# ENERGY NEUTRAL WWTPS – A DREAM OR A REALITY FOR NEW ZEALAND?

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**ABSTRACT**

There has been much coverage recently at conferences and in technical publications about "resource recovery" in wastewater treatment plants. The term "green factories" is being used to describe wastewater facilities which are manufacturing "green" energy or biofuels, recovering nutrients and recycling water for reuse. Many utilities globally have achieved – or are at least aiming for – "energy neutrality" at their wastewater facilities and, in some instances, a net positive energy balance has been achieved across the plant site.

In an investigation to see how different WWTPs in the USA are achieving a positive energy balance or at least energy neutrality – or are taking initiatives towards this goal – one of the authors visited six utilities on the west and east coasts of the USA in late 2016:

- Gresham, Oregon
- Columbia Boulevard, Oregon
- South East WPCP, San Francisco, California
- East Bay MUD WWTP, Oakland, California
- Blue Plains WWTP, Washington DC
- Alexandria RENEW, Virginia

The plants were very different in terms of their scale and treatment processes, and with a range of effluent standards based on their specific receiving environments, spanning from relatively straightforward BOD removal to advanced biological nutrient removal. The energy demands for liquid stream treatment processes and for the treatment of solids streams – which is driven by the enduse of the biosolids – have a huge influence on total energy utilisation and potential generation of biogas at a particular site, and hence on the net energy balance across the site.

This paper will summarise the key energy aspects of these six "Water Resource Recovery Facilities", and will then relate their similarities and differences to a range of New Zealand counterparts to assess whether energy neutrality is a realistic goal for them – or is a dream which will be difficult to achieve.

**KEYWORDS**

**Bioenergy, energy neutrality, resource recovery, WWTP operations**

**PRESENTER PROFILE**

Both authors are Technical Directors with Beca Ltd, one of New Zealand's largest and most diverse engineering and management consulting consultancies. The presenter has over 40 years' experience in NZ and overseas in a wide range of wastewater projects and technologies. He has a long involvement with the WEFTEC Technical Program Committee and WEF as the Water NZ WEF Delegate and past member of the WEF Board of Trustees.

# 1 INTRODUCTION

There has been much coverage recently at conferences and in technical publications about "resource recovery" in wastewater treatment plants, to the extent that many plants in North America are being rebranded as "Water Resource Recovery Facilities" (WRRF). The term "green factories" is being used to describe wastewater facilities which are manufacturing "green" energy or biofuels, recovering nutrients and recycling water for reuse. Many utilities globally have achieved – or are at least aiming for – "energy neutrality" at their wastewater facilities and, in some instances, a net positive energy balance has been achieved across the plant site.

In 2011, the Water Environment Federation (WEF) produced a position statement which declared:

*WEF believes that wastewater treatment plants are NOT waste disposal facilities, but rather water resource recovery facilities that produce clean water, recover nutrients (such as phosphorus and nitrogen) and have the potential to reduce the nation's dependence on fossil fuel through the production and use of renewable energy".*

Since that time, WEF has assisted many utilities and WRRFs work towards these objectives through the collaborative production of a suite of three Resource Recovery Roadmaps – on Energy (WEF, 2012), Nutrient Management (WEF, 2014) and Water Reuse (WEF, 2016). These roadmaps do not seek to reinvent the wheel, as they reference a lot of solid research and technical material, but rather focus on the NEW paradigm (Nutrients, Energy and Water) for water and wastewater asset owners, operators, designers and political decision makers. WEF has also collaborated with WERF (now WE&RF) in the production of WERF Reports on best practices at WRRFs and Utilities of the Future (WERF 2010 (2x) and WERF 2014 respectively) as well as reporting on innovative resource recovery technologies (through the LIFT programme).

