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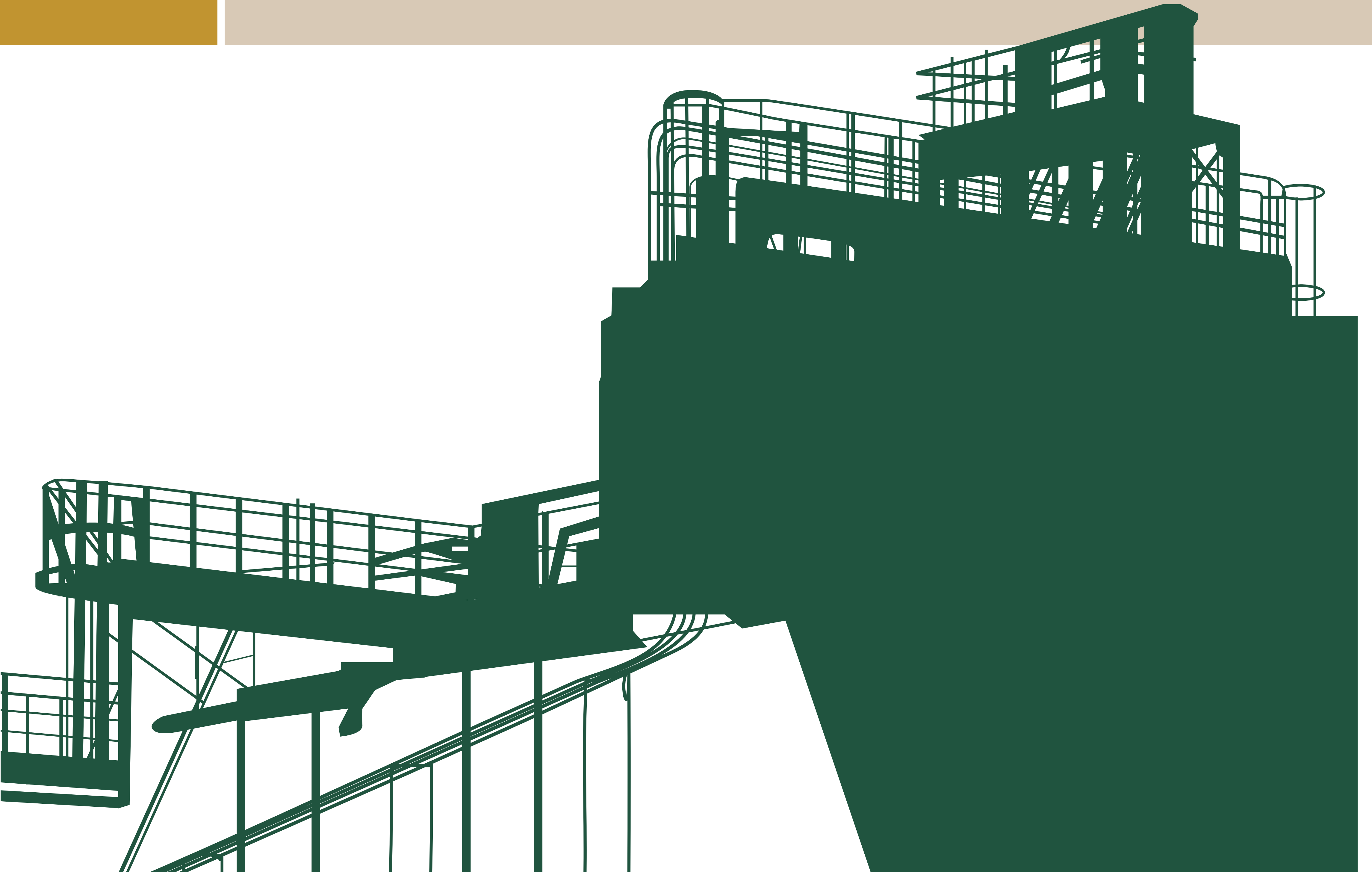
Guideline on Energy Efficiency and Renewable Energy in Municipal Water and Wastewater Infrastructure

SALGA ENERGY GUIDELINE SERIES



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GLOSSARY

BOD	Biochemical oxygen demand
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalents
CBD	Central Business District
CDM	Clean Development Mechanism (under the Kyoto Protocol)
CER	Certified Emissions Reduction
CHP	Combined Heat and Power
DEA	Department of Environmental Affairs
DME	Department of Minerals and Energy
DO	Dissolved oxygen
DoE	Department of Energy (Formally DME)
DWA	Department of Water Affairs
EE	Energy Efficiency
EEDSM	Energy Efficiency Demand Side Management
EPA	U.S. Environmental Protection Agency
ERWAT	East Rand Water Care Company
ESCO	Energy Services Company
GHG	Greenhouse gas
GIS	Geographic Information System
GJ	Gigajoule
HRAP	High-rate algal ponds
KPI	Key Performance Indicators
Kℓ	Kilolitre
kW	Kilowatt
kWh	Kilowatt-hour
LCA	Life cycle analysis
LED	Light emitting diode
MFMA	Municipal Finance Management Act
Mℓ	Megalitre
MW	Megawatt
MWh	Megawatt hour
O_2	Oxygen
PLC	Programmable Logic Controller
PPA	Power Purchase Agreement
PPP	Public-private-partnership
PV	Photovoltaic
PRV	Pressure reducing valve
RE	Renewable Energy
REIPPP	Renewable Energy Independent Power Producers Programme
RSA	Republic of South Africa
SALGA	South African Local Government Association
SANS	South African National Standards
SBR	Sequencing batch reactor
SDC	Swiss Agency for Development and Cooperation
SWH	Solar Water Heater
TJ	Terajoule
UNFCCC	United Nations Framework Convention on Climate Change
UV	Ultraviolet
VSD	Variable speed drive
WRC	Water Research Commission
WWTW	Wastewater Treatment Works

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1. INTRODUCTION

Water and wastewater infrastructure is often one of the major consumers of energy by municipalities. It has been estimated that water and wastewater facilities can account for around 35% of a typical municipality's energy footprint. Consequently, this infrastructure is often identified as a high priority for investment by municipalities wanting to reduce energy consumption and associated costs. New national policy also places municipalities at the forefront of leading the charge to address climate change, in which the reduction of energy consumption and generation of renewable energy from municipal infrastructure are both becoming increasingly important.

While there are a growing number and range of energy efficient water and wastewater treatment and distribution technologies, the process of prioritising interventions and choosing locally appropriate technologies can be extremely daunting. It is therefore the purpose of this Guideline to provide a resource for municipal officials that addresses:

- The process a municipality should follow in assessing and planning how to reduce energy consumption in water and wastewater infrastructure in a cost effective manner (i.e. identifying interventions that will create the best energy saving per Rand spent, and an appropriate plan for rollout of implementation);
- How to choose the right energy efficiency technologies for the particular context, needs and limitations of the municipality; and
- Cost effective and serviceable options for generating renewable energy from water and wastewater infrastructure.

In order to demonstrate the experiences of some of the municipalities in South Africa that have already engaged in energy efficiency and renewable energy generation in their water and wastewater infrastructure, a range of Case Examples is also presented.

