Energy Efficiency in the South African Water Industry:

A COMPENDIUM OF BEST PRACTICES AND CASE STUDIES

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WATER RESEARCH COMMISSION

TT 565/13

Energy Efficiency in the South African Water Industry: A Compendium of Best Practices and Case Studies

Report to the
Water Research Commission

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WRC Report No. TT 565/13
June 2013

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The publication of this report emanates from a project entitled *Energy Efficiency in the South African Water Industry: A Compendium of Best Practices and Case Studies* (WRC Project No. K5/2092//3)

ISBN 978-1-4312-0430-4

Printed in the Republic of South Africa

Executive Summary

Energy will in future remain a high cost item for municipalities and utilities which operate and maintain water and wastewater processes. Energy consumption will continue to increase as more people are provided with water and sanitation and new technologies are implemented to meet stricter effluent and potable water quality requirements.

To position the water sector globally with regard to energy consumption, the Global Water Research Coalition (GWRC) has embarked on a project entitled *Energy Efficiency in the Water Industry: A Compendium of Best Practices and Case Studies*, which looks at these best practices worldwide. The project is supported by the GWRC partners as represented by the four Continental Coordinators in Australasia (Australia and Singapore), Europe, South Africa and North America. Each continental group created a report of best examples submitted by utilities in their region.

The report by the UK Water Industry Research Ltd. (UKWIR, 2010) on energy efficiency in the British water and wastewater sector concluded that overall energy efficiency gains of between 5 and 15% may be achieved, with up to 25% energy efficiency improvement in wastewater treatment processes (mainly activated sludge processes).The report further indicates that renewable energy, mainly in the form of combined heat and power (CHP) from sludge gas, could contribute significantly to the net energy demand of the water industry. A similar report was compiled by the Water Environment Research Foundation (WERF, 2010) in the USA, and provides best practices for the energy efficient operation of wastewater industry assets in North America.

The Water Research Commission of South Africa (WRC), as a member of the GWRC, has funded the current project to develop a Compendium for the South African water industry. The scope of work covered the principal activities of water and wastewater businesses and focused on the identification of current best practice, tools and technologies. The study evaluated both incremental improvements in energy efficiency through optimisation of existing assets and operations, and substantial improvements in energy efficiency from the adoption of new technologies. It also highlighted new processes, plant types and systems, which realise more substantial energy gains. Water and wastewater treatment plant surveys were conducted to document case studies and examples of best practice.

The aims of the project were to:

1) Perform a detailed examination of current best practice and technologies, to identify promising developments and future opportunities to help deliver incremental improvements in energy efficiency through optimisation of existing assets and operations.

2) Perform a detailed examination of current best practice and technologies, to identify promising developments and future opportunities to help deliver more substantial improvements in energy efficiency from the adoption of novel (but proven at full scale) technologies.

3) Conduct water and wastewater treatment plant surveys to document case studies and examples of best practices.

4) Develop a compendium of best practice in energy efficiency technologies and approaches in the water and wastewater sector.

A desk study and literature review was carried out to focus attention on the key areas of the water industry with most potential for energy efficiency improvements. The desk study and review covered national as well as international literature and case studies.

A matrix was developed showing the areas where potential savings are expected, together with the identification of case studies that were studied (which appear in the matrix), as received from the South African water utilities. By clicking on the subject area in the matrix, a fact sheet on this subject opens in a new window.

A Priority Short List was prepared from the desk study to highlight the parts of the Water Cycle Matrix which has most potential for making energy savings from incremental and more significant efficiency improvements.

A Compendium Framework was prepared to form the basis of the Compendium document. It was developed to present the case studies against the science and engineering principles of the different subject areas (as are contained in the matrix).

Case study guidelines were prepared to explain the objectives of the case studies and to ensure consistent quality of data from the sources (WSAs, WSPs and water companies). It presents a table of data required for each study, a set of energy usage matrices and some explanations for the priority areas from which case studies

will be expected. Sample Fact Sheets were also drawn up, to be used for collection of information from various water service providers.

From the list of case studies that were identified, case study information was obtained for population of the risk matrices. The fact sheets were completed in detail for all of the case study findings, and include information on:

- incremental improvements (detailed matrices of water, waste water and sludge areas showing minor changes to existing processes and plant);
- substantial improvements (detailed matrices of water, waste water and sludge areas showing new processes realizing more substantial gains but requiring significant investment).

The case studies (which include the fact sheets) are provided in electronic format on CD as appendices to the Compendium.

The following recommendations are made from the energy efficiency case studies and best practices reported on in this compendium:

1) The guidelines and best practices should be used as a basis for development of energy efficiency and energy conservation targets for the South African water sector. These targets can then be implemented, encouraged and regulated through the Department of Water Affairs' Blue Drop and Green Drop programs.

2) Municipalities should already start using the guidelines for energy conservation and energy generation in their strategic planning processes, and include specific targets for energy efficiency in their operations in the Water Services Development Plans (WSDPs). Energy audits should be undertaken on a yearly basis.

3) Energy efficiency should form a major criterion when planning new or upgrading existing water supply and sanitation projects, and funding programs should use specific targets in the decision-making process.

4) Wastewater treatment facilities should be encouraged to implement biogas energy production projects, and incentives should be provided for this purpose (e.g. assistance with feasibility studies and technical support).

5) Similarly, water supply and distribution projects should investigate the feasibility of mini-hydropower generation in water distribution systems.

6) As water demand management programs also result in energy savings, energy efficiency should be included in water services providers' water demand management and water conservation programs.

7) Loose liaison should be established and maintained with energy suppliers (Eskom), and water services providers and authorities should be aware of and pursue the offerings in the rebate program.

8) The concept of "Negawatts", i.e. water supply and sanitation processes that use no energy, should be actively encouraged. Examples of these systems are on-site sanitation, slow sand filtration and rainwater harvesting (use of storage tanks).

9) "Toolboxes" should be developed to provide water and wastewater treatment plant supervisors and process controllers with technical solutions and support for improving energy efficiency in their facilities.

10) Investigate the feasibility of using alternative renewable energy technologies with relation to initial capital costs, site conditions, specific climate conditions and return-on-investment. Financial incentives should be provided for such investigations and projects.

11) Development of new or alternative wastewater treatment processes and systems (both centralized and decentralized) should aim towards low-energy processes, especially regarding the high energy requirements for aeration in biological systems.

Acknowledgements

The research in this report emanated from a project funded by the Water Research Commission project entitled: "Energy Efficiency in the South African Water Industry: A Compendium of Best Practices and Case Studies".

The Reference Group responsible for this project consisted of the following persons:

Dr J Burgess	Water Research Commission (Research Manager)
Dr V Naidoo	Water Research Commission
Mr S Deacon	Johannesburg Water
Mr M Rabe	Re-Solve Consulting
Mr G Gericke	Eskom
Mr D Kawesha	Sasol
Mr D Nozaic	DJ Nozaic cc
Mr P de Souza	Emanti Water Management
Mr G Mackintosh	Emanti Water Management
Mr K Sampson	City of Cape Town
Prof C Buckley	University of KwaZulu-Natal

The financing of the project by the Water Research Commission and the contribution of the members of the Reference Group are acknowledged gratefully.

The project was only possible with the cooperation of a number of individuals and institutions. The authors therefore wish to record their sincere thanks to the following:

Johannesburg Water

eThekwini Municipality (Durban)

Mr Wayne Fortuin, Eskom

Mr Dave Nozaic

Veolia Water

University of KwaZulu-Natal

Umgeni Water

University of Pretoria

ERWAT

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Glossary of Terms

Billing is the process of producing and delivering a bill (an account or invoice) for payment by a customer, calculated from the tariff schedule or as per agreement between the parties and, for the majority of customers, the consumption measured and recorded by the metering system.

Bulk supply is a single point of supply to an intermediate distributor or reseller for resale to other customers.

Capital cost is the expenditure on plant, equipment and other resources in order to provide capacity. A connection charge will be payable as an upfront payment in addition to the tariff for new connections or additional capacity.

Dual-phase supply is a supply at a declared phase-to-neutral voltage of 230 V where the phases are vectorially 180 degrees apart and cannot be paralleled.

Electrification and rural subsidy is a charge transparently indicating the contribution towards socio-economic subsidies.

Energy charge is a charge for each unit of energy consumed, typically charged for a c/kWh.

Energy demand charge is a charge per premise that recovers peak energy costs, and is seasonally differentiated and based on the chargeable demand.

Environmental levy is a governmental levy to non-renewable generators based on the energy they produce.

Local authority supplies are supplies to municipal bulk points.

Loss factors recover technical energy losses on the transmission and distribution systems.

Maximum demand is the highest averaged measured in kVA or kW during any integrating period within a designated billing period.

Non-local authority supplies are supplies to Eskom direct customers excluding municipal supplies.

Power factor is the ratio of kW to kVA measured over the same integrating period.

Abbreviations and Acronyms

A	ampere
AC	alternating current
AD	anaerobic digestion
ASP	activated sludge plant
BNR	biological nutrient removal
BOD	biological oxygen demand
BOOT	build, own, operate and transfer
c	cents
c/kWh	cents per kWh
CEF	Central Energy Fund
CHP	combined heat and power
COD	chemical oxygen demand
CoJ	City of Johannesburg
CPI	consumer price index
DAF	dissolved air flotation
DC	direct current
DME	Department of Minerals and Energy
DO	dissolved oxygen
DOE	Department of Energy
DSM	demand side management
DTI	Department of Trade and Industry
DWA	Department of Water Affairs
EPP	Electricity Pricing Policy
FP	focused pulsed
GAC	granular activated carbon
GWh	gigawatt-hour
GWRX	Global Water Research Coalition
KSEF	KwaZulu-Natal Sustainable Energy Forum
kV	kilovolt
kVA	kilovolt-ampere
kW	kilowatt
kWh	kilowatt-hour
MF	microfiltration
MFC	microbial fuel cell
MFMA	Municipal Finance Management Act
MGD	million gallons per day
MWh	megawatt-hour
NERSA	National Energy Regulator of South Africa
NEWRI	Nanyang Environment and Water Research Institute
NMD	notified maximum demand
NREL	National Renewable Energy Laboratory
O&M	operation and maintenance
OSEC	overall specific energy consumption
PAC	powder activated carbon
PEF	pulsed electrical field
PF	power factor
PRV	pressure reducing valve
RAS	return activated sludge
RBC	rotating biological contactor

RO	reverse osmosis
SADC	Southern African Development Community
SAEE	South African Association for Energy Efficiency
SANEDI	South African National Energy Research Institute
SBR	sequencing batch reactor
UASB	upflow anaerobic sludge blanket
UKWIR	UK Water Industry Research Ltd
UKZN	University of KwaZulu-Natal
UPS	uninterruptible power supply
USD	United States dollars
UV	ultra-violet
V	volt
VFD	variable frequency drive
VSD	variable speed drive
W	watt
WERF	Water Environment Research Foundation
WFE	Working for Energy
WRC	Water Research Commission
WSA	Water Supply Authority
WSP	Water Services Provider
WWTP	wastewater treatment plant

1. INTRODUCTION

Energy will in future remain a high cost item for municipalities and utilities which operate and maintain water and wastewater processes. Energy consumption will continue to increase as more people are provided with water and sanitation and new technologies are implemented to meet stricter effluent and potable water quality requirements.

To position the water sector globally with regard to energy consumption, the Global Water Research Coalition (GWRC) has embarked on a project entitled Energy Efficiency in the Water Industry: A Compendium of Best Practices and Case Studies, which documents these best practices worldwide. The project is supported by the GWRC partners as represented by the four Continental Coordinators in Australasia (Australia and Singapore), Europe, South Africa and the USA. Each continental group has produced a report of best examples submitted by utilities in their region. When all four continental reports are available, they will be compiled into the global compendium.

The report by the UK Water Industry Research Ltd. (UKWIR, 2010) on energy efficiency in the UK water and wastewater sector concluded that overall energy efficiency gains of between 5 and 15% may be achieved, with up to 25% energy efficiency improvement in wastewater treatment processes (mainly activated sludge processes).The report further indicates that renewable energy, mainly in the form of combined heat and power (CHP) from sludge gas, could contribute significantly to the net energy demand of the water industry. A similar report was compiled by the Water Environment Research Foundation (WERF, 2010) in the USA, and provides best practices for the energy efficient operation of wastewater industry assets in North America.

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The aim of the project was to create a compendium of best practice in energy efficiency technologies and approaches in the water and wastewater sector. The aim was broken down into the following objectives:

a) Perform a detailed examination of current best practice and technologies, to identify promising developments and future opportunities to help deliver incremental improvements in energy efficiency through optimisation of existing assets and operations.

b) Perform a detailed examination of current best practice and technologies, to identify promising developments and future opportunities to help deliver more substantial improvements in energy efficiency from the adoption of novel (but proven at full scale) technologies.

c) Conduct water and wastewater treatment plant surveys to document case studies and examples of best practices.

The development of the compendium comprised the following six steps:

1. Desk study and literature survey

A desk study and literature survey was carried out to focus attention on the key areas of the water industry with most potential for energy efficiency improvements. The desk study and survey covered national as well as international literature and case studies.

2. Development of a Water Cycle Matrix

A matrix was developed showing the areas where potential savings are expected, together with the identification of case studies that were studied (which appear in the matrix), as received from the South African water utilities (Water Supply Authorities (WSAs) and Water Services Provider (WSPs). By clicking on the subject area in the matrix, a fact sheet on this subject opens in a new window.

3. Drawing up of a priority short list of opportunities

A Priority Short List was prepared from the desk study to highlight the parts of the Water Cycle Matrix which has most potential for making energy savings from incremental and more significant efficiency improvements.

4. Development of the Compendium Framework

A Compendium Framework was prepared to form the basis of the Compendium document. It was developed to present the case studies against the science and engineering principles of the different subject areas (as are contained in the matrix).

5. Development of a standardized case study example and sample fact sheet

Case study guidelines were prepared to explain the objectives of the case studies and to ensure consistent quality of data from the sources (WSAs, WSPs, and water companies). It presents a table of data required for each study, a set of energy usage matrices and some explanations for the priority areas from which case studies were expected. Sample Fact Sheets were also drawn up, to be used for collection of information from various water service providers.

6. Documentation of case studies

From the list of case studies that were identified, case study information was obtained for population of the risk matrices. The fact sheets were completed in detail for all of the case study findings, and include information on:

a) incremental improvements (detailed matrices of water, waste water and sludge areas showing minor changes to existing processes and plant).

b) substantial improvements (detailed matrices of water, waste water and sludge areas showing new processes realizing more substantial gains but requiring significant investment).

Each case study is identified by a code. By clicking on the code in the matrix, the full case study can be opened in a new window.

The case studies and fact sheets are attached as appendices in electronic form on the CD in the back of the document.

2. OVERVIEW OF THE GLOBAL ENERGY EFFICIENCY COMPENDIUM

The overall water supply and sanitation cycle can be divided into the main components and sub- components shown in Table 2.1.

Table 2.1: Components of the water cycle

CLEAN WATER	RAW WATER ABSTRACTION	Pumping
	TREATMENT	Pre-treatment
		Chemical dosing and mixing
		Clarification (sedimentation; dissolved-air flotation (DAF))
		Filtration
		Disinfection (chlorine, ultraviolet radiation (UV))
		Membrane processes (clarification; desalination)
		Membrane processes (clarification; desalination)
		Advanced oxidation processes (ozone; UV/H_2O_2)
		Other advanced treatment processes (granular activated carbon (GAC); powder activated carbon (PAC)
		Waterworks sludge (residuals) disposal
	DISTRIBUTION	Pumping
WASTE-WATER (SEWAGE)	SEWERAGE	Pumping
		Odour control
	TREATMENT	Screening
		Grit removal
		Sedimentation (primary and secondary)
		Aeration
		Sludge recycle (RAS)
		Disinfection
		Tertiary treatment
		Advanced treatment processes
	FINAL EFFLUENT DISPOSAL	Pumping
	SLUDGE HANDLING AND DISPOSAL	Sludge thickening
		Sludge dewatering
		Digestion / co-digestion
		Sludge drying
		Disposal to land

2.1. Energy sources for water supply technologies

2.1.1. International examples

2.1.1.1. Urban Water Cycle

Power supply options for metropoles are well-documented. The supply options in South Africa are presented in Section 2.4.

2.1.1.2. Rural Water Supply and Sanitation

There are several power source options for rural water supply applications. The options for moving water include diesel and petrol-driven pumps, grid-connected electric pumps, wind pumps, solar pumps, biofuel pumps, animal-drawn pumps, and hand pumps. Hand pumps require human labour to pump the water and in most cases are difficult to pump at higher elevations, especially for women and children, who are the main users. Fossil- fuel-operated pumps, grid-connected electric pumps, wind pumps, and solar pumps do not require animal or human labour, but they are often prohibitively expensive for low-income communities (NREL, 2003).

Diesel and petrol engines are internal combustion engines with instant start-up capabilities, and a high power-weight ratio. These capabilities make them attractive to power small isolated machines such as water pumps.

The optimum efficiency of most engines is achieved at around 70-80% of the rated power. Optimum efficiency is the point at which fuel consumption is the smallest. Therefore, derating engines around 70-80% is recommended (NREL, 2003).

The cost of internal combustion engines depends mainly on the size and speed because a higher power- weight ratio is normally achieved by running an engine at high speed. When the engine runs at a higher speed, more air and fuel are burned, and more energy will be produced. Therefore, for the same rated power, smaller-sized, higher speed engines are less expensive than the heavy, lower-speed engines. However, higher-speed engines wear faster, so there should be a trade-off between the heavy, lower-speed, expensive engines and the lightweight, higher-speed engines (NREL, 2003).

Transmitting the power from the engine to a pump depends on the type of engine and pump design. Power transmission can be directly coupled to the pump, gearbox transmission, or belt drives.

Diesel engines need to be heavier and more robust than petrol engines, to allow for the pressure needed to cause compression ignition. The high compression ratio allows a diesel engine to draw more air per stroke in relation to the combustion space, while the fuel injection allows the air-fuel mixture to run more smoothly for ignition unlike spark ignition engines. They are generally more efficient (between 30-40%) than spark ignition engines (25-30%). However, small diesel engines tend be less efficient (as low as 15%). Several factors contribute to this lower efficiency, mainly the size, type, design quality, and age of the engine. The efficiency can be as low as 10% and as high as 35% depending on these factors (NREL, 2003).

Petrol engines are lighter and more compact than diesel engines. They are generally less expensive than diesel engines. Such engines cannot be designed for a high compression ratio like a diesel engine because the fuel-air mixture would ignite prematurely and cause knocking. The caloric values of such fuels are also quite low compared to diesel fuel.

Petrol engines are usually designed for small applications (up to the 3 kW range) and are the best option for small, lightweight, and portable applications. They are simple to maintain and affordable for irrigation or for lighting a few households. These types of engines are ideal for low-head and high-discharge (mainly floating) pumps. However, they have a shorter operational life compared to diesels.

Grid-connected pumps use electricity from the national grid to run the electric motor. In developing countries, the grid power source is mainly from hydropower, coal, and diesel generator plants. Localized grids, such as a mini-hydropower grid or diesel generators, are very popular in developing countries to provide power for isolated and remote towns, where electric motors are used to pump water for the town’s water supply (NREL, 2003).

