercially available package units that have been specifically designed for biosolids can reduce the overall project costs. However, be aware of the exclusions in their quoted price, and ensure due diligence is carried out on the supplier's offerings.

Be aware of restrictions on biosolids' properties for performance guarantees and maintenance contracts. As a plant owner or operator you need to fully understand the fuel characteristics and how that relates to guarantees from equipment providers, as well as the equipment's ability to handle impurities, particularly heavy metals (such as Ni, Cu, Zn, Cd, Hg). The effect of these impurities could be amplified if the site imports wastes from other facilities.

Is your plant suitable for this technology?

For the purposes of this initial assessment, the residual materials could be a revenue or a cost, depending on the site, the process and the available market (e.g. the market for ash as a fertiliser or soil supplement). As a result, this aspect has been treated as an 'unknown' and has therefore been excluded from this assessment. However, you do need to recognise this issue and include any potential costs or revenues as appropriate. **Appendix G** provides details on calculations to determine if your plant is suitable for energy generation from biosolids.

TIP: Project funding

Biosolids are a renewable energy source, and thus is likely to be eligible for State or Federal government funding.

Alternatively, share the cost of the project with other interested parties or an industry consortium.

Additional considerations when generating electricity

When not exporting to the grid

When connecting power generation to a site's electricity supply, a network connection agreement (NCA) is required. The connection application process typically increases in complexity and cost with generation size. Distributors may impose additional requirements for larger generators, such as remote monitoring, zero export control, inter-tripping, etc. Even if you have no intention of exporting electricity to the network, an NCA is still required.

If your consumption and demand falls below set thresholds, connection of embedded generation may alter the current network tariff you are on, and the network provider may charge you for a minimum site demand regardless of your actual recorded value.

In some electricity contracts, there is a take-or-pay clause that requires a minimum consumption from the grid, or payment for that consumption even if it is not used. This clause may limit the maximum output from your generator.

If you would like to export to the grid

If you would like to supply excess electricity to the grid, there are two requirements:

- An export agreement with an energy retailer, who will pay for the electricity you send to the grid. It may be worthwhile obtaining your own retail licence if your export is >10 MW
- Technical compliance with the network. The network operator will require safeguards to ensure your generator does not cause instabilities in the network. Usually a variety of hardware, administrative controls and control access by the network operator is required.

Case study: Gasification

What is it?

Gasification is the process of converting biomass, in this case sewage sludge combined with municipal waste, into a low-emission fuel commonly called syngas, short for synthetic gas – a mixture of mainly carbon monoxide and hydrogen. This fuel can then be used to provide power for a treatment works.

How does it work?

Organic material (feedstock) is heated to more than 700 degrees C in the presence of a controlled amount of oxygen without combusting. This causes the carbon monoxide, hydrogen and carbon dioxide present in the organic matter to react to form syngas. **Figure A** shows the stages in a typical gasification process.

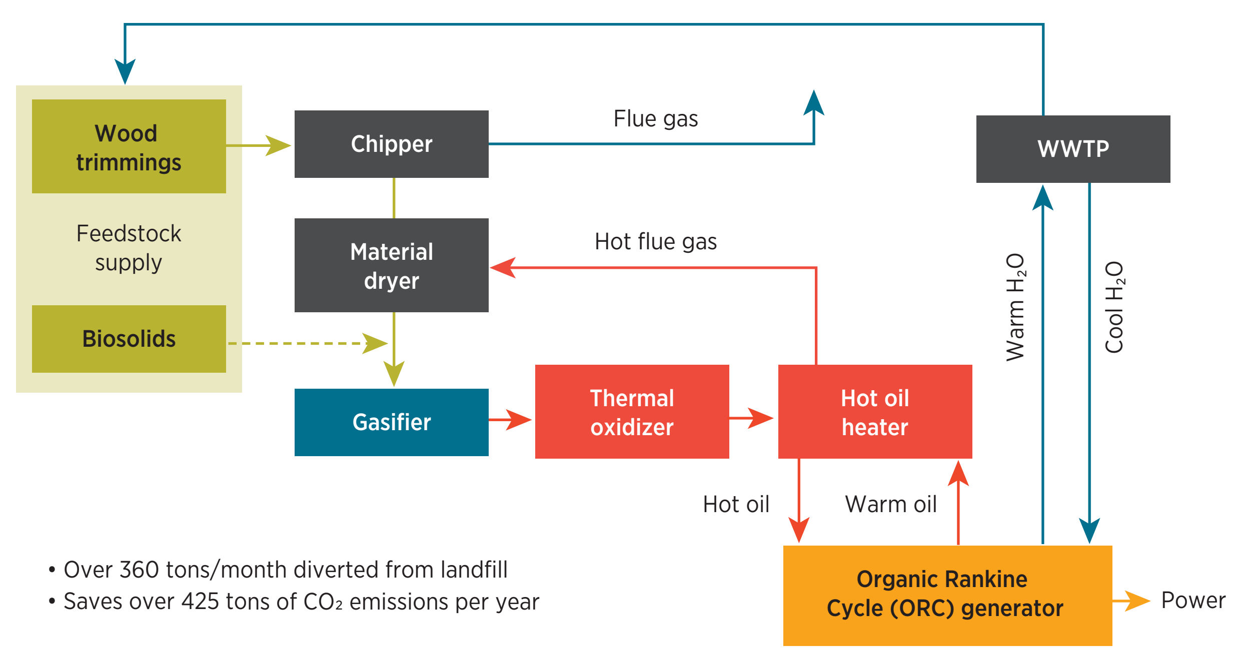

Figure A: Downdraft gasification process

Overseas gasification plants

There are a number of successful downdraft gasification plants operating overseas. A $4.5 million plant in Lebanon, Tennessee USA, the world's largest downdraft gasification plant, is currently converting three tonnes of sewage sludge, three tonnes shredded tyres and 26 tonnes of shredded wood waste per day to gas plus biochar that is recycled or sold for agricultural or industrial uses. When operating at full capacity it can convert more than 64 tonnes of organic waste per day to produce gas that when combusted can produce up to 400 kilowatts per hour of electricity. At full capacity, the plant can divert 8000 tonnes of waste from landfill annually and reduce annual greenhouse gas emission by 2500 tonnes.

The Lebanon plant has earned a number of environmental awards during 2017, including Tennessee's highest, the Environmental Stewardship Award for energy and renewable resources.

A smaller plant, costing $3 million, operates in Covington, Tennessee. This plant converts around 10 tonnes of organic waste (1.5 tonnes of sludge and 8.5 tonnes of wood waste) to gas per day, with the electricity generated used to power the site.

Gasification plant, Lebanon, Tennessee (USA). Photo: Lebanon City Council

As well as saving on power costs, both plants provide further savings for the operators by reducing waste handling, tipping fees and transport costs.

Operators of the two plants identified the following as the key benefits from gasification:

- provision of a low-emission fuel which will cut operating costs
- creating value from sludge streams
- reducing disposal costs
- helping achieve sustainability goals.

Gasification in Australia

Although there are no operational gasification plants utilising sewerage sludge in Australia at the time of publication, there are plans to install a number of gasifiers in Queensland. Each proposed site will convert around 45-50 tonnes of wood and non-recyclable organic wastes to gas, with plans to extend the waste stream to include sewage sludge. Each site will have the capacity to generate more than 35 gigawatts of power, produce high value Biochar, reduce waste handling and transport costs, and reduce greenhouse gas emission.

> **‘We’re reducing landfill use, creating clean energy and keeping thousands of tons of carbon out of the air each year … all with a positive cash flow. This is a win.’**
>
> **Bernie Ash**
> Mayor of Lebanon, TN

Appendix A: Types of WWTP

This guide uses the classification of WWTPs set by the Water Services Association of Australia 2013–14:

Type 1	Activated sludge treatment with separate sludge stabilisation, including primary sedimentation, anaerobic digestion, with onsite cogeneration from biogas (Figure A outlined in green)[1]
Type 2	Activated sludge treatment with separate sludge stabilisation, including primary sedimentation, anaerobic digestion, without onsite cogeneration from biogas (Figure A shaded blue)
Type 3	Extended aeration activated sludge, including aerobic digestion. Also known as oxidation ditch plants (Figure B)
Type 4.1	Trickling filters only
Type 4.2	Tricking filters in combination with activated sludge
Type 5.1	Aerated lagoons
Type 5.2	Lagoon and/or wetland systems without aeration.