In our Australasian region, such a focus on resource recovery has been more recent, with perhaps more emphasis on energy utilization and energy generation potential at WWTPs than on recovery of other resources such as water, nutrients and biosolids as a soil conditioner or fertilizer. In particular, the NZ Water industry has not been very successful - with a few exceptions such as BioBoost – in reuse of wastewater-sourced biosolids on pastoral or agricultural soils which is the easiest way to usefully recover and recycle nutrients from our waste streams. Additionally, the abundant supplies of freshwater in NZ means that water reuse is not as relevant as in water-short regions of other countries such as California, Texas, Arizona and parts of Australia. Hence, the main focus of our utilities has been - and is likely to remain – on energy generation/recovery from biogas and biosolids and the reduction of energy use at our WWTPs

One of the most comprehensive recent reports was by Water Services Association of Australia (WSAA, 2014) which benchmarked 142 WWTPs operated by 17 water utilities across Australia. This paper will refer to a subsequent paper (de Haas et al, 2015) which summarised the WSAA report and provided a useful definition of wastewater types by which to divide NZ WWTPs into five groups and five size classes.

# 2 OPPORTUNITIES FOR ENERGY NEUTRALITY AND RESOURCE RECOVERY FOR PRODUCT SALE

## 2.1 USA EXAMPLES

Before considering how NZ WWTPs might increase the recovery of resources from waste streams or reduce their overall energy costs, it is worth considering some examples of what some leading USA water utilities are doing in this field. In an investigation to see how different WWTPs in the USA are achieving a positive energy balance or at least energy neutrality – or are taking initiatives towards this goal – one of the authors visited six utilities on the west and east coasts of the USA in late 2016:

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### 2.1.1 GRESHAM, OREGON

The City of Gresham Wastewater Treatment Plant wastewater plant serves 114,000 residents and discharges secondary treated effluent to the Columbia River. Faced with high energy costs of $0.5M per annum, the utility embarked on a programme to become energy self-sufficient. It achieved its first net-zero energy consumption day on February 12, 2015. All of its electricity is produced from onsite renewable power. Approximately 95% is produced from two cogeneration CAT engines fueled by biogas and. approximately 5% of the energy comes from a 420-kilowatt solar photovoltaic (PV) system on plant property. Biogas produced in the plant’s existing anaerobic digesters was significantly increased by actively encouraging delivery of fats, oils and grease from local restaurants and organic waste tankering businesses. The latter wastes are charged and bring in $0.25M as a valuable secondary income stream for the utility.

### 2.1.2 COLUMBIA BOULEVARD, OREGON

The City of Portland owns and operates the Columbia Boulevard WWTP, serving over 600,000 people. Its secondary treated effluent also discharges to the Columbia River. Since 2009, two 850 kilowatt cogen sets with a total generating capacity of 1.7 megawatts have utilised biogas generated onsite supplying about 40 percent of the plant's electrical needs. A pretreatment system removes hydrogen sulfide, siloxane and moisture to prepare the biogas to be used as fuel. The treatment plant also compresses approximately 20% of its biogas and delivers it via pipeline to a nearby industrial facility to use for process heating. In a new initiative, to generate another income stream and displace fossil fuels petrol and diesel, the utility intends to produce compressed natural gas (CNG) for offsite use. Possible uses being considered are refuse collection vehicles, the city’s own vehicles or trucks hauling biosolids for land application.

### 2.1.3 SOUTH EAST WPCP, SAN FRANCISCO, CA

The Southeast Water Pollution Control Plant, operated by the San Francisco Public Utilities Commission, is located in the southeastern portion of the city in the Bayview-Hunters Point neighbourhood. It treats 80% of the city's wastewater and discharges 230,000 cu.m/day (dry weather flow) of secondary treated effluent into San Francisco Bay. Constructed in 1952, the 16ha facility is about to be completely remodelled. Facility planning has centred on optimised unit process location and better process containment with a much higher degree of odour control in response to encroachment from adjacent residential areas. All new digesters are planned with more efficient mixing and thermal hydrolysis process (THP) introduced to increase the stability of the biosolids and boost biogas generation. To some extent, increased onsite bioenergy generation will reduce imported energy costs, thereby helping to offset the increased operating costs of enhanced odour control.