Grid-connected pumps are simple to install with low service requirements (especially for submersible pumps) and can be controlled electrically. Aside from the grid connection, the investment costs are relatively low. The biggest obstacle in many developing countries is the lack of infrastructure – the cost of extending a grid is very high.

The investment costs of such systems depend on the cost of the grid extension and on the size of the transformer used. Usually power from a high-voltage, grid-power transmission line is not used for small pumping systems due to the high cost of the step-down transformer. The operating cost depends mainly on the electricity tariff. High electricity tariffs contribute to high pumping costs.

Wind pumps operate by mechanical or electrical means, using a wind energy source. The American windmill, made of steel, with a multi-bladed, fan-like rotor, became the most popular water-pumping technology. Today more than 1 million windmills are estimated to be in use, mostly in the United States, Argentina, and Australia (they are also commonly found in South Africa). Traditional windmills are, however, much less efficient than modern wind turbines, because the blades are not true airfoils, and the overall operating efficiency is only about 4-8% (NREL, 2003).

Commercialized mechanical wind pumps are good for low wind speeds due to their high solidity rotor, which limits the piston pump speed to no more than 40 or 50 strokes per minute. The overall conversion efficiency of mechanical pumps using average wind speed is 7-27% (NREL, 2003). The best water resource is normally located on lower ground, which is a poor location for winds, thus there needs to be a compromise between best wind location and best water source. For this reason, mechanical wind pumps are limited to flat plain areas.

Attempts have been made to locate windmills further from their boreholes by using remote power transmission mechanisms such as electrical, pneumatic, hydraulic, and mechanical transmissions. Using an induction generator to produce electricity, coupled with an induction motor and a pump, is the best alternative technology among these options.

Electrical wind turbines are designed to produce alternating current (AC) or direct current (DC) electric output and can be used to pump water by directly connecting to AC or DC motors. Electrical wind turbines are designed for low solidity rotors and are best suited for centrifugal pumps. Unlike windmills, this technology also solves the problem of locating wind turbines over water wells. Because wind is best at the crest of a hill, and water is found on lower ground, wind turbines can be located where the winds are strongest at the optimum-cost cable length from the well.

Commercial electrical wind turbines are available from as low as 50 watts to a few megawatts (NREL, 2003). Generally, electrical wind turbines become competitive with windmills above an average wind speed of 5-6 m/s for water pumping applications. Therefore, the pumping location's wind regime determines whether mechanical or electrical wind pumps will be used. Electrical wind turbines have several potential advantages over mechanical wind turbines. They are versatile: Surplus electric power can be stored in batteries and used for lighting or other purposes. The wind turbine does not need to be located directly over the borehole or even near the site where the power is needed. It can be located at the best wind regime location and the power produced can be wired to the site.

As the name implies, solar pumps are powered by solar radiation energy impinging on the surface of semiconductor materials by electromagnetic means. Currently available standard PV modules range in output from <2 watts (W) to about 110 W (NREL, 2003). The PV module constitutes the basic building block from which any size PV array can be configured to suit the application. The PV array converts the solar radiation into DC power, and this power is then used directly or indirectly (converted into AC using an inverter) to power the electrical motor to drive the pump.

Unlike other alternative pumping options, solar pumps generally incur a high investment cost; however, this cost can be offset by a long service life since operation and maintenance (O&M) costs are minimal over its economic life. Solar pumps are a very reliable technology and can be matched quite closely to the amount of water needed.

Biogas-substituted diesel engines are a proven technology that can save 80% of diesel fuel needs in a diesel engine. This fuel is a mixture of methane, carbon dioxide, and trace gases that can be produced using an anaerobic digester. The biogas produced can be used for lighting, cooking, and heating, as well as refrigeration. Using biogas saves a considerable amount of money and also provides an opportunity for local employment.

2.1.1.3. Renewable Energy (UKWIR, 2010)

Hydro-turbine generators are the conventional way of recovering energy from a high pressure system and there are examples of clean and wastewater applications. They are hydraulically direct replacements for pressure reducing valves (PRVs) although they are usually installed in parallel with such valves to allow flow transfer in the event of generator failure.

One case study shows a Francis turbine used for in-line flow between a high level reservoir and the inlet to a water treatment works and the other shows a wastewater application using an Archimedean screw pump.

It is likely that this technology will become more common as electricity prices rise and utilities investigate pressure reducing valves (PRVs) and other head loss devices as potential sources of income rather than an operating and maintenance cost items. However, direct comparison with energy saving exercises with pumps and similar plant is unfavourable as generators also need additional electrical switchgear and metering to input the power to the local grid.

Table 2.2 shows ranges of energy savings possible from renewable energy (UKWIR, 2010).

2.1.1.4. Energy efficiency in wastewater treatment and reuse

Lazerova *et al.* (2012) also reports that significant energy savings may be accomplished in the wastewater treatment and sludge management sectors. Potential savings are shown in Figure 2.1.

Approaches to sludge gas and CHP energy vary across the UK. Some utilities restrict CHP to large works, some concentrate their sludge at strategic treatment centres and some employ a more general approach.

Table 2.2: Energy Saving from Renewable Energy (UKWIR, 2010)

Means of saving	Mini-Hydro Turbine	Biogas / Combined Heat and Power (CHP)
Generation (MWh/year)	~ 2400	525-2000

The type of process and plant varies too, with pump types, mixers and gas blowers being subject to corporate preferences. Most generators are powered by reciprocating engines but gas turbines are apparently less susceptible to the effects of siloxanes and a unit of about 65 kW is the subject of one case study (UKWIR, 2010).

ENERGY SAVINGS 10-20% (fine bubble controlled aeration, energy efficient motors and pumps)	**RENEWABLE ENERGIES** 5-10% (wind power, photovoltaic, solar thermal power, geothermal power)
ENERGIES FROM SEWAGE FLOWS 2-10% (hydro-turbines, heat pumps, in-sewer heat exchangers)	**SLUDGES** 40-100% (anaerobic sludge digestion, pre-treatment to increase digestibility)

Figure 2.1: Energy savings potential in the wastewater treatment sector (Lazarova *et al.*, 2012)

2.1.2. South Africa

2.1.2.1. Renewable energy (Van Vuuren, 2010)

Renewable energies were defined by the Department of Minerals and Energy (DME) in the White Paper on the Renewable Energy Policy (2003) as “naturally occurring non-depletable sources of energy that are used to produce electricity, gaseous and liquid fuels, heat or a combination of these energy types.” They offer an attractive alternative to conventional fossil fuel power generation because they produce little or no green-house gasses (GHGs) and rely on inexhaustible natural energy.

Internationally, renewable energy is recognized as being a major contributor in the protection of the environment and climate and provides “a wide range of environmental, economic and social benefits that will contribute towards long term global sustainability” (NERSA, 2008). The electricity crisis being experienced in South Africa highlights the role that renewable energy can play by augmenting traditional electricity generation. The emphasis on renewable energy obtained momentum when DME (2003) stated that the Government has set a target of 10 000 GWh per annum to be produced from renewable resources by 2013.

The different types of renewable energy are briefly described below:

Solar energy: Photovoltaic systems are used to capture the energy in sunlight and convert it directly into electricity, or alternatively the sunlight is focused with mirrors to produce a high temperature and drive a steam turbine producing electricity.

Wind energy: Modern turbines are placed in 'wind farms' and the energy of the wind are used to drive the windmills and generate electricity.

Biomass energy: Biomass is plant material and includes agricultural residues, wood waste, paper waste and municipal solid waste from landfill sites. This can be used to generate electricity.

Hydropower: The flow of water under gravity through a turbine generates electricity.

Wave and tidal power: Technologies used to harness these energies and generate electricity are being developed for commercialization (in coastal locations).

Geothermal activity: This comes from the heat in the earth's core, for example natural geysers and can produce steam to drive turbines and generate electricity.

In 2003, the DME stated that the Government has set a target of 10 000 GWh per annum to be produced from renewable resources by 2013, which is approximately 4% of the forecast for electricity demand in 2013 (41 539 MW) (Van Vuuren, 2010). This is to be achieved "primarily through the development of wind, biomass, solar and small scales hydro" (NERSA, 2008). There is therefore a need for the implementation of renewable energy projects in South Africa and their integration into the mainstream energy economy.

Due to the largely non-consumptive nature of renewable energy technologies, a further benefit resulting from their use is the saving of resources. "Conventional coal fired plants are a major consumer of water during their requisite cooling processes. It is estimated that the achievement of the 10 000 GWh target will result in savings of approximately 16.5 million kL of water, compared with wet cooled conventional power stations" (NERSA, 2008).

2.2. Water-related energy research in South Africa

Van Vuuren (2010) undertook a scoping study for the WRC to investigate the potential power generation by retrofitting a hydropower generation facility at existing dams and utilising the untapped energy on the supply side of storage reservoirs in water distribution systems where the excess heads are normally dissipated across control valves.

A conceptual retrofitting model was developed to determine the viability of hydropower development considering, amongst other, environmental impact, cost and sustainability. This model was tested on the hydropower development at Sol Plaatjes and the model results reflected a good comparison with the practical results obtained during the investigation.

The potential hydropower generation at the inlets to storage reservoirs was evaluated with a pilot installation which was erected at the Queenswood Reservoir (Tshwane Metropolitan District). Although the hydropower generation pilot unit installed here was not optimized, the initial results reflected the benefit and expected return from such an investment, even if the system is only operated at a duty of 50%.

The potential of hydropower generation from existing dams, pressurized conduits and other water infrastructure is under-utilized in South Africa and the following actions need to be considered:

a) Create a register of water infrastructure that has a potential for power generation;
b) Establish the hydropower potential of these water infrastructure assets;
c) Characterise the implementation potential for hydropower generation;
d) Establish the optimum generating potential at storage reservoirs by assessing the parameters of storage volume, demand patterns and operating cycles and operating life of the control valves;
e) Compile a cost benefit model for the development of these hydro power generation schemes (quantifying all the cost and benefits);
f) Generate mechanisms to develop it; and
g) Provide incentives to invest in these schemes.

Burton *et al.* (2009) recognised opportunities exist to improve the current wastewater treatment processes by applying new solutions and technologies that can also reduce energy inputs or generate energy, and undertook a study for the WRC to explore the various waste streams and the appropriate technologies that could be used to generate energy.

Burton *et al.* (2009) surveyed the quality and quantity of wastewaters in South Africa and identified the top three sectors having the greatest potential energy recovery as the formal and informal animal husbandry sector (cows, pigs and chickens), fruit and beverage industries (distillery, brewery, winery, fruit juicing and canning) and domestic blackwater (sewage). An estimated 10 000 MWh can be recovered from the wastewaters in the whole of South Africa, representing 7% of the current Eskom electrical power supply.

Burton *et al*. (2009) came to the following conclusions:

- Numerous technologies are being explored internationally for obtaining energy from wastewaters.
- In South Africa, there are very few documented reports of technologies being used for effective energy recovery from wastewater.
- The review of established and emerging technologies provided information indicating that anaerobic digestion (AD) used for biogas production is the most commonly recognised technology. Anaerobic digestion is a proven technology and is currently being operated at various scales. In developed countries, this has been implemented at large scale, whereas in developing countries it is generally operated at small scale for domestic applications.
- Utilisation of waste heat through heat integration is relatively common internationally, in some cases in very large scale plants.
- Combustion and gasification are restricted to application with concentrated waste streams (containing <40% water) due to the cost of removing water prior to combustion.
- Plant biomass production for combustion and algal biomass for biodiesel production is suited to dilute waste streams. Carbon dioxide sequestration and wastewater oxygenation by algal photosynthesis are obvious additional benefits. There are no large scale algal biodiesel production processes operating at present in spite of published claims that the technology is technically feasible, and economically attractive in the case of ponding.
- Bioethanol production by fermentation is suited to concentrated high carbohydrate/ sugar wastewaters. It suffers from the disadvantage that considerable energy is expended when using traditional distillation methods. Dunder is a by-product.
- Microbial fuel cells (MFC) can operate with dilute waste streams and can produce electricity directly. These may ultimately be suitable for application in remote/rural sites with no infrastructure, but the technology is still in early development.

Interesting information that came to light during the execution of the project was the compilation of responses of attendees at a workshop held to discuss the barriers and needs for energy production from wastewater. A number of questions were posed, and the responses to those questions can be found in the report by Burton *et al*. (2009).

2.3. Case studies of best practices in energy efficiency

The following sections summarise the case studies compiled in North America, Europe, and Australasia.

2.3.1. North America

(http://www.werf.org/a/k/Search/ResearchProfile.aspx?ReportID=OWSO4R07e)

Energy Efficiency in Wastewater Treatment in North America: A Compendium of Best Practices and Case Studies of Novel Approaches (WERF, 2010)

A report was compiled by the Water Environment Research Foundation (WERF, 2010) as part of the GWRC Global Project, and provides best practices for the energy efficient operation of wastewater industry assets in North America.

The WERF researchers summarized existing information on well-established energy optimization / energy recovery best practices, and documented a series of case studies of novel (yet full-scale proven) technologies/practices in wastewater treatment, primarily in North America.

The report documents the case studies of energy optimization / energy recovery technologies and/or practices considered being novel and full-scale proven in at least one installation. Information from these case studies was obtained from a variety of means, including engineering reports, journal articles, interviews and facility visits.

For each of the case studies, as much as possible information that was available was presented under the following headings:

- Process description
- Potential benefits
- Concerns
- Range of potential savings
- Application potential

By way of example for this progress report, the first four case studies are summarised below. The other eight case studies are listed in Table 2.3.

Table 2.3: Examples of case studies from US Energy Compendium (WERF, 2010)

Case Study	Process description	Potential benefits	Concerns	Range of potential saving	Application potential
Advanced anaerobic digestion and CHP – Columbus biosolids flow through thermophilic treatment technology	• Advanced anaerobic digestion system • CHP system • FOG receiving and processing system • Continuous- feed, stirred tank reactor, 30 minutes detention, thermophilic temperatures	• Shorten digestion batch times • CHP system produces thermal and electrical energy • First in USA to use CHP thermal energy • FOG system increases gas production by 50% • Will result in net carbon footprint reduction of 9,600 metric tons	• First of its kind, limited operational experience • Sensitive to digester gas contaminants in particular hydrogen sulphide and siloxanes • Requires continuous cooling.	• Construction cost: US$3 million less than conventional • Reduce retention time from 24 h to 30 minutes • Approx. 40% of electrical demand is offset by power generated by CHP system • Electric energy savings USD 0.075/kWh • Payback less than 10 years	• First of its kind • Hundreds of successfully operating CHP systems around the world • Addition of FOG system has become very popular
Codigestion of dairy manure with WWTW sludge	• Capturing of methane gas from manure • More than 70% of US WWTWs use anaerobic digestion • Require additional facilities for pretreatment, gas-handling and treatment	• Improved digestibility and biogas production • Source of revenue from tipping fees • It is a renewable energy source • Reduction in GHG emissions • Reduction in NH_4 emission	• Increased NO_x and SO_x emissions • Unreliable delivery of manure • Additional facilities required • Inappropriate dilution and loading may result in digester failure • Transporting and piling may result in odour problems	• Project cost is highly case specific • Cost savings also highly project- specific	• Successfully applied in Germany, Austria, Denmark and other European countries • About 75,000 dairy farms in USA (2006)
Sludge reduction technologies – Focused Electrical Pulse	• Focused pulsed (FP) technology is the full-scale application of pulsed electric field (PEF) technology • Make organic material in WAS more bio-available through the mechanism of electropolation	• Improved digestibility and biogas production • Reduced biosolids handling and disposal fees • Reduced dewatering polymer requirements • Increased additional energy produced • Reduced odour and pathogens • Reduced cost and safety concerns	• Requires new or upgraded facilities for gas cleaning, handling and utilization • Digester recycle streams contain higher concentrations of nutrients that may require further treatment • Reduced solids mass may temporarily trigger minimum use clauses	• Economic value of increased biogas production outweighs the energy and other operating requirements of FP pretreatment • FP O&M costs typically range between USD20 and USD30 per dry ton treated	• Attractive for 2-5 MGD and above • Improves the digestibility of agricultural and high-strength organic waste • May render the biomass more amenable to digestion

2.3.2. Europe

Energy Efficiency in the Water Industry: A Compendium of Best Practices and Case Studies (UKWIR, 2010)

The report by the UK Water Industry Research Ltd. (UKWIR, 2010) for the GWRC on energy efficiency in the UK water and wastewater sector concluded that overall energy efficiency gains of between 5 and 15% may be achieved, with up to 25% energy efficiency improvement in wastewater treatment processes (mainly activated sludge processes).The report further indicates that renewable energy, mainly in the form of combined heat and power (CHP) from sludge gas, could contribute significantly to the net energy demand of the water industry.

2.3.2.1. Methodology

The methodology for the project was discussed and developed at meetings with UKWIR in London and GWRC members in Dubendorf, Zurich, and Amsterdam. A Project Resume was prepared for publicity purposes, and a web portal established for global communications.

A Priority Short List report was prepared from an initial desk study to highlight the parts of the water cycle matrix which had most potential for making energy savings from incremental and more significant efficiency improvements.

2.3.2.2. Results

The results are the core of the report and their presentation is structured on the sequence of the water cycle starting with abstraction of clean water, its treatment and distribution, and followed by sewage collection, treatment and disposal.

At the top of the matrix are issues which affect the complete cycle such as water conservation, leakage reduction and sewage infiltration. Actions in these areas affect the whole of the matrix.

Below the main processes but key to the industry are sludge treatment, building services associated directly with the industry and opportunities for reducing demand through generating renewable energy. We have not included wind or solar energy examples as these will usually be contracted out of the water industry, but CHP and hydro-turbines are covered.

The results are presented in matrix format order as this has proven to be a convenient way to illustrate the complete picture.

Each subject or process area is introduced by a factsheet. This explains the technology at various levels and establishes a balanced appraisal of the engineering issues involved.

The fact sheets are compiled under the following headings:

- Description of Process
- Potential Interventions
- Range of Potential Savings

An example, for Activated Sludge Plant aeration, is shown on page 11.

2.3.2.3. Case Studies

A summary of case studies reported on in the UK Compendium is shown in Table 2.4 (page 13).

Wastewater – Activated Sludge Plant (ASP) Aeration

Aeration typically accounts for 50% of a sewage treatment works energy demand

Description of Process

Aeration is required for secondary treatment to oxidise pollutants, in particular organic matter, measured as biological oxygen demand (BOD), and ammonia. Aeration is supplied by blowers through a series of pipes and diffusers into the mixed liquor in the ASP tank.

Aeration efficiency is influenced by the following factors:-

- Blower inlet air conditions,
- Blower condition, wear, seal, bearing and lubrication system maintenance,
- Control system accuracy, response time, instrument cleaning and calibration,
- Air distribution system sizing, pipes, control valves and flow measurement,
- Diffuser condition, type, internal cleanliness and size of bubbles,
- Depth of aeration tank, and diffuser floor coverage,
- Strength of mixed liquors, upstream treatment, homogeneity,
- Matching of different components in the system.

The control system should allow for varying sewage strengths and diurnal flow variations through its variation of and response to instrument settings. It is important for energy efficiency that the parameters and set points match the effluent consent.