A typical process flow diagram for a Type 1, 2 and 3 WWTP is shown in **Figure A** and **Figure B**.

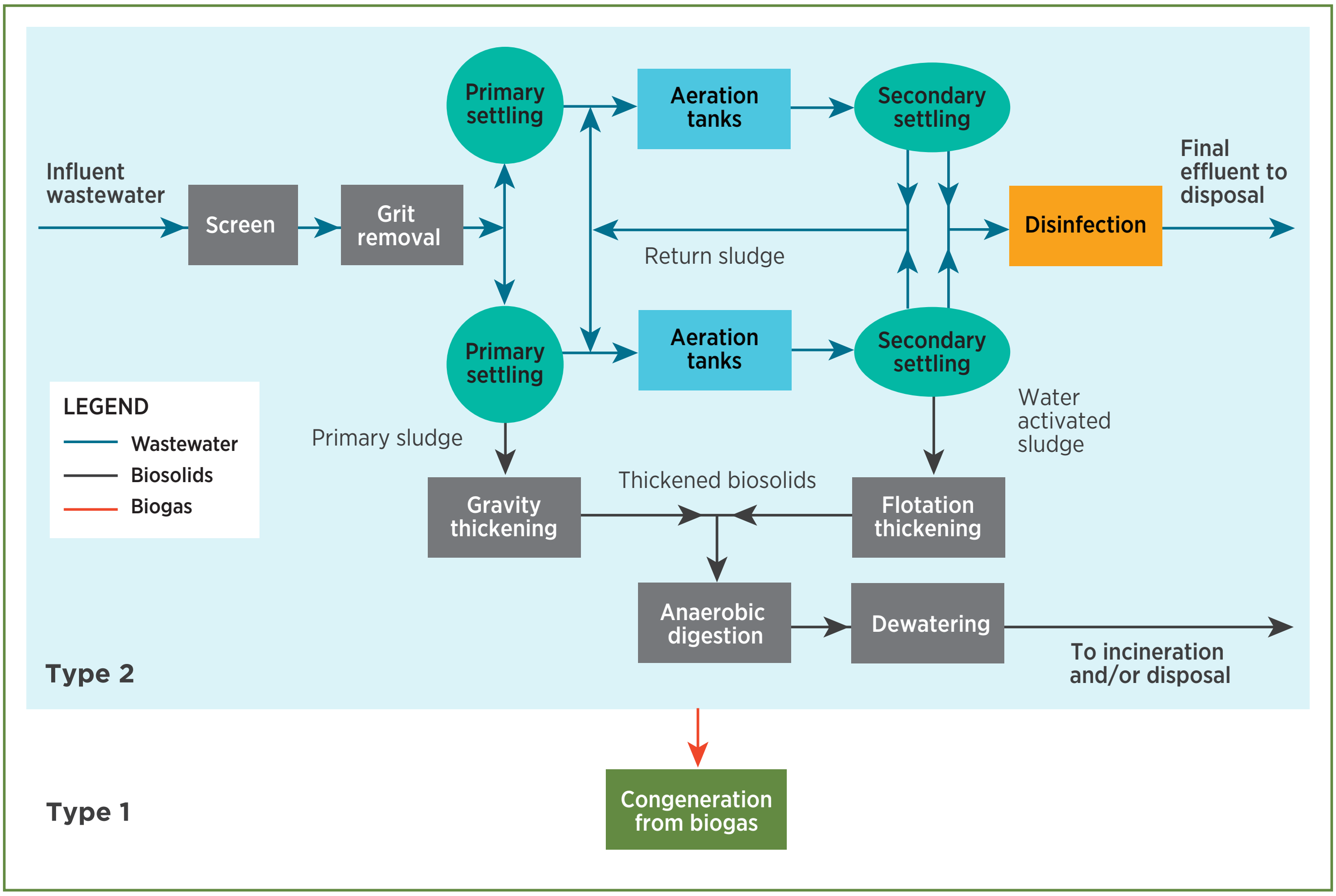

Figure A Typical process flow diagram for a Type 1 and 2 WWTP: activated sludge treatment.

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[1] Plants with primary treatment and anaerobic digestion plus onsite cogeneration from biogas, but lacking activated sludge (or some other form of secondary treatment), by default have been classified as Type 1 in the WSAA approach, to date.

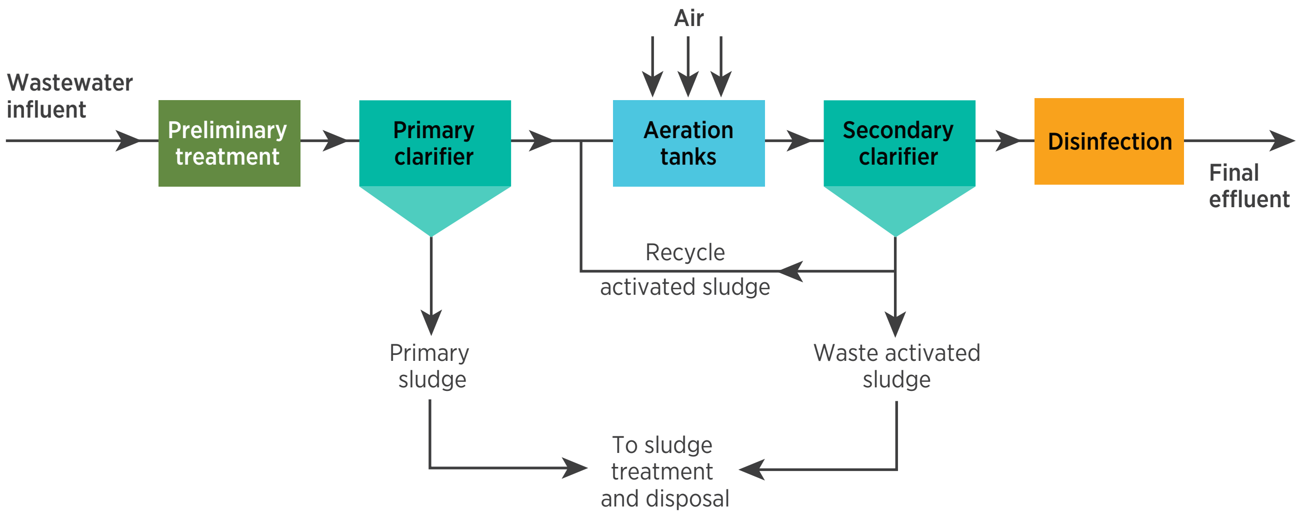

Figure B Typical process flow diagram for a Type 3 WWTP: extended aeration activated sludge treatment[2]

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[2] http://www.water-chemistry.in/2009/08/what-is-extended-aeration accessed 19 May 2017.

Appendix B: Summary of further opportunities

	Title	Overarching process	Process / technology	Description	Plant type[1]							Treatment stage[2]			
					1	2	3	4.1	4.2	5.1	5.2	P	S	T	SL
1	Membrane aeration bioreactor (MABR)	Aeration and blowers	System, MABR	Investigate the use of an MABR system to meet aeration requirements in a new WWTP or new train. Aeration efficiency of 0.167 kWh/kg O2 are claimed, which is ~ 30% less than the most efficient fine bubble diffusion system.	x	x	x	x	x	x			x		
2	Replace surface aeration or coarse bubble aeration system with fine bubble diffusers	Aeration and blowers	System, diffusers	Aeration systems with fine bubble diffusers are ~ 50% more efficient than coarse bubble aeration and up to 65% more efficient than surface aerators. Note some systems may require additional mechanical equipment (e.g. mixers).	x	x	x		x	x			x		
3	Optimise aeration requirements with automatic aeration control	Aeration and blowers	System, control	Automate control of air delivery for an aeration system based on dissolved oxygen (DO) or ammonia (NH3) sensors.	x	x	x		x	x			x		
4	Diffuser monitoring and maintenance	Aeration and blowers	System, diffusers, maintenance	Monitor diffuser condition by tracking backpressure. Use the backpressure data to optimise a cleaning schedule. Diffuser cleaning can range from injection of acid vapours into the aeration pipework to mechanical cleaning when the tank is drained.	x	x	x		x	x			x		
5	Benchmark diffuser performance and optimise replacement timing	Aeration and blowers	System benchmarking	Benchmark your diffuser system efficiency (e.g. kWh/[EP Year]) to indicate when your diffusers need to be replaced.	x	x	x		x	x			x		
6	Reduce aeration demand – e.g. improve primary processes	Aeration and blowers	Process optimisation	Where primary sludge is moved directly to the digester, improved primary treatment (not energy intensive) for removal of oil and grease, suspended solids, and organic material will reduce aeration demand during secondary treatment (energy intensive).	x	x	x					x	x		
7	Fix leakages in air pipes	Aeration and blowers	Pipes	Any leaks in air pipes will increase the load on air blower and compressor system. Check for and fix leaks on a regular (six-monthly) basis.	x	x	x	x	x	x		x	x	x	x