2. HOW ENERGY IS CONSUMED IN WATER & WASTEWATER INFRASTRUCTURE

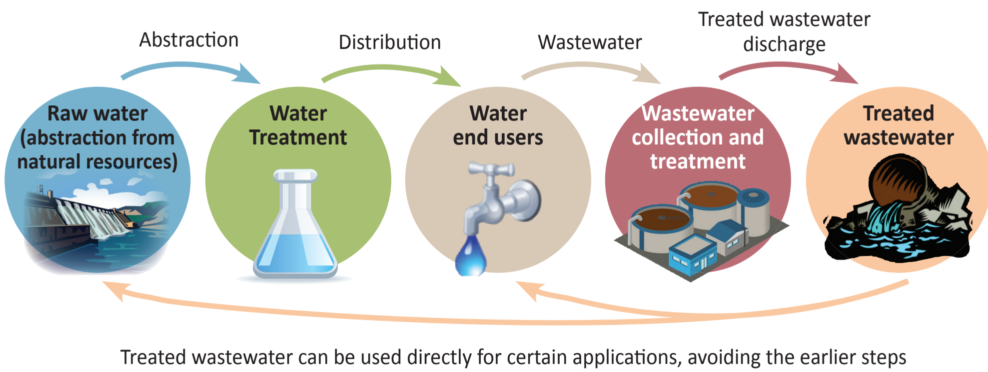
Energy is consumed at a number of points in the water and wastewater treatment infrastructure cycle (see Figure 1). Pumps and equipment used in distribution and treatment processes are the primary users of energy:

- Raw water abstracted from dams, rivers or groundwater systems usually have to be pumped into a bulk reticulation system that takes the water to a water treatment works. The pumping is an ongoing requirement and uses significant quantities of energy.
- The bulk reticulation system in which raw water flows to a treatment plant may require pumpstations – depending on the topography and the distance between the point of abstraction and the treatment plant.
- Water treatment is a process and requires a range of equipment for aeration, dosing, sterilisation, filtration and mixing of the raw water. Treatment plants operate for lengthy periods of the day and night (if not constantly) and thus are prime consumers of energy.
- Treated (potable) water enters the bulk water reticulation system either by gravity, or more often is pumped to a range of storage reservoirs at high points from which the treated water can gravity feed to consumers. Energy is consumed by pumps required within the reticulation.
- Water is usually gravity fed to consumers, although in some cases booster pumps may be required to obtain a suitable water pressure in the reticulation.
- Potable water is used by consumers (household, business, industry etc.) and is flushed into the sewerage network.
- Wastewater is pumped through the sewerage network to the nearest wastewater treatment works. The pumping of wastewater requires significant energy.
- Wastewater treatment works' operate almost continuously and include a range of equipment for aeration, dosing, mixing etc. that all utilise electricity.
- Treated wastewater is usually gravity fed to the nearest discharge point (back into the natural environment), although in some cases treated wastewater effluent is pumped out of the wastewater network for re-treatment to potable standards or for use as second grade water in industrial processes.

Where water has to be abstracted from brakish / saline sources and desalinated, or if treated wastewater effluent is put through a reverse osmosis process to improve the quality, the energy consumption to produce water of a potable standard is especially high.

There are usually a number of different government agencies responsible for the water and wastewater infrastructure in the cycle in Figure 1. National government, district and local municipalities manage different parts of the infrastructure, and in some cases parastatals such as Rand Water / Umgeni Water manage components of the water supply system.

Figure 1: The water services cycle



(Source: EPA, 2013)

As shown in Table 1, the provision (abstraction, distribution and treatment) of potable water can consume up to 1,100 kWh/Mℓ[1]. Similarly, pumping wastewater to treatment plants and undertaking the treatment process can consume up to 2,150 kWh/Mℓ.

Table 1: Energy consumption range for the South African water supply chain

Process	Min. (kWh/Mℓ)	Max. (kWh/Mℓ)
Abstraction	0	100
Distribution	0	350
Water treatment	150	650
Reticulation	0	350
Wastewater treatment	200	1800

(Source: Swartz *et al*, 2013)

Preliminary estimates from Europe and the United Kingdom indicate that energy savings of between 5% and 30% can readily be achieved through investments in energy efficiency and renewable energy at water supply and wastewater treatment facilities. Information from a recent South African Cities network study indicates that treatment works can reduce energy consumption by 5% through installing energy efficient motors and by a further 15% through installing variable speed drives (VSDs).

3. WHY INVEST IN ENERGY EFFICIENCY AND RENEWABLE ENERGY?

There are a number of reasons why municipalities should be investing in energy efficiency and renewable energy generation in their water and wastewater infrastructure. Some of these are highlighted in the following sections.

3.1 Direct Operational Cost Savings

Municipalities can achieve significant operational cost savings by optimising the energy efficiency of their water and wastewater services infrastructure[2]. While little attention was paid to the cost of electricity in the past due to South Africa's relatively low electricity prices, the recent increases in the cost of electricity has made water supply and wastewater treatment a significant cost item for municipalities[3].

In South African municipalities, water and wastewater infrastructure has been reported to account for between 20% and 70% of the total energy consumed by a municipal administration.

Improvements in the energy efficiency of water and wastewater treatment facilities are therefore financially attractive for two reasons. Firstly, due to the long hours of operation of pumps and other equipment, the pay-back periods[4] of investments in energy efficiency are generally quite short, making them highly attractive investments. Secondly, as these facilities are public infrastructure, they are unlikely to be discontinued or replaced and so the cost savings associated with reduced energy consumption will accrue over a long time period, again making the investments highly attractive from a cost-efficiency point of view.

1 Swartz *et al*, 2013.
2 American Council for an Energy-Efficient Economy, undated.
3 Water Research Commission, 2013.

4 Pay-back period is the term used to describe the amount of time taken (usually in years) for the cost of an investment in energy efficient technologies to be cancelled out by the financial savings created through the reduced consumption of electricity.

3.2 Sustainability in Municipal Service Delivery

In addition to the direct operational savings, investments in energy efficiency and renewable energy in water supply and wastewater treatment infrastructure can also improve the sustainability of municipal service delivery. Reducing electricity demand can decrease the load on the distribution network, reducing the risk of brownouts or blackouts during high energy demand periods. Further to this, investment in renewable energy generation improves surety of electricity supply, particularly for critical equipment, such as water and wastewater pumps, which need to operate continuously. For example, it is estimated that in South Africa, wastewater treated at the country's 968 municipal treatment works' could generate up to 780 MW[5] of power.

In the past, municipalities were perhaps cautious of adopting energy efficiency technologies in their water supply and wastewater treatment facilities as there was a concern that this could compromise water quality standards[6]. There are, however, a number of recent examples, some of which are presented in Section 5, of energy efficiency and renewable energy technologies that have been successfully implemented in South Africa without compromising compliance with water quality standards. Improving energy efficiency was perhaps also not considered a priority, as this is not the core mandate of water and wastewater utilities. However, with rising electricity prices and the need to provide services to ever-increasing municipal populations, municipalities increasingly have to focus on all possible measures to improve the cost efficiency of service delivery in order to be financially sustainable.

Investments in energy efficiency can also extend the lifespan of water supply and wastewater treatment infrastructure, as energy efficient equipment often has a longer service life and requires less maintenance than older, less efficient technologies. If energy efficiency is combined with a water conservation strategy, the life of existing infrastructure can be further extended due to lower demand, and the need for costly future infrastructure expansions can also be avoided or delayed.

3.3 Climate Protection

Improving energy efficiency and generating renewable energy in water and wastewater infrastructure can help to reduce air pollution and Greenhouse Gas (GHG) emissions by decreasing consumption of fossil fuel-based energy. This is particularly relevant in South Africa where 90% of electricity is generated by coal-fired power stations. In this way, municipalities can contribute to a reduction in global warming and the potential impacts of climate change, such as sea level rise.

4. PLANNING FOR ENERGY EFFICIENCY AND RENEWABLE ENERGY

Careful and well-directed planning processes can help to ensure that investments in energy efficiency and renewable energy generation in municipal infrastructure results in the best possible outcomes for the least possible amount of expenditure.

4.1 Baseline Setting

The first step in planning for energy efficiency and renewable energy in water and wastewater infrastructure is to calculate the energy baseline - or the actual amount of energy used under current operating conditions. At a municipal-wide scale, it is most strategic to start by undertaking an energy audit for all municipal water and wastewater infrastructure to determine this energy use baseline. This way it becomes much easier to identify which installations are the most energy intensive / energy inefficient and thus where the greatest savings could be made.

If undertaking an energy baseline assessment of the whole municipal area at once is too onerous (or costly) an exercise, other options include:

1. Separate the municipal area into regions based on water / wastewater catchments and undertake energy audits one region at a time.
2. Install energy meters to monitor energy consumption at major installations, to inform energy auditing and management interventions.

[5] Burton *et al.*, 2009.

[6] Science Applications International Corporation, 2006.

3. Undertake energy audits on the infrastructure components known / thought to be the most energy intensive (e.g. all wastewater pumpstations) first, then move onto other components of the infrastructure as funding becomes available for further audits.
4. Undertake a simplified version of an energy audit for infrastructure (or components thereof) by taking monthly meter readings of water and wastewater infrastructure to determine which facilities utilise the greatest amounts of electricity.