Potential Interventions

- Check blower flow and head against metered electrical input.
- Check system pipework, valves and control set-points for best settings.
- Change control regime to Real Time Control using incoming flows and loads and the effluent consent by installation or upgrade of PLC controls.
- Install ammonia derived DO control (including ammonia and DO instruments).
- Install variable speed drives to surface aerators.

Table 2.4: Summary of Case Studies from the British Compendium (UKWIR, 2010)

Case study	Specific energy problem	Process / plant changes	Range of potential savings	Energy efficiency gains
Leakage Reduction	Reduction in leakage will have a direct (proportional) reduction in pumping and treatment energy usage.	None	Up to 38% from case studies.	Leakage reduced from 35 ML/d in 1992/93 to less than 24.5 ML/d in 2008/09. Consumption 0.91 kWh/m^3 supplied. 2.4% saving of total annual energy usage, and 25% saving based on energy usage in 1999.
Water Supply – Conservation	Conservation reduction will have a direct (proportional) reduction in pumping and treatment energy usage.	None	Up to 31% from case studies.	117 devices fitted in 2008/09, average water savings 0.05 m^3/day/household or 9.1 m^3/person/year Consumption 0.91 kWh/m^3 supplied.
Pump Efficiency Factsheet 1 – Duty Point Selection	High volume of water pumped on a daily basis. When two pumps wells operated together the interference caused the well level in both wells to drop by an additional 6 metres.	Control of pumps is by variable speed drive with normal operation close to maximum frequency. Operational change to reduce operational frequency on VSD by several Hz. Pumping rate reduced from 32 to 25 ML/d increasing pump operating times but reducing friction head on system.	Up to 11% from case studies	Average annual kWh usage reduced by approx. 115,000 kWh per year or 12% (0.020 kWh/m^3) Saving: 91K kWh/year and 0.012 kWh/m^3
Pump Efficiency Factsheet 2 – Duty Range Selection			Up to 3% from case studies	
Pump Efficiency Factsheet 3 – Changes of Duty			5 to 20% for single pumps from experience.	
Pump Efficiency Factsheet 4 – Variable Duty Selection	Energy efficiency was low when pumped with old, fixed speed, high lift pumps. Before VSD installation, the pump was not energy efficient with a throttled valve.	The control software of the pumps is re-programmed.	Up to 12% from case studies.	Approx. 20%; falling from 950 kWh/ML to 780 kWh/ML. Saving 0.17 kWh/m^3 Saving: 179K kWh/year 0.027 kWh/m^3
Wastewater – ASP RAS Pumping	Cost of pumping RAS	Fixed RAS flow reduced from 1330 m^3/d to 660 m^3/d	Up to 55% of RAS pumping energy	Saving 320 kWh/d
Wastewater – Activated Sludge Plant (ASP) Aeration	Focus on optimising process leading to less aeration	Installation of ammonium control which regulates DO input according to ammonium measured in last pocket of each lane	Up to 40% from case studies.	Approximately 480,000 kWh/y reduction, 30%. 0.063 kWh/m^3
Wastewater – ASP Nutrient Removal	Over treating in aeration process leading to little or no ammonia in effluent. NH_4 consent level 10 mg/l	Fit ammonium control system to reduce aeration when ammonium levels in the AS lanes is low	Up to 60% from case studies	Approximately 350 000 kWh/y reduction 0.291 kWh/m^3

Table 2.4: Summary of Case Studies from the British Compendium (UKWIR, 2010)

Case study	Specific energy problem	Process / plant changes	Range of potential savings	Energy efficiency gains
Water Treatment – Clarification DAF	Reduced the absorbed power on the DAF recycle pumps due to more energy efficient nozzles.	Refurbishment of plant and replaced all nozzles.	Up to 30% from case studies	30% energy reduction 20% increase in raw water throughput
DAF Case Study	Decrease energy use by bypassing an item of process treatment.	Implement bypass depending on raw water quality.		214 445 kWh per annum. 0.021 kWh/m^3 21.4%
Wastewater – Ultraviolet (UV) disinfection	A two channel UV layout did not need to operate all of the time but did not have the facility for upstream isolation. Estimated that 40% power saving available 50-75% of the time if flow could be controlled	New software to control UV operation with flow setpoints	Up to 40% from case studies	Approximately 134 000 kWh/y direct energy saving; 0.014 kWh/m^3
Sludge Treatment – Digestion		Fitting a macerator and increasing the pump bore has enabled digester feed to be run without blockages, enabling up to two extra tanker loads of sludge to be accepted each day.	Lack of biogas production due to interruption of sludge feed to digesters caused by blockages.	Approx. £32k/year extra energy generation benefit.
Building Services		Installation of new voltage optimisation device	Install voltage optimisation device with aim to reduce kWh	~ 100 000 kWh
Energy Recovery – Mini Hydro Turbines	Annual generation between 1000 MWh and 12 000 MWh	Installation of hydro-generator – Archimedean screw	N/A	0.018 kWh/m^3
Combined Heat and Power (CHP) Systems	CHP is capable of running a complete sewage treatment works, saving imported power and yielding ROCs or Carbon Credits.	Additional new 320 kW CHP engine to reinforce an existing CHP generation comprising 104 kW and 165 kW engines previously optimised	Energy efficiency – carbon reduction – reduces imported energy requirements	Approx. 2.0 GWh/year 0.101 kWh/m^3

2.3.3. Australasia (Australia and Singapore)

Water and energy in the Urban Water Recycle: Improving Energy Efficiency in Municipal Wastewater Treatment (NEWRI, 2010)

Nanyang Environment and Water Research Institute (NEWRI) entered into an agreement in 2009 with PUB of Singapore to generate a report on municipal wastewater treatment which determined current energy consumption patterns, potential for improvement, as part of the target of achieving 80% energy reduction in the urban water cycle by 2030.

The report that was published (NEWRI, 2010) presents the findings on the variations in unit process configurations and new unit processes which can be considered to achieve the above target.

The project included a review of literature and GWRC reports, site visits, contributions from invited international researchers and professionals, and feedback from workshops organized specifically for the projects. A survey document was developed en sent out, and an international discussion platform also set up in the form of an e-collaboration website to augment the workshops and e-mail communications.

The findings from the NEWRI/PUB/GWRC study are summarised in Table 2.5.

Table 2.5: Energy consumption at Wastewater Treatment Plants in other countries (NEWRI, 2010)

Region	Country/city/plant	Primary treatment processes	Secondary treatment processes	Energy recovery systems
North America	USA Canada	Screens and grit chambers, sedimentation	Activated sludge, aerated lagoons, oxidation ditches, RBC, TF, lagoon	Cogeneration, CHP, biogas utilization
Europe	Germany, Sweden, Austria	Screens and grit chambers, sedimentation	Activated sludge with nutrient removal (nitrification and denitrification)	Cogeneration, CHP, biogas utilization
	Austria (Strass)	Screens, grit chamber and sand trap	Two-stage sequencing batch reactor with nutrient removal	
South East Asia	Singapore	Screens and grit chambers, sedimentation	Activated sludge with nutrient removal (nitrification and denitrification)	Cogeneration, CHP, biogas utilization
	Vietnam	Screen and grit chambers, sedimentation	Activated sludge, SBR (with nutrient removal)	N/A
	Thailand	Screen and grit chambers, sedimentation	Aerated lagoon, oxidation ditches, stabilization ponds, activated sludge	N/A
	The Philippines	Screen, grit chamber, balancing	SBR	Cogeneration, CHP, biogas utilization
	Malaysia	Screen, grit chamber, grease chamber, sedimentation	Activated sludge, SBR (with nutrient removal), oxidation ditch, extended aeration	N/A

Table 2.5: Energy consumption at Wastewater Treatment Plants in other countries (NEWRI, 2010)

Region	Country/city/plant	Primary treatment processes	Secondary treatment processes	Energy recovery systems
Middle-East	Iran	Screens and grit chamber, sedimentation	Activated sludge	CHP, biogas digester, space heating, transport fuel
North-East Asia	Japan	Screens and grit chamber, sedimentation, equalization	Oxidation ditch, biofilm, trickling filter, conventional aerated sludge, step-feed bioreactor (floating media), SBR, aeration	Biogas utilization
	South Korea	Screens and grit chamber	Oxidation ditch, aerated lagoon, activated sludge, extended aeration, RBC	N/A
China	Beijing	Screens and grit chamber, sedimentation	Activated sludge, with nutrient removal	Cogeneration, CHP, biogas utilization
	Tanghstan	Screens and grit chamber, sedimentation	Activated sludge, coarse and fine bubble aeration	
Australia/New Zealand	Yatala, Sydney, Melbourne, Brisbane. Perth	Screens and grit chamber, sedimentation	UASB, aerobic moving-bed bioreactor, RO, MF infiltration	Cogeneration, CHP, biogas utilization
	Auckland	Screens and grit chamber, sedimentation	Biological filters, lagoons, primary treatment. New plants are activated sludge	
South America	Brazil	Screens and grit chamber, sedimentation	Aerated lagoon or activated sludge	N/A
Africa	South Africa	Screens and grit chamber	Activated sludge	Biogas utilization

Figure 2.2 provides the overall specific energy consumption (OSEC) values in plants in a number of countries, and shows differences in energy consumption arising from the differences in specifics at the various locations.

Table 2.6 shows energy consumption figures for different sections of wastewater treatment plants for each of the countries under consideration.

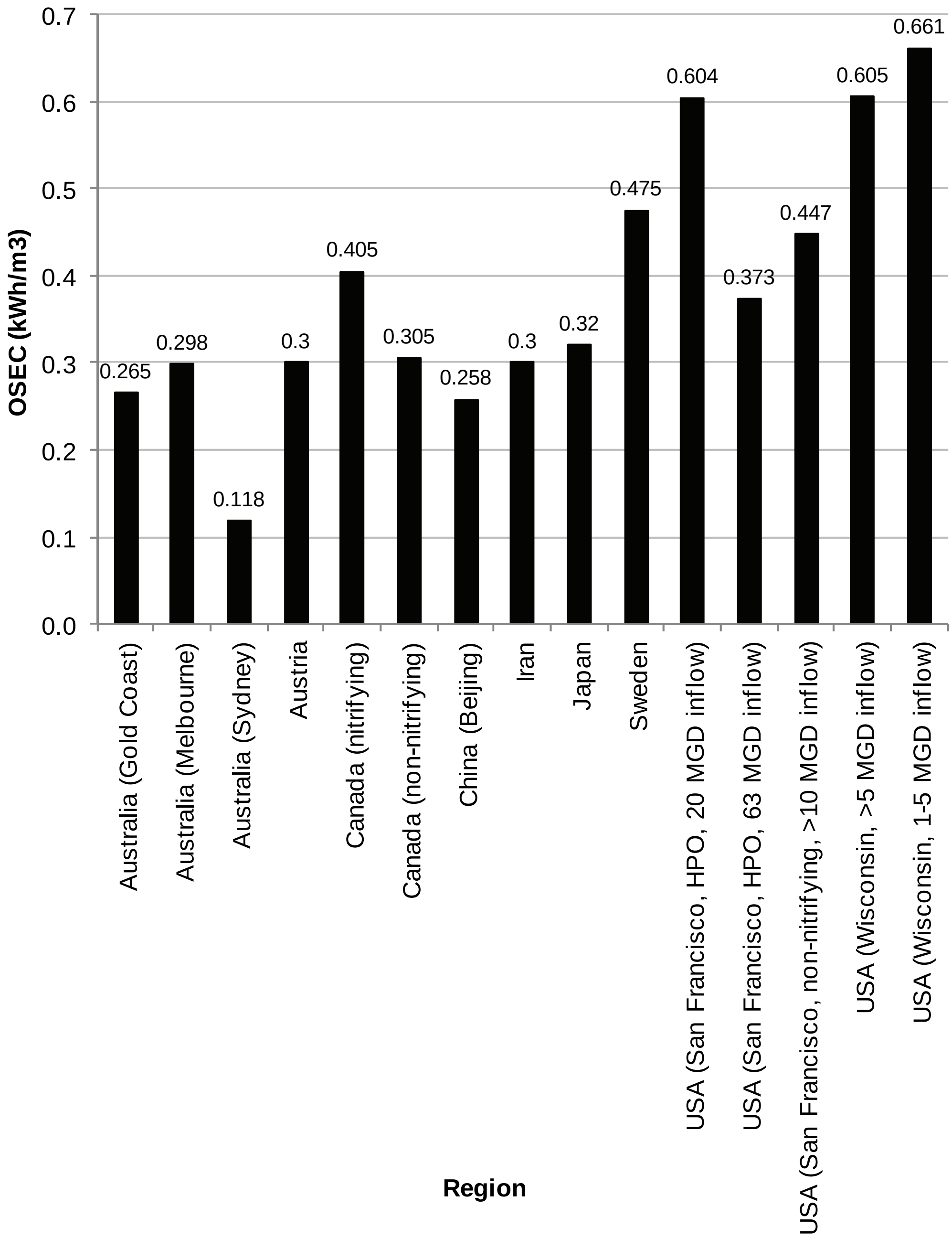

Figure 2.2: Overall specific energy consumption (OSEC) at wastewater treatment plants in other regions (NEWRI, 2010)

Table 2.6: Energy consumption figures for selected countries (NEWRI, 2010)

Energy consumption (kWh/m^3)	**Austria**	**Austria (Strass)**	**Sweden**	**China (Beijing)**	**Japan**	**Iran**
Total	0.304	0.317	0.475	0.258	0.320	0.300
Preliminary	0.039	0.068	0.136	0.083	0.013	0.013
Primary	-			0.015		0.001
Aeration	0.212	0.181	0.226	0.148	0.148	0.231
Sludge thickening	0.040	0.040	0.068	0.002	0.100	0.021
Sludge dewatering				0.003		
Sludge digestion				0.007		
Pumping	0.013	0.028	0.045	-	0.059	0.034
Total energy generation	-	0.346	-	0.081	0.170	0.182
Energy Efficiency (%)	-	109	-	31	50	60.67

Table 2.7: Energy consumption figures for wastewater treatment options in the USA (NEWRI, 2010)

Energy consumption (kWh/m^3)	Facultative ponds, lagoons, RBCs, trickling filters	Conventional activated sludge	Oxidation ditch
USA (Wisconsin)	1.926 (lagoons) (<1 MGD inflow)	1.437 (0-1 MGD inflow)	1.824 (<1.2 MGD inflow)
		0.661 (1-5 MGD inflow)	
		0.604 (>5 MGD inflow)	

2.3.3.1. Conclusions

The following conclusions were presented by NEWRI (Nanyang Technological University) at the GWRC Workshop that was held on 28 June 2010 (NEWRI, 2010):

- Treatment processes and plant configurations affect energy consumption.
- Application of centrifugal blowers and fine bubble diffusion, and mixer location are important (lowest specific energy consumption – China).
- Oversized plants may significantly increase specific energy consumption (Iran).
- Energy consumption in sludge treatment processes can be reduced by employment of gravity thickening and belt filter presses, internal and external sludge heating systems, gas and mechanical mixing and polymer addition China).
- Application of CHP generators (Strass) to achieve energy self-sufficiency.
- Chemicals addition to improve anaerobic digestion (Japan).

They also proposed the following approaches and technologies towards reaching a medium-term target of 50% and higher energy efficiency in the wastewater treatment sector (NEWRI, 2010):

- Fine bubble air diffusion (15-40% higher oxygen transfer efficiency).
- Dissolved oxygen control (30-60% saving in energy consumption).
- Variable frequency drives (VFDs) (up to 50% savings for pumping energy consumption).
- Utilization level vs. design capacity (Iran).
- Anaerobic digestion and biogas production (20-61% energy production in surveyed countries).
- Equipment renewal/upgrading.
- Application of CHP generators (Strass WWTP, Tabirz WWTP)
- Feedstock pretreatment.

2.3.4. South Africa

Contrary to the UK and US Energy Compendia, South Africa has not been actively pursuing and implementing energy savings projects on a large scale, mainly as result of the abundance of readily available and cheap electricity in the country. This means that case studies and operational data are not readily available. In cases where energy savings applications have been made, the data are poorly recorded and not verified. Hence, the South African Compendium may need to be developed to guide towards best practice a 'developmental industry', as opposed to being a Compendium of best practice by way of case study documentation.

It is further suggested that the matrix be used to capture best practice factsheets in each subject area. Clicking on the factsheet code, will open a full fact sheet in a new window with full details regarding the background, application potential and implementation of relevant technology against the particular subject.

The following section gives an overview of the water sector and energy in South Africa.

2.3.5. The water industry and energy in South Africa

2.3.5.1. Energy and the South African Water Industry

The WRC commissioned a project to help understand the potential impact that current energy supply challenges are having on South Africa's water and wastewater services. The aim of this project was to provide the South

African water and wastewater treatment sectors with an objective and logical evaluation of the current and expected impact and consequences of power outages on water and wastewater treatment services.

From a time of overcapacity in the 1980s, the years from 2007 have been difficult for South Africa's power sector in terms of generation, transmission and distribution capacity. When demand has outstripped supply there has been a need for load shedding. In particular, power outages were experienced between November 2007 and January 2008. There are ambitious plans to bolster South Africa's generation, transmission and distribution capabilities, however long project lead times places South Africa in a precarious position until these projects are commissioned.

South Africa has one of the most advanced water and wastewater sectors on the continent. Understanding the complexity of South Africa's water supply chain is a critical component of analysing the impact of power outages on this sector. Numerous factors influence the amount of energy utilised in the water supply chain including the stage of the water supply chain, technology utilised, the use of pump or gravity feeds and the quality of the water being treated. Figure 2.3 provides a relative energy consumption breakdown across the water value chain. It is not possible to calculate how much electricity is needed, on average, to treat a megalitre of water or wastewater. Various factors influence the amount of energy consumed in these treatment processes, which include (Frost and Sullivan, 2011):

Treatment plants that can use gravity to distribute water or wastewater will save significant amounts of energy because pumps are not required.

The quality or water or wastewater influences the amount of electricity consumed. In wastewater treatment, the more concentrated the effluent (higher COD 'Chemical oxygen demand'), the more efficient your treatment becomes. Even though your effluent may be more concentrated, the treatment process would use less energy to treat the same volume of solids, when compared to a diluted effluent mix.