	Title	Overarching process	Process / technology	Description	Plant type[1]							Treatment stage[2]			
					1	2	3	4.1	4.2	5.1	5.2	P	S	T	SL
8	Streamline aeration pipework	Aeration and blowers	Distribution/ transfer	Avoid unnecessary lengths, changes in direction or diameter or other obstructions in aeration pipework.	x	x	x		x	x			x		
9	Use mixer(s) instead of an aeration (or sparging) system	Aeration and blowers	Blowers, mixing	If air is diffused (or sparged) into a tank for the sole purpose of bulk volume mixing, replace (or install) a mixer (where suitable). Mixers are much more efficient at mixing than blowers and aeration systems.	x	x	x			x			x		
10	Blower performance monitoring	Aeration and blowers	Blowers, aeration system, benchmarking	Performance indicators for your blowers will provide insight on the efficiency of the blowers, and aeration system as a whole.	x	x	x		x	x			x		
11	Optimise blower maintenance	Aeration and blowers	Blowers, aeration system, benchmarking	Using blower performance monitoring above, optimise when to undertake maintenance.	x	x	x		x	x			x		
12	Blower sequencing and control philosophy	Aeration and blowers	Blowers, aeration system	Optimisation of blower control system to identify the required rate of aeration and deliver that rate using the most efficient combination of available equipment.	x	x	x		x	x			x		
13	Blower air supply – passively reduce inlet air temperature	Aeration and blowers	Blowers, aeration system	Blower efficiency increases when the inlet temperature is cooler. It is only energy efficient with passive cooling, e.g. increased blower room ventilation, or shading of blowers, blower rooms and surrounds.	x	x	x		x	x			x		
14	Install blower with good efficiency at partial load (e.g. VSD)	Aeration and blowers	Blowers, aeration system	If the typical air requirement in your plant is substantially less than your smallest blower, then acquisition of a smaller blower, with VSD, may be more economical than operation an existing large-sized blower.	x	x	x		x	x			x		
15	Decentralised aeration blower	Aeration and blowers	Blowers, aeration system	Where blower system pressure is raised due to the requirements of a single process area e.g. due to friction losses along a long pipe run, consider using a small, standalone blower for this duty to allow the rest of the system to operate at lower pressure.	x	x	x		x	x			x		

	Title	Overarching process	Process / technology	Description	Plant type[1]							Treatment stage[2]			
					1	2	3	4.1	4.2	5.1	5.2	P	S	T	SL
16	Optimise blower outlet pressure by using dynamic control based on most-open-valve logic.	Aeration and blowers	Blowers. aeration system	Most-open-valve logic will control blower output to deliver the required air flow to all aeration zones at the lowest possible discharge pressure. For complex systems, consider segregating aeration system, including blowers, into discrete systems that can be readiliy optimised	x	x	x		x	x			x		
17	Filter backwash compressed air system	Compressed air	Filter backwash, compressed air	For intermittent duty, e.g. filter backwash, select smaller compressor with larger storage capacity.	x	x	x	x	x	x	x			x	
18	Optimising the duration and frequency of filter backwash cycles	Compressed air	Filter backwash, compressed air	Reduce backwash volume by fully or partially draining filter tanks before commencing backwash. Perform trials to determine minimal backwash interval (or implement automatic controls). Use online monitoring of filter pressure drop or flux to signal backwash requirement. If possible, schedule cycles and stagger between filters to use off-peak electricity and avoid increasing site demand.	x	x	x	x	x	x	x			x	
19	Compressed air systems	Compressed air	Compressed air	Optimise compressed air system with low- and no-cost strategies. See the OEH *I am your compressed air guide* available at www.environment.nsw.gov.au.	x	x	x	x	x	x	x	x	x	x	x
20	UV disinfection control – variable energy input	Disinfection	UV disinfection	Control UV lamp intensity based on effluent flow rate and transmissivity.	x	x	x	x	x	x	x			x	
21	UV disinfection control – lamp replacement	Disinfection	UV disinfection	Replace UV lamps when they become inefficient and/or lose intensity. Refer to product manuals for more details.	x	x	x	x	x	x	x			x	
22	Use VSD for pumps, blowers, fans and mixers with variable duty	Energy cost management	Pumping, blowers	Use VSD to match motor output to process requirements. Reducing motor speed can often provide significantly greater energy reduction than other methods of controlling output.	x	x	x	x			x	x	x	x	x
23	Turn off unnecessary equipment	Energy cost management	Process optimisation	Where possible, turn off equipment that is not being used.	x	x	x	x	x	x	x	x	x	x	x

	Title	Overarching process	Process / technology	Description	Plant type[1]							Treatment stage[2]			
					1	2	3	4.1	4.2	5.1	5.2	P	S	T	SL
24	Mainstream anaerobic ammonium oxidation or side-stream deammonification technology	Energy cost management	Process modification	Anaerobic ammonium oxidation (anammox) is a relatively new technology for the efficient removal of ammonia from a sewage stream by direct conversion to nitrogen (N2). Specific flow requirements apply (ammonia concentration and filtrate flow rate), contact your supplier for more information.	x	x	x	x	x	x			x		
25	Peak demand reduction	Energy cost management	Price optimisation	Reduce variability of electrical load, implement load shifting, load shedding, power factor correction or reduce overall energy consumption.	x	x	x	x	x	x		x	x	x	x
26	Peak demand reset	Energy cost management	Price optimisation	Capacity charges are usually applied based on peak demand over a 12-month period. If demand has been significantly reduced, request a reset of capacity charges from retailer.	x	x	x	x	x	x		x	x	x	x
27	Power factor correction	Energy cost management	Power quality, energy cost reduction	Power factor correction (PFC) can reduce capacity charges that are based on actual load (kVA) rather than energy consumption (kWh) e.g. peak demand charges. Check that your PFC system is operating correctly, is suitably sized, and not failing during the hottest times of the year (when you need it the most).	x	x	x	x	x	x		x	x	x	x
28	Voltage optimisation	Energy cost management	Power quality	For some electrical loads, e.g. motors, voltage optimisation can reduce the power consumed. See the OEH *Voltage Optimisation Guide* at http://www.environment.nsw.gov.au.	x	x	x	x	x	x		x	x	x	x
29	Filter backwash scheduling	Energy cost management	Filtration	Schedule filter backwash cycles based on online monitoring of filter flux and/or backpressure. Where online monitoring is unavailable, perform trials to determine optimum backwash interval for plant conditions.	x	x	x	x	x	x	x			x	
30	Plant-wide benchmarking	Energy cost management	EnMS, benchmarking	Benchmark your plant's efficiency to track performance over time. You can also compare with other plants with similar technology and size.	x	x	x	x	x	x	x	x	x	x	x