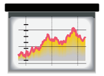
While the baseline is generally measured in kWh/Mℓ, it can also include Biochemical Oxygen Demand (BOD) or number of persons benefiting from the service (e.g. water with a higher BOD may require a more intensive treatment process that uses more energy than water with a lower BOD, so recording this information can be useful in identifying why certain treatment facilities are more energy intensive and how much BOD reduction is achieved per kWh used; or how many people receive treated water per kWh). This more comprehensive form of baseline analysis will help decision-makers identify which components of the municipal water and wastewater infrastructure are playing the most important role in the system.

Energy audits should assess installed equipment and associated energy consumption (where this is metered). Where energy metering is not in place, energy use can be estimated by calculating the energy use of different equipment from hours of operation. Good practice in energy management requires proper measurement of energy use, so making such estimates is not ideal and should be addressed over time through the installation of meters.

It is recommended that the monthly energy use is plotted on a graph to show changes in consumption over time. This should ideally be plotted against flow to show changes in energy use with flow changes. Importantly, times of use equipment should also be recorded, as this will allow decision to be taken on whether load shifts offers significan cost saving benefits.

The type of energy audit undertaken is largely dependent on the level of detail that is required and ranges from taking a walk through the facility to identify high-priority areas, to metering of specific equipment over set time periods. It is recommended that facilities operators are consulted as they are the most familiar with daily operations and equipment. The municipality may choose to undertake its own energy audit or contract a specialist for this purpose. If funding from sources such as the Department of Energy's Energy Efficiency Demand Side Management Programme (EEDSM) are to be used for implementation, there may be a requirement that an Energy Services Company (ESCO) approved by Eskom undertakes the audit (note that this would just be for the equipment / facilities for which the energy efficiency retrofit was to be paid for through the EEDSM programme).

4.2 Identifying Energy Interventions and Targets



Using the information from the baseline assessment(s), the next step is to identify the range of possible interventions that could be implemented to achieve a reduction in the baseline. Ordinarily, interventions will only be identified for processes, equipment or systems which present a notably high energy use profile in the energy audit / baseline assessment. They may include:

1. Operational changes (e.g. shift demand to off-peak periods where electricity costs are lower); and / or
2. Equipment upgrades (e.g. replacing pumps);
3. Generating renewable energy to replace grid energy use in infrastructure facilities.

Depending on the municipality's internal capacity, the identification of energy interventions may be done in-house, or a specialist may be contracted in for this. Experiences from other municipalities in South Africa seem to indicate that outsourcing this function can be useful, as external consultants often have a working knowledge of the best and most recently developed technologies available for energy interventions.

Through identifying a suite of possible energy interventions, it is also possible to determine energy targets. A target is a measurable performance requirement. Energy targets can be very specific (e.g. reducing demand during energy peak periods) or notional (e.g. 30% reduction in wastewater pumping costs in the municipality by 2016), but need to be based on what is deemed possible within the limits of the municipality's financial and technical constraints.

Energy targets can be set for specific types of operational processes, equipment, facilities or regions. The setting of energy targets needs to be done in conjunction with the process of identifying energy interventions that will reduce energy consumption, reduce energy costs, and / or generate renewable energy. Without an understanding of the latter, energy targets are likely to be unrealistic, impractical, and possibly even lacking in ambition.

One of the ways in which to set targets is to use best practice benchmarking. In this approach, the targets are based on what could be achieved through implementation of best practice energy efficiency and renewable energy measures.

Note that the targets should be regularly reviewed and updated as necessary to ensure that there is continuous improvement.

4.3 Deciding which Interventions to Prioritise

The next step in the process is to evaluate, prioritise and schedule potential energy improvement and renewable energy projects and activities.

Operational changes are usually the cheapest and quickest to implement. Equipment upgrades, however, require capital investment and so take longer to get started and need to be prioritised on the basis of the following kinds of criteria:

- The total cost of the intervention(s) vs. available funding;
- Choosing technologies for which funding support can be leveraged from the National Department of Energy[7] or other funders;
- Achieving the highest possible energy savings per Rand spent (i.e. projects with the highest financial feasibility, or shortest pay-back period[8]);
- Upgrading or replacing old or faulty equipment with energy efficient technologies as part of standard maintenance cycles;
- Choosing technologies that will reduce maintenance costs / requirements;
- Avoiding technologies that will create added workloads / burdens on existing staff;
- Where possible, choosing products that are locally produced, for which parts are locally available and / or expertise to service the products is locally based.

Each municipality will have its own priorities and so may weight the above criteria differently in making their decisions about which energy efficiency projects to prioritise. There may be other criteria that municipalities may also want to consider, which are specific to their own context(s).

Once the list of criteria has been established, the extent to which each project meets each of the criteria can be evaluated. Based on this assessment, interventions should be prioritised for implementation in a phased manner. The phasing will in large part be informed by available funding and the capacity within the municipality to rollout implementation.

4.4 Project Business Plan

A Project Business Plan document should then be prepared, which details the schedule / programme of rollout of the energy interventions in a phased manner and presents the expected costs and savings associated with the implementation for each phase. The Project Business Plan may present the long-term plan for rollout, but will include significant detail on interventions that will be implemented in the short term.

In general, most investments in improving energy efficiency of water and wastewater infrastructure require substantial up-front or capital investment. Project Business Plans need to be sufficiently detailed to be used to motivate for implementation funding.

The Project Business plan will need to include information and budgets for the following:

- **Project Description** – the project description needs to explain to readers how the project has come about, where it is located, what it aims to achieve, when it will be / needs to be implemented and who will be responsible.
- **Project Feasibility** – The Project Business Plan is likely to be used to motivate for funding for implementation. Proving the financial feasibility is therefore an important aspect of the Plan.

  There are a number of ways that this can be done:

  1. **The Pay-back period** – which refers to the duration, usually in years, that it will take to recover the cost of an investment through either cost savings (as a result of reduced energy consumption), or fees / charges / another form of income (such as from the sale of renewable energy, or a green energy tariff).
  2. **The Cost-effectiveness method** – which is usually used to identify which option, among two or more, is the best when they either have the same benefits or the benefits are unknown or undefined.
  3. **A Benefit-cost analysis** – which is usually used when both the benefits and costs of a project are known. Such an analysis compares the benefits, often over time, with the cost of a project. If the benefits exceed the costs, then the project is deemed feasible. If not, then the project is not feasible.

[7] The National Department of Energy's Energy Efficiency Demand Side Management Programme can provide funding for energy efficiency retrofits for energy efficient building lighting, street lighting, traffic lighting, and water purification and pumping plants.

[8] See SALGA's Toolkit for Financing Energy Efficiency and Renewable Energy Investments (www.salga.org.za).

- **Project Technical Design** – if there is no in-house capacity, a service provider may need to be appointed to design the upgrades or develop the specifications for equipment replacements. This can be a costly upfront investment which may need to occur before funding can be sourced. The state to which the project design has been completed, and further design work that is needed, must be presented in the Project Business Plan.
- **Regulatory compliance** – certain types and scales of renewable energy projects may trigger the need for an Environmental Impact Assessment to be conducted. Similarly, any water / wastewater infrastructure that is governed by a Water Use License may require some form of permission from the Department of Water Affairs / amendment of the License in order for the interventions to be legal.
- **Equipment** – the purchasing of new equipment, such as energy efficient pumps or variable speed drives, can make up a significant proportion of the cost of a project. Similarly, the installation of renewable energy initiatives, such as solar PV or biogas digesters, can also be costly.
- **Installation and Commissioning** – the schedule and cost of specialised installers and labour needs to be included.
- **Controls** – the upgrading of control systems can also improve energy efficiency. It is important to note that it is not only the cost of the control panels, but also wiring and labour costs.
- **Renovation** – in some instances renovations may be required, which can be costly if these are extensive. Note that the cost of labour and machinery also needs to be considered.
- **Training and capacity building** – facilities managers and operators will require additional training on changes in operations and maintenance. As part of the training, it must be clearly demonstrated where the current inefficiencies are and the benefits of energy improvements, using case studies. This is important to get their buy-in. Further to this, all levels of facilities management will need to be engaged to manage expectations and to delegate responsibilities.
- **Certification** – Depending on the type of project, some form of certification process may be required. For projects where carbon finance is to be used to fund the implementation, certification of the project with the relevant body (e.g. United Nations Framework Convention on Climate Change (UNFCCC) Clean Development Mechanism (CDM) Executive Board for CDM projects) will be required. This can significantly affect the scheduling and the budget for the project.
- **Monitoring and Verification** – energy interventions should always include monitoring, which determines whether the estimated energy savings (or renewable energy generation) has in fact been achieved. Where the intervention has been financed through a third party, there is often also a requirement for independent verification of the monitoring results. It is often the case that facilities are not set-up for energy monitoring, and as part of the energy intervention, meters need to be installed in order to allow accurate monitoring to take place.
- **Servicing and maintenance** – capital budgeting for the installation and commissioning of energy interventions is not where it ends; equally important is budgeting for operational costs associated with servicing and maintenance of energy equipment and systems.
- **Project Budget** – the project budget must present the capital and operational costs of the interventions.
- **Project Schedule** – the project schedule must present a Ganntt Chart of the proposed rollout of planning / design, regulatory authorisations, procurement, installation, commissioning, operation, certification, training, monitoring and verification.