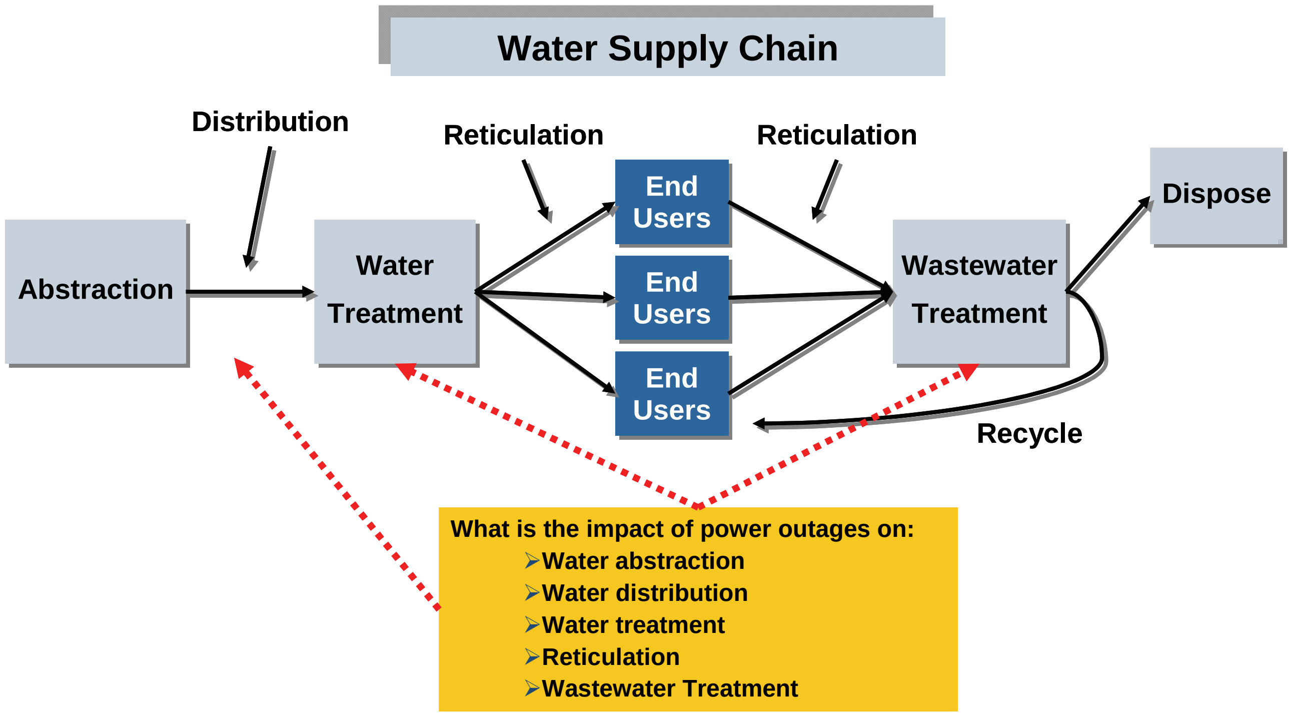

Figure 2.3: Areas of impact of power outages in the South African water supply chain (Frost and Sullivan, 2011)

Certain treatment technologies consume more energy than others. For example, reverse osmosis membranes use significantly more energy than other filtration techniques.

With so many variable factors contributing to the amount of energy consumed in the water value chain it is difficult to quantify exactly how much energy is being consumed in total. However, it is possible to breakdown the water supply chain in terms of the energy consumed by each process over a range. Table 2.8 illustrates the energy consumption range for each water supply chain stage in South Africa.

Table 2.8: Energy consumption range for the South African water supply chain (Frost and Sullivan, 2011)

	kWh/ML	
Process	**Min.**	**Max.**
Abstraction	0	100
Distribution	0	350
Water treatment	150	650
Reticulation	0	350
Wastewater treatment	200	1 800

Wastewater treatment is by far the largest consumer of energy with a range of 200-1800 kWh/ML treated. Water treatment typically reflects lower energy consumption figures at 150-650 kWh/ML treated (Frost and Sullivan, 2011). Abstraction, distribution and reticulation vary depending on whether gravitational feeds are utilised or not.

2.3.5.2. National Energy Regulator

The National Energy Regulator (NERSA) is a regulatory authority established as a juristic person in terms of Section 3 of the National Energy Regulator Act, 2004 (Act No. 40 of 2004). NERSA's mandate is to regulate the Electricity, Piped-Gas and Petroleum Pipeline industries in terms of the Electricity Regulation Act, 2006 (Act No. 4 of 2006), Gas Act, 2001 (Act No. 48 of 2001) and Petroleum Pipelines Act, 2003 (Act No. 60 of 2003). The structure of the Energy Regulator consists of nine members, five of whom are part- time and four are full-time, including the CEO. The Energy Regulator is supported by a secretariat under the direction of the CEO.

While the Electricity industry has been regulated for the past ten years, the piped-gas and petroleum pipeline industries in South Africa will be regulated for the first time. In 2002, the Cabinet decided that the NER would be used as the basis to create the National Energy Regulator. In anticipation of the future development of these industries the Gas Act of 2001 and the Petroleum Pipelines Act of 2003 were passed to promote the orderly development of the Piped-Gas and Petroleum Pipelines industries. Both Acts mandated the establishment of a regulator.

2.3.5.3. Eskom

Eskom generates approximately 95% of the electricity used in South Africa and approximately 45% of the electricity used in Africa. Eskom generates, transmits and distributes electricity to industrial, mining, commercial, agricultural and residential customers and redistributors. Additional power stations and major power lines are being built to meet rising electricity demand in South Africa. Eskom will continue to focus on improving and strengthening its core business of electricity generation, transmission, trading and distribution.

Eskom buys electricity from and sells electricity to the countries of the Southern African Development Community (SADC). The future involvement in African markets outside South Africa (that is the SADC countries connected to the South African grid and the rest of Africa) is limited to those projects that have a direct impact on ensuring security of supply for South Africa.

- One of the 10 largest electricity utilities in the world by generation capacity
- Supplies ~ 95% of electricity used in South Africa
- Supplies ~ 45% of electricity used in Africa
- Permanent employees: ~ 39 200
- Electricity customers: ~ 4 463 000
- Electricity sales: ~ 218 000 GWh pa
- Net maximum capacity: 40 867 MW
- Power lines: ~ 380 000 km (all voltages)
- Eskom has 27 power stations, 13 coal-fired, one Nuclear, one wind, two pumped storage, six hydro and four gas.

2.3.6. Energy initiatives and projects in South Africa

2.3.6.1. Western Cape Energy Projects

The following are amongst energy projects in the Western Cape that are currently in planning stages:

- Hessequa Municipality: Energy generation from biogas
- Oudtshoorn Municipality: Energy utilization from anaerobic digestion biogas
- Cape Agulhas Municipality: Green City Project (includes generation of electricity)

2.3.6.2. KwaZulu Natal (KZN) Sustainable Energy Forum (KSEF)

The primary role of the KZN Sustainable Energy Forum (KSEF) is to act as a focal point where current and future SE research projects taking place in KwaZulu-Natal and the eThekwini Municipal Area can be introduced and discussed. The KSEF seeks to both guide and coordinate the effective implementation of these SE projects introduced at the various meetings.

Therefore, the activities of the KSEF are as follows where each activity is a preliminary step to the activity that follows:

- A platform where new and current SE projects are introduced to the relevant stakeholders (those who attend the forums)
- Serves as a forum through which these projects are put to question and where input may be made by other stakeholders and I&APs who have relevant expertise.
- Raise institutional barriers to SE projects and seek to conceptualise solutions to these barriers
- Serves as a forum where an informed discussion will contribute to the most appropriate and practical implementation of SE research projects
- Membership for the KSEF is not limited to any specific group or people. The Forum will, however, stay relevant through the active participation of a number of significant role players. Importantly, the Forum is open to any group or member of the public as SE is a wide reaching sector and has implications for a wide spectrum of groups across KZN. There is, as a result, no formal 'sign up' or membership required to be part of the forum. The key role players and representatives are listed below:
- Representatives from eThekwini Municipal Energy Office.
- Representatives from research institutions and tertiary institutions engaging in SE research in KZN.
- Representatives from the business community involved in SE research and production in KZN.

2.3.6.3. Durban Water Recycling

This is a well known project and provides a considerable benefit to industries in the form of lower tariffs when compared to the normal tariff paid by industries for potable water. The two largest customers so far are the Mondi Paper Mill in Merebank and the Sapref Refinery, owned by Shell and BP. This is the first private water-recycling project in South Africa, this plant is the culmination of a 20-year Build Own Operate and Transfer (BOOT) contract awarded to treat 10% of the city's wastewater. Vivendi Water is the major stakeholder in Durban Water Recycling and its partners are Zetachem, Khulani Holdings, Umgeni Water and Marubeni Europe. The plant frees up sufficient drinking water for approximately 300 000 people. Of course, this project is really more about water efficiency rather than energy efficiency.

2.4. Options for improvement of energy efficiency

2.4.1. Europe

2.4.1.1. Outcomes and Benefits (UKWIR, 2010)

The UK Compendium summarizes the findings from data collected throughout the United Kingdom water industry and contains information on current energy usage across the water cycle, highlighting where energy saving actions could be focused. There are factsheets and technical guidance on the subject areas with greatest potential, with case studies and examples of energy saving projects.

Generally the case studies are focused within components of the water cycle identified as priority areas in the matrix (see Section 5), but some improvements can have a wider impact on the water cycle than within a single component or part of the process. There are some examples where data are not formally recorded but anecdotal information is incorporated into the text. These examples may represent opportunities for the future.

Incremental improvements have not been separated from the more substantial gains to preserve continuity through water cycle matrix.

The benefits of the Compendium to the water industry will be increased comprehensive guidance on energy efficiency, reduced energy use and cost and a reduction in carbon footprint. There may also be benefits in communication of status and expectations of the industry's contribution to national and global energy and carbon reduction targets.

2.4.1.2. Current Energy Use (UKWIR, 2010)

The energy demand for both services is about equal; 52% for water and 48% for sewerage. Pumping represents upwards of 70% of water supply energy demand and at least 30% for waste water. For sewage services the major single energy demand is for aeration; up to 60% or more of the usage for the service. Clearly the best opportunities for reducing energy demand are linked to these high usage components. The table demonstrates that the range of energy usage for the water service split between raw water pumping and treatment, and distribution varies in percentage terms is between 16/83 and 97/3, with a UK industry wide average being 49% / 51%. The wide variation amplifies the geography, source water and population density factors within the UK. To a lesser extent the percentages also recognise the limited energy demand for water treatment processes.

For sewage the Ofwat reported figures differentiate between sewerage, treatment and disposal with an industry average of 21/68/11. The ranges within each component are significantly narrower than for the water service; being 11-42/57-81/23)-23. However these figures highlight the benefit gained from renewable technology being used to power sewage treatment processes, mainly energy from waste. The numbers also hide extreme differences, for example, between percolating filter treatment which uses minimal energy, and activated sludge. The potential savings are shown in Table 2.9 and Figure 2.4.

Table 2.9: Potential energy saving percentages (OFWAT, 2009)

	Water			Sewage			
	Abstraction and treatment	Water distribution	Water service total	Sewerage	Sewage treatment	Sludge treatment and disposal	Sewage service total
By service component (£million)	110.522	130.286	240.808	44.436	149.085	28.346	221.867
Average (%)	48.6	51.4		21.1	68.1	10.8	
Maximum company (%)	96.7	83.8		42.1	80.5	23.1	
Minimum company (%)	16.2	3.3		11.1	57.1	-22.6	
Whole water cycle (average, %)	23.9	28.2	52.0	9.6	32.2	6.1	48.0
Initial estimates (%)	35	65	45	25	60	15	55
Range of returns (%) from individual companies[1]	45-60	40-55	45	28-30	68-70	0-2	55

[1]Limited data returned – not representative of UK industry

Case studies indicate that energy savings from pumping vary widely depending on the circumstances (Figure 2.4), but overall savings of between 5 and 30% of current energy demand appear achievable (Table 2.10). Energy efficiency gains from new pumping technology will be limited to about 5% since the technology is generally mature. However, more significant improvements should be feasible in submersible and borehole pumps where hydraulic and electrical configurations are more challenging. The case studies and examples tend to focus on these two areas but there is a broad range of activities across the UK from leakage reduction to renewable energy.

Table 2.10: Energy savings from pumping interventions (UKWIR, 2010)

Means of saving	Variable speed drives (VSDs)	Duty point	Intrinsic pump	Duty change	Waste water	Duty range
Saving (%)	12 to 30	3 to 63	6 to 11	10	8.4	3

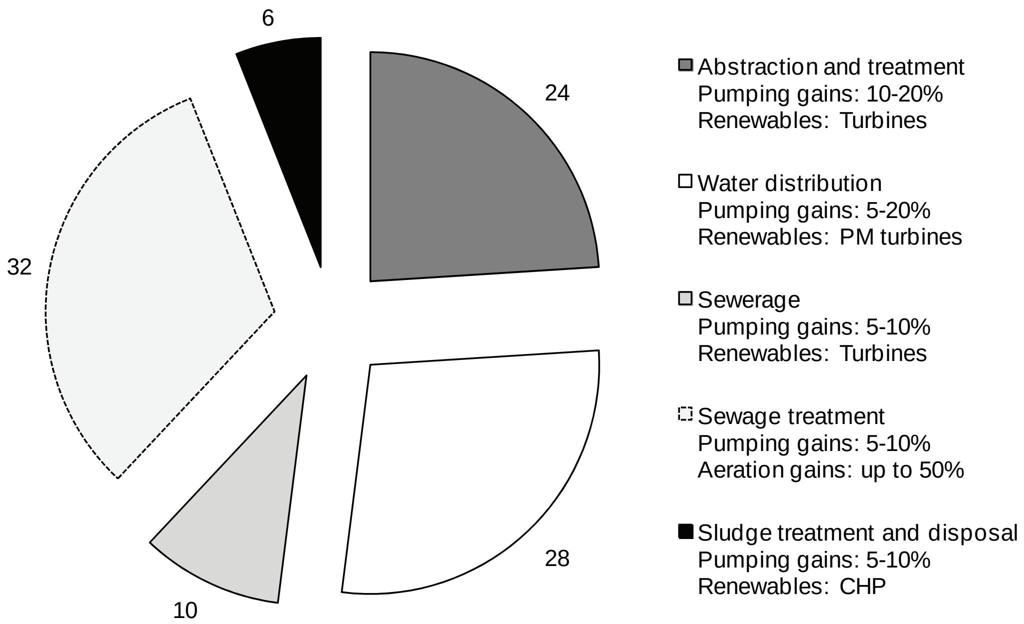

Figure 2.4: Energy usage by service component (% of cost) and interventions with greatest potential

Up to 50% energy savings have been demonstrated by case studies in waste water processes focused on aeration (Figure 2.5). Simple changes in control methods and set points have frequently shown substantial quick wins and checks on plant, control methods, operational routines and maintenance have proven worthwhile.

The above savings relate specifically to a single component of the water cycle. However improved water efficiency (leakage reduction and demand conservation) represents a significant opportunity for improved energy efficiency across the whole water cycle in that reducing the demand for water reduces the volume to be abstracted, treated and distributed with a corresponding reduction in sewage to be collected and treated and effluent and sludge disposal; for example a 5% reduction in consumer demand will be mirrored energy reduction through all components of the water cycle. Interventions include consumer education, installation of water saving devices and maintenance, and replacement of the infrastructure.

Water companies have not offered many case studies of clean water process improvement. There is potential in areas such as dissolved air flotation (DAF) and there may be opportunities to investigate membrane technology, Ultra-Violet (U/V) systems and ozone packages at older plants. However the relatively low energy use in these processes may account for the low potential for savings and hence lack of case studies. In Table 2.11, hierarchies of potential energy efficiencies for water, sewage and sludge treatment processes are shown.

By optimising current processes it is feasible to increase primary sludge production which reduces load on aeration blowers and increases digester biogas production. Net energy efficiency is thereby increased particularly with sludge digestion and CHP on site.

For sludge handling, suggestions are given for energy efficient mixing, pumping and thickening with a hierarchy of thickening processes, as shown in Table 2.11. Increased uptake of advanced sludge treatment is expected to enhance quality and increase biogas yields with the various proprietary sludge treatment processes available. Combined heat and power (CHP) from sludge biogas is mature technology but more uptakes will increase the net energy efficiency of waste water utilities.

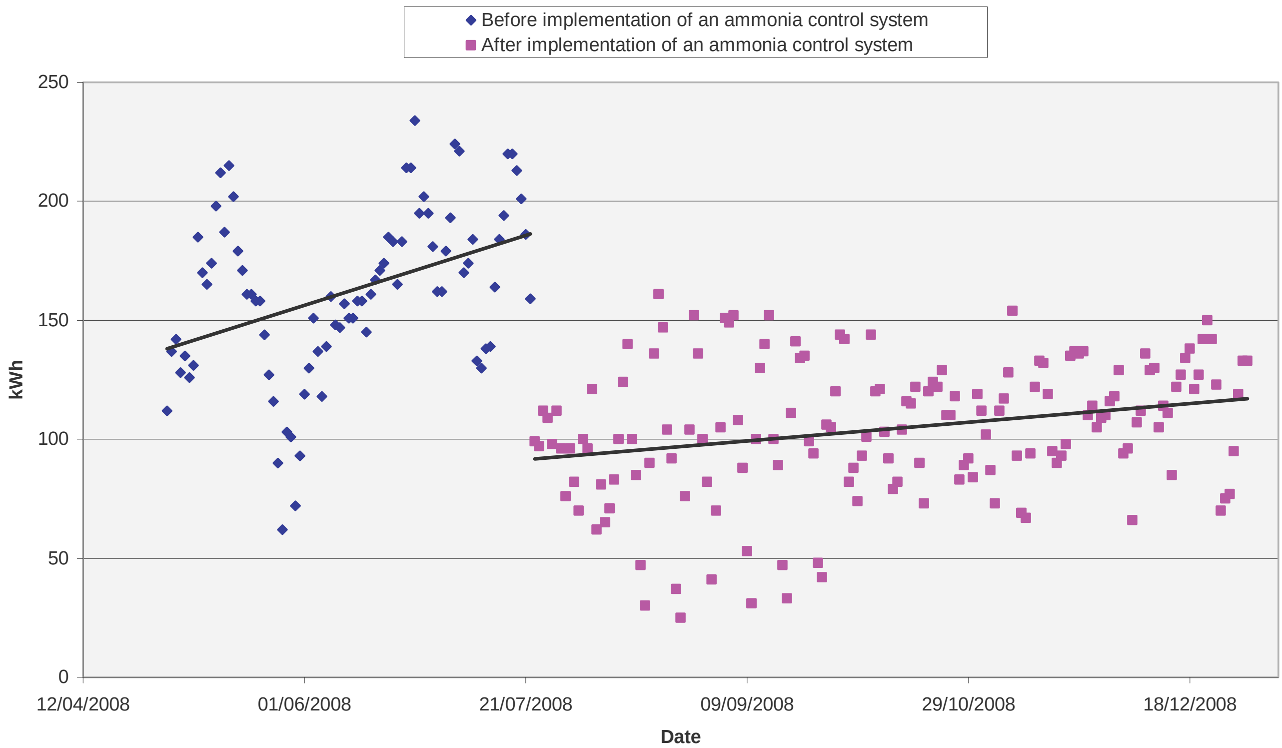

Figure 2.5: Example of aeration energy reduction following process changes: Blower power consumption at Taunton (UK) activated sludge plant (UKWIR, 2010)

There is also the possibility of using anaerobic effluent treatment. This needs to be confirmed, but promises similar effluent quality with the bonus of greater yields of biogas than would come from digesting sludge from aerobic treatment. The net energy saving is therefore significant.

Table 2.11: Hierarchy of water, sewage, and sludge treatment processes by potential energy efficiency (UKWIR, 2010)

	Low	⇦	ENERGY USE		⇨	High
Water treatment processes	Clarifiers	Hydraulic mixers	Media backwash	Chemical dosing	UV disinfection	Dissolved air flotation
Sewage treatment processes	Biological (percolating) filters	Anaerobic membrane bioreactor	Bio-aerated flooded filter	Step fed activated sludge (ASP)	Nutrient removal ASP	Conventional membrane bioreactor
Sludge treatment processes	Picket fence thickeners	Drum thickeners	Belt thickeners		Belt presses	Centrifuges

For building services the trend towards the use of air conditioning should be challenged as plant-specific cooling is more efficient. Reductions in lighting loads are feasible with new equipment, but all schemes should include health and safety considerations.