	Title	Overarching process	Process / technology	Description	Plant type[1]							Treatment stage[2]			
					1	2	3	4.1	4.2	5.1	5.2	P	S	T	SL
31	Energy performance indicators (EnPI)	Energy cost management	EnMS, benchmarking	Choose and calculate EnPI to track performances of various processes or portions of your WWTP. Track their performance over time to identify faults early.	x	x	x	x	x	x	x	x	x	x	x
32	Implement energy management system (EnMS)	Energy cost management	EnMS, benchmarking	An EnMS will set the framework for setting and reviewing energy objectives and targets. The international standard for EnMS is *ISO 50001:2011 Energy management systems: Requirements with guidance for use.*	x	x	x	x	x	x	x	x	x	x	x
33	Pay bills on time (or early)	Energy cost management	Energy cost management	Some energy retailers will charge interest if you pay your bills after the due date. Some energy retailers will also provide discounts if you pay your bills early.	x	x	x	x	x	x	x	x	x	x	x
34	Shop around and negotiate a better contract	Energy cost management	Energy cost management	Use competitive procurement processes for energy supply contracts.	x	x	x	x	x	x	x	x	x	x	x
35	Bill checking	Energy cost management	Energy cost management	Errors in bills are much more common than expected; correction of these errors can result in significant savings.	x	x	x	x	x	x	x	x	x	x	x
36	Energy storage	Energy cost management	Energy cost management	Store energy to shift demand from peak electricity prices to off-peak, and smooth load variability. Energy storage forms include battery, water storage, and biogas.	x	x	x	x	x	x	x	x	x	x	x
37	Data management	Energy cost management	Energy cost management	Automate bill checking using an energy intelligence software platform.	x	x	x	x	x	x	x	x	x	x	x
38	Demand response – onsite generators	Energy cost management	DR/DSM	Some network operators offer demand response (DR) programs; financial incentives to reduce load at times of high network demand. Diesel (or other onsite) generators that are a backup for a site power supply may be operated to offset grid electricity during these periods.	x	x	x	x	x	x		x	x	x	x

	Title	Overarching process	Process / technology	Description	Plant type[1]							Treatment stage[2]			
					1	2	3	4.1	4.2	5.1	5.2	P	S	T	SL
39	Load shedding	Energy cost management	DR/DSM	Identify equipment that can be temporarily switched off or prevented from operating during periods of high overall load. Implement control to shut down these systems based on incoming site load setpoint to avoid increasing demand charges. Some network operators will offer financial incentives to shed load at certain times.	x	x	x	x	x	x		x	x	x	x
40	Load shifting	Energy cost management	DR/DSM	Schedule processes to operate outside peak period to reduce peak demand charges and/or take advantage of lower off-peak tariffs.	x	x	x	x	x	x		x	x	x	x
41	PV electricity	Energy generation	Solar	PV solar power can be generated to offset grid electricity with renewable energy. Consider available space for rooftop, ground-mounted or even floating solar arrays. Renewable energy certificates (SRES or LRET) can offset implementation cost.	x	x	x	x			x	x	x	x	x
42	Solar thermal	Energy generation	Solar	Use solar heating for process warming requirements to reduce electricity or gas consumption. May be eligible for renewable energy certificates under SRES.	x	x							x		
43	Pyrolysis/ combustion of biosolids	Energy generation	Biosolids, cogeneration	Combustion or pyrolysis of waste biosolids can provide heat for process requirements and/or generation of electricity.	x	x	x	x	x			x			x
44	Gasification of biosolids	Energy generation	Biosolids, cogeneration	Gasification of dry biosolids will generate syngas which can be used in a gas turbine to generate electricity. Waste heat can be recovered and used in the gasifier or for drying biosolids.	x	x	x	x	x			x			x
45	Digester: add other organic material	Energy generation	Biosolids, cogeneration	Increase biogas output from digester by adding other organic material, e.g. biosolids from other WWTPs, or waste from food manufacturing.	x	x	x								x
46	Cogeneration with biogas	Energy generation	Biogas, cogeneration	Generate heat and power (electricity) using biogas. See the OEH Energy Saver Cogeneration Feasibility Guide and tool.	x	x	x	x	x			x	x		x

	Title	Overarching process	Process / technology	Description	Plant type[1]							Treatment stage[2]			
					1	2	3	4.1	4.2	5.1	5.2	P	S	T	SL
47	Cogeneration with biosolids and/or biogas	Energy generation	Biogas, biosolids, cogeneration	Generate heat and power (electricity) using biosolids and/or biogas. Combination of #12 and (#13 or #14). See the OEH Energy Saver Cogeneration Feasibility Guide and tool.	x	x	x	x	x			x	x		x
48	HVAC – process areas	HVAC	HVAC	Control HVAC systems based on occupancy and required comfort levels. Implement different controls for electrical equipment that does not require heating, and only requires cooling. Consult your electrician or electrical equipment manual on room-specific cooling requirements.	x	x	x	x	x	x	x	x	x	x	x
49	Ventilation optimisation	HVAC	HVAC	Match ventilation flows to area requirements.	x	x	x	x	x			x	x	x	x
50	Lighting controls	Lighting	Lighting	Use occupancy sensors to automate lighting.	x	x	x	x	x	x	x	x	x	x	x
51	Lighting upgrade	Lighting	Lighting	Replace lamps and fittings with energy-efficient LED luminaires. Energy savings certificates (ESCs) can be created to offset implementation cost.	x	x	x	x	x	x	x	x	x	x	x
52	Maintenance – probes sensors	Maintenance	Maintenance	Maintain efficacy of process instrumentation to allow effective control system operation.	x	x	x			x			x		
53	Vegetation management	Maintenance	Maintenance	Prevent ingress of vegetation (e.g. leaves) and other solids at pump inlets which reduce pump efficiency and flow rate.	x	x	x	x	x	x	x	x	x	x	x
54	Odour control suction blowers	Odour control	Odour control	Depending on your system design, creating only a slight negative pressure in your enclosed area may be sufficient to prevent odour issues in the environment. Modulate your fan speed based on pressure sensors to maintain the slight negative pressure.	x	x	x	x	x			x	x		
55	Odour fan control – H2S sensors	Odour control	Odour control	Modulate fan speed based on variable requirement.	x	x	x	x	x			x			x
56	Odour control suction blowers	Odour control	Odour control	In spaces with odour control, improve the seals around gaps to reduce leakage. Consequently, a lower fan speed (thus less energy) is required to maintain a slight negative pressure.	x	x	x	x	x			x	x		
57	Substitute electric water heaters	Process optimisation	Thermal	Use biogas or natural gas where available for process heating.	x	x							x		

	Title	Overarching process	Process / technology	Description	Plant type[1]							Treatment stage[2]			
					1	2	3	4.1	4.2	5.1	5.2	P	S	T	SL
58	Optimise anaerobic sludge digestion	Process optimisation	Digestion	Improving conversion of solids in digesters leads to (a) reduced load in downstream dewatering processes, (b) reduced sludge volume for disposal, and (c) increased biogas yield. There is an optimum temperature for your system which can be between 32°C–38°C for mesophilic anaerobic digestion. Lower temperature will impede sludge digestion, while higher temperatures can be harmful to the bacteria. Monitor digester and benchmark operation against design condition and best practice.	x	x	x								x
59	Install thermal hydrolysis (TH) for pre-treatment of TWAS feed into digester	Process optimisation	Digestion	TH pre-treats sludge prior to anaerobic digestion, where sludge is heated (~ 165°C) under pressure for 20–30 minutes. This treatment results in the rupture of cell walls to make it more readily biodegradable by anaerobic digestion. TH advantages include increased biogas production rate, increased digestion rate, sludge pasteurisation, reduced odour in final product, final sludge more readily dewatered (up to 37%).	x	x	x								x
60	Optimise dewatering process	Process optimisation	Biosolids	Optimise biosolids dewatering process to reduce amount of biosolids to be transported off-site, and reduce load on biosolids drying (#12)	x	x	x	x	x						x
61	Biosolids drying	Process optimisation	Biosolids	Use solar energy or available waste heat to further reduce the water content of dewatered biosolids. Use passive ventilation where possible (highly location and site dependent). Subsequent combustion/gasification/pyrolysis for power generation will then be more efficient.	x	x	x	x	x						x
62	Mixed liquor recycle (MLR) and/or RAS flow rate	Pumping	RAS flow rate	In many plants, the MLR and RAS flow rates are set to design flow rate when the WWTP is operating at full capacity. Yet, most WWTP operate only at a fraction of full capacity. Modulate process MLR and RAS flow rates based on variations in treatment process load while ensuring appropriate food-to-microorganism ratio and maintain effective sewage treatment.	x	x	x	x	x				x		

