POLICY BRIEF

February 2018
The WRC operates in terms of the Water Research Act (Act 34 of 1971) and its mandate is to support water research and development as well as the building of a sustainable water research capacity in South Africa.

Reducing energy in biological nutrient removal activated sludge plants

The challenges of continually rising energy costs, increasing population and urbanisation, climate change as well as stricter potable water and wastewater standards have made energy management one of the most prominent issues facing water and wastewater utilities worldwide. In its continued quest to improve energy use in the wastewater treatment sector the Water Research Commission (WRC) has conducted a case study to test methods to reduce energy use in biological nutrient removal activated sludge plants.

Background

In the past five years a number of international studies have been carried out to identify energy efficiency best practices in the water and wastewater sectors.

Some of the key findings related to wastewater treatment from these studies were that:

- About 55% of energy used in the water cycle is for wastewater treatment. The bulk of this energy is for aeration in biological processes, accounting for upwards of 60% of total energy consumption.
- Up to 15% of wastewater energy demand can be offset by biogas generation from sludge and combined heat and power (CHP).
- Adoption of best practices identified in the global case studies can realise energy efficiency gains of between 5% and 25% in the water cycle.
- Aeration energy savings of up to 50% can be achieved through implementing aeration energy conservation measures at wastewater treatment plants.
- On the basis of these studies most water and wastewater utilities now view energy management as top priority to ensure long-term sustainability.

South African challenge

In addition to the pressures identified globally, South Africa also faces critical electricity shortages. Among others, this has resulted in sharp increases in the electricity tariff as well as load shedding and postponement of new supply connections, disrupting both industrial and domestic customers nationwide.

In order to guide the South African water sector through these challenges, the WRC has taken a leadership role by funding energy-related studies and projects. One such study, titled "Energy Efficiency in the South African Water Industry: A Compendium of Best Practices" was completed in 2013. The study confirmed the global findings that wastewater treatment uses about 55% of the sector's total energy consumption.

The bulk of this energy is used for aeration at biological nutrient removal (BNR) activated sludge plants, which are widely employed for municipal wastewater treatment in order to meet the Department of Water and Sanitation's tight final effluent discharge regulations.

The study recommended a three-pronged approach to energy efficiency, consisting of demand side management (conservation), supply side management (generation) and regulatory incentives (Figure 1).

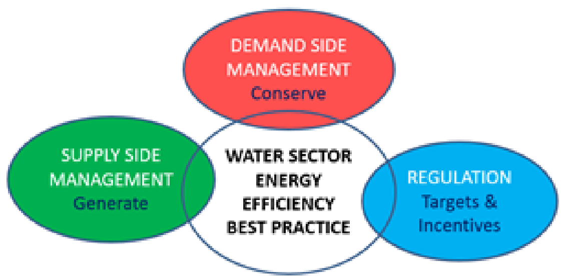


Figure 1. Three-pronged approach to energy efficiency.

It is currently estimated that the six large Metropolitan Municipalities i.e. City of Johannesburg, eThekwini, City of Cape Town, Ekurhuleni, City of Tshwane and Nelson Mandela Bay operate around 103 wastewater treatment plants, discharging on average approximately 3 600 Ml/d (average dry weather flow).

About 69% of these plants are energy intensive BNR activated sludge processes due to aeration requirements. Of these, almost 85% employ low efficiency conventional surface aeration while the remainder use fine bubble diffused aeration (FBDA), which can have up to three times higher oxygen transfer efficiency.

In order to reduce both energy use and costs in the face of continued electricity cost increases and shortages while complying with tight final effluent standards, it is therefore imperative that the municipalities focus on finding aeration energy use reduction strategies.