Opportunities for other renewable energy sources are usually site-specific. Large wind turbines have been used and some applications exist for small solar and wind packages combined with battery storage, usually for remote instruments. Hydro-turbines are expected to be increasingly exploited, and while this technology is mature, there may be transient control issues. Adoption of CHP technology for digester biogas has not been universal, so there is still potential for significant net energy saving, as implied in the Ofwat figures.

For all innovations aimed at energy efficiency it is evident that cost/benefit analyses should use future energy prices projected to about half the design life of the proposed plant.

Overall energy efficiency gains in the UK water industry are estimated at 5-15%. With the right financial incentives a substantial portion of these gains could be achieved.

2.4.1.3. Key Points from the UK Compendium (draft report) (UKWIR, 2010)

Two areas show the most potential: pumps of most types and functions, and aerobic wastewater treatment systems.

Simple gains are possible in some pumping situations where the operational set up has been changed from the design condition. Gains of between 5% and 30% may be realised. More complex and large scale pumping energy savings are feasible but frequently show marginal payback using current financial analyses.

Simple gains of up to 50% are possible on some aerobic wastewater systems by aligning control parameters with the discharge consent. There is potential for optimising waste water processes towards increasing primary sludge production, reducing secondary treatment loads and increasing gas yields to CHP plant with minimal investment.

There may be unrealised potential in clean water processes opportunities associated with older DAF, membrane packages, U/V systems and ozone plants.

Negotiations on discharge consent standards should include a net pollution assessment to balance pollution removed by treatment against pollution caused through increased energy demand. The balance must include electrical power distribution efficiency (about 20%) and the common metric is carbon footprinting.

Cost benefit analyses should use electricity price increases projected to about half the design life of the plant; i.e. at least ten years into the future.

Opportunities also exist for:

- reducing chemical use in clean and wastewater treatment,
- investigating anaerobic treatment of wastewater linked with biogas and CHP to approach carbon neutral treatment,
- comparing the energy demand of sludge thickening and enhanced treatment processes, and
- co-digestion of sludge with other compatible wastes.

Because of rapid changes in the water industry this UK compendium should be updated within two years. It should focus on current energy usage to monitor the effectiveness of changes and the ultimate level of feasible savings. It should also encourage more input from academia and account for any regulatory changes resulting from current reviews.

2.4.2. South Africa

Burton *et al.* (2009) made the following conclusions with regard to the potential of energy from wastewater in South Africa:

a) From the first order estimate of the quality and quantity of wastewater in the whole of South Africa, an estimated 10 000 MWh can be recovered. This is approximately 7% of the current Eskom power supply (approximately 140 000 MWh or 42 000 MWe).

b) As an example, domestic blackwater (human faeces) could generate 842 MWh. The energy from wastewater that can be generated is best viewed as on-site power for essential services (WWTP, schools, hospitals and clinics) since it provides a mechanism for sustainable energy usage and a means to help fulfil national and international legislation and obligations for clean, renewable energy.

c) The most appropriate technologies and their limitations are partly determined by the value of the required energy product (heat, electricity, combined heat and power or fuel) and the driving market forces that determine how this fuel can be used with our current technology. The ease of separation of the energy fuel product from water is often the key to feasibility. For example, biogas separates easy from the wastewater by natural partitioning whereas bioethanol requires energy intensive distillation.

d) Anaerobic digestion is suitable for application with rural/household sewage, (particularly since 40% of South African communities are not serviced with waterborne sewerage), as well as municipal WWTP and agricultural communities. However, skilled management and skills-training is required if AD is to be applied successfully in South Africa.

e) Heat integration could be applied effectively in heavy industry in South Africa. Limitations to implementation include human resource capacity and the need for pre-planning.

f) Combustion / gasification could be applied in limited cases such as treatment of dewatered and solar-dried (or previously stockpiled) sewage sludge.

g) Fermentation for bioethanol has potential in the agricultural sector, but is currently limited to the availability of high COD, carbohydrate-containing wastewaters such as those in the fruit processing and sugar-cane processing industries.

h) Production of algal biomass for use in combustion/gasification or for production of oils for biodiesel is not yet feasible in South Africa, but rapid progress is being made, incentivised by the recent increases in diesel prices.

i) Additional benefits (such as certified emission reductions) and the production of other secondary products (such as fertiliser) could tip the balance of economic feasibility when implementing an energy from wastewater project.

3. IDENTIFICATION OF CASE STUDIES FOR SOUTH AFRICAN COMPENDIUM

3.1. Opportunities for improved energy efficiency on supply side through energy generation

Opportunities for the generation of energy in the water sector are mainly focused on production of electricity from biogas produced at wastewater treatment works, and hydro-power generation in pressurised distribution systems. Both of these sources of energy were investigated in various forms in this project.

3.2. Opportunities for improved energy efficiency through demand side management

Approximately 60% of electrical power supplied to a typical WWTW is consumed by electrical motors. The extent to which treatment plants have electrically-dependent equipment fitted can be summarised by the following functionalities:

- Generates electricity (a generator or emergency generator)
- Stores electricity (batteries, stand-by power supply, uninterruptible power supplies [UPS])
- Changes electricity from one form to another (transformers)
- Transports or transmits and distributes electricity throughout the plant site (wiring distributions systems)
- Measures electricity (meters)
- Converts electricity into other forms of energy (rotating shafts – mechanical energy, heat energy, light energy, chemical energy, or radio energy)
- Protects other electrical equipment (fuses, circuit breakers, relays)
- Operates and controls other electrical equipment (motor controllers)
- Converts some conditions or occurrence into an electrical signal (sensors)
- Converts some measured variable to a representative electrical signal (transducers or transmitters).

Specific areas and mechanical-electrical equipment along the treatment process can be targeted for improved energy efficiency.

- Aerators and pumps have to work to and in harmony with their respective fluid distribution systems. When they are operated either side of their ideal operating conditions (too much / too little flow / pressure) their reasonable efficiencies can drop off at a dramatic rate. The ideal operating range is therefore conducive to an energy efficient system.
- Maintenance programs should ensure that all equipment is operating as per the suppliers' recommendation to limit losses attributable to poor maintenance. Failure to adjust tolerances on wear plates of pump impellors can increase power consumption and reduce flow. Excessive vibration can lead to electrical motors heating up and energy wastage in this process.
- The required flow rate must match the delivered flow within a specific time frame.
- Distribution systems analysis to find ways to reduce impedance / friction to flow.
- Ensure that the pump or aerator is the correct one for the application and is operating at close to optimal conditions. If not, reconsider the pump/aerator selection.
- Adding soft starters to the motors to reduce peak demand spikes.
- Add methods of speed reductions to accommodate variances in duty requirements and reduce energy requirements. When the speed of a centrifugal blower or pump is reduced by 50%, the flow delivered is reduced by 50% but, the power required to drive that blower/pump may be reduced by up to 87.5%. Methods of speed reductions include a two speed motor, sheave or pulley changes, the use of a mechanical variable speed device, or the use of an electrical variable speed drive appropriate to the application at hand. Even small reductions in centrifugal pump speed will result in large reductions in power. The benefits of variable speed drives are:
    - Reduced energy consumption
    - Eliminate the need for a separate motor starter
    - Improve aerator and pump control

- Increases the life span of equipment
- Reduce maintenance and downtime.

- Increase more, lower rated motors, as duty motors to add flexibility to the operation and reduce instantaneous power consumption

- Changes after the initial design of a system can result in inefficient aerator / blower / pump operation. This results when the conditions imposed upon the aerator / blower / pump are not ideal for the type and/or size of aerator / blower / pump. By re-considering the design and operating conditions of the aerator / blower / pump, it may be possible to make changes that will result in higher efficiency and reduced power consumption.

- Investigate and minimise the influx of stormwater ingress, which could effectively load the hydraulic contribution to the plant significantly and increase energy consumption.

- Other energy saving opportunities include the following:
  - Addition of a balancing tank to plant to ensure a more stable supply to the plant and improve process stability and process performance.
  - Human behaviour contributes substantially to the consumption of electricity as a whole, and could therefore affect savings. This is done by the negligent use of energy anywhere on the plant. People often forget to turn off the lights, computers and air-conditioning when they leave an office or building. The energy used during these periods is accumulated when left overnight and over weekends.
  - Humans also influence the quality of maintenance of the energy consuming technologies. The irregularity or lack of maintenance of these systems could affect their productivity, thereby decreasing their energy efficiency.
  - Process optimisation on the biological systems will improve biogas production and energy wins on on-site gas generators.
  - Solar panels for electricity generation of on-site lighting in offices and geysers.
  - On oxidation ponds, the sludge can be withdrawn to a primary settling tank with further diversion of the sludge to an anaerobic digester and overflow back to the oxidations pond. The produced biogas will be sufficient to run the (minimal) energy requirements of the plant.
  - Installation of variable speed drives on aerators which will be controlled by the dissolved oxygen ensuring that the operation adjusts automatically to the influent conditions and power consumption is optimised.
  - Change operation of larger motors to coincide with off peak periods thereby reducing energy costs.

3.3. Energy related initiatives in South Africa

The following energy related initiatives in South Africa were also identified as relevant to the project:

3.3.1. Enerkey (Reference to Module 5, Energy Supply)

- Enerkey Research Seminar was held in November 2011

- The study was done in conjunction with the University of Johannesburg (UJ)

- The seminar focused on:
  - Cost – potential curve for CO_2 emission reduction
  - The LCA of coal power plants (Master thesis, Oliver Miedaner)
  - Bioethanol and Biodiesel – taxes and levies
  - Yields
  - Sugar cane bioethanol – assumptions
  - Wind – potential, costs and assumptions
  - CSPO – potential, costs and assumptions
  - Hot water demand in Gauteng
  - Technical potentials of SWH on residential buildings
  - Total residential roof area for SWH in Gauteng
  - Potential of incoming solar energy on residential building roofs for Gauteng

Enerkey's main partners are: University of Johannesburg, Cities of Johannesburg, Ekurhuleni and Tshwane, Eskom, CSIR, SEA, PEER Africa, SESSA and SENSEA. German partners are IER, IZT, Fraunhofer, TUEV, INEP, Stuttgart, AHK and ProBEC.

Following DWA Gauteng involvement in the Enerkey project in November 2010, the DG made a submission to the Minister of Water Affairs to motivate for DWA's involvement and collaboration with Eskom and DoE on this project. The DG of DWA is currently handling this project internally within DWA.

3.3.2. Eskom DSM (Demand Side Management) and IDM (Integrated Demand Management)

- The IDM / DSM's role is to ensure single ownership of demand side management strategies, objectives and operations throughout Eskom.
- General focus:
  - o Energy efficiency Demand Side Management
  - o Energy Management Programme
  - o Solar Water Heating Programme
  - o Power Awareness
  - o Coordinated internal energy efficiency programme
  - o Energy conservation scheme
  - o Demand response
  - o Internal energy efficiency programme

3.3.3. Comparative Suppliers Programme with DTI

- DTI Promotes capital investment and skills development
- Launched a new tax incentive for the manufacturing sector. The section 12i incentive replaces the previous strategic industrial projects programme, which also promoted investment in capital projects and skills development – and created 6600 jobs.

3.3.4. Energy Efficiency

- SAEE (South African Association for Energy Efficiency)
- The Southern African Association for Energy Efficiency (SAEE) is one of 70 international chapters of the American Association of Energy Engineers (AEE). The SAEE supports the AEE's mission to promote the scientific and educational interests of those engaged in the energy industry and to foster action for sustainable development.
- Partners include AEE, SAEEC, IIEO, CMVPSA.

3.3.5. Central Energy Fund Group of Companies (CEF)

- One of the group of companies = National Energy Efficiency Agency (NEEA)
- NEEA was established in March 2006 through directive issued by the Minister of Minerals and Energy
- CEF focus:
  - o International allocates for PetroSA
  - o Local drive for efficient lighting
  - o Billion dollar solar project
  - o Turning wood waste into energy
  - o iGAS – at the helm of making Gas happen in South Africa
  - o Darling wind farm project
  - o SANEDI – nurturing the future of energy
  - o Carbon storage atlas for South Africa in the making
  - o CEF launches new carbon hub in London
  - o Producing fuel from crops
  - o Torbanite project to contribute to security of energy supply
- Partners include AE, CEF Carbon, EDC, iGAS, Energy Efficiency, OPC, PetroSA, Promotion Agency SA, SANEDI, SASDA, SFF and CEF Sustainability.

3.3.6. Responsible Entrepreneurs Achievement Programme

- Responsible Entrepreneurs Achievement Programme (REAP) with UN
- A number of South African Companies joined the UN Global Compact. The National Business Initiative (NBI). The focal point to the South African Local Network of the UN Global Compact

3.3.7. South African National Energy Development Institute (SANEDI)

- Working for Energy (WFE)
- South African Renewable Energy Programme
- Mission:
- Job creation and poverty alleviation;
- Skills development and enterprise development;
- Reducing electricity demand and overall energy utilization;
- Developing and enhancing co-generation projects and developing new energy sources and efficiency enhancements;
- Enhancing existing infrastructures;
- Developing new green field projects for low cost housing electrification;
- Reducing environmental impact and green-house gas emissions;
- The Department of Energy is the sector department responsible for the Working for Energy Programme and coordinates with other stakeholders in the water, environmental, energy and public works, Arts and Culture, and other sectors, to ensure both synergy and full programmed integration. The Department of Energy (DoE) has the line function responsibility to initialize the programme, “Working for Energy”. The DoE is partnered with SANEDI to implement the programme.

3.4. Information reported on in the Case Studies

3.4.1. Introduction

The Energy Compendium will, similar to the UK Compendium, use Case Studies to present the results of the local investigations.

3.4.2. Reliability of data (scientific base)

The information will also be based on scientific principles so that results are quantified (as far as possible – much less information is available in South Africa compared to the other continental partners of the GWRC) and that risks are known and can be managed. The information required for case studies will present the background, type and size of the process, the situation before and after any changes, the changes themselves, and the results.

Where data are lacking and/or the reliability of data is in doubt, those projects will be shown as generic examples rather than as detailed case studies.

3.4.3. Information required

The information required to describe an energy efficiency project will vary from an example of a simple basic system or concept, to a complex and complete case study.

As a simple basic system, the following will at least be included:

- Starting point and problem or opportunity
- Actions, measured and repeatability
- End point and solution or measured energy efficiency gain.

In reality, problems and opportunities are often more complex, and much more information should be provided. For this reason, the template for the Case Study encompasses detailed information so as to provide a comprehensive picture of the energy saving measure, device or technology.

All the fields in the template will be addressed and completed as thoroughly as possible. In some cases, projects may already be in progress, in which case the existing data can be used to address the fields. In most of the cases, however, this data will need to be obtained through close liaison with the utilities or research organisations undertaking the projects.

3.4.4. Case Study Selection Criteria

As the South African Compendium will also be integrated into the Global Compendium, it was important that it should be aligned with the format of the other compendia, which are already incorporated in the Global Compendium. The following therefore received careful attention in compiling the local Compendium:

Scope:	to cover incremental and significant changes,
Process:	to cover all important parts of the water cycle matrix,
Geography:	to cover flat and steep catchments and various environments,
Climatic:	to cover regions with cool, temperate and tropical conditions,
Regulatory:	to cover public, private, regulated and non-regulated utilities,
Scale:	to cover large and small works in rural and urban areas,
Technology:	to cover simple low-tech and complex high-tech solutions,

3.4.5. Case Study Templates and Factsheets

Because of the potential magnitude of information to be presented in the Compendium, it was important that this information be presented in a way that would make it interesting and user-friendly to users of the Compendium. It should also be uniform, both to ensure easy use as well as comparison where required.

Technical information is presented in factsheets, which are used to explain the basics of the technology to middle management or senior engineer level personnel. It therefore does not contain too much technical detail in the factsheet. The factsheets are hence one to two pages. More details are presented on the CD enclosed in this compendium, which are more applicable for subject matter experts or project implementation managers. The Factsheets are followed by the Case Studies themselves, showing best practices selected according to criteria established for the Compendium, as described above. This is reinforced by examples showing comparative projects.

All case studies and examples are referenced on the CD in as much detail as permitted by the available data.

The Fact Sheet and Case Study templates are shown in Sections 4 and 6, with examples in Sections 5 and 7.

4. CASE STUDY TEMPLATE

The Case Study template that was drawn up for the South African Compendium is shown in Table 4.1.

Table 4.1: Case Study template for the South African Compendium

Ref	Item	Response information, description and remarks
1	Location: Country, urban or rural	
2	Sector: Water, wastewater or sludge	
3	Works Owner or Operator:	
4	Size: Flows and loads or population equivalent	
5	Energy Provider:	
6	Process: Physical, chemical, or biological description	
7	Component: All or part of the works	
8	Motivation of the case study:	
9	Process/Plant changes: Mechanical, electrical or controls	
10	Civil/Physical Changes: To water /effluent quality, civil works, or process	
11	Operational Changes: Skill levels, procedures and maintenance routines	
12	Risks and Dependencies: Risk assessment of project and changes	
13	Implementation:	
14	Energy Efficiency gains: kWh and kWh/m^3	
15	Cost / Benefit analysis: Financial appraisal or payback time	
16	Project review: Could it be improved or further developed?	
17	Confidence grade: On data provided	

5. EXAMPLES OF SOUTH AFRICAN CASE STUDY FORMAT

Table 5.1: Example of Case Study information and data: CHP Systems for Biogas to Energy using Anaerobic Sludge Digestion: Johannesburg Water

Ref	Item	Response information, description and remarks
1	Location:	Northern Wastewater Treatment Plant situated in South Africa, Gauteng Province. High density urban space. Central Gauteng with plant located in the northern catchment.
2	Sector:	Sewage sludge.
3	Works Owner or Operator:	The plant is owned by the City of Johannesburg (CoJ) Metropolitan Municipality and operated by Johannesburg Water of behalf of CoJ, as part of the City of the Future – Municipal Entities. Similar projects are initiated by other ME's in the City, e.g. biogas at landfill sites, solar geysers, etc.
4	Size:	Plant size is 450 ML/day; actual flow is 447 000 m^3/dy. Produce 85 tons dry sludge/day. PE estimated at 990 000 households, with an average of 6 persons per household, water consumption: 75 ℓ/c/d; sewer production: 60 L/c/d (=80% of water consumption).
5	Energy Provider:	Power is in form of electricity, provider by the national electricity agency, ESKOM. Plant requires 8.0 MW energy, with potential to generate 4.4 MW electrical energy and 110.8 MWh/d heat.
6	Process:	Anaerobic digestion of sewage sludge with optimization of methane gas for energy production purposes.
7	Component:	Sludge digestion, whereby 'sludge' consist of primary-. excess secondary-, and waste activated sludge.
8	Motivation of the case study:	Key driver is the increased electricity tariffs by ESKOM, whereby electrical power costs will treble over the next 7-10 years, with 25% increases already incurred over past 3 years. ESKOM has incentives in place for off-peak power use, and for green energy development. A further driver is compliance to the Sludge Utilization and Disposal requirements, as regulated by the Water Regulator (Department of Water Affairs).
9	Process/Plant changes:	The plant employs enhanced biological nutrient removal (BNR) with primary sludge fermentation technology for VFA production. This practice reduces the mass of primary sludge available for anaerobic (mesophilic) digestion with some waste activated sludge. Cell lysis is used to disintegrate cell membranes prior to sludge digestion for optimized biogas production. Scrubbing of biogas is pivotal in terms of gas cleaning before use in prime movers (engines/turbines) for CHP. This factor is key in terms of prolonging asset lifespan and good maintenance practice.
10	Civil/Physical Changes:	Cell lysis (via mechanical, ultrasonic or electrokinetic disintegration); scrubbing (for the removal of solids, ammonia, silicon, moisture and H_2S) and installation of prime movers (reciprocating engine, gas turbine, generator, heat recovery system and electrical connections
11	Operational Changes:	Outsourcing of the operation and maintenance function of the biogas scrubbing and CHP production operations to the equipment supplier and appointment of a competent Electrical Technological for the management of the system.
12	Risks and Dependencies:	Low risk involved due technology being existing, tried and tested. Risk remaining include i) omitting of biogas scrubbing ii) selection of suitable cell lysis, scrubbing and CHP equipment; iii) competent O&M staff; iv) open market in SA need to caution against unsustainable technologies and applications.