### 2.1.4 EAST BAY MUNICIPAL UTILTIES DISTRICT (EBMUD), OAKLAND, CA

EBMUD's Oakland wastewater treatment plant is on the eastern side of San Francisco Bay, opposite the Southeast WPCP. It treats wastewater from a population of almost 700,000 people in a conventional secondary plant, before recycling or discharging it to the Bay. EBMUD has been recycling, reusing, and producing renewable energy at its wastewater plant since the mid-1980s. EBMUD was one of the first "energy neutral" plants in the USA and has received many honors and awards for its efforts to protect public health and the Bay environment as well as recover resources from wastewater. EBMUD supplements wastewater solids with high-strength organic waste, such as food scraps and FOG, to generate electricity from approximately 11MW of installed capacity, more than enough renewable energy to meet all onsite power demands.  Excess power is sold to Port of Oakland, overall saving EBMUD some $3M per annum in power charges.

### 2.1.5 BLUE PLAINS WRRF, WASHINGTON DC

Unlike the above four west coast plants, the Blue Plains WFFP plant is an advanced nutrient removal plant, one of the largest ABNR plants in the world. Operated by the District of Columbia Water and Sewer Authority (DC Water), it services a population of over 2 million people in Washington and adjacent counties in Virginia and Maryland. The effluent that leaves Blue Plains is discharged to the Potomac River and meets some of the most stringent permit limits in the United States. The plant site now totals 60ha in total area and first started in 1938 as a primary treatment facility, with advanced treatment capacity added in the 1970s and 1980s. In recent years, liquid stream processes have been further upgraded to reduce nitrogen and phosphorus to the limits of technology, primarily in support of water quality goals of the Potomac River, but also for the restoration of the Chesapeake Bay.

Most recently, emphasis has been on extracting more bioenergy from the solids stream and producing a marketable biosolids for reuse. In 2015, DC Water began operating a CAMBI thermal hydrolysis system at Blue Plains, for improved solids stabilisation and quality and higher gas yields from its existing digesters. This was the largest thermal hydrolysis facility in the world as of 2016. The new system generates high quality sludge that is used as soil amendment (up to 200,000 tons/year). It also generates 10 MW of electricity that is used elsewhere at the treatment plant. DC Water is off-setting the increased costs of treatment and the reducing options for biosolids reuse in Virginia by "building a market" for its own dewatered class A cake, branded as "BLOOM".

### 2.1.6 ALEXANDRIA RENEW, VIRGINIA

The Alexandria Sanitation Authority (rebranded as AlexRenew in 2012) was created in 1952 to build and operate a system to collect and treat wastewater from the City of Alexandria and part of Fairfax County. Sited virtually across the Potomac River from the Blue Plains WRRF, it serves a population of 320,000 and has to meet the same stringent effluent standards as its sister plant. The feature which sets the WRRF apart from many others is the very close proximity of its residential and commercial neighbours, who virtually encircle the 13 ha site. This mandates very strict odour standards and the plant processes are almost fully contained – foul air handling and treatment being a very significant operating cost. The AlexRenew resource recovery programme is comprehensive: biosolids are stabilized for reuse on Virginia farms; over 30% of plant energy is generated onsite from biogas; and in 2015 the utility commenced a Reclaimed Water System to provide up to 25,000 cu.m/day of recycled water to the City of Alexandria. As part of their drive towards lowering the energy cost of operations, and to promote greater resource recovery, AlexRenew is investigating THP and has implemented the Annamox DEMON process for side-stream nitrogen reduction, the first full-scale deammonification system in the USA