	Title	Overarching process	Process / technology	Description	Plant type[1]							Treatment stage[2]			
					1	2	3	4.1	4.2	5.1	5.2	P	S	T	SL
63	Benchmarking – pumps (kWh/ML.m)	Pumping	Pumping	Monitor performance and efficiency of pumps. Measure power, flow rate and differential pressure over full range of operating conditions. Compare efficiency of pump systems to benchmark as well as pump design conditions. Also use indicator to schedule maintenance when performance starts to drift.	x	x	x	x	x	x	x	x	x	x	x
64	Jockey pump (small) adjacent to full-rate pump	Pumping	Pumping	Where a large pump is required for peak flows, greater than normal operation, install an adjacent, smaller (jockey) pump selected for efficiency at normal/low flow conditions.	x	x	x	x	x	x	x	x	x	x	x
65	Pump control – variable flow	Pumping	Pumping	Modulate flow rate in response to process requirements.	x	x	x	x	x	x	x	x	x	x	x
66	Pump control – smoothing intermittent flows	Pumping	Pumping	For intermittent flows, reduce pump speed to operate pumps continuously at a lower flow rate. Benefit is reduced friction losses and peak demand spikes. May not be applicable in systems with significant static head.	x	x	x	x	x	x	x	x	x	x	x
67	Pump control – VSD	Pumping	Pumping	For centrifugal pumps, reducing speed to modulate output can result in a disproportionate reduction in energy consumption. May not be suitable in systems dominated by static head.	x	x	x	x	x	x	x	x	x	x	x
68	Pump optimisation	Pumping	Pumping	Operate pumps at or close to best efficiency point (BEP) by moderating/controlling flow rate and/or differential pressure (head) where possible.	x	x	x	x	x	x	x	x	x	x	x
69	Pump staging control	Pumping	Pumping	Where multiple pumps are employed to deliver variable output, configure pump controls to use the most efficient combination of available pumps at any given output.	x	x	x	x	x	x	x	x	x	x	x
70	Pump system optimisation against load profile	Pumping	Pumping	Develop a load duration curve for a pump system, identifying the prevalence of normal, low and peak flow conditions. Optimise pump selection and controls for efficiency in the most prevalent conditions.	x	x	x	x	x	x	x	x	x	x	x

	Title	Overarching process	Process / technology	Description	Plant type[1]							Treatment stage[2]			
					1	2	3	4.1	4.2	5.1	5.2	P	S	T	SL
71	Pump efficiency	Pumping	Pumping	Select pumps based on best efficiency for the required range of operating conditions. Avoid repurposing available pumps that are not matched to the specific duty required. Energy cost can dwarf the purchase price over the operating life of a pump.	x	x	x	x	x	x	x	x	x	x	x
72	Pump motor/drive efficiency	Pumping	Pumping	Select high-efficiency motors and drives specified for the required duty. Motor and VSD should be matched to the required duty and selected together where possible. Consider replacing old motors with new high-efficiency motors, especially when motors require major overhaul/reconditioning. Recent synchronous reluctance motors can achieve combined efficiency as high as ~ 95%.	x	x	x	x	x	x	x	x	x	x	x
73	Pump transmission efficiency	Pumping	Pumping	Minimise mechanical losses between motor and pump incurred in belt, chain or geared transmission; use direct coupling where possible.	x	x	x	x	x	x	x	x	x	x	x
74	Pump overall efficiency	Pumping	Pumping	Design and specification of pump, motor and VSD as a package can allow greater overall efficiency than individually specified components.	x	x	x	x	x	x	x	x	x	x	x
75	Raw sewage pump efficiency	Pumping	Pumping	Optimise equipment selection and controls for varying influent flows. Avoid unnecessary changes in elevation e.g. deep influent pits.	x	x	x	x	x	x	x	x	x	x	x
76	Recycled effluent pumping	Pumping	Pumping	For distribution of water to multiple end users, optimise supply pressure based on end-user requirements. If required pressure varies, consider a separate supply or booster pump to service high-pressure requirements.	x	x	x	x	x	x	x	x	x	x	x
77	Substitute oversized pumps	Pumping	Pumping	Where normal operating conditions are below the designed operating range for a pump, replace with a pump/motor combination selected for efficiency under normal operations. Employ standby pumps for occasional peak load requirements.	x	x	x	x	x	x	x	x	x	x	x

	Title	Overarching process	Process / technology	Description	Plant type[1]							Treatment stage[2]			
					1	2	3	4.1	4.2	5.1	5.2	P	S	T	SL
78	Replace pump motors/ drives	Pumping	Pumping	Technological advances and minimum energy performance standards have significantly improved the performance of electric motors. Modern motor and VSD packages can provide greater overall efficiency than when these items are sourced separately.	x	x	x	x	x	x	x	x	x	x	x
79	Assess total cost of ownership when purchasing new equipment	Pumping	Pumping	Selection should always be based on total cost of ownership over the operating life of the equipment. This includes energy (consumption, capacity and environmental charges), operating, maintenance and other relevant costs as well as the initial purchase and delivery, installation and commissioning costs. The energy cost alone can often eclipse the purchase price within a year.	x	x	x	x	x	x	x	x	x	x	x
80	Optimise pipe system	Pumping	Pumping	Reduce the amount of work a pump has to do by avoiding unnecessary changes in elevation and minimising flow restrictions in the pipe network. Examples include: reduce pipe length, increase pipe diameter, avoid unnecessary changes in direction and diameter, service filters regularly, select non-restrictive valves, instruments, filters/ screens, eliminate restriction orifice plates and control valves and modify pump speed instead.	x	x	x	x	x	x	x	x	x	x	x
81	Transfer pathway – piping	Pumping	Distribution/ transfer	Eliminate intermediate storage, unnecessary changes in elevation and flow restrictions to reduce energy consumption in transfer pumping.	x	x	x	x	x	x	x			x	

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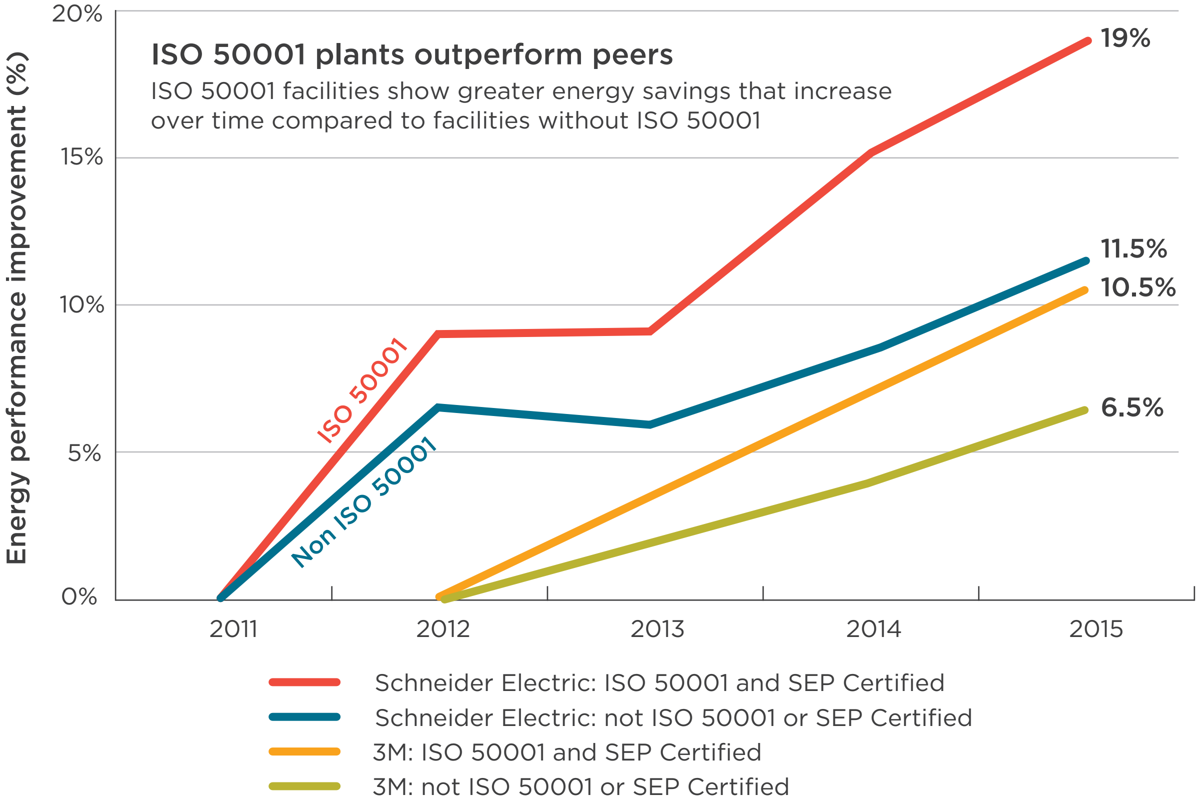
[1] Plant types:
1 – Activated sludge treatment with separate sludge stabilisation, including primary sedimentation, anaerobic digestion, with onsite cogeneration from biogas.
2 – Activated sludge treatment with separate sludge stabilisation, including primary sedimentation, anaerobic digestion, without onsite cogeneration from biogas.
3 – Extended aeration activated sludge, including aerobic digestion. Also known as oxidation ditch plants.
4.1 – Trickling filters only.
4.2 – Tricking filters in combination with activated sludge.
5.1 – Aerated lagoons.
5.2 – Lagoon and/or wetland systems without aeration.