4.5 Project Financing

There are several different options available for municipalities to finance energy efficiency and renewable energy projects. Finance for project implementation may be sourced internally (e.g. from the municipal fiscus) or externally (e.g. from a commercial bank, donor funder, national energy efficiency grants programme such as EEDSM, through Public Private Partnerships, carbon finance, or energy performance contracting[9]).

In order to motivate successfully for finance (from either internal or external sources), the Project Business Plan needs to present a favourable financial feasibility, or cost efficiency, of the proposed interventions. The expected financial savings or other benefits need to be clearly articulated in the context of the capital investment that will be required for implementation.

[9] See SALGA's Toolkit for Financing Energy Efficiency and Renewable Energy Investments – www.salga.org.za.

5. IMPLEMENTATION

Once the municipality has decided which energy efficiency or renewable energy generation interventions it wishes to pursue, the associated energy targets have been set, the Project Business Plan drafted, the detailed costs calculated, and funding secured, the next step of the process is implementation.

5.1 Preparations for Installation

Prior to installation taking place, it is very important that the buy-in and support from management at the various facilities is obtained to ensure that there is alignment between the project and the facility in respect of objectives, staff time allocations, and budget.

The next step is to develop 'operating controls', which is essentially a document outlining the specific way in which certain activities or operations must be executed. Note that this needs to be established prior to commissioning of the installed energy intervention. Typical operating controls include:

- **Training** – evaluate current level of training and determine if specific energy management training must be incorporated into existing training program.
- **Controlling documents and managing records** – review and evaluate current document control and records procedures. Update procedures to ensure these take into account changes at the facility.
- **Standard operating procedures** – Incorporate procedures for maintenance, calibration, and operation of new equipment in existing operating procedures. Importantly, these must be communicated to staff, their effectiveness discussed with staff, and appropriate changes to procedures made.

Prior to installation, a formal action plan must be developed which outlines responsibilities and timeframes to keep implementation on track and to ensure that participants are aware of their role in implementation. While the level of detail of the action plan is dependent on the complexity of the project, the following should be included:

- **List of the tasks** that need to be performed.
- Assigning of **responsibilities** for performing these tasks.
- **Deadlines** for completing these tasks. Note that these deadlines must be realistic and consistent with the overall project timeline.
- **Estimation of facility staff time and costs** for implementation (e.g. equipment, labour and other services). These must be approved by staff managers.

5.2 Installation and Commissioning

Installation is likely to take place by an outside contractor. The installation process can be disruptive to the operations of the facility, and so needs to be scheduled at an appropriate time in consultation with the facility manager.

Commissioning takes place immediately after installation and will require the close co-operation of facility managers and staff, such that this period can be used not only to test the installation, but also to build the operational capacity of in-house staff.

5.3 Monitoring

The next step is to monitor and measure the results of the interventions. The results of the monitoring should be used to re-assess and adjust how the equipment is managed or operated in order to optimise energy efficiency (or renewable energy generation). Progress towards meeting the energy targets (if these were set during project planning) should be regularly evaluated. If the monitoring reveals that the installation is performing below the anticipated efficiency, before modifying the targets, procedures or equipment, the following questions should be asked to determine the source of the problem:

- Was the target realistic?
- Were the implementation tasks sufficient to achieve the targets?
- Were some tasks not completed?
- Did anything change (e.g. energy prices, staff, energy consumption)?

As compliance with water quality and effluent standards is one of the primary goals of water and wastewater facilities, it is important to monitor or reassess the compliance status to ensure that the energy intervention(s) have not compromised these standards.

5.4 Maintenance

Having a solid servicing and maintenance plan for equipment (and implementing it) is vital to the continued success of the investment. This should include a maintenance schedule for each piece of equipment or system, typically including the following:

- Who is responsible for maintenance.
- How often maintenance needs to be performed.
- The actions for maintenance.
- The necessary resources which must be available (e.g. fuel, spare parts, filters etc.).
- Whether or not an outside contractor must be brought in to perform maintenance.
- Where to record maintenance and performance of equipment.

6. ENERGY EFFICIENCY AND RENEWABLE ENERGY FOR WATER AND WASTEWATER INFRASTRUCTURE

This section presents a list of potential energy efficiency (EE) and renewable energy (RE) projects that can be implemented in municipal water and wastewater infrastructure. For each project, a short description is provided, as well as where in the water services cycle the project intervenes (see Figure 1).

It is important to note that in addition to the interventions listed below, modifications to facility buildings themselves can also be made to reduce energy consumption. This includes for example, fitting energy efficient lights, solar water heaters or heat pumps, and improving ventilation.

6.1 Energy Efficiency Interventions and where in the Water Services Cycle they are applied

PROJECT	DESCRIPTION	INTERVENTION TYPE	Raw water (abstraction)	Water Treatment	Potable Water Distribution	Sewerage Reticulation	Sewage Treatment
Leak detection and repair	Reconciliation of unaccounted for water losses, and implementation of leak detection and repair programme to reduce water losses (and energy savings through reduced pumping requirements).	Reduce energy demand through optimisation of reticulation system	X		X	X	
Develop computer model of facility and distribution network	Model used to assess impact of improvements to distribution system e.g. adjusting pressures, pump rates, operational sequences etc.	Reduce energy demand through optimisation of reticulation system	X	X	X	X	X
Match power demand to system demand (i.e. user consumption)	Evaluate user water consumption and electrical power demand and identify interventions to better match power demand to system demand.	Reduce energy demand through optimisation of reticulation system			X	X	
Staging of treatment capacity	As treatment systems operate more efficiently when loaded near their design capacity, staged systems will generally function more efficiently as the system grows.	Planning for process energy efficiency		X			X
Biosolids processing options	When planning and designing new facilities or expansions, assess the costs and benefits of various biosolids process options e.g. aerobic vs. anaerobic.	Planning for process energy efficiency					X
Flexible sequencing of basin use	Ensuring that the capacity of basins matches the current loadings at all times can significantly affect the energy consumed during the life-time of a facility. This can be achieved through best selection of basin sizes and sequential loading of basins until the design capacity is met.	Planning for process energy efficiency		X			X
Optimise flows with control	Assess variation in facility flows and apply control systems to ensure a more constant flow through the treatment processes.	Reduce energy demand through optimisation of operations		X			X
Operational flexibility	Evaluate facility loadings and treatment systems to identify, plan, and design the most efficient and effective ways to operate the existing system.	Reduce energy demand through optimisation of operations	X	X	X	X	X
Managing for seasonal / tourist peaks	Design and implement a flexible system which allows wastewater treatment facilities to adjust and operate more efficiently during peak seasonal loadings, as well as during the off-season. This may include adding or removing additional tanks.	Reduce energy demand through optimisation of operations					X