Aeration energy conservation case study

As part of the continued WRC's funding of energy-related studies in the water sector, a study, titled "Energy Use Reduction at Biological Nutrient Removal Wastewater Treatment Plants" has been conducted. The study used two case study plants, namely the City of Tshwane's Zeekoegat wastewater treatment plant, with a design capacity of 85Ml/d average dry weather flow and fine bubble diffused aeration and ERWAT's JP Marais wastewater treatment plant, with a design capacity of 15Ml/d) average dry weather flow and conventional surface aeration.

Advanced process modelling and simulation was applied as a tool to evaluate optimal process and aeration control strategies. This approach ensured that implementing the aeration ECMs would also result in final effluent compliance with regulatory standards.

Key findings from the study were (Table 1):

- Identified aeration energy conservation methods (ECMs) can potentially save 9 – 45% of aeration energy consumption and cost. The reduction in energy consumption also results in reduction in greenhouse gas emissions.
- ECMs vary from simple to complex. Simple measures involve optimised process operation with existing aeration and control equipment and simple dissolved oxygen control. This requires little to no additional capital investment apart from operator training. Consumption and cost savings of between 16 and 23% were identified for JP Marais with 9 and 10% for Zeekoegat.
- Complex measures involve replacing less efficient conventional surface aerators with more efficient technologies such as FBDA (with latest blower technology) or combined aerator/mixer or implementing advanced process and aeration control strategies such as ammonia based control. These give the highest consumption and cost saving of 41 and 45% respectively for JP Marais.
- Implementing the identified ECMs which include optimal process and aeration control results in improved biological nutrient removal and compliance with final effluent nitrogen and phosphorus limits.

In order to realise these savings, local authorities need to develop a clear energy management strategy and put in place robust systems and structures towards achieving this strategy.

Table 1: Summary of Key Parameters for JP Marais and Zeekoegat Case Studies

Aeration Energy Parameter	J P Marais			Zeekoegat		
	Baseline	Simple Measures	Complex Measures FBDA/APC	Baseline	Simple Measures	Complex Measures FBDA/APC
Consumption (MWh/yr)	2,518	2,109	1,596	4,678	4,265	3,674
Consumption Savings (MWh/yr)		409	922		413	1,004
Maximum Demand Savings (kW)		47	105		47	115
% Consumption Saving		16	37		9	21
% Consumption Cost Saving		23	41		10	23
Carbon Reduction (t/yr)		405	913		409	992
Average Final Effluent Concentrations						
Ammonia	10	1	3.5	0.4	0.3	0.8
Ortho P (mgP/l)	0.5	0.2	<0.1	0.3	0.1	<0.1
Nitrate/Nitrite (mgN/l)	5	4	3	6	3	1

Future Outlook

Energy Conservation

Applying the energy use and cost benchmark data determined in the above study, it is estimated that the 6 largest Metropolitan Municipalities currently consume an estimated 445 GWh/yr of electrical energy to aerate their activated sludge plants, at a cost of about R376 million.

Both the consumption and cost will continue to increase in future, in line with increases in quantity of wastewater to be treated and the cost of electricity. Assuming that wastewater discharge increases at the current annual population growth rate of 1.5% and Eskom tariff rates continue to increase at an average of 14% per year, predicted future aeration energy consumption and cost were analysed for the following scenarios:

- Baseline – current situation (do nothing)
- Implementing simple and complex aeration ECMs as described above.

The following key findings were deduced from this analysis (Figures 1 and 2):

If **nothing is done**, the future aeration annual energy consumption and cost (present value) increase above current 2015 baseline values is estimated to be:

- 2020 (5 years) – consumption 480 GWh/yr (8% increase), cost R780 million/yr (107% increase).
- 2020 (10 years) - consumption 516 GWh/yr (16% increase), cost R1.6 billion/yr (330% increase)
- 2035 (20years) - consumption 600 GWh/yr (35%increase), cost R7 billion (1,750% increase)

Implementing identified aeration ECMs will ensure reduced future consumption and costs at the same percentage savings identified in Table 1.