## 2.2 AUSTRALIAN STATISTICS FOR WWTP ENERGY EFFICIENCY

The WSAA report and subsequent paper by de Hass concluded that, in general, Australian WWTPs have process designs that pre-date the most recent periods when rising energy costs, energy efficiency and greenhouse gas emissions have emerged as leading drivers for modern treatment plant design. The overall conclusion is that these WWTPs have a relatively high energy consumption (measured as either kWh/ML or kWh/EP), and none of the plants reported were anywhere near energy self-sufficient. Factors advanced for relatively high energy consumption included many that are also a feature of NZ WWTPs:

- More advanced treatment to meet higher environmental standards - nutrient removal and UV disinfection being the prime reasons in the liquid stream and higher biosolids stabilisation to enable reuse vs landfilling;
- Effluent pumping to achieve greater assimilation in receiving waters or to reach more suitable or acceptable effluent disposal locations;
- Increasing urban areas and how WWTPs are located and wastewater services provided (centralized with associated economies of scale vs. decentralized with lower conveyance costs but higher unit processing costs);
- A trend towards not providing conventional primary treatment (ie. fine screening and grit removal straight to secondary biological treatment) and therefore no anaerobic digestion and potential for co-generation.

A useful definition of WWTP types is re-presented below (from WSAA 2014 and de Haas 2015) in Table 1.

*Table 1: Definition of WWTP Types*

| Type | Description |
|---|---|
| Type 1 | Activated sludge treatment with separate sludge stabilisation including those with primary sedimentation, anaerobic digestion (or alternative – refer Note 1) and with onsite co-generation using biogas |
| Type 2 | Activated sludge treatment with separate sludge stabilisation including those with primary sedimentation, anaerobic digestion (or alternative – refer Note 1) BUT without onsite co-generation using biogas |
| Type 3 | Extended aeration activated sludge including aerobic digestion. No biogas production and no onsite cogeneration (refer Note 2) |
| Type 4 | Trickling filters or trickling filter-activated sludge combinations. Plants may include primary sedimentation and anaerobic digestion sometimes with onsite cogeneration using biogas |
| Type 5 | Aerated or unaerated lagoons. No biogas production and no onsite cogeneration |
| *Note 1* | *Alternative sludge stabilisation includes: incineration, covered anaerobic lagoons, alkaline/lime treatment. Plants with aerobic digestion for sludge stabilisation are classified as Type 3* |
| *Note 2* | *Membrane bioreactor plants are included in Type 3 if no primary treatment is present with separate sludge stabilisation (as in Types 1 and 2)* |

WWTP size is also an important parameter, whether this be measured in Average Daily Flow (ADF ML/day) or in Equivalent Population (EP or PE – normally based on BOD per capita of 60-75 gpcd). The Australian energy benchmarking report used five size classes in its analysis as in Table 2, which is useful to categorise our NZ WWTPs and to benchmark against WWTPs in other countries to see if there is any correlation between Plant Type (1 to 5), Plant Size Class (SC1 to SC5) and flow-specific or load/EP-specific energy use.

*Table 2: Definition of WWTP Size Class*

| Size Class SC1 | SC2 | SC3 | SC4 | SC5 |
|---|---|---|---|---|
| <1000 EP | 1001-5000 EP | 5001–10000 EP | 10001–100,000 EP | >100,000 EP |