PROJECT	DESCRIPTION	INTERVENTION TYPE	Raw water (abstraction)	Water Treatment	Potable Water Distribution	Sewerage Reticulation	Sewage Treatment
Dissolved oxygen control	Dissolved oxygen monitoring and control technology to maintain dissolved oxygen at desired levels in the aeration tank. Then air flow rate can be adjusted accordingly.	Reduce energy demand through optimisation of operations		X			X
Automatic controls	Install automatic controls to better control and monitor system functions.	Equipment	X	X	X	X	X
Replacement of throttle valves with variable speed drives	Replace existing pump throttle valves with energy efficient variable speed drives (VSDs) to better match motor output speeds with load requirements, and avoid running at constant full power, thereby saving energy.	Equipment	X	X	X	X	X
Ultraviolet (UV) disinfection options	Assess design of UV system and reconfigure setup to improve energy efficiency. This may include reducing the number of lights, bulb orientation, and bulb type.	Equipment		X			
Optimise aeration system	Determine whether the aeration system is operating at maximum efficiency as possible for the required level of treatment. Consider the costs and potential benefits of improvements, such as fine-bubble aeration, dissolved oxygen control, and variable speed air blowers.	Equipment		X			X
Variable blower air flow rate	Aeration systems and aerobic digester blowers that have variable air supply capability to meet existing low-load and high-load conditions.	Equipment		X			X
Aerobic digestion options	Assess existing aerobic digester operation to determine if fine-bubble diffusers and equipment and / or controls with adjustable airflow rates can reduce energy usage.	Equipment					X
Promote water conservation	Reducing water consumption decreases the amount of water that needs to be treated and distributed, and consequently, energy usage. This may include awareness raising, promoting low-flow plumbing fixtures, and block pricing systems.	Water demand management	X	X	X	X	X
Manage high volume users	Meet with top water users to identify potential modifications to their operations that may reduce their water consumption, and consequently, save energy.	Water demand management	X	X	X	X	X
Final effluent recycling	Making use of final effluent in industrial processes may save energy by limiting the volume of water abstracted and treated.	Water demand management	X	X	X	X	X

6.2 Renewable Energy Technologies and where in the Water Services Cycle they are applied

PROJECT	DESCRIPTION	INTERVENTION TYPE	Raw water (abstraction)	Treatment	Distribution	Sewerage	Treatment
Mini-hydropower turbines	Installation of mini-hydropower turbines within the bulk and / or reticulated water network (where there is sufficiently high flow volumes and velocity, and large enough pipe sizes) to generate electricity which can be used to power lights, pumps, controls etc.	Renewable energy generation in water network	X		X		
Biogas / Combined Heat and Power (CHP)	Installation of biogas digesters and CHP plants at wastewater treatment facilities to generate electricity from sludge digestion, which can be used to power lights, pumps, controls etc., as well as to feed excess into national grid. Excess heat can also potentially be used to heat digesters or in the composting process.	Renewable energy generation at wastewater treatment facilities					X

7. CASE EXAMPLES

The following case examples are taken from the 2013 Water Research Commission (WRC) report, *Energy efficiency in the South African water industry: a compendium of best practices and case studies*. The case examples have been grouped according to the following categories:

1. Assessment and planning for energy efficiency
2. Water demand management to reduce energy consumption
3. Energy efficiency in treatment processes and equipment
4. Renewable energy from mini-hydropower turbines
5. Renewable energy from biogas

7.1 Assessment and Planning for Energy Efficiency

Project title	Location	Project leader	Phase of water cycle	Project description	Project outcomes / benefits	Lessons learned
Life cycle assessment (LCA) of water supply, treatment and recycling	Durban	eThekwini Municipality	All phases	The information used in the LCA is largely based on research undertaken by the University of KwaZulu-Natal on the water cycle in the urban context. The LCA was carried out using the standard ISO 14040 methodology. The outcomes of the LCA are based on the collective results of 5 standalone LCAs undertaken for each step of the water services cycle. The project involved measuring of actual performance, identifying improvements, and assessing implications of changes, and focused on two areas: reducing water losses in the potable water distribution system (i.e. to reduce amount of water treated), and improve energy efficiency of wastewater treatment. The project is complete.	Proposed the development of electricity index (e.g. kWh/Kℓ) used to track electricity consumption of whole system and each sub-system, used to identify problems and opportunities for cost savings. Limiting airflow to thermal unit of ozonation unit can potentially reduce energy consumption by 70% (1,173 kWh/day). Using chemical pre-treatment can potentially reduce energy usage by 685 - 767 kWh/day. Reducing water losses (20% water loss) could save 82 Mℓ/day.	Energy consumption can be used as an indicator of environmental performance of a water and sanitation system (electricity is responsible for the majority of the environmental impacts). As such, using an energy audit may be preferable to a detailed LCA when investigating the reduction of the environmental impact, as it is quicker to perform. That the use of a holistic approach is necessary to gain an effective assessment of the environmental performance of water and wastewater services. Wastewater discharge quality requirements may act as a driver to recycling, especially in inland locations. That the use of an Electricity Index could provide an easy to use indicator of environmental performance in benchmarking urban water systems and could facilitate identifying substantial energy savings.
Efficiency of mechanical and fine-bubble aeration systems	Johannesburg	City of Johannesburg (Johannesburg Water)	Treatment	Johannesburg used a multi-criteria analysis to compare the energy efficiency and life cycle costs of fine-bubble diffused aeration, aerated turbine aeration, jet aeration, and mechanical surface aeration systems. Mechanical surface aeration system was used as the benchmark. Research was undertaken in-house. The project is complete.	Mechanical surface aeration is the preferred system of Johannesburg despite fine-bubble aeration being more energy efficient (11-19%), as fine bubble aeration does not score well on several criterion including initial costs, maintenance costs, system robustness, and standby capacity.	Important factors to minimise power consumption and maximise performance in mechanical surface aeration systems: i) control of oxygen concentration in aerated liquid within 1 - 2 mg/ℓ, where control can be facilitated by providing for controllable outlet weirs on the reactor; ii) provision of the minimum required aeration intensity; iii) inspection and service for uninterrupted operation. Energy efficiency in fine bubble systems is critically dependent on matching component sizing and flexibility with process demand. Energy is wasted when oxygen supply does not match the process demand. Flexibility can be positively altered by: i) add or remove (capacity) multiple aeration basins; ii) adjust diffuser aeration by controlling air flow rates (O_2 turndown ability); iii) provide multiple lowers with max to min air flow ration of 5:1; iv) control of air flow rate and present DO concentration. Aeration system blowers use a lot of energy. Proper selection can improve efficiency. For dynamic compressors, turndown is best achieved using inlet throttling using adjustable inlet guide vanes.

Project title	Location	Project leader	Phase of water cycle	Project description	Project outcomes / benefits	Lessons learned
Water distribution energy optimisation through off-peak pumping	Durban	eThekwini Municipality	Distribution, Sewerage	Research undertaken by the University of KwaZulu-Natal. Developed a model to represent the distribution network. The aim is to use the model to optimise the distribution network by pumping according to the daily tariff structure (i.e. during off-peak periods) and maintaining minimum emergency levels in all reservoirs (i.e. minimise pumping). Model to also be used to test effect of additional reservoirs, new pumps, new links, reservoir levels etc. Only required operational changes. Staff will however need to be re-trained and new operational procedures developed. Project is still in research phase and has not been implemented.	Energy gains are entirely dependent on management of the system. Optimising the system for example to gravity feed from one reservoir to another to cater for high demand periods during peak tariff periods and then replenishing both reservoirs by pumping during low tariff periods can realise significant savings in electricity costs. Another potential savings is in infrastructure development. Presently many distribution systems are larger than required in order to compensate for the limitations of human control. Effective water distribution optimisation will allow for the construction of smaller networks or in the case of existing infrastructure avert or at least delay costly upgrades as demand increases. Finally, effective distribution optimisation can ensure that chlorine residuals are maintained at effective levels and avoid the need for costly chlorine booster pump stations. Payback period likely to be short as changes are largely operational.	Optimisation of water distribution of large systems needs to be automated and the modeling required to achieve optimal performance needs to be based on extensive historical records. If minimum emergency levels are not maintained in all reservoirs, it may become necessary to pump during peak periods which will negate any energy savings achieved. Careful control of the chlorine / disinfectant residual is needed in order to ensure adequate disinfection in the distribution system, while at the same time not exceeding allowable limits or compromising water quality or taste.