Based on these estimated savings:

- It will take until 2026 (11 years) to exceed current 2015
- consumption if simple measures are implemented and beyond 2035 (>20 years) if complex measures are implemented
- Current 2015 consumption cost will be exceeded in 2017 (2 years) with simple measures and 2020 (5 years) with complex measures.

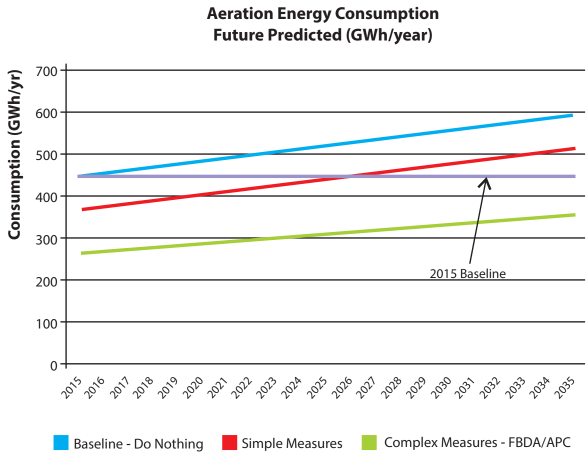


Figure 1: Future Predicted Aeration Energy Consumption.

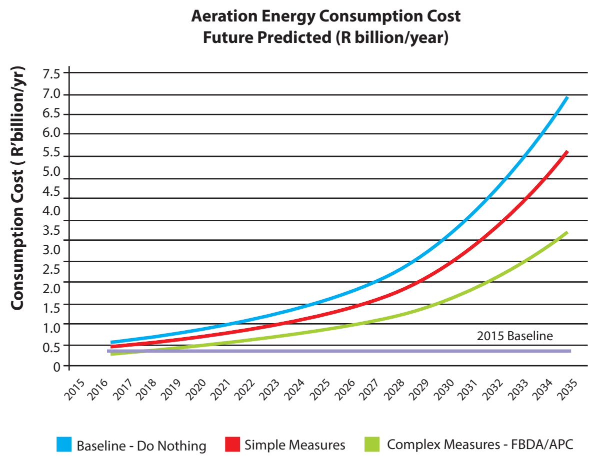


Figure 2: Future Predicted Aeration Energy Cost.

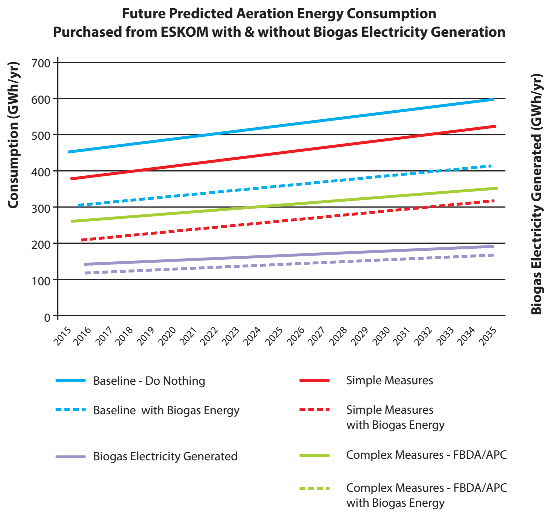
Energy conservation and generation

Generation of biogas from anaerobic digestion of wastewater sludge is a well-established technology. With continued improved efficiency of anaerobic digestion and electricity from biogas generation technologies, it is feasible to generate substantial electricity that can be used to offset the demand at wastewater treatment plants; essentially moving the plants towards "energy neutrality.

It is estimated that the 6 largest Metropolitan Municipalities currently generate on average about 332 000 tDs/yr of sludge (both primary and waste activated) from their activated sludge plants, which, if anaerobically digested can potentially yield an estimated 97 700 m^3/yr of biogas.