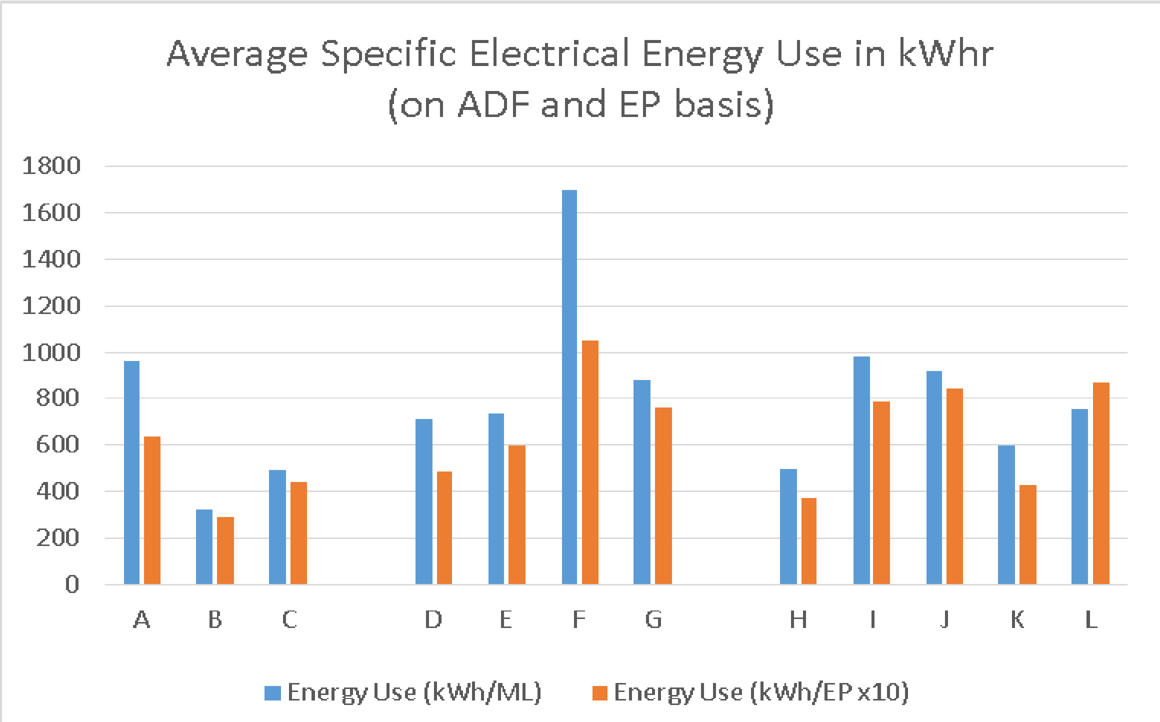
Based on the selected data for 12 large Australian WWTPs of Types 1, 2 and 3 of different size classes (10 SC5 and 2 SC4) reported by de Hass, it can be seen from Figure 1 below that there is a wide range of specific electrical energy use, both between different Plant Types, and within the same Type category. It is clear though that plants with anaerobic digestion and cogeneration (Type 1) have a distinct energy advantage over similar activated sludge plants that do not generate onsite power (Type 2). Extended aeration plants (Type 3) – again with no onsite cogeneration from biogas – would appear to be more energy inefficient again than similar scale Type 2 activated sludge plants.

From these 12 plants, the "energy self-sufficiency" of the three Type 1 facilities ranged between 31% and 44% so they have a significant margin to make up on imported power before being able to claim energy neutrality.

However, many site-specific factors (some of which are outlined above) can influence energy use for any given plant so it is recommended that a detailed breakdown of energy use is done before making comparisons between plants, even if of similar size class and plant type. Some of the specific plant features which are required to even contemplate becoming energy neutral are covered below.