7.2 Water Demand Management to Reduce Energy Consumption

Project title	Location	Project leader	Phase of water cycle	Project description	Project outcomes / benefits	Lessons learned
Leakage reduction and water conservation	Sebokeng / Vereeniging	Emfuleni Municipality	Distribution	Prior to implementation of the project, reported leakages in Sebokeng were in excess of 70% (2800m^3/hour). Project involved the installation of a pressure reduction chamber to reduce pressure during off peak periods and restore to higher pressure during high demand period. Included cutting into existing water mains and replacing sections with smaller diameter pipes and equipment. Project was funded through a public-private-partnership. Project cost was approximately R10 million. Investment was repaid in 5 years from savings in water and electricity. Design, build and installation was undertaken by a service provider. Emfuleni Municipality is responsible for operations. Project has been completed.	Cost savings of R 38 million per annum. Energy saving of 14 million kWh per annum. Water saving of 8 million Kℓ per annum. Avoided GHG emissions of 12,000 tons CO_2e. Payback period – 3 months.	Water leakage accounts for a significant portion of energy along the value chain of the water cycle. Leakage for a well-managed system is typically below 15% . Pressure reduction is a 1st order intervention to be followed in series or parallel with complimentary actions within a holistic Leakage Management strategy. Proactive reduction of water losses to a target value, reducing pressures to minimum targets in identified areas, pursuing asset renewal projects, metering to check and monitor supply zones for losses, and minimise repair times for visible and detected leaks. Reactive pressure control would imply a response is only afforded once the municipality becomes aware of a supply or pressure problem. Performance contracting in terms of water supply is key for low capacity municipal suppliers.

Project title	Location	Project leader	Phase of water cycle	Project description	Project outcomes / benefits	Lessons learned
Pressure management in municipal distribution systems	Durban	eThekwini Municipality	Distribution	Prior to start of the project, water demand in the CBD was approximately 38 Mℓ per day, of which approximately 10 Mℓ was being lost through leaks and illegal connections. 3 pressure reducing valves (PRVs), real time loopback algorithm equipment (to controls PRVs), and variable speed drives were installed to reduce the pressure head from 60m, which is well above recommended pressures, to 26m. Only existing stock worth approximately R 2 million was used. Included modifications to buildings higher than 6 storeys to pump water from a basement tank to rooftop tanks using jockey pumps so that the floors below can be gravity fed. The reduced head resulted in there not being enough pressure to supply the higher floors (i.e. > 6). The bylaws were also changed to require buildings greater than 6 storeys in height to install their own systems. Project was designed and implemented by service providers, and funded by the eThekwini Municipality. Project has been completed.	Cost savings of R 20.8 million per annum. Water saving of 6.8 million Kℓ per annum. Payback period – 2 months. Reduced number of pipe bursts by 14% overall. In the CBD area this was reduced from from 1.5 bursts per week to zero.	As a result of the pressure reduction to date eThekwini's water purchases from Umgeni Water dropped from 912 Mℓ/d to 845 Mℓ/d, despite the fact that 10 000 new customers have been added per year. The use of real time pressure algorithm control of the PRVs has been estimated to save the municipality R1.1 million per annum. Energy savings using variable speed pumps have allowed for additional savings of approximately 50% of energy consumed by these pumps. Pressure reduction in the distribution system results in reduced water losses at an approximately 1:1 ratio. Or a 10% reduction in pressure = 10% reduction in water losses.
Prepayment metering and pressure management in drinking water supply	Kagiso	Mogale Municipality	Distribution	Prior to implementation of project, Kagiso was characterised by high water losses and a culture of non-payment (10% recovery rate). A Water Demand Management and Prepayment Policy was formulated and adopted by council to ensure implementation. Required an inter-departmental approach involving water technicians, meter readers (finance department), billing department, GIS department, councillors and community facilitators. Installed bulk water meters and conventional meters to establish baseline water usage. Employed additional staff to oversee billing accounts, maintenance and repairs. Replaced conventional meters with prepayment meters (payment levels increased from 10% to 95%). Project implemented by Mogale Municipality. Service providers were used to install the meters. USAID and Alliance to Save Energy were closely involved in the planning and implementation of the project. Project commenced in 2006 and is still ongoing. Approach is to be used to rollout similar projects in other problem areas in Mogale Municipality.	Estimated cost savings of R 21 million per annum. Estimated energy saving of 15.4 million kWh per annum. Estimated water saving of 6 million Kℓ per annum. Estimated avoided GHG emissions of 13,700 tons CO_2. Improved billing and payment from 10% to 95%. Estimated payback period – 3 months.	Overall, the model worked well and serves as a replicable model for other South African scenarios.

7.3 Energy Efficiency in Pumping and Treatment Processes

Project title	Location	Project leader	Phase of water cycle	Project description	Project outcomes / benefits	Lessons learned
Renovation and relocation of Point Pump Station	Durban	eThekwini Municipality	Sewerage	Point pump station is Durban's largest sewage pump station (60Mℓ/ day), and was commissioned in the 1970s. The pump station needed to be relocated 200m away from its previous site and the odour control system upgraded. Instead of refurbishing old pumps, new energy efficient pumps are to be installed and fitted with variable speed drives by a service provider. The eThekwini Municipality funded the project and will be responsible for operations. Some additional training of the operator will be required. The project was due to be completed by October 2013.	Estimated cost savings of R 200,000 per annum. Estimated energy saving of 401 MWh per annum. Payback period – 11 years, since the current pumps needed to be replaced / refurbished, the payback period is calculated based on the capital cost of the variable speed drives only.	Optimal energy savings are achieved by combining newer, more efficient pumps with variable speed drives. Without the variable speed drives, optimal energy savings cannot be achieved.
Replacement of brush and surface aerators with fine-bubble aerators	Carl Grundlingh WWTW, Nigel	East Rand Water Care Company (ERWAT)	Treatment	Due to high cost of electricity, maintenance of aerators, and need to increase the oxygen transfer rate, ERWAT investigated replacing the brush and surface aerators with floating fine-bubble aerators. The 3 Mℓ/day Carl Grundlingh WWTW was selected to be the pilot project. Yet to be implemented, the project is still in the research phase. Research is being undertaken in-house using available literature.	Estimated reduction of energy consumption for aeration is 52%, with same level of oxygen. Or increased oxygen levels (from 1.26 O_2/kWh to 2.7 O_2/kWh) with the same amount of energy.	The cost of electricity is a significant component of the overall cost of wastewater treatment. The aeration of the mixed liquor suspended solids in the activated sludge process constitutes a major portion of the electricity consumption on a plant. The majority of plants in South Africa use mechanical surface aerators for aeration, with some variations in bubble diffused aeration systems. International experience with Floating Fine-bubble aeration reduces energy usage by 50 - 70 % compared to mechanical surface aeration.
Installation of energy efficient fine-bubble aerators to increase treatment capacity and energy savings	Bushkoppies WWTW, Johannesburg	City of Johannesburg	Treatment	The Bushkoppies WWTW needed to be expanded from 200 Mℓ to 250 Mℓ without extending the activated sludge bed. A feasibility study and pilot scale tests were undertaken to determine the optimal number and positioning of diffusers. The upgrade will include the installation of one new energy efficient blower (85% efficiency). As the new blower will provide 50% of the air requirement, the use of the existing, less energy efficient blowers can be reduced. It is proposed that eventually all three exiting blowers will be replaced with new, more energy efficient blowers. A service provider was appointed to design / implement the project.	Estimated energy saving of 21% - 3,154 MWh per annum with all 3 blowers installed. Payback period – 10 years. Avoided cost of not having to extend activated sludge bed.	The savings in energy used to power the blowers will be around 7%. The new blower will provide almost half the air requirement, while the balance will be provided by the existing small blowers, since the new blower has an 85% efficiency rating compared to that of 70% for the smaller blowers. Operating the three smaller blowers, the energy usage is 2 400 kW, but the effective utilisation is only 1 680kW, compared to an effective energy utilisation of 1 800 kW when using 2 of the smaller blowers together with the new, more energy efficient blower (i.e. a savings of 120 kW or 7.1%). This correlates to an energy savings of 1 050 MWh/annum per blower.
High-rate algal ponds (HRAP)	Belmont Valley WWTW, Grahamstown	Rhodes University and Makana Municipality	Treatment	Research project to compare oxygen transfer rates of High Rate Algal Pond (HRAP) and conventional aeration systems, e.g. surface aerators (high / low speed), bubble aeration (course / fine), and turbines / jets. HRAP uses a paddlewheel to create a wave that moves around the raceway, creating turbulence and introduction of O_2 and CO_2. A pilot plant was constructed alongside the Belmont Valley WWTW. This was funded by Makana Municipality. The research is being undertaken by Rhodes University and is ongoing.	Preliminary estimates are that the oxygen transfer rate of HRAPs are 15 kg O_2/kWh, which is 10 times better than the best mechanical aerator. HRAP produces effluent that meets DWA standards.	A major risk is that the national Department of Water Affairs imposes high effluent standards, which makes simpler systems such as HRAPs passed over when funding is considered, in favour of high technology systems, even though HRAPs produce an effluent that is fully compliant.