Table 5.1: Example of Case Study information and data: CHP Systems for Biogas to Energy using Anaerobic Sludge Digestion: Johannesburg Water

Ref	Item	Response information, description and remarks
13	Implementation:	The project was procured via a design/build process with a respectable contractor. Acceptance testing, followed by an O&M period was included as part of the contract.
14	Energy Efficiency gains:	Energy efficiency gains will result from energy saved from purchase, estimated at ~ 8.0 MW.
15	Cost / Benefit analysis:	Payback period of 5 years in asset terms, reduction of 35 000 ton CO_2 in terms of emissions / environmental benefit.
16	Project review:	A project review will only be possible further along implementation, as is part of the project lifecycle. Purpose of the review would be to identify areas where project implementation or process could have been improved, as well as limitations in funds, knowledge, peoples' skills or technology.
17	Confidence grade:	Project is in implementation phase only, and physical data is not yet available.

6. FACTSHEETS ON THE ENERGY SAVING MEASURES OR TECHNOLOGIES

Each subject or process area reported on the South African Energy Compendium will be introduced by a factsheet. The factsheets explain the technology at various levels and establishes a balanced appraisal of the engineering issues involved. The factsheets are compiled under the main headings of: Description of Process, Potential Interventions, and Range of Potential Savings. The template that was used for the factsheets is shown in Table 6.1.

Table 6.1: Fact Sheet template for the South African Compendium

Case Study Title:

Water Utility or Research Organisation

Introductory paragraph providing:

Background

Status

Description of process

Potential interventions

Range of potential savings

7. EXAMPLES OF SOUTH AFRICAN ENERGY EFFICIENCY FACT SHEETS

Table 7.1: Example of a Fact Sheet: CHP Systems for Biogas to Energy using Anaerobic Sludge Digestion: Johannesburg Water

CHP Systems for Biogas to Energy using Anaerobic Sludge Digestion:

Johannesburg Water

Energy intensive technology, such as activated sludge plants, will be unaffordable with increasing energy cost and demand-supply scenario in South Africa. The introduction of sludge digestion with cell lysis and appropriate scrubbing and primer technologies will increase conventional biogas production by 30%, thereby addressing the energy demand between 60-100% depending on type of treatment technology applied.

Description of process

Anaerobic sludge digestion is used to convert organic matter in sewage sludge to produce biogas via the various stages of hydrolysis, acidogenesis, acetogensis and methanogenesis. A typical sewage of 450-1000 mg/l will produce a biogas with 62-65% methane gas, which is a valuable source of energy. The efficiency of anaerobic digestion is directly linked to its biogas yield, and various methods can be employed to optimize biogas production: operating digesters at mesophilic conditions (32-38^{o}C), intermittent mixing; expanded retention times of 15-30 days; varying sludge feeding regimes, pretreatment and augmentation of sludge with biodegradable COD/BOD sources.

Combined Heat and Power (CHP) refers to the thermodynamic of cleaning and combustion of gas that will result in 60% of the energy source as heat and 40% as electrical power. CHP is done via prime movers such as generators or reciprocating engines, following a recommended course of cell lyses and biogas scrubbing. The value of the latter 2 processes is in its ability to disintegrate cell membranes with subsequent increase in biogas yield and the removal of impurities from the biogas to extend the life value of the asset and keep maintenance in balance.

Potential interventions

- Ensure a business model whereby CHP will as a minimum cover 60-100% of the electricity demand or generate a profit
- Outsource the O&M function to the equipment supplier, whilst developing (training) and electrical technologist within the municipality
- Optimise the digesters for maximum biogas output and methane yield by ensuring that good process control practice is in place
- Do not omit biogas scrubbing for the removal of H_2S, moisture, siloxanes and solids

Range of potential savings

CHP is capable of producing 10.2 MW electrical energy and 256.8 MWh/d heat in the City of Johannesburg, from 5 wastewater treatment plants which treat 1 047 000 m^3/day. Additional benefits include the reduction in carbon emission and trading in Carbon Credits.

Case study no.

8. CASE STUDIES

The Case Studies that were selected for inclusion in the South African Compendium are listed below, together with a brief description of each of the case studies. Full details on the case studies can be found in Appendix A on the CD enclosed in this compendium. Table 8.1 (page 40-41) provides the case study number, title, location and institution involved in the implementation or development work. This is followed by the Water Cycle Matrix (Table 8.2, page 42) from which the case studies and fact sheets can be accessed directly in the electronic version by clicking on the case study number.

Demand side (energy conservation): Incremental improvements in energy efficiency (retrofitting)

Supply side (energy generation): Substantial improvements in energy efficiency

8.1. Demand side (energy conservation): Incremental improvements in energy efficiency

The following case studies were identified for presentation in the compendium as initiatives or management systems that will lead to incremental improvement in energy efficiency through optimisation of existing assets and operations:

8.1.1. Pressure management in municipal water distribution systems (Durban)

Advanced pressure management was implemented in the Durban Central Business District (CBD). The objective of this initiative was to promote responsible management and usage of potable water and although this strategy includes both consumer and operator responsibilities, the main emphasis is on efficiency of water distribution from Water Service Authorities.

The commissioning of a pressure management system in the Durban CBD reduced the water loss levels in this area by 18.7 ML/day (which represents approximately 2% of the daily treated water purchases from Umgeni Water, the bulk water provider)and has resulted in an annual reduction of water purchases of R20.8 million for a capital investment of just 10% of the annual benefit (i.e. a payback period of less than 2 months).

8.1.2. Leakage reduction and water conservation (Emfuleni Local Municipality)

The project involved the design, installation and commissioning of a pressure reduction chamber with appropriate sizing, fitting and operation of the valves, pipes, meters, strainers and monitoring equipment. This consisted of cutting into existing water mains and replacing section with smaller diameter pipes and equipment. The chamber was operated to reduce pressure during off peak periods and restore to higher pressure during high demand period.

Reported leakage for a well-managed system is typically below 15% whereas in Sebokeng it was estimated to be in excess of 70% due to a number of factors including many years of low investment and poor maintenance. The reported cost saving from this project has been US$ 3.8 million/annum, 14 million kWh/annum and 8 million kilolitre water saved. The annual GHG emissions avoided was 12,000 tonnes. Payback on investment was three months.

8.1.3. Off-peak pumping (Durban Metro)

The Durban water distribution network is operated by Durban Metro Water Services (DMWS) and includes some 250 reservoirs, each of which has a level signal which is transmitted to a central SCADA system. Some pumps and valves in the network can be actuated remotely from this control point.

Optimisation of the operation of the distribution system by pumping at off-peak periods, while ensuring minimum emergency levels in all reservoirs, will not only effect an energy savings in terms of electrical energy used for pumping, but may also delay upgrades to the distribution system. 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 realize significant savings in electricity costs

8.1.4. Baseline energy audit approach

With escalating electricity costs and worldwide attention being focused on energy usage, some organisations are conducting audits on their energy consumption in an attempt to minimise usage and identify energy efficiency projects. Umgeni Water, a large water utility providing potable water in the greater Durban and Pietermaritzburg areas of KwaZulu Natal as well as in parts of the Eastern Cape, recently appointed consultants to conduct energy audits at a number of major sites. This case study provides a comprehensive audit methodology that can be used by organisations and utilities to assess energy baselines and identify energy saving initiatives.

The total estimated savings are 292.5 kW and around 91 000 MWh/annum. This equates to approximately R60 million per annum. The study indicated that the energy saving potential was highest from measures implemented on equipment, a total savings of 89 000 MWh/annum being possible, which correlates to a 45.6% savings on the current electrical energy usage for equipment. The potential energy savings that could be achieved from the implementation of lighting efficiency measures was much lower at only around 1 450 MWh/annum, although this constituted a 60.2% savings on the current baseline usage.

The total capital costs associated with these energy efficiency measures is approximately R40 million. The estimated Eskom rebate is R29 million making the final capital cost R11 million.

Considering the capital costs, rebates and annual saving the overall payback period for this project will be 2.2 months. This calculation makes provision for an escalation in the electricity price of 15% per annum which is considered conservative.

8.1.5. Life-cycle management

Historically, electricity efficiency measures have not been a priority in the South African water industry due to the relatively low cost of electricity. Over the last 5 to 10 years this situation has rapidly changing due to the increased demand, lack of electricity generating infrastructure and subsequent increase in electricity costs. This case study is an extraction from a larger environmental Life Cycle Assessment (LCA) study (developed through a series of individual LCAs), that was conducted on the water supply, treatment and recycling in the eThekwini Municipality. Specific focus of this case study revolves around the impact of energy consumption in the water treatment process and the potential in using electricity consumption as an environmental performance indicator.

8.1.6. Solar heating and composting

The introduction of the 2006 South Africa Sludge Guidelines heralded a new era in the management, treatment and disposal of sludge. Coupled with considerable increase in electricity costs from 2009 onward, thought had to be afforded to produce high quality sludge at reduced production cost. This case study describes the optimisation of mechanical assisted solar sludge drying and composting without the need for bulking agents and curing, with the sludge sourced from mesophilic digesters.

Fermented raw sludge and waste activated are stabilised through mesophilic digestion prior to dewatering on belt filter presses. Dewatered sludge with 20% dry solids content is spread on concrete beds. These beds were previously used for sludge composting using woodchips as a bulking agent. The dewatered sludge is turned daily using mechanical sludge turners and the dried sludge is removed from the beds once the dry solids concentration has reached about 50%. The drying period takes between 10-14 days in summer and 24-30 days in winter.

Sludge dried to the required total solids concentration allows for the sludge to be heaped to three meters high without the heap slumping or forming large clods. It also allows air to freely pass into the heap, which is essential for the composting process to proceed.

Temperatures in the heaps rise rapidly to 40-50°C and when the average temperature reaches above 60°C, the heaps are broken down and rebuilt using a mechanical turning. After rebuilding, temperatures are allowed to rise again and the rebuilding process repeats when temperatures rise > 60°C. Satisfactory stabilisation of the final product is achieved when the volatile solids concentration has been reduced to below 0.45 kg / kg DS.

8.1.7. Digester mixing optimization for energy efficiency

Anaerobic digestion efficiency is directly related to the success of the mixing equipment that brings microorganisms in contact with the substrate under optimised conditions. This case study explores early results after switching from conventional mixing systems to vertical linear motion mixing.

The digester mixing system consists of a flat horizontal plate fixed to the end of a metal shaft which is attached to a cam, driven by an electrical motor. As the cam slowly rotates, the rod and horizontal plate rise and fall, causing mixing of the digester content. The rod and plate are positioned inside the digester while the cam and motor rest on the roof. The hydro-disk throws out an upward moving liquid core on each downstroke, and a downwards moving core of liquid on each upstroke. These high energy cores dissipate into the slurry and produce a steady bulk circulation in the reactor. The disk is oscillating, but the majority of the liquid in the reactor does not oscillate but circulates in response to the directional movement from the hydro-disk. The advantage is that the energy consumption for a given mixing performance is a small fraction of the consumption using conventional mixers, as result of the radial/axial circulation.

Cost saving is estimated at R 830,000 per annum per digester, based on 350 kWh/day saving in energy. Ultimately Johannesburg Water will be operating 30 sludge digesters on their various works. Conservatively, it is estimated that a 50-60% power consumption reduction can be achieved using the mixing with the radial/axial circulation, as opposed to rotary fluid motion mixing.

8.1.8. High-rate algal oxidation ponds

This case study consisted of a comparative Analysis between the oxygenation capacity and oxygenation efficiency of the EBRU IAPS High Rate Algal Ponds and conventional aeration systems (CAS).

Preliminary estimates by researchers at EBRU, Rhodes University for high rate algal ponds are 15 kg O_2/kWh, based on the installed power of a paddlewheel. Further quantification of energy aspects were not included as part of the study and will receive attention in future work.

8.1.9. Submersible versus self-priming pumps

The study compares a submersible installation versus that of a self priming pumping installation and some of the criteria considered to select the more appropriate application. The testing conditions considered equal operating hours and the same energy cost for both applications. A conservative blockage ratio of 5 blockages per year was assumed for both submersible and self priming. Performance was considered as a function of the following categories: Performance data, operations data, capital cost and repairs cost.

The submersible installation has an initial lower listing price and accumulated cost in terms of electrical and mechanical staff and time. However, the self-priming installation cumulative costs are lower that the submersible from year 1.5 onwards and continue along the trend towards year 14. Energy has been used as a constant during the case study, but further field work should be done with energy consumption and cost over the asset life is a critical test parameter.

8.1.10. Load shedding and load shifting

This case study considers how a holiday resort with on-site water and sanitation services identified specific areas to shift- and shed electricity loads through demand management and a multi-phased energy optimisation project.

The Sun City project is in early days, but already efforts are recognised and data recorded and published. Sun City’s efforts in bringing the water and energy nexus closer through a focused strategy is acknowledge by the Department of Water Affairs through the Green Drop Certification process.

8.1.11. Water distribution system optimization

The Pollution Research Group, University of KZN in Durban conducted an investigation with the aim of optimizing the operation of potable water distribution networks. The main control objective defined during the preliminary steps was to maximise the use of low-cost power, maintaining at the same time minimum emergency levels in all reservoirs. The combination of dynamic elements (e.g. reservoirs) and discrete elements (pumps, valves, routing) was solved using Mixed Integer Non-linear Programming.

8.1.12. Prepayment metering and rehabilitation of water infrastructure

This case study considers a multi-faceted intervention project that focused on the rehabilitation of the Soweto water network and private plumbing fixtures, of which the installation of a prepayment metering system was paramount to the success.

8.1.13. Prepayment metering and pressure management

This case study considers a low income community with characteristics of a non-payment culture and high water losses. A technical approach was followed to reduce the unaccounted for water and improve the billing approach within the municipality.

The Kagiso model has been close to an ‘ideal’ model and is used to replicate similar scenarios across South Africa. An extension of the project to neighbouring zones (residential areas) would have maximised the output from the project.

8.2. Supply side (energy generation): Substantial improvements in energy efficiency

The following case studies have been identified for presentation in the compendium as new technologies or systems which will lead to substantial improvement in energy efficiency:

8.2.1. CHP Biogas to electricity

Energy intensive technology, such as activated sludge plants, is fast becoming a high-cost item on municipal budgets amidst the rising electricity tariffs and vulnerable demand-supply dynamics in South Africa. The introduction of sludge digestion with cell lysis and appropriate scrubbing and primer technologies will increase conventional biogas production by 30%, thereby addressing the energy demand between 60-100% depending on type of treatment technology applied.

In the City of Johannesburg, CHP is capable of producing 10.2 MW electrical energy and 12.2 MW heat from five wastewater treatment plants treating 1 047 000 m^3/day.

8.2.2. Cost-benefit model for biogas production

Anaerobic digestion and biogas generation technology is well established in South Africa. However, the development of models to allow for scenario simulation to provide approximate costing and biogas yields projections associated with CHP are not widely used or available. This case study explores the use of a simplified model to assist planning and financing requirements, as a replicable approach for further case studies.

CHP is capable of producing 9.2 MWe electrical energy and 10.0 MW heat from 5 wastewater treatment plants treating 1 022 700 m^3/day (2011). The simulation model serves to project and predict the associated cost and biogas yield against variable input flow scenarios.

8.2.3. Energy recovery devices in desalination systems

Desalination plants are infamous for their high electrical consumptions. In South Africa over 75% of electricity is generated from fossil fuels. The growing need to lower carbon emission has led to a desire to lower electricity consumption in all sectors of South Africa. The use of ERDs has shown to reduce the energy consumption of desalination plants by 20-40%.

The energy savings ranged from 47.7-50% for the Pressure Exchanger used at Plettenberg Bay, 30.3-30.6% for the Pelton Turbine used at Knysna, and 29.4-43.3% for the East London plant using a Pressure Exchanger ERD. At Mossel Bay, around 30% energy savings were measured (the plant uses 60 MWh/d with the ERDs).

8.2.4. Energy recovery for reverse osmosis

This case study considers the upgrade of Reverse Osmosis at the Albany Water Treatment Works alongside the incorporation of an energy recovery system to reduce electrical cost.

8.2.5. Fine bubble diffused air systems

As results of sharp increases in the price of electricity and the need to conserve energy, Johannesburg Water has studied the energy efficiency of different aeration systems by investigating the cost and energy efficiency of various aeration systems.

Based on energy efficiency as only criteria, the fine bubble aeration system is a preferred system. Based on overall suitability and total life cycle cost or NPV, mechanical surface aeration is the preferred system in Johannesburg Water.

8.2.6. Diffused air injection (vertical aligned diffusor pipes)

As a result of continuing severe increases in the price of electricity and high maintenance cost of the Brush aerators, ERWAT has investigated new energy efficient Floating Fine-bubble Aeration systems. The literature oxygen efficiency for brush aerators is 1.8 kg O_2/ kWh. This will reduce to 1.22 kg O_2/ kWh when adjusted for altitude and sewage water. With all four brush aerators, each with 18.5 kW motors, the maximum oxygen supply from 74 kW total is 90 kg O_2/ kWh At current conditions with one brush aerator out of service and another operating at 66% capacity, the brush aerators can deliver a maximum of 49.2 kW of power and supply **60 kg of oxygen per hour** to the water.

The two surface aerators have a combined power rating of 60 kW, drawing approximately 54 kW with the capability of delivering 1.8 kg O_2/ kWh at sea level in clean water. Adjusted for altitude and sewage water this would drop to 1.22 kg O_2/ kWh. This would add approximately **65.9 Kg Oxygen to the water per hour.** The Total Power consumption for aeration is estimated at 103.2 kW (49.2 + 54) which can supply a maximum of 129.5 kg per hour (60 + 65.9)

8.2.7. Hydro-power generation with mini hydroturbines in pressurized distribution networks

Water in water distribution networks is often fed under gravity from a higher reservoir to another reservoir at a lower level. The high pressure head at the receiving reservoir is then dissipated through the control valves (altitude valves) or in some cases, orifice plates. In this hydropower generating application, electricity is generated in a cross-flow turbine using the available pressure head.