*Figure 1: Specific Electrical Use for 22 Large Australian WWTPs*

A,B,C = Plant Type 1 D,E,F,G,= Plant Type 2 H,I,J,K L = Plant Type 3




# 3 IMPLICATIONS FOR NZ WWTPS

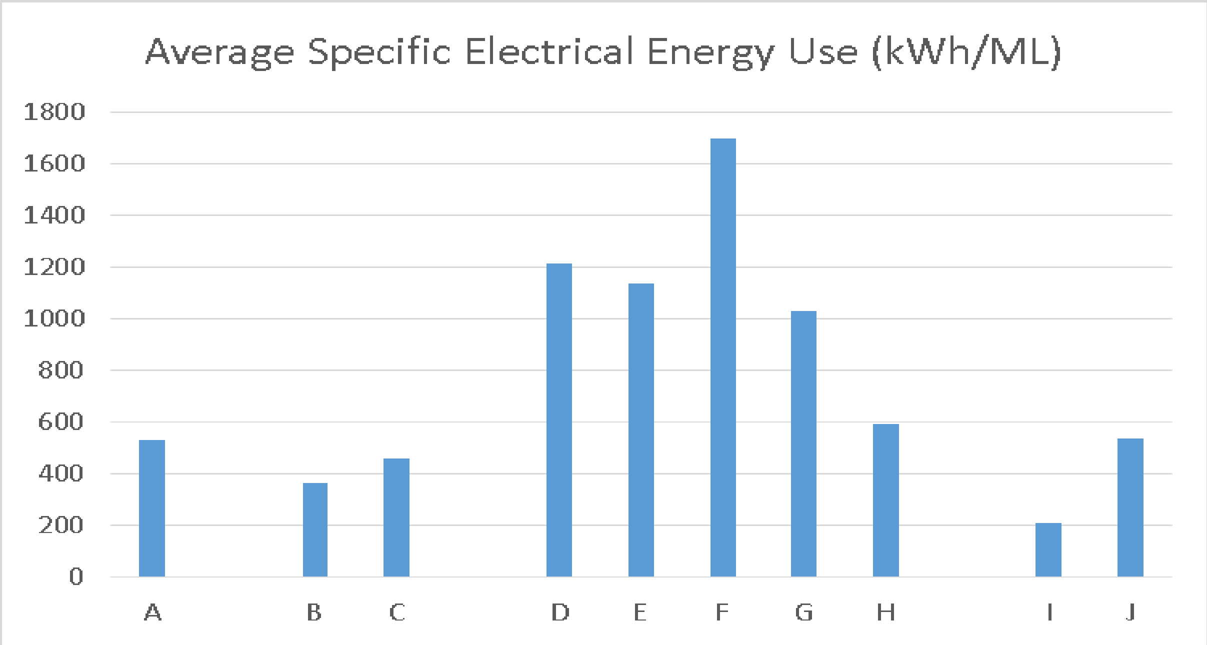
## 3.1 ENERGY USE COMPARISONS FOR NZ

For this paper, a very quick survey of energy use was undertaken across ten different types and size classes at NZ WWTPs, in order to see how NZ plants compared with the Australian plants reported in Figure 1. NZ WWTPs are generally smaller in capacity and population served so the sample set included three SC2 plants; as well as four SC4 plants and three SC5 plants. The simple analysis – in kWh/ML – is shown in Figure 2 below.

The closest plant to being energy neutral is Plant I, one of our largest WWTPs, which has invested significantly in very efficient anaerobic digestion processes and cogeneration plant such that it is very close to being self-sufficient. The three plants with the highest specific energy use (D,E and F) are all relatively small (SC2) and not only do not benefit from economies of scale but must meet high effluent quality standards as Type 3 plants. The other six plants are in a similar energy use bands to their Australian counterparts.

*Figure 2: Specific Electrical Use for 10 New Zealand WWTPs*

A = Plant Type 1 B,C = Plant Type 2 D,E,F,G,H = Plant Type 3 I,J = Plant Type 4




What has not been widely reported is the specific energy use for small aerated ponds and simple waste stabilisation ponds where 10-15kW power consumption is likely to cover a couple of surface aerators, a screen and a few small peripherals. Most of these would fall into Plant Type 5 and size range SC1 or SC2. It would be useful to have some comparative data on their specific energy use - on either a plant flow (ADF) or load (EP) basis - to consider if there are ways in which their energy needs could be cost-effectively met from non-power grid electricity sources such as solar PV arrays and power storage banks.