Project title	Location	Project leader	Phase of water cycle	Project description	Project outcomes / benefits	Lessons learned
Sequencing Batch Reactor (SBR) system (Nereda)	Gansbaai WWTW, Western Cape	Overstrand Municipality	Treatment	Upgrade the existing Gansbaai WWTW from 2 Mℓ to 4.5 Mℓ at a cost of R 25 million. Due to spatial limitations, the size of the WWTW required could not be accommodated on the site – hence implementation of a SBR system. Nereda is an advanced biological wastewater treatment technology which uses aerobic granular biomass for treatment of wastewater. SBR system uses anaerobic sludge granules which settle at a higher rate than in conventional systems, and allow for higher microbial density. WWTW designed and implemented by a service provider (RHDHV) and funded by Overstrand Municipality. WWTW is operational.	Energy savings are usually around 25% relative to that of conventional wastewater treatment plants, but can be as high as 35%. If one uses typical energy consumption figures for activated sludge of around 0.35kWh/m^3 then the energy saving is around 0.088 to 0.11kWh/m^3. Construction costs were around 20 to 40% lower than that of conventional works. Chemical addition for phosphate removal is not required. Highly automated system – reduced operational requirements. Smaller footprint than conventional WWTW.	Careful control of the plant is required in order to achieve the treatment objectives. This is achieved through the use of Programmable Logic Controller (PLC) and the only labour required is for checking of the head of works, control of chlorine stocks and ground keeping. The Nereda system has allowed for a much smaller footprint compared to that of conventional treatment plants. The number of unit processes is reduced and so the carbon footprint of the works is also much smaller. The effluent quality can be manipulated by adjusting plant operation. For example good phosphate and ammonia removal can be achieved through correct control of the plant. Nitrate removal (denitrification) can be achieved as well, but careful plant tuning is then required.
Digester mixing (vertical mixing)	Driefontein and Bushkoppie WWTW, Johannesburg	City of Johannesburg and Johannesburg Water	Treatment	Replacement of conventional impellor draft tubes, mechanical mixers and gas draft tubes with vertical linear motion mixers. Initially installed at Driefontein and Bushkoppie WWTW as part of refurbishment of existing digesters. Has not yet been rolled out to other WWTW. Service provider was appointed to design, build, operate and maintain (for specified time period) the project.	Energy saving of between 50 - 60% or 350 kWh/day per digester. It is expected that there will be a reduction in energy use of about 10 500 kWh/day in Johannesburg for the total sludge digestion operation (350 kWh/day per digester). Cost saving of R 83,000 per annum per digester. Reduced maintenance requirements. Limited civil / physical changes required – retrofit mixers to existing plant.	Fitting to existing digesters can be done by basic reverse engineering. New digesters can be sized and fitted during design stage to adopt vertical mixers. Optimise the digesters for maximum biogas output and methane yield by ensuring that good process control practice is in place, which include monitoring the minimum mixing cycles required.
Solar heating and compositing of sludge without using bulking agents	Johannesburg	City of Johannesburg and Johannesburg Water	Treatment	With the publication of the 2006 SA Sludge Guidelines, Johannesburg was then not fully compliant and a new operation had to be developed or the existing high cost composting operation extended. The new process involves spreading dewatered sludge on concrete beds (without bulking agent). Once the sludge reaches 50% dry solids concentration, it is stockpiled in 3m high piles to dry in the sun. When the volatile solids concentration reaches 0.45 kg / kg dry solids, the sludge is sold to farmers. Service provider was appointed to design, build, operate and maintain (for specified time period) the project. Project has been operational since 2007.	Cost saving of R 290/ton sludge treated when compared to composting using bulking agent. Payback period – less than 2 years. Consistently produce Class A1a final product which is sold to 19 maize farmers – waiting list with further 20 farmers.	Sludge treatment and disposal options normally involve high electrical energy requirements (i.e. incineration, pasteurisation). The composting/ solar process requires electrical energy for screening the composted product i.e. 7.5 kW for 100 dry tons per day of sludge treated. Full compliance with the 2006 SA Sludge Guidelines (at all times) is crucial to meet service delivery performance. The low level of technology used ensures that the operation is sustainable and cost effective. Laboratory analysis of all heaps ensures compliance with the guidelines and protects public health when used for landscaping etc.

7.4 Renewable Energy from Mini-Hydropower Turbines

Project title	Location	Project leader	Phase of water cycle	Project description	Project outcomes / benefits	Lessons learned
Western Aqueduct Mini-hydropower Turbines	Durban	eThekwini Municipality	Distribution	Implementation through public-private partnership. EThekwini will purchase the generators. Private partner will purchase the rest of the equipment, as well as operate and maintain the generators. The private partner will be assured of a market for the electricity generated through a 20 or 30 year contract with eThekwini which will include the selling of electricity to eThekwini Electricity. Initially two 2.7 MW generators will be installed in the Western Aqueduct, a new bulk water supply aqueduct to augment eThekwini's water supply (additional 400 Mℓ/d). Feasibility studies have been completed. Project implementation is dependent on the completion of the Western Aqueduct which is expected to be in 2016.	Potentially generate 662,256 MWh per annum. Payback period – 12 years.	The generation of electricity must never take precedence over the supply of water and must not negatively influence the cost of water to the rate payers. Various situations have been modelled in an attempt to assess the impact of different flow rates in the aqueduct on electricity generation and although the pressure increases that occur in pipelines when flow rates drop compensate the effects to some degree, if the flow rate drops below a critical volume, the 2.7 MW generators would be too large to work effectively.
Pierre van Ryneveld Conduit Hydropower Plant	Pierre van Ryneveld Reservoir, Pretoria	Tshwane Municipality, University of Pretoria and Water Research Commission.	Distribution	Installation of 15 kW cross-flow turbine at Pierre van Ryneveld Reservoir. Cross-flow turbine was used as it is a slow-speed system that is well suited for locations with low-head, but high flow. Electricity generated is used on site for the lighting, telemetry system, alarm system and electric fence. Feasibility studies were undertaken by the University of Pretoria in collaboration with the Water Research Commission. Hydropower plant was commissioned in 2011.	Estimates are that this will generate 131,000 kWh per annum. Payback period – relatively short. Limited civil works required compared to conventional hydro power projects.	Due to very low profile of small scale hydropower development in SA during two last decades there are no defined approaches and methods for financing of hydroelectric installations. Currently the Municipalities or Water Boards would utilize their own budgets to finance such projects. The results of testing also indicated that pressure surges do occur in the system and this will be used as a benchmark to ensure that the hydropower plant does not result in an increase in risk for the pipe system.