The feasibility studies conducted thus far indicated that these types of hydro power installations have a relatively short payback period. The reason for this is the minimum amount of 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 Municipality's or Water Board's would utilize their own budgets to finance such projects.

8.2.8. Mini hydropower generators

eThekwini Metropolitan conducted a feasibility study on the Northern Aqueduct in the Durban potable water distribution system. This Northern Aqueduct is fairly complex, consisting of 39 reservoirs and water demand is often in danger of exceeding the supply. The feasibility study was based on the installation of six mini hydro generators, each capable of 150 to 180 KW. Based on this study, invitations for tender were put out by eThekwini Metropolitan for 6 turbines. However, these were going to cost in the region of R35 million which was deemed too expensive and as a result the specifications of the tender were modified in order to reduce costs. The modified request for tender was for two turbines, but to date, the Council has rejected this option. The cost of these turbines is expected to be between R6 million and R8 million each. In the meantime, eThekwini Metropolitan is exploring the option of funding from Eskom, the national electricity supplier. Eskom has projects in which electricity generation of between 1000 kW and 1 MW are funded at a rate of R0.70/kW for a period of 3-5 years after commissioning. Should this funding be obtained, the project for two mini hydro generators in the Northern Aqueduct is expected to go ahead.

8.2.9. Novel sewage treatment systems

Royal Haskoning DHV (RHDHV) claim that the Nereda process can be used to treat both domestic and industrial wastewaters to produce final discharge water that conforms to effluent standards as set down by the Department of Water Affairs. The technology is based on aerobic sludge granules which not only settle at a much higher rate than activated sludge found in conventional biological nutrient removal (BNR) plants, but also allows for a much higher microbial density than that found in conventional activated sludge plants. The increased efficiency of the process therefore allows for very compact treatment works.

The Nereda technology allows energy savings as high as 35% compared to conventional BNR plants, while construction costs are around 20-40% lower than that for conventional works. In addition, chemical addition for phosphate removal is not required.

Table 8.1: Details of the identified case studies

Case Study No.	Title	Location	Project / Case Study owner
DEMAND SIDE (Energy Conservation)			
Water management			
SA-EM1	Pressure management	Durban	eThekwini Municipality
SA-EMF	Leakage reduction and water conservation	Sebokeng / Vereeniging	Emfuleni
SA-UW1	Baseline energy audit approach	Greater Durban area	Umgeni Water
SA-AM1	Water energy reduction action plan	Eastern Cape	Amatola Water
Pumping and pumps			
SA-CT2	Submersible vs. self-priming pumps	Pretoria	City of Tshwane
SA-KZN	Off-peak pumping	Durban	UKZN
SA-EM2	Pumping scheme arrangements	Durban	Bluff WWTW

Table 8.1: Details of the identified case studies

Case Study No.	Title	Location	Project / Case Study owner
Desalination			
SA-SC	Energy recovery devices in desalination systems	South-Cape	Veolia Water (Southern Cape desalination plants)
SA-AM2	Reverse osmosis system	Amatola Water	Kenton-on-Sea
Life-cycle management			
SA-EM3	Life-cycle assessment	Durban	eThekwini Municipality
Aeration			
SA-ERWAT	Diffused air injection	East Rand	ERWAT
SA-JW1	Blower efficiency	Johannesburg	Johannesburg Water (Dave Nozaic)
SA-JW2	Fine-bubble aeration	Johannesburg	Johannesburg Water
Wastewater Treatment Ponds			
SA-RU	High-rate algal ponds	National	Rhodes University
Sludge Management			
SA-JW3	Digester mixing (vertical mixer)	Johannesburg	Johannesburg Water
SA-JW4	Solar heating and composting	Johannesburg	Johannesburg Water
Novel Wastewater Treatment Technologies			
SA-OM	SBR system (Nereda)	Gansbaai Wemmershoek	Municipalities of Overstrand and Stellenbosch
Load Shedding			
SA-SUN	Load shedding and load shifting	North West Province	Sun City
Water Distribution			
SA-EM4	Water distribution optimisation	Durban	UKZN
SA-EMF1	Prepayment metering and fixtures	Soweto	Emfuleni
SA-KAG	Prepayment metering and pressure management	Kagiso	Mogale City
SUPPLY SIDE (Energy Generation)			
Biogas to Energy			
SA-JW5	CHP biogas	Johannesburg	Johannesburg Water
SA-EM5	Biogas energy generation	Durban	eThekwini
SA-JW6	Cost-benefit decision support tool for biogas production	Johannesburg	Johannesburg Water
Energy Generation with hydro-turbines in Water Distribution Systems			
SA-CT3	Energy generation with mini-hydroturbines	Pretoria	University of Pretoria
SA-EM6	Mini-hydropower generators	Durban	eThekwini
SA-EM7	Western Aqueduct	Durban	eThekwini

Table 8.2: Water Cycle Matrix of the South African compendium

WATER CYCLE ENERGY SAVING MATRIX		Drinking Water			Wastewater		
		Raw Water	Treatment	Distribution	Sewerage	Treatment	Disposal
Energy Estimate (% of whole)		25	10	65	25	60	15
Demand Management	Conservation (Water & Energy)	SA-MB	SA-MB	SA-MB			
	Leakage Reduction			SA-EMF; SA-EM1			
	Prepayment metering			SA-EMF1; SA-KAG			
Pumping	Optimise Gravity Flow						
	Pumping and pumps	SA-KZN; SA-CT2; SA-CT1	SA-CT1	SA1; SA-KZN; SA-CT1	SA-KZN; SA-CT2; SA-CT1; SA-EM2	SA-CT2; SA-CT1	SA-CT1
	Management systems	SA-AM1; SA-UW1; SA-EMF	SA-AM1; SA-UW1; SA-EMF	SA-AM1; SA-EM1; SA-EM4; SA-UW1; SA-EMF	SA-EM3; SA-SUN	SA-EM3; SA-JW6; SA-SUN	SA-EM3
Treatment	Pond systems					SA-RU	
	Aeration					SA-JW1; SA-JW2; SA-ERWAT	
	Mixing / Coagulation						
	Nutrient Removal						
	RAS Pumping						
	Membrane Treatment		SA-SC; SA-AM2				
	Disinfection / UV						
	New WWT systems					SA-OM	
Sludge	Thickening / Dewatering						
	Digestion / Co-digestion					SA-JW3	
	Sludge Drying					SA-JW4	
	Building Services						
Generation	Mini Hydro-Turbines			SA-CT3; SA-EM6; SA-EM7			
	Wind Turbines						
	Solar Power						
	Biogas / CHP					SA-JW5; SA-EM5; SA-JW6	

The confidence grade of the data reported for the various case studies is also important, as this will direct the use or application of the case study data. The confidence grade of each of the case studies is provided in Table 8.3.

Table 8.3: Confidence grade of data reported in the South African case studies

Case Study No.	Title	Location	Project/Case Study owner	Confidence grade
DEMAND SIDE (Energy Conservation)				
Water Management				
SA-EM1	Pressure reduction management	Durban	eThekwini Municipality	High. This project has been running for 3 years and the estimated savings have been realized.
SA-EMF	Leakage reduction and water conservation	Sebokeng / Vereeniging	Emfuleni	Medium to high. Data focus on financial aspects with supportive data and information. However, audited results would imply that engineering and scientific fact is in place and factual. Energy monitoring data are not necessary since the water savings are accurately monitored and the associated energy savings are calculated directly from the water savings. The energy savings err on the conservative side
SA-UW1	Management reports as planning tool	Greater Durban area	Umgeni Water	High. The recommendations have not yet been implemented, but the technology is proven, so the confidence grade is high.
SA-AM1	Water energy reduction action plan	Eastern Cape	Amatola Water	Medium. The case study is based on projected versus actual data. Further work is needed and is continuing.
Pumping and Pumps				
SA-CT2	Submersible vs. self-priming pumps in wastewater pumping	Pretoria	City of Tshwane	Low. Developmental work and impact on decision making in terms of pump selection.
SA-KZN	Off-peak pumping	Durban	UKZN	Low. Still in the research stage.
SA-EM2	Pumping scheme arrangements	Durban	Bluff WWTW	High. The technology being used has been successfully used elsewhere, so although the project has not been completed yet, the confidence grade is high.
Desalination				
SA-SC	Energy recovery devices in desalination systems	South-Cape	Veolia Water (Southern Cape desalination plants)	Medium. Because the Mossel Bay plant has only been operational for 3 months (to date of writing) the data, assumptions and conclusions made cannot be fully trusted. Only at a later stage can more concrete date be collected. The Plettenberg Bay and Knysna plants are not operating (at date written). The data gathered is also of a small time period and can therefore also not be trusted. The East London plant has been fully operational for over a year now, therefore it can be assumed that the data gathered at this plant is trustworthy.
SA-AM2	Reverse osmosis system	Amatola Water	Kenton-on-Sea	High. The case study is based on material and data analysed by specialist a group. Further work is continuing.

Table 8.3: Confidence grade of data reported in the South African case studies

Case Study No.	Title	Location	Project/Case Study owner	Confidence grade
Life-cycle Management				
SA-EM3	Life-cycle assessment	Durban	eThekwini Municipality	Medium to High: Data collected from various sources, quality of data varied, due to use of calculated data when real data were not available. Background process in a sub-system used secondary data, and Processes of the primary suppliers and processes within the plant were defined as foreground and site specific data was collected.
Aeration				
SA-ERWAT	Diffused-air injection	East Rand	ERWAT	Medium. The document forms the design basis of the case study which requires to be validated in practice based on material and data analysed during the trials. Further work is continuing. International experience with similar “Pasveer” type plants has shown over 50% energy saving.
SA-JW1	Aeration blower efficiency	Johannesburg	Johannesburg Water	Medium-high. This project is still in the planning stage, but the technology has been used before and so there is a high level of confidence in this project.
SA-JW2	Fine-bubble aeration	Johannesburg	Johannesburg Water	High. The case study is based on material and data analysed by specialist a group. Further work is continuing.
Wastewater Treatment Ponds				
SA-RU	High-rate algal ponds	National	Rhodes University	High, in terms of energy-oxygenation requirement. Medium, in terms of more research required to incorporate cost-energy comparisons with other technologies.
Sludge Management				
SA-JW3	Anaerobic digester mixing (vertical mixer)	Johannesburg	Johannesburg Water	Low. This is work in progress and performance need to be monitored over a two year project cycle. The main concern that Johannesburg has at present is failure of the plate fixture to the metal rod. This will need to be inspected when the digester is emptied for cleaning out of any settled material.
SA-JW4	Solar heating and composting	Johannesburg	Johannesburg Water	High. The data has been well documented and verified over more than two operational years. The data shows that, to date, only a limited number of composted batches failed the guideline requirements. Such batches have either been reformed or mixed with new dried material. The operation has consistently produced a class A1a final product which is sort after by maize farmers. At present, 19 farmers use the product with a waiting list of a further 20 farmers.

Table 8.3: Confidence grade of data reported in the South African case studies

Case Study No.	Title	Location	Project/Case Study owner	Confidence grade
Novel Wastewater Treatment Technologies				
SA-OM	SBR system (Nereda)	Gansbaai Wemmers-hoek	Municipalities of Overstrand and Stellenbosch	High. The confidence level is high, since some systems have already been in use for some 4 years already and have operated successfully.
Load Shedding				
SA-SUN	Load shedding and load shifting	North West Province	Sun City	High. The data focus on financial aspects with supportive data and information regarding the energy consumption before and after interventions. The energy savings are based on real time monitoring and transparent tariff recording and calculations. The corresponding energy and water footprint could receive further attention.
SUPPLY SIDE (Energy Generation)				
Biogas to Energy				
SA-JW5	CHP biogas from sludge digestion	Johannesburg	Johannesburg Water	Medium. Project is in implementation phase only, and physical data is not yet available.
SA-EM5	Biogas energy generation	Durban	eThekwini	High. Confidence is good as this is not new technology and has been successfully implemented elsewhere. However, not many biogas projects have been implemented in South Africa, so the technology is fairly new to this country.
SA-JW6	Cost-benefit decision support tool for biogas production	Johannesburg	Johannesburg Water	Low. The confidence level is low until such time that model output data can be verified with actual output data.
Energy Generation in Water Distribution Systems				
SA-CT3	Mini hydro-power generation in water distribution systems	Pretoria	University of Pretoria	High. It is a research project by University of Pretoria for the Water Research Commission.
SA-EM6	Mini-hydropower generators	Durban	eThekwini	High. Although the project has not been completed, or even implemented, the technology is proven and the confidence level that it will be successful is high.
SA-EM7	Western Aqueduct	Durban	eThekwini	Medium to high. Although the project has not been completed, or even implemented, the technology is proven and the confidence level that it will be successful is fairly high until at least 2030.

9. GUIDANCE SECTION ON ENERGY EFFICIENCY

9.1. What is an energy audit?

Optimize energy consumption and identify energy savings opportunities by means of an energy audit. Such audits require plant operational data and monthly electrical accounts for the plant. Drawings and data of electrical equipment will ease the process of such an assessment. The price structure of the plant's electrical account will benefit in understanding the cost structure for the WWTP during assessment stages. Issues such as electrical load management during peak demand periods must be clear and understood by the plant operations staff. **E**nergy savings opportunities from demand side management (DSM) programmes include reduction in energy costs by shifting the power consumption from "on-peak" to "off-peak" hours. Such options need careful consideration for large treatment plants. Small and seasonal WWTPs may benefit from such an opportunity.

9.2. THE PRICING ASPECTS AND TRENDS

9.2.1. South Africa's electricity supply

Eskom produces the bulk of power generated in South Africa, while large municipalities and a small number of private power producers generate small percentages. Eskom also owns and operates the national high voltage transmission grid, which conveys electricity from Eskom power stations to the main load centres across the country. Eskom holds >55% of the distribution and retail market in terms of energy supplied, while the remainder of its energy is sold to Municipalities who retail it to other end-users. For Eskom, the overall price of electricity is regulated and is based on approved costs plus a return on investment as determined by the National Electricity Regulator of South Africa. NERSA decides on a revenue requirement and from this calculates an average price increase. This average increase is the difference between the total revenue requirement and kWh sales for the year before and the revenue and sales for the year under review.

9.2.2. Eskom's electricity pricing

Eskom's average price for electricity is based on the overall cost of supply but, in order to determine tariffs, overall costs are broken down into relevant cost categories. Common cost drivers are:

- R/customer/month or R/customer/day – typically for customer service and administration costs
- R/kVA – typically for network costs
- c/kWh – typically for energy costs
- c/kvarh – reactive energy costs
- Energy loss factors for energy loss costs

The cost of providing electricity to customers varies according to:

- The quantity of electricity used and the period (time or season) when the electricity is used
- The size/capacity of the supply required
- The geographic location of the customer
- The voltage at which supply is provided
- The cost of connecting a supply

9.2.3. Electricity cost and trends analysis

Eskom's tariffs are adjusted on an annual basis. The average tariff adjustments for the last 15 years are indicated in the table below. Some tariffs, due to structural changes, have experienced a higher or lower impact than the average tariff adjustment. *The average price adjustment for 2013/14 has been approved by NERSA to be 8%.*

Table 9.1: Eskom's average tariff adjustment for the last 15 years

Year	Average price adjustment (%)	CPI (%)
1 January 1997	5.00	8.62
1 January 1998	5.00	6.87
1 January 1999	4.50	5.21
1 January 2000	5.50	5.37
1 January 2001	5.20	5.70
1 January 2002	6.20	9.20
1 January 2003	8.43	5.80
1 January 2004	2.50	1.40
1 January 2005	4.10	3.42
1 April 2006/7	5.10	4.70
1 April 2007/8	5.90	7.10
2 April 2008/9*	27.50	10.30
2 April 2009/10	31.30	6.16
3 April 2010/11	24.80	5.40
4 April 2011/12	25.80	4.50
1 April 2013/14	8.00	

* Comprises two increases in 2008/9, average of 14.2% on 1 April 2008 and 34.2% on 1 July 2008

Eskom's tariff adjustment can be depicted as shown in Figure 9.1, as a % of CPI (cumulative graph)– base = 1990.

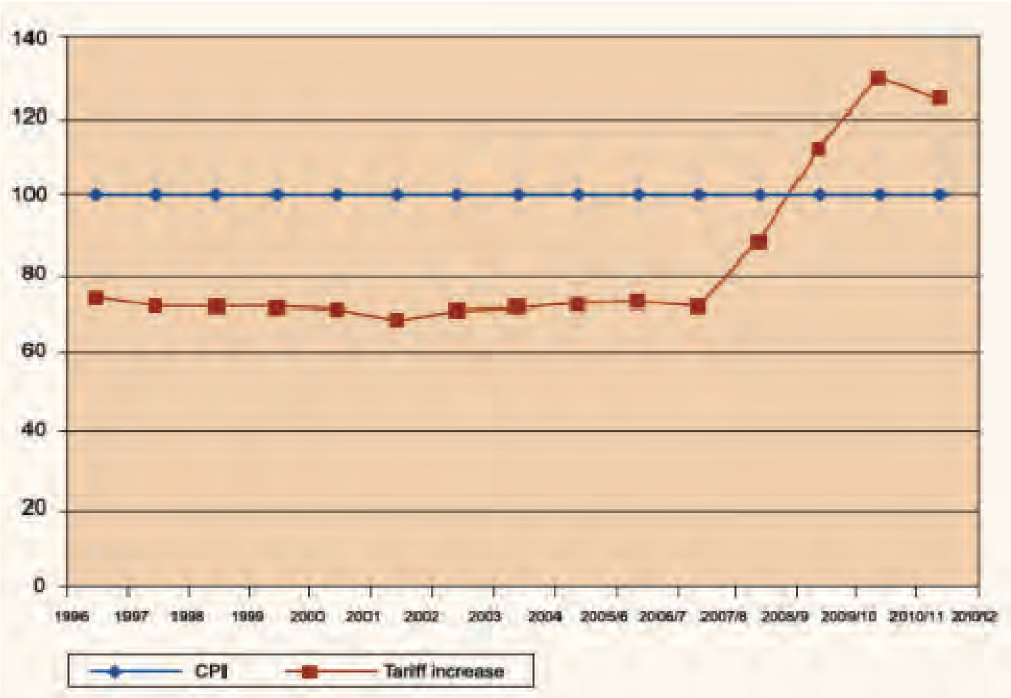

Figure 9.1: Eskom tariff adjustments over the last 15 years compared to the CPI

9.2.4. Municipal electricity tariffs

Municipalities are local distributors of electricity and are subject to 'regulation by comparison'. Currently, a high proportion of municipalities supplying electricity have tariffs that are not formally approved by NERSA or Eskom. However, NERSA provided benchmarks whereby municipalities could implement Inclining Block Tariffs (IBTs) as from June 2009, in line with the Electricity Pricing Policy (EPP) (Table 9.2). Municipalities are required to implement such IBTs concurrently with price increases.