[2] Treatment stages: P = primary; S = secondary; T = tertiary; SL = sludge

Appendix C: Benefits of Energy Management Systems

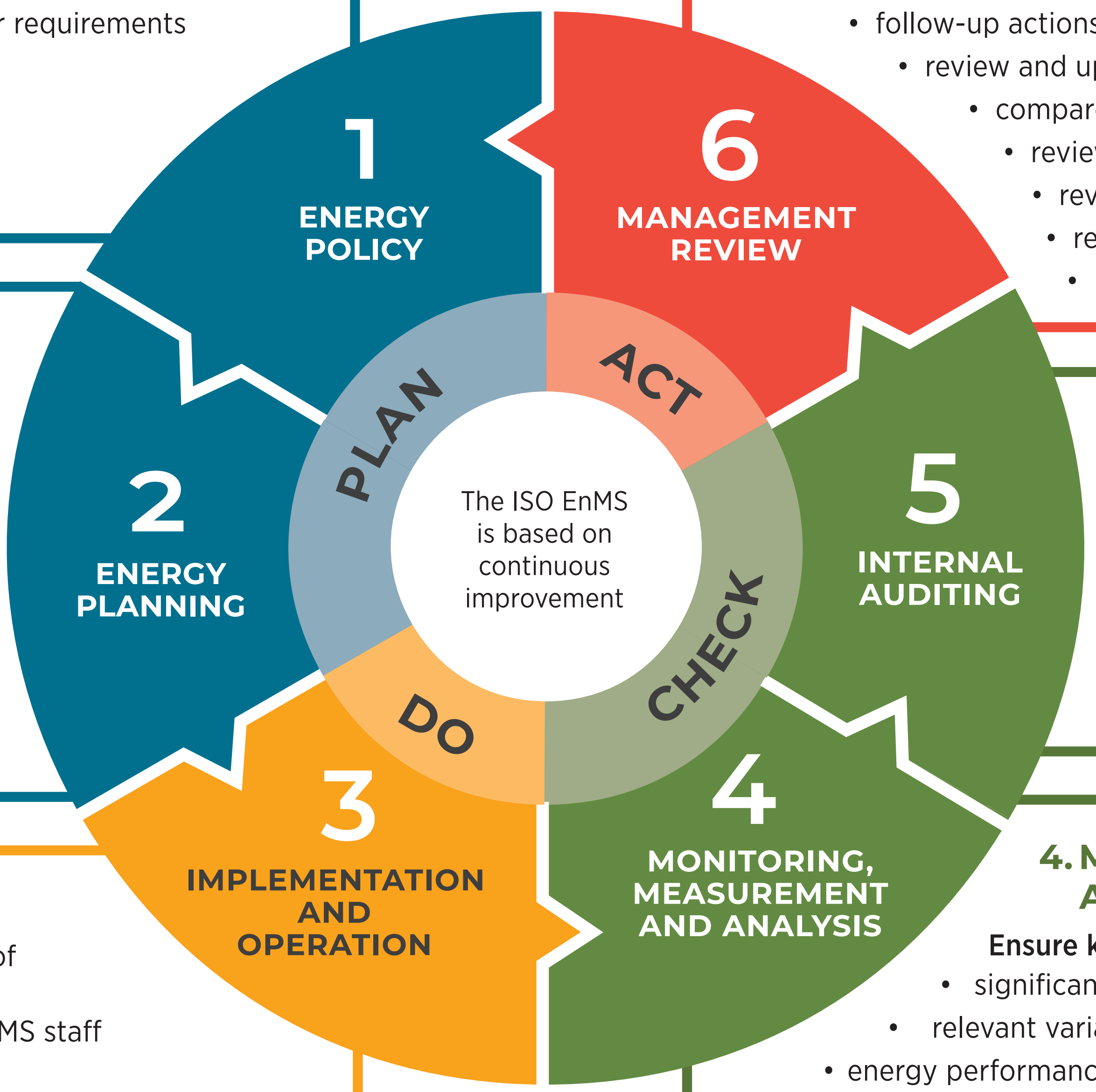
EnMS have been shown to improve operational efficiency in all industry sectors. It improves risk management, boosts productivity and profitability and, ISO 50001 sites show greater energy savings than non-ISO 50001 sites.

The graph below compares the energy efficiency in ISO 50001 sites with non-ISO 50001 sites operated by 3M and Schneider Electric and shows that ISO 50001 sites outperformed other sites by up to 65%. Although not WWTPs the results indicate the potential benefits of EnMS.



Appendix D: Implementing an Energy Management System (EnMS) for Wastewater Treatment Plants

Based on *ISO 50001 Energy Management Systems – Requirements with guidance for use*
See Appendix **F** for Implementing Details



1. ENERGY POLICY

Develop a policy document that:

- reflects legal, regulatory, community, and stakeholder requirements
- sets corporate energy objectives and targets
- makes data available for resourcing and budgets
- is a framework for energy objectives and targets
- is effectively communicated to all levels

2. ENERGY PLANNING

Review your energy use:

- what, where and how much
- identify significant users
- influencing factors
- identify and prioritise improvement opportunities
- incorporate results into your policy

Set your energy baseline and Energy Performance Indicators (EnPIs) – see **Appendix G**

Set energy objectives and targets, develop action plans – see **Appendix G**

3. IMPLEMENTATION AND OPERATION

- ensure personnel are competent, trained and aware of benefits of EnMS
- clearly define roles, responsibilities, authorities of EnMS staff
- clearly communicate the EnMS to all staff
- implement process for all staff to provide feedback
- meet all EnMS requirements
- adjust operations and maintenance activities to meet objectives
- evaluate energy performance of new systems
- establish procurement policies and procedures consistent with EnMS

4. MONITORING, MEASUREMENT AND ANALYSIS

Ensure key characteristics are monitored including:

- significant energy users, e.g. blowers and largest pumps
- relevant variables, e.g. volume of sewage treated
- energy performance indicators, e.g. MWh/kL
- effectiveness of action plans
- verify savings using the IPMVP

In addition:

- compare predicted energy consumption with measured data
- investigate significant deviations between predictions and data
- develop a plan for additional metering/monitoring if required

5. INTERNAL AUDITING

Ensure compliance with ISO50001 by:

- planning and conducting regular internal audits
- checking EnMS is effectively implemented and maintained
- reporting audit results to senior management
- undertaking required corrective and preventative actions

6. MANAGEMENT REVIEW

Senior management shall regularly review the EnMS:

- follow-up actions from previous reviews
- review and update energy policy
- compare actual energy performance against targets
- review internal (and external) audit results
- review status of corrective and preventative actions
- review and update objectives, targets and EnPIs
- review & update resource and budget allocation

Disclaimer: this document is intended as an informative high-level overview of Energy Management Systems and ISO 50001. It is not intended as a comprehensive, detailed guide to EnMS or ISO 50001

Appendix E: Implementing an energy management system

See **Appendix D** (Infographic) and **Appendix F** (Implementing details).

Plan

Energy policy

- Determine top management commitment to energy performance improvement. What is the vision in this area?
- What are the site's energy priorities and overarching objectives?
- Review legal, regulatory, community, and other stakeholder requirements.
- Develop a plan to communicate energy policy and objectives to people at all levels within your organisation.

Review your energy use

- Determine what is used, where and how much (See Section 1: Reduce your electricity costs).
- Identify areas of significant energy use (and significant energy users).
- Determine what influences energy use (e.g. BOD, serving population, rainfall, etc.).
- Identify opportunities in site energy use to reduce energy use or increase energy efficiency.
- Prioritise opportunities, based on specified criteria (e.g. emission targets, payback periods, complexity, etc.).
- Set your energy baseline and energy performance indicators (EnPIs).
- Set energy objectives and targets, develop action plans.
- If necessary adjust the energy policy to reflect priorities, objectives and targets.