7.5 Renewable Energy from Biogas

Project title	Location	Project leader	Phase of water cycle	Project description	Project outcomes / benefits	Lessons learned
Cost-benefit model and simulation for biogas generation	Northern WWTW, Johannesburg	City of Johannesburg and Johannesburg Water	Treatment	Developed a simple model to project and predict the associated cost and biogas yield against variable input flow scenarios. Simulated installation of Combined Heat and Power (CHP) plant at Northern WWTW. This study was completed in 2010. A service provider was appointed in 2011 to design, build, operate and maintain the pilot CHP plant at the Northern WWTW. The plant was commissioned in 2013.	Model estimated that Johannesburg's five WWTW can generate 9.2 MW of electricity (and 10 MW heat). Model estimated that Northern WWTW can generate 4.4 MW of electricity (and 4.8 MW heat) with a through flow of 100 Mℓ/d. Payback period < 3 years. Avoided GHG emissions of 35,000 tons CO_2.	Ensure a cost-benefit model is in place whereby Combined Heat and Power (CHP) can be modelled and simulated in the planned environment. Ensure that biogas yield, input flow, sludge volume energy cost, capex and opex figures are contained in the CHP model in order to simulate various scenarios. Ensure that the % heat and % electricity from CHP is determined upfront.
Biogas to energy generation from WWTW in Durban	Northern and Southern WWTW, Durban	eThekwini Municipality	Treatment	Currently in feasibility phase. Northern WWTW will be the pilot study. Looking at installing fuel cells instead of a conventional gas engines. All energy produced will be used internally. At Southern WWTW, the digesters need to be refurbished and it is proposed that two gas engines be installed as part of the refurbishment. The energy produced will be used to power the WWTW, with excess energy fed into the national grid. It is proposed that a service provider will be appointed to design, build, operate and maintain the gas engines at the Southern WWTW. Similarly, a service provider will be appointed to design, build, operate and maintain the fuel cells at the Northern WWTW.	Estimated grid energy saving of up to 3,504,000 kWh per annum at Northern WWTW (25% of facility's total energy demand). Estimated grid energy savings of up to 17,520,000 kWh at Southern WWTW (100% of facility's total energy demand). Excess heat can be used to heat digesters and to dry sludge. Potential to pelletise sludge for agricultural use.	The digesters will need to be optimized to ensure that biogas generation is sufficient for adequate electricity generation. Effective scrubbing of the gas will be critical to the success of the project as impurities will result in damage to the gas engines and affect electricity generation. Careful selection of the type of transformer is needed and based on whether energy generated will be used internally (i.e. one-way transformer) or used internally and fed into the grid (i.e. two-way transformer). An effective heat exchange system needs to be installed to ensure that waste heat energy from the gas engines is used to heat the digesters. This in turn will assist in optimising biogas production and ensuring adequate electricity generation. An Eskom subsidy or other additional funding, as well as some additional modifications to the existing municipal electricity tariffs will be required in order to make this project viable.

8. FURTHER RESOURCES

American Council for an Energy Efficient Economy (ACEEE) website – www.aceee.org.

Agence Française de Développement (AFD) website – http://www.afd.fr/lang/en/home/pays/afrique/geo-afr/afrique-du-sud/AFD-AfriqueduSud.

Africa Water and Sanitation Local Authorities (AWASLA) Network website – www.awasla.org.

City Energy Support Unit (CESU) website – www.cityenergy.org.za.

Department of Energy: Working for Energy – http://www.energy.gov.za/files/wfe_frame.html.

Department of Energy: Energy Efficiency Supply and Demand Management Programme (EEDSM) website – www.energy.gov.za.

Department of Environment Affairs (DEA): SA Green Fund – http://www.sagreenfund.org.za/Pages/default.aspx.

Department of Water Affairs (DWA): Integrated Water Resource Planning Document Portal – http://www6.dwa.gov.za/iwrp/dss/DashboardEngine.aspx?DashboardID=IWRP\Map_Search.

EPA Local Government and Energy Strategy Series website – http://epa.gov/statelocalclimate/resources/strategy-guides.html.

Eskom: Integrated Demand Management website – http://www.eskom.co.za/sites/idm/Pages/Home.aspx.

Water Institute of Southern Africa (eWISA) website – www.ewisa.co.za.

Industrial Development Corporation (IDC): Green Energy Efficiency Fund (GEEF) – http://www.idc.co.za/development-funds/geef.

South African Local Government Association (SALGA) website – www.salga.org.za.

Sustainable Sanitation and Water Management (SSWM) website – www.sswm.info.

UK Water Industry Research (UKWIR) website – www.ukwir.org.

Water Environment Research Foundation (WERF) website – www.werf.org.

Water Research Commission (WRC) website – www.wrc.org.za.

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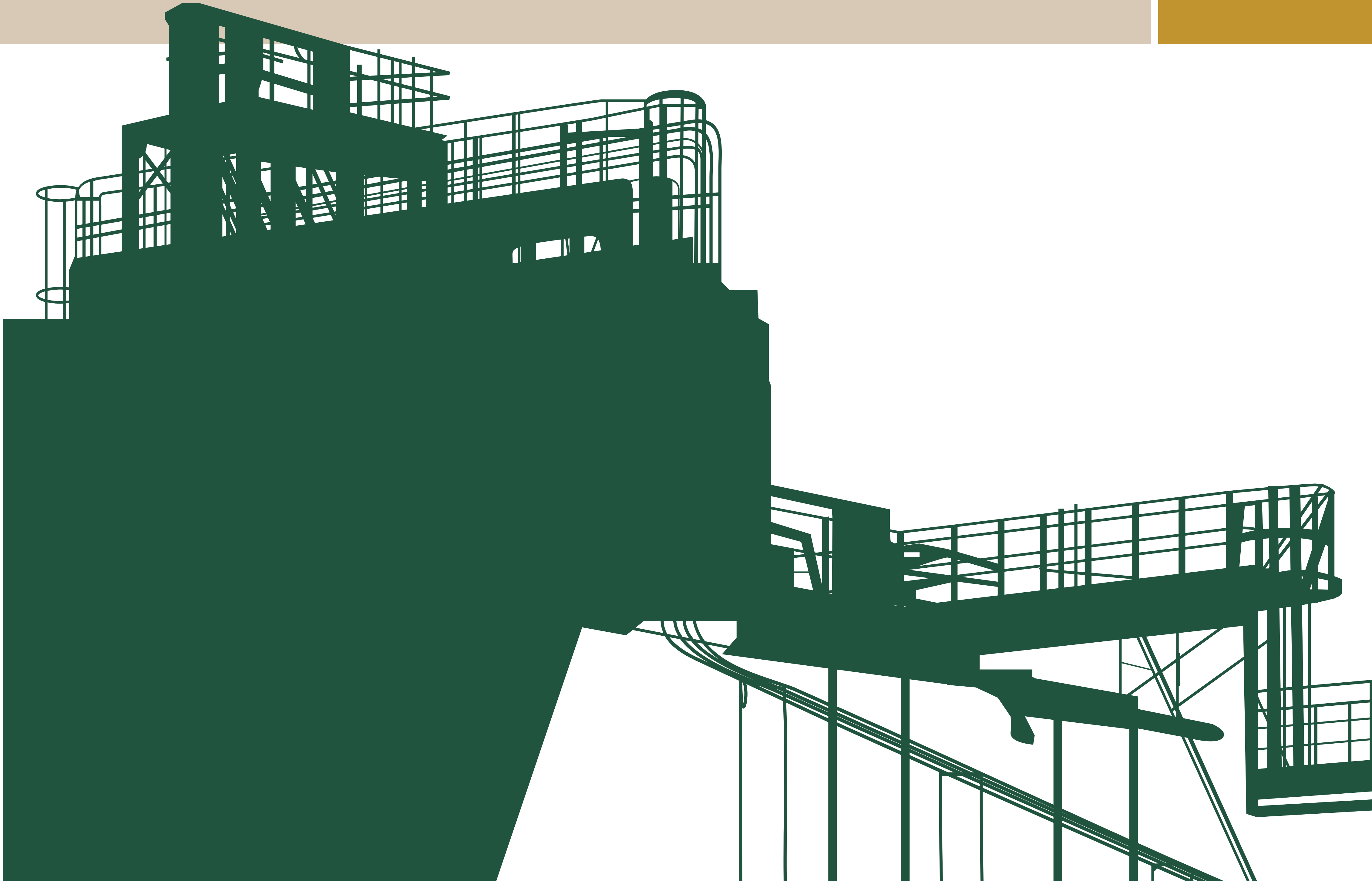

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