Table 9.2: NERSA benchmarked Inclining Block Tariffs (IBTs)

Monthly Consumption Level	2010/11	2011/12	2012/13
Block 1 (1-50 kWh)	5.60%	5.50%	5.50%
Block 2 (51-350 kWh)	7.30%	7.73%	8.00%
Block 3 (351-600 kWh)	15.33%	16.03%	16.16%
Block 4 (>600 kWh)	15.33%	16.03%	16.16%

Due to the new national pricing regime and national tariff re-structures, many municipality electricity tariffs previously offered (prior to 2008) are no longer cost reflective and are being phased out in municipalities. Non cost reflective tariffs attract higher than average increases and municipal customers purchasing electricity on these tariff structures are encouraged to investigate their electricity consumption profiles and evaluate the feasibility of migrating to alternate cost effective tariff structures. Large/medium sized customers (e.g. municipal bulk water and wastewater operators) that consume electricity on a 24 hour basis should consider the option of time of use tariffs. Whilst the tariff structure is more complex, customers will reap the benefit of cheaper off peak electricity rates. By incorporating load shifting /load clipping techniques and energy efficiency measures to reduce peak loading, customers can realize further savings.

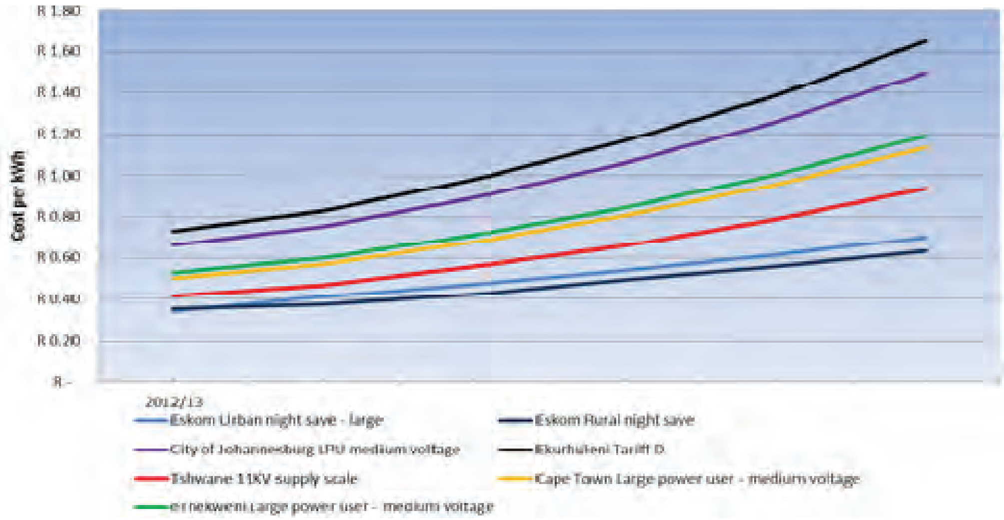

Figure 9.2: Comparison of the 2012/14 price between Eskom and three metro cities in South Africa as estimated R/kWh increase as per tariff:

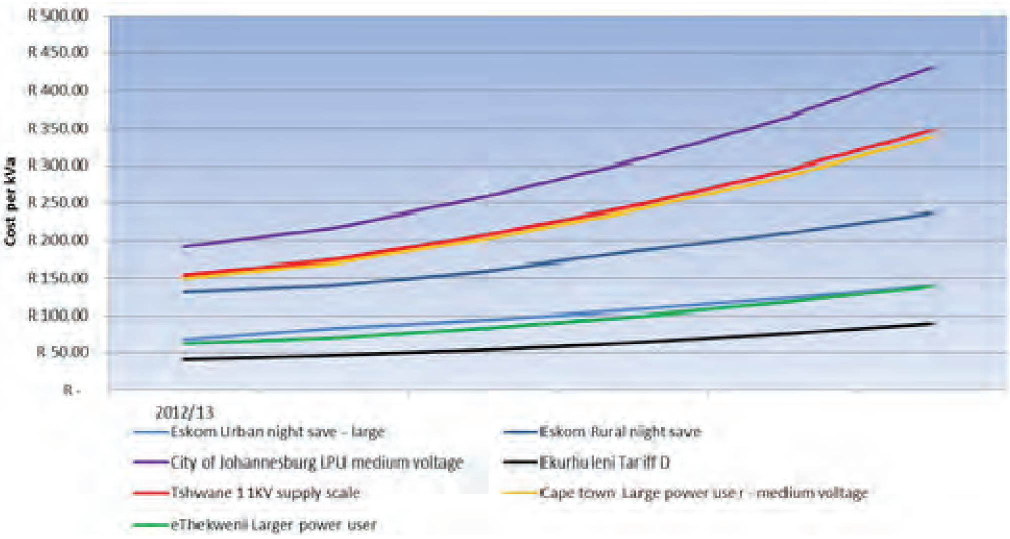

Figure 9.3: Graphic representation of estimated Rand per kVa increase as per tariff

9.2.5. Future supply projections

In line with the Department of Energy's (DoE) IRP 2010 report, South Africa needs to increase its capacity by 45 000 MW by 2030. This figure excluded Eskom's present capacity expansion projects which run up to Kusile Power Plant and present IPP agreements.

For illustration purposes Eskom has incorporated these IRP 2010 requirements into the MYPD 3 proposal and as established tariff price increases for two scenarios. Both scenarios means Eskom has to increase its planned supply capacity above that of the planned 2017/18 capacity, which includes Kusile power plant and PPI agreements. This means that Eskom needs to increase its capital and thus would have to increase its tariffs in the immediate to longer term future:

65% – Eskom is responsible for 65% capacity and IPP are responsible for remainder 35%.

100% – Eskom is responsible for the complete demand capacity till 2030.

9.2.5.1. 65% Scenario

In the event that DoE prescribes 65% of supply responsibility for the increase in capacity, Eskom would need to increase their proposal for the MYPD 3 period from 16% to 20%. For the periods of the MYPD (2018/19 to 2013/24) an additional 9% increase is calculated for a further 5 years, after which it will decrease to average of 5% until 20130.

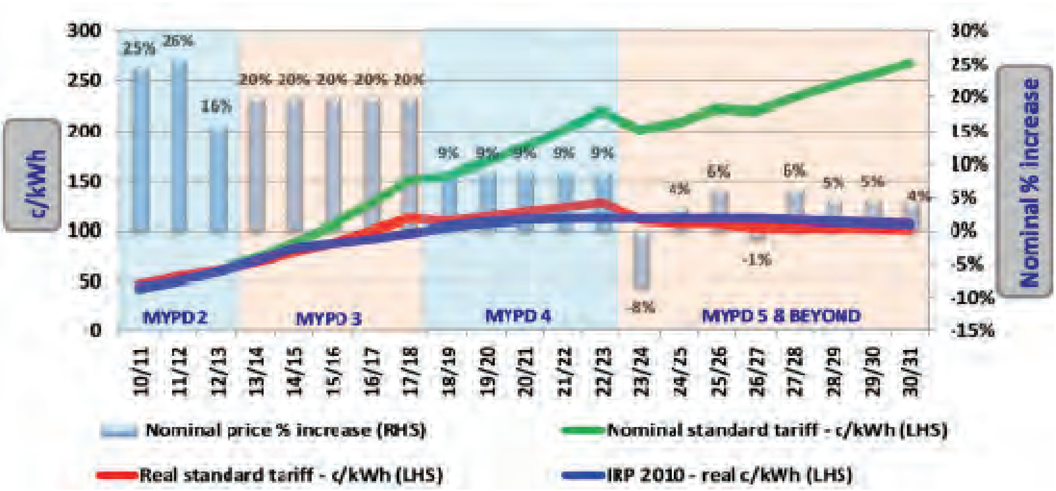

Figure 9.4: Estimated price increase for the period 2013/14 to 2030/31 based on the 65% scenario

9.2.5.2. 100% Scenario

Eskom confirmed that the additional 35% to make up 100% would not have a major impact on the immediate price increase. For the periods 2013/14 to 2017/18, an increase of 20% is still proposed after which an increase of 11% for 2018/19 (compared to 9%) and 9% thereafter is recommended. Further small variation occurs for the periods 2023/24 to 2030/31 compared to the "65%" scenario.

At present, both scenarios remain a discussion point, but provide meaningful impression as to the longer term increased pricing impact on the water sector. The price increases are therefore used conceptually to emphasize the need to for water services providers to calculate the viability of "energy efficient" projects and technology.

9.2.5.3. Cost reflection by a typical municipality – eThekwini

Following the electricity tariff increase of 16% by Eskom for 2012/13, the eThekwini municipality shared its concern as follows: "Overall electricity consumption in South Africa is increasing at a much quicker rate than the new national power station build program. This has serious impacts on the existing reserve margin, shrinking it day by day as we progressively consume more. In an effort to manage our supply demand constraint, I appeal to all electricity users to embrace an energy efficient culture and help our country pull through the energy crisis. I trust that you will join us in the nationwide drive to save electricity and help our city and our country to maintain a stable and continuous electricity supply..."

In the same statement, eThekwini shared is positive approach: "NERSA has approved an average price increase of 16% on Eskom tariffs effective 01 April 2012. This equates to a 13.5% increase in electricity costs for municipalities effective from 01 July 2012. In line with this, eThekwini Electricity has proposed an overall average tariff increase of 11.00% as per the regulators guideline. We have endeavoured to keep increases as low as possible and have passed on a 12.00% increase to business and industrial customers, 9.8% increase to residential customers and our indigent customer category will continue to receive 65 kWh free per month and will be subject to a 5.41 % increase for energy purchased thereafter. Obsolete and discontinued tariffs are no longer cost reflective and will be subject to a 12.5% increase in the next financial year. Customers purchasing electricity on these tariffs are urged to investigate their load profiles and migrate to alternate cheaper tariff structures where possible.

9.2.5.4. Cost reflection in a typical municipality – Johannesburg

Energy has become a key driver in the wastewater treatment value chain of Johannesburg and every effort is being made to produce “green energy” and reduce power consumption. Johannesburg Water operates and maintains six wastewater treatment works and treated about 1 054 000 m^3 of sewage per day in 2010. All of the sewage treated was by the activated sludge process and about 90% of the 260 dry tons of sludge produced per day, consisted of waste activated sludge.

It is estimated that by 2020, the cost of electricity for the treatment of wastewater in Johannesburg would have risen from R 97 m per annum (2010) to > R 300 m per annum (2013), making the existing wastewater treatment operation possibly unaffordable. Failure of the wastewater treatment operations would have a devastating effect on the economy, environment, health services and social activities of the City.

Table 9.3 shows the effluent compliance, energy consumption, ferric chloride use and cost per m^3 wastewater treated over time (2000-2012), noting the measures taken to achieve electricity savings.

Table 9.3: Effluent compliance, energy consumption, ferric chloride use and cost per m^3 wastewater per year for the period 2000 to 2010

Operational years	Final Effluent Compliance (%)	Electricity consumed (kWh/ML)	Ferric chloride dosage (kg soln/ML)	Cost (cent/m^3)
2000-2001	87.9	500	ND	29.9
2001-2002	92.8	468	500	ND
2002-2003	95.6	358	468	ND
2004-2005	98.1	340	358	40.9
2005-2006	97.8	337	340	44.5
2006-2007	95.7	345	337	48.0
2007-2008	96.0	331	345	47.1
2008-2009	95.6	387	331	59.1
2009-2010	95.9	378	387	65.0

Energy improvement was achieved by the City of Johannesburg through:

- Power factor correction installed.
- Targets set and annual reduction in the limits for power and ferric use.
- Automation of the aeration systems.
- Control of the maximum and minimum dissolved oxygen concentrations.
- Hydraulic balancing of bioreactor influents.
- Guidelines and Best Practices in demand side management (energy conservation)

Water distribution:

- Optimisation of water distribution of large systems needs to be automated and any modelling 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.

- Extensive community and council consultation of the causes and intervention proposed to reduce water losses is essential.
- Use local skilled and unskilled labour to repair and replace faulty or dilapidated plumbing fixtures.
- Replace redundant or aged water distribution infrastructure.
- Install prepayment meters and management systems where required.
- Establish community centres to buy credit for use above 6 kl Free Basic Water.
- Adopt a Water Demand Management and Prepayment Policy in council.
- Install bulk check meters and zone meters to configure a baseline.
- Use a multi-disciplinary approach that involves the water technicians, meter readers from the finance department, billing department, GIS staff, councillors and community.
- Do repairs and maintenance of the water network and plumbing faults.
- Pressure reduction management in water distribution systems (networks):
- The supply of water to adjacent supply zones must be taken into consideration and integrated into the design of the pressure management system.
- The existing level of service for water supply to customers is not affected during peak demand periods. This places a minimum residual peak pressure requirement of 30 m head for service connections.
- The fire-fighting capacity of the system should not be compromised.
- PRV's should be installed above-ground in line with the prevailing standards of the Client, and in as small a space as practically possible.

Leakage reduction and water conservation:

- Pressure reduction is a first 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 in an area. Be sure to respond timeously to reported bursts, consumer complaints, and unexpected changes in flow or pressure.
- Performance contracting to water supply is key to low capacity municipal suppliers.

Pumps and pumping efficiency:

- "Pump efficiency" can differ in definition depending on the various performance-, operational- and cost parameters used to determine 'efficiency'. Standard practice should be a comparison of pump options under specific operating conditions prior to pump selection, i.e. density and type of medium, flow velocity, pipe design, spares availability, maintenance and repairs skill at hand, etc.
- Pump efficiency is critically dependent on maintenance and operational aspects. Decision making and selection of pumps, whether submersible or self-priming, should always include these aspects as part of the life cycle considerations. It is possible that initial higher capital cost pumps may have a longer life cycle and lower operations and maintenance cost associated.
- 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.

Aeration in wastewater treatment plants:

- To minimising power consumption and maximising performance in mechanical surface aeration systems, the following are important: i) control of the present oxygen concentration in aerated liquid within 1-2 mg/L, where control can be facilitate 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.
- Blowers for aerations systems are a major source of energy consumption. Proper selection can result in high efficiencies. Proper maintenance of aeration diffusers is critical to preset head loss due to fouling and to reduce energy costs. For dynamic compressors, turndown is best achieved using inlet throttling using adjustable inlet guide vanes.
- Large modern installations all operate on dissolved air control in order to obtain optimal energy efficiency.
- The blower control mechanism is on PLC which optimizes the duty point for maximum efficiency.

Life-cycle assessment:

- Locate industries closer to wastewater works for supply of recycled water.
- Specific actions at various units will results reduced energy consumption (cost saving) and in improved environmental impacts, actions such as:
  - o 70% reduction in electricity use by limiting airflow to the thermal unit of the ozonation unit = saving of 1 173 kWh/d.
  - o sludge management activities such as: aeration efficiency improvement, varying operating conditions, using chemical pre-treatment. The latter showed a potential saving of 250-280 MWh/y (roughly equals 685-767 kWh/d).
- Proactive measures taken in Collection & Distribution, through reducing leakage will lead to water savings and electricity savings:
  - o supplier demand – Water loss management (target of 20% by 2012) = water saving of 82 Mℓ/d
  - o consumer demand -introduction of rising block tariff = a potential water saving of 27 Mℓ/d.
- For water and wastewater system, the use of an energy audit may be preferable to a detailed LCA, depending on the output desired and the intended use of the audit information.
- Treatment plant and pump station operators using an Electricity Index and consumption measurements at the various units to identify problem areas, could facilitate more efficient energy management (cost saving) and improved environmental impacts.

Load shedding:

- Adoption of an Energy Management Strategy that link water, energy and other areas of facility management into an integrated approach.
- Upgrading of electricity grid and installation of consumption metering in real time, and a management system.
- Identify units with high energy consumption during maximum demand periods when high tariffs apply.
- Shifting of work periods of identified equipment to time spans when lower tariffs apply.
- Maintaining supply MVA against setpoint MVA, revert to load shedding when exceeding set point.
- Replacement of electrical geysers with solar geysers.
- Upgrade of technology for pool heating and boiler to improve performance and save energy.

Best practices in supply side management (energy generation)

Hydro-power generation in water distribution systems:

- Electricity generation will be negatively affected during periods in which demand exceeds supply, so ensuring an adequate water supply in reservoirs upstream of the generators will be important in ensuring optimal energy generation.

- Generation of electricity will be carried out by a Public Private Partnership in which eThekwini Metropolitan will purchase the generators, but the cost of all other equipment and all the costs of operation and maintenance will be borne by the private partner.
- The private company will be assured of a market for the electricity generated through a 20 or 30 year contract with eThekwini Metropolitan which will include the selling of electricity to Durban Electricity, a subsidiary of eThekwini Municipality.
- 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.
- Biogas energy production:
- 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 in the gas will result in damage to the gas engines and affect electricity generation.
- Careful selection of the type of transformer needs to be made. The decision needs to be made as to whether the transformer should be a one way transformer only capable of powering the wastewater treatment works, or a two way transformer capable of returning power to the grid.
- 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 (National Electricity supplier in the Southern African region) 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.
- Ensure a business model whereby CHP will as a minimum cover 60-80% of the electricity demand or generate a profit
- Outsource the O&M function to the equipment supplier, whilst developing (training) and electrical technologist within the municipality
- Optimise the digesters for maximum biogas output and methane yield by ensuring that good process control practice is in place
- Do not omit biogas scrubbing for the removal of H_2S, moisture, siloxanes and solids.
- Ensure a cost-benefit model is in place whereby 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.

10. RECOMMENDATIONS

The following recommendations are made from the energy efficiency case studies and best practices reported on in this compendium:

The guidelines and best practices should be used as basis for development of energy efficiency and energy conservation targets for the South African water sector. These targets can then be implemented, encouraged and regulated through the Department of Water Affairs' Blue Drop and Green Drop programs.

Municipalities should already start using the guidelines for energy conservation and energy generation in their strategic planning processes, and include specific targets for energy efficiency in their operations in the Water Services Development Plans (WSDPs). Energy audits should be undertaken on a yearly basis.

Energy efficiency should form a major criterion when planning new water supply and sanitation projects, and funding programs should use specific targets in the decision-making process.

Wastewater treatment facilities should be encouraged to implement biogas energy production projects, and incentives should be provided for this purpose (e.g. assistance with feasibility studies and technical support).

Similarly, water supply and distribution projects should investigate the feasibility of mini-hydropower generation in water distribution systems.

As water demand management programs also result in energy savings, energy efficiency should be included in water services providers' water demand management and water conservation programs.

Lose liaison should be established and maintained with energy suppliers (Eskom), and water services providers should be aware of and pursue the offerings in the rebate program.

The concept of "Negawatts", i.e. water supply and sanitation processes that use no energy, should be actively encouraged. Examples of these systems are on-site sanitation, slow sand filtration and rainwater harvesting (use of storage tanks).

"Toolboxes" should be developed to provide water and wastewater treatment plant supervisors and process controllers with technical solutions and support for improving energy efficiency in their facilities.

Investigate the feasibility of using alternative renewable energy technologies with relation to initial capital costs, site conditions, specific climate conditions and return-on-investment. Financial incentives should be provided for such investigations and projects.

Development of new or alternative wastewater treatment processes and systems (both centralized and decentralized) should aim towards low-energy processes, especially regarding the high energy requirements for aeration in biological systems.

This compendium should be updated on a bi-annual basis.

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APPENDIX: Case Studies

The appendix is present only in the electronic version on the CD in the back of this report.