Do

Manage energy in your daily processes

- Ensure personnel are competent, trained and aware of the energy management system (EnMS) and its importance; engagement of all staff will maximise impact of behavioural changes.
- Clearly define roles, responsibilities, authorities, benefits, impacts and consequences (actual and potential) of the EnMS.
- Clearly communicate the EnMS to all staff.
- Implement a process for all individuals to provide feedback and suggest improvements to the EnMS.
- Meet EnMS documentation requirements (as required in all management systems).
- Adjust operations and maintenance activities to meet objectives.
- Evaluate energy performance of new systems or when making major modifications to existing systems.
- Establish procurement policies and procedures consistent with EnMS, e.g. include evaluation of energy efficiency of new equipment.

Check

Monitoring, measurement and analysis

- Ensure key characteristics are monitored including:
    - significant energy users, e.g. blowers and largest pumps
    - relevant variables, e.g. volume of sewage treated
    - energy performance indicators, e.g. MWh/kL
    - effectiveness of action plans.
- Verify savings using the International Performance Measurement and Verification Protocol.

In addition:

- compare predicted energy consumption with measured data
- investigate significant deviations between predictions and data
- develop a plan for additional metering and monitoring if required.

Internal auditing

Ensure compliance with ISO50001 by:

- planning and conducting regular internal audits to ensure compliance with plans
- checking that the EnMS is effectively implemented and maintained
- reporting internal audit results to senior management
- undertaking corrective and preventative actions as required.

Act

Management review

The EnMS needs to be regularly reviewed by senior management.

Source: Office of Energy Efficiency and Renewable Energy, Getting Started with ISO 50001, https://www.energy.gov/eere/amo/getting-started-iso-50001

Appendix F: Energy Management Systems (EnMS) Implementing Details for WWTPs

1. Some examples of EnMS objectives, targets and action plans:		
Objective	**Target**	**Action Plan**
Track site energy use and keep all staff informed	Record and chart site's monthly electricity use and communicate to all staff	Accounts to provide monthly bills to Energy Manager. Energy Manager to develop spreadsheet to record and chart electricity use. Energy Manager to email chart to all site staff on a monthly basis. **When:** to commence by end of Q1
Identify and monitor largest energy users on site	Identify all equipment that consumes 60% of the site's power usage	Identify largest motors on site, estimate operating hours, and determine energy consumption. If required, install power meters on identified equipment. **When:** identification by end of Q2
	Track and record energy consumption by identified equipment	Collate monthly power consumption by identified equipment, record and chart the numbers. Email chart to relevant site staff. **When:** to commence by end of Q3
Reduce energy consumption of the largest three energy users on site	20% reduction of energy consumed by three largest energy users on site	Install VSD on equipment that can be operated at variable speeds. Change control programs to reduce operating speed where possible. **When:** by end of Q4
Increase energy efficiency knowledge and awareness	Increased knowledge in 90% of personnel	Hold monthly knowledge sharing sessions. Include EnPIs and performance issues in operations meetings reports. **When:** to commence by end of Q3

2. Some examples of key responsibilities for EnMS at WWTP	
Level / Title	**Roles / Responsibilities / Authority**
Senior Management	Introduce EnMS, set site wide objectives and targets.
Procurement group	Procure efficient new equipment, e.g. pumps with low Total Cost of Ownership.
Energy Manager	• Prepare monthly or quarterly reports on energy usage at site, including benchmarks and EnPIs • Distribute reports to all site personnel and senior management • Report on opportunity implementation progress.
Site manager	• Allocate resources and budget for EnMS • Set objectives targets for specific process/equipment to meet site wide objectives and targets • Identify potential efficiency projects for the site (in conjunction with engineering/maintenance team).
Engineering/Maintenance team	• Perform engineering calculations to quantify potential savings and implementation costs of opportunities • Prioritise opportunity list based on economics (e.g. simple payback) and accounting for ease of implementation (in conjunction with site manager) • If required, provide specifications (e.g. of new pump) to Procurement group • Implement opportunities, and update Energy Manager • Provide site operations data to Energy Manager.

Appendix G: Calculations – details for Sections 1–5

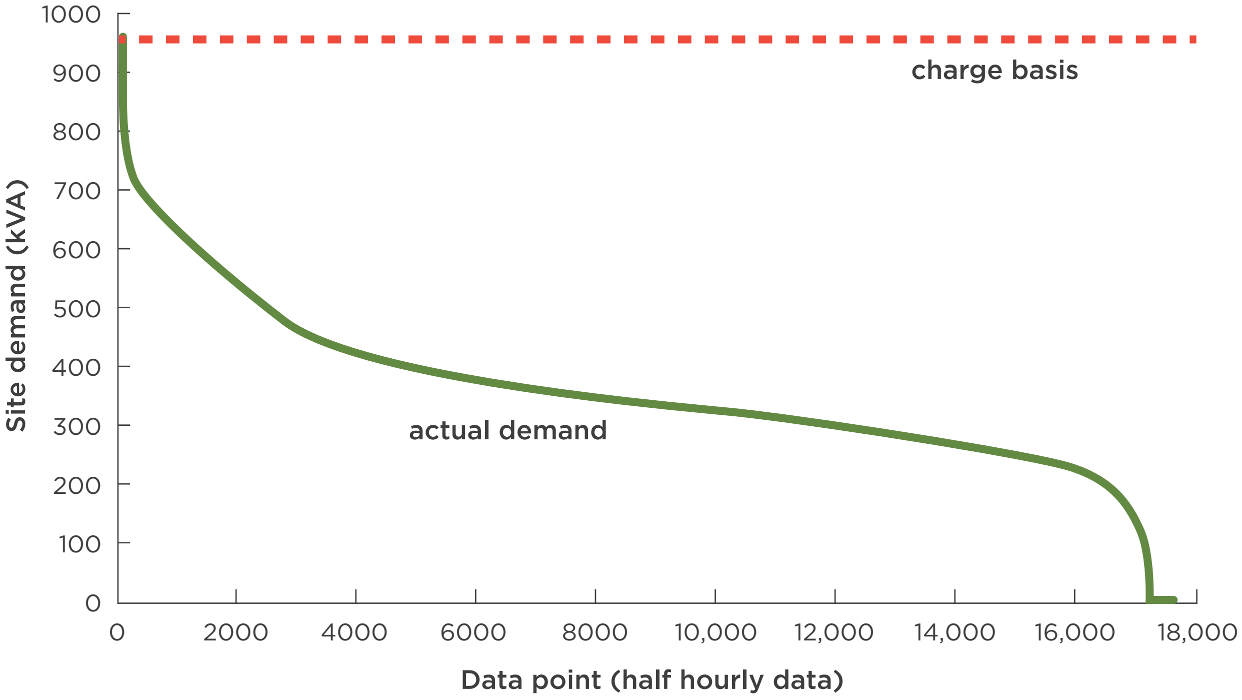
1. Reducing energy costs

Calculating your site demand

1. Request or download your electricity interval data for the past 12 months. Data should be available from your energy retailer in 15-, 30- or 60-minute intervals, upon request or downloadable from a dedicated portal.

Using your preferred spreadsheet or data analysis software:

2. Calculate your demand for all time intervals if required:
   Demand (kVA) = Active power (kW) ÷ Power Factor
   Some retailers provide the demand values.
3. Select your demand values (only) and sort from largest to smallest.
4. Graph the sorted demand values to generate a site demand profile for your facility.



Estimating energy usage of equipment

For equipment with power metering: record energy consumption (usually in kWh), for a day, week or month.

For equipment with variable speed drives (VSDs) and advanced controllers: many VSDs or advanced controllers measure or estimate power consumption; these values can usually be exported to an onsite SCADA (or similar) system.

For other equipment:

1. Take the nameplate rating (kW)
2. Determine usage per day (hours per day)
3. Apply load factor (0.7[1]):

energy consumption (kWh/day) = nameplate rating (kW) × usage (hours per day) × load factor

If you estimate energy usage for all equipment on site, and the total is similar to invoiced amounts, you can be confident in your calculations.

Benchmarking your site – calculating EP

To benchmark your site:

- Classify your plant: refer to the WSSA classification in Appendix A and identify your plant type.
- Calculate your benchmark figure: to calculate your benchmark use the Australian benchmarks agreed by the wastewater industry which were collated and published by WSAA in 201420. The unit for the benchmark is energy consumption (kWh) per equivalent person per year (EP Year).
    - ○ Energy consumption (kWh) is the total consumption from the grid and from any onsite generation.
    - ○ Equivalent person (EP) is identical to the 'persons equivalent' in European literature.