This biogas can conservatively generate about 142 GWh/ year of electricity (based on low value electricity from biogas of 5.8 kWh/m^3 and 25% engine efficiency). Using this electricity to offset aeration energy consumption results in the following estimated savings on consumption and cost (present value) on electricity that would be purchased from Eskom (Figures 3 & 4):

- If **nothing is done** then potentially 32% savings on electricity purchased from ESKOM can be realised. The 2015 baseline electricity purchased is estimated to drop by 143 GWh/yr from 445 to 302 GWh/yr and cost from R376 to 225 million/yr.
- If aeration ECMs are implemented then the savings will increase to about 50% for simple measures and 78% for complex measures.



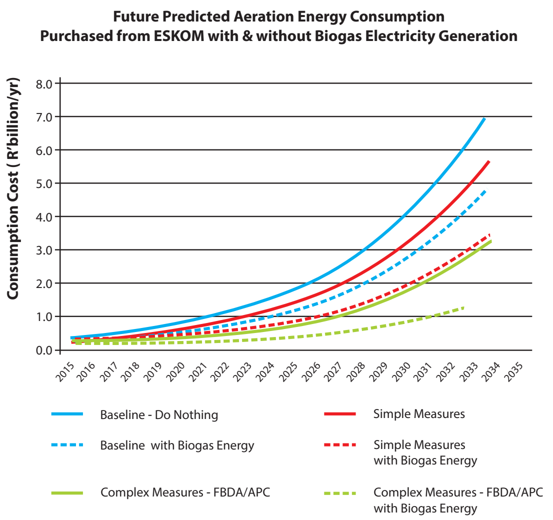


Figure 3 and 4: Future Predicted Aeration Energy Consumption and Cost – With and Without Biogas Electricity Generation.

Recommendations

The findings of the project have illustrated that municipalities can save substantial energy and cost by focusing and prioritising aeration energy conservation at their BNR activated sludge plants.
Adopting technically superior tools such as advanced mathematical modelling and simulation that enable evaluation of both aeration conservation measures and process control strategies, as demonstrated in this project, yields additional benefits that would not be realised through just aeration equipment changes i.e.

- Ensures final effluent compliance and achieving Green Drop status
- Implementation of economically viable solutions through desktop comparison of various options and scenarios
- Better understanding of process performance under various process and aeration control strategies
- Empowerment of wastewater operations personnel through knowledge exchange and training by specialist service providers

In order to take the findings of this project to a national level and ensure successful implementation of aeration energy conservation measures within municipalities, it is recommended that, firstly, a nationwide benchmarking survey is carried out to determine current aeration energy consumption levels and potential for electricity generation from anaerobically digested sewage sludge biogas. Municipalities can use these benchmark figures as a platform to launch aeration energy efficiency programmes.

Secondly, it is recommended that municipalities put in place robust policies and systems to drive energy efficiency. These include:

- Establishment of an Energy Management Programme under the leadership of a dedicated Energy Manager and accountable to an Energy Management Committee that includes Senior Management. This will ensure that energy efficiency has support from the highest management levels and that a clear strategy with achievable and measureable goals is set.
- Sustainable operations and maintenance budgets to ensure continual performance of instruments and control systems as well as operator training.
- Flexible and transparent supply chain management practices that are not just cost driven. This enables procurement of specialist services and equipment

ensuring implementation of quality solutions and installation of robust equipment hence long-term sustainability of energy efficiency programmes.
- Clear incentives to motivate employees and garner organisational-wide commitment to energy efficiency.

Thirdly, it is recommended that DWS incorporate energy efficiency as part of the Green Drop assessment to incentivise municipalities to adopt practices that ensure both energy efficiency and final effluent compliance.

It is further recommended that Eskom and the Department of Energy put in place incentives for achieving energy efficiency in wastewater treatment. The savings in energy will benefit the national grid and increase energy available to other sectors.

To order the report, *Energy use reduction in biological nutrient removal wastewater treatment plants: A South African case study* (**Report No. TT 654/15**), contact Publications at Tel: (012) 761-9300, Email: orders@wrc.org.za or Visit: www.wrc.org.za to download a free copy.