## 3.2 CONCLUSIONS FOR NZ WWTP OWNERS

It appears that our specific electrical energy use (in kWh/ML treated) is within similar ranges to those reported for medium to large wastewater facilities in Australia with whom our plants face similar challenges and have much the same characteristics. To increase the efficiency of power use we should continue to look across the Tasman as well as replicate best-practice from some of our own leading plants.

For NZ owners to be able to match the USA west coast WRRFs the challenge of "energy neutrality" is more daunting. By not having to meet strict nutrient limits – and with the benefit of already having historically installed primary sedimentation and anaerobic digestion facilities – these conventional secondary treatment plants can really ramp up biogas generation through co-digestion with high-strength wastes and use modern gas turbine generators to maximize power yields. Only a few NZ WWTPs have these perquisites and can therefore aspire to match their counterparts and make energy neutrality a reality – for the rest of our plants this is probably a dream.

However, there are avenues other than net energy efficiency that can lower WWTP owners' operating costs – which is really what "energy neutrality" is targeting through effectively "going off-grid" and being less exposed to rising electricity costs from a third party. For example, many plants own large tracts of land as odour and visual buffer zones, and, as the price of photo voltaic panels and storage batteries keeps coming down, owners could follow the Gresham and AlexRenew utilities examples of installing large PV panel arrays to generate their own onsite power.

The value of nutrients in biosolids will steadily appreciate – particularly with respect to phosphorus. The sale of well-prepared - and that probably means dried and meeting appropriate quality standards – and well-marketed biosolids will eventually become viable and a sustainable revenue source as it is already for DC Water, Milwaukee, Sacramento and many other "organic fertilizer" manufacturers in the USA.

At present, only a small number of treatment plants worldwide are recovering resources from wastewater off which revenues can be generated (like CNG, phosphorus or biochar) or operating costs offset (through Green Credits or exporting electricity) but there is a growing global trend towards producing saleable products from wastewater treatment processes. Keeping up with these innovative approaches suggests that for NZ WWTPs a more appropriate longer-term target than energy neutrality may be one of "operating cost (opex) neutrality" through the profitable sale of products from resource recovery techniques.

## ACKNOWLEDGEMENTS

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Also acknowledged are the owners and operators at the six USA WWTPs which were visited in 2016, both for their hospitality and willingness to share their successes achieved and challenges faced (and overcome) in their quest for energy neutrality and more cost-effective treatment practices.

## REFERENCES

De Hass et al (2015) 'Benchmarking Wastewater Treatment Plant Energy Use in Australia'. OZWater '15 Conference, 12-14 May 2015, Adelaide, Australia

De Hass, D and Dancey, M (2015) 'Wastewater Treatment Energy Efficiency', *WATER* November 2015 (published by AWA)

WEF (August 2013), *The Energy Roadmap,* Water Environment Federation, Alexandria, VA

WEF (July 2015), *The Nutrient Roadmap,* Water Environment Federation, Alexandria, VA

WEF (November 2016), *The Water Reuse Roadmap Primer,* Water Environment Federation, Alexandria, VA

WERF (2010), *Best Practices for Sustainable Wastewater Treatment – Initial Case Study Incorporating European Experience and Evaluation Tool Concept*. Report No OWSO4R07a, Water Environment Research Federation, Alexandria, VA – principal investigator G Crawford, CH2M HILL

WERF (2010), *Energy Efficiency in Wastewater Treatment in North America: A Compendium of Best Practices and Case Studies of Novel Approaches.* Report No OWSO4R07e, Water Environment Research Federation, Alexandria, VA – principal investigator J Sandino, CH2M HILL

WERF (September 2014), *Utilities of the Future Energy Findings*. Report No ENER6C13 Water Environment Research Foundation (now WE&RF), Alexandria, VA – prepared by Stephen Tarallo, Black & Veatch Corporation

WSAA (2014), *WWTP Energy Benchmarking (Part 2, Technical Report),* published by for Water Services Association of Australia, Melbourne, Australia – prepared by GHD Pty Ltd