Calculate your EP:

1. **Organic load in raw wastewater influent to plant** (for each time stamp, e.g. day):
   Chemical oxygen demand (COD): EPO = COD destroyed (g/day) ÷ 120
   Or if there is no COD data:
   BOD: EPO = BOD destroyed (g/day) ÷ 60
   e.g. EPO = 13,320,000 g/day as COD÷ 120 (g/(EP Day)) = 111,000 EP
2. **Nitrogen load in raw wastewater influent to plant** (for each timestamp, e.g. day):
   Total Kjeldhal nitrogen (TKN): EPN = TKN destroyed (g/day) ÷ 12
   Or if there is no TKN data:
   Total nitrogen (TN): EPN = TN destroyed (g/day) ÷ 12
   Or if there is no TN data:
   Ammonia: EPN = Ammonia (NH_3) destroyed (g/day) ÷ 8.4
   e.g. EPN = 1,214,280 g/day as TKN 12 gN/(EP Day)÷ = 101,190 EP
3. **EP used in calculations** (for each time stamp, e.g. day):
   Average of EPO and EPN if both datasets are available
   e.g. EP = (111,000 + 101,190) ÷ 2 = 106,095
4. **Determine the average EP for all time stamps for the period of interest** (e.g. calendar year 2017).
   Note: the minimum data requirement for benchmarking is either COD or BOD load in raw wastewater influent (to calculate EPO) and the use of EPN estimates can improve the data accuracy, but is not essential.

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[1] Load factor is the ratio of actual energy consumption to maximum possible by the equipment; as a general rule of thumb, the average load factor for a WWTP is in the range of 0.6–0.8.

Calculate your benchmark:

The WSAA adopted benchmark (2013–14) is then calculated by:

365 × energy consumption (kWh/day) ÷ EP = kWh/EP Year.

Use the chart below to compare your plant against the benchmarks (best practice and average). You can also benchmark your historical performance to see trends in energy consumption.

2. Optimise your aeration and blower system

Calculate annual energy savings:

Energy before (kWh/[EP Year]) – energy after (kWh/[EP Year]) × total influent volume per year.

3. Optimise your pumping

Benchmarking your site

1. Set EnPIs for your selected pumps. Suggested EnPIs are:
    - pump average energy consumption (kWh/[ML/m head]), which can range from 2.72 (100% theoretical efficiency) to 27.2 (10% efficiency)
    - pump overall efficiency (%) – kinetic energy output as % of electrical energy input.
2. Gather data for calculation of these EnPIs. Data is required for these parameters across the full range of operating conditions:
    - pump suction pressure (may be below atmospheric)
    - pump discharge pressure
    - flow rate
    - real power.
3. Calculate your chosen EnPIs.
4. Compare to available benchmarks. Suggested comparisons include:
    - historical plant performance; if no historical data is available, start tracking your selected EnPIs
    - for individual pumps: compare observed operation (flow, head) to manufacturer's data (pump curve). An operating point below the pump curve may indicate loss of performance; an operating point on the pump curve, but away from the best efficiency point (BEP) may indicate poor pump selection
    - for pump systems: compare average energy consumption (kWh/[ML/m head]) to other pump systems on your site or other sites in your organisation.

4. Optimise your RAS flow rate

To calculate annual energy savings:

[Pump energy consumptionBefore (kWh/[ML.m]) × HeadBefore – Pump energy consumptionAfter (kWh/[ML.m]) × HeadAfter] × annual flow (ML).

5. Generate heat and power from biosolids

To determine whether your plant is suitable:

1. Perform rough calculations to determine if energy from biosolids is worthwhile for your WWTP or a collection of WWTPs.

The following is a simplified calculation method and should be useful to secure a preliminary understanding of the suitability of this technology at your facility. For more complex applications, or for optimising performance, e.g. through maximising heat recovery, you should consider specialist assistance.

a. Determine mass of biosolids available per year, considering biosolids available from other WWTPs
e.g. 30,000 tonnes p.a. (wet)

b. Determine savings from avoided biosolids transport and disposal, and gate fees from accepting other waste where applicable (assumed to be an average of \$100 per tonne)
e.g. 30,000 × \$100 / tonne = \$3,000,000 p.a

c. Calculate the potential electrical energy from biosolids by applying the following steps:

   i. Determine the dry biosolids mass – assuming biosolids are first dried (in tonnes p.a.), and using a typical moisture content of (wet) biosolids of 85%[2]
   Total (wet) biosolids mass (tonnes p.a.) × (100 – typical moisture content [% wet basis]) ÷ 100 = dry biosolids mass (tonnes p.a.)
   e.g. 30,000 × (100 – 85) ÷ 100 = 4,500 tonne p.a

   ii. Determine the heat value of dry biosolids (in MJ p.a.), assuming an average lower heating value of 12,000 MJ/tonne[3]
   Dry biosolids mass (tonne p.a.) × lower heating value = biosolids energy content (MJ p.a.)
   e.g. 4500 × 12,000 = 54,000,000 MJ p.a

   iii. Calculate the expected electrical energy generation potential (in MWh p.a.) using an average overall conversion efficiency of 25%[4]
   Biosolids energy content (MJ p.a.) × overall conversion efficiency ÷ 3600 = potential electrical energy (approximate) (MWh p.a.)
   e.g. 54,000,000 × 25% ÷ 3600 = 3,750 MWh p.a.

d. Determine the potential electricity cost savings, using an average electricity cost of \$150/MWh[5]
Potential electricity cost savings = potential electrical energy (MWh p.a.) × electricity costs (\$/ MWh)
e.g. 3,750 × 150 \$/MWh = \$562,500 p.a.

e. Establish the revenue opportunity through accessing appropriate energy certificates (e.g. large-scale generation certificates) and assuming an average certificate value of \$50/MWh[6]
Potential certificate value = potential electrical energy (MWh p.a.) × certificate value (\$/MWh)
e.g. 3,750 × 50 \$/MWh = \$187,500 p.a.

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[2] Dewatered biosolids have a typical moisture content of 80–90%.

[3] Lower heating value (LHV) is also known as net calorific value (NCV). Use 12,000 MJ/tonne as the LHV for dry biosolids in the absence of analysis data for your biosolids.

[4] Overall conversion efficiency will differ depending on the technology used, but start with 25%.

[5] Calculate your average electricity cost by taking total bill (\$) ÷ total energy (MWh) consumed; to be more conservative, subtract fixed costs (supply, metering, connection) from your bill to determine the variable component of your electricity cost.

[6] Certificate values are highly market driven and will change over time; start with \$50/MWh to be conservative, but their value can be as high as \$88/MWh.

   f. Total potential savings per year = b + d + e – operating and maintenance costs
      e.g. 3,000,000 + 562,500 + 187,500 – 300,000[7] = $3,450,000 p.a.

   g. Simple payback = Total capital expenditure[8] ÷ total potential savings per year
      e.g. $15,000,000 ÷ $3,450,000 = 4.3 years.

2. If the simple payback determined in #1 is promising, collect at least one biosolids sample for testing. A suggesting sampling regime is:
   - during dewatering operations, grab one representative sample of sludge per hour, blend into a daily composite sample, mix well; double bag your samples with all air expelled to preserve sample moisture and quality
   - using ~100 g from each daily sample (but not more than half your sample), ask your preferred analysis company (or in-house if you have the equipment), to determine moisture and ash content for each daily sample
   - ask your preferred analysis company to prepare monthly composite samples from the daily samples, and analyse for moisture and energy content.
3. Repeat calculations in step #1 with data from the analysis.
4. If the numbers from step #3 are still promising, perform the characterisation listed above (proximate, ultimate, ash composition, and ash fusion temperature) for at least one monthly composite sample and provide your analysis to a package unit supplier for a budget estimate.

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[7] In this example, we have assumed a maintenance cost of $40/MWh plus one and a half full-time equivalent operators; the actual operating and maintenance cost will vary depending on system type, complexity and size.

[8] Total capital expenditure will strongly depend on technology type and size. Start with $15 million for 30,000 tonnes p.a. wet biosolids throughput to provide a broad indicative payback.