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

TECHNICAL BRIEF

Water-Energy Nexus

Advanced hydropower energy generation

A scoping study funded by the Water Research Commission (WRC) investigated the possibility of generating energy using low head hydro technologies.

Background

The demand for energy increases continuously and those demands need to be met in order to stimulate worldwide development. Fossil fuels contribute to a large majority of global energy, but due to the dangers of global environmental impacts, the expansion of fossil fuel as an energy source is in some cases resisted. This forces our current generation to focus on the development of renewable resources.

This WRC-funded project emanated from the need identified to focus on renewable energies. Hydropower contributes only 3% of global energy consumption, which is only a fraction of its potential.

Africa is the most underdeveloped continent with regard to hydropower generation, with only 6% of the estimated potential exploited. This thus leaves enormous room for opportunity.

It is believed that there are many untapped opportunities to generate electricity using hydropower technologies. Technologies have also improved over the last couple of decades which now allows the development of previously unfeasible sites.

Potential for low head hydropower in South Africa

In South Africa, mainly due to relative scarcity of surface water storage, there is a prevailing perception that the potential for the conventional hydropower development is rather low. At present, only seven of the country's dams are equipped with hydropower generation plants, the largest being the Gariep hydropower plant situated on the Orange River.

It is believed that the country's extensive bulk water supply network may provide accessible and economical low head hydropower.

Defining low head power generation

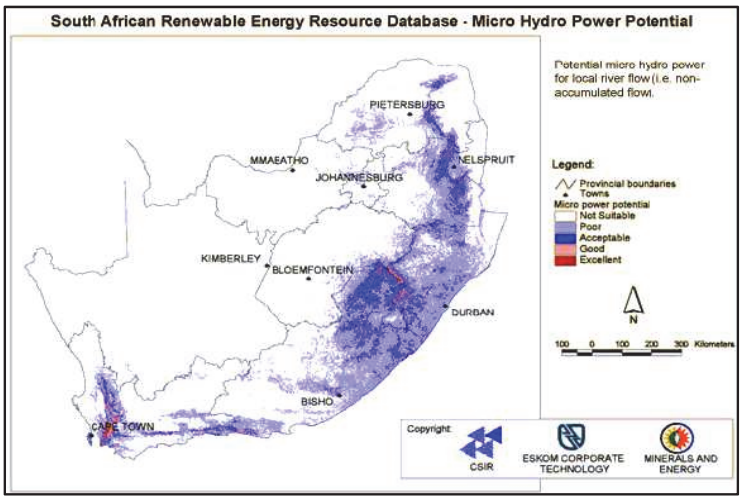
Low head hydropower generation refers to electricity generated from a relatively low pressure head, normally found in rivers or irrigation channels, and is applicable to sites with less than 5 m of head.

The WRC study's main focus was to identify and evaluate the potential low head hydropower applications in existing irrigation systems, river systems and wastewater infrastructure.

Hydropower potential at dams and barrages

There exists an opportunity to retrofit existing dams and reservoirs with hydropower plants. Instead of dams being constructed for the purpose of hydropower and then having different functions, reservoirs that are already in existence for other purposes can be fitted with hydropower plants in order to meet base or peak electricity demands.

Obviously the application of this form of hydropower is limited as there are a fixed number of dams in existence, but the advantages are numerous because the energy is there waiting to be harnessed and additional environmental impacts are minimised. The WRC lists several South African dams where small hydropower plants can be added.



Run-of-river hydro-power potential

Hydropower potential in rivers

The distribution of seasonal precipitation around South Africa is rather diversified, making only certain areas suitable for the development and operation of run-of-river micro-hydropower.

Suitable sites for small-scale hydropower installations can vary from fast-flowing streams in mountains to wide rivers in lower areas. In some places existing infrastructure can be utilised for the construction of a hydropower plant, but in many cases entirely new construction would be required.

Measuring weirs as potential sites for low head hydropower installations

Measuring weirs provide a specific example of structures in many South African rivers where hydropower installations may be considered. The challenge at these sites would be to install a hydropower plant that does not affect the accuracy of the measuring weir.

Hydropower plants at dams and weirs will normally be built into the dam wall, or constructed right next to the dam with a short diversion. Siphon turbines or Archimedean screws can also be installed at many existing dams and weirs.

Small schemes may be retrofitted, or planned, at weirs that are built for other purposes such as flood control, measuring, irrigation, recreation or water abstraction.

Irrigation systems at potential hydropower sites

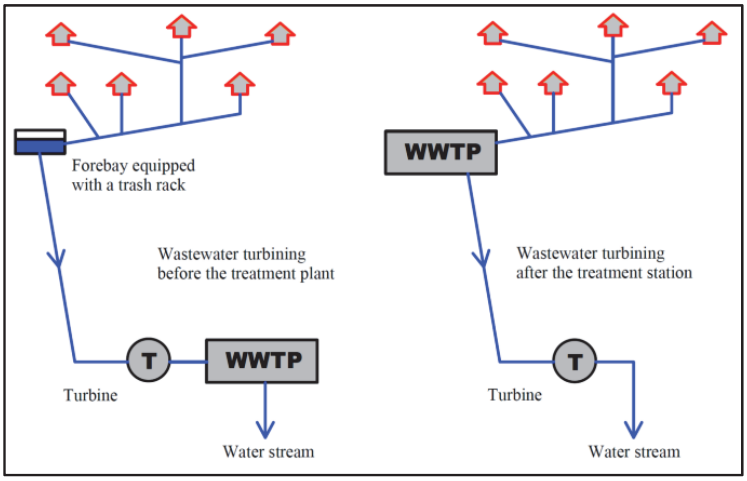
In some irrigation canal systems, turbines can be installed to generate electricity, either through diversion or in the canal system itself. These systems will normally consist of high-flow, low-head installations.

Diversion structures, used to canalise water from natural rivers to irrigation canals, may be ideal sites for the implementation of low head hydropower projects. Firstly, because the existing infrastructure can be used to lower construction cost and secondly, because many diversion structures span right across rivers, allowing for the utilisation of all the flow for a hydropower plant.

Similarly to dams and weirs in rivers, turbines can be built into the diversion structure wall, or constructed right next to the structure.

Alternatively, vehicle, cattle and pedestrian bridges may provide many opportunities for easy installation of very low head turbines in irrigation canals. These structures can provide anchorage for various types of hydrokinetic turbines. The power produced by these turbines is based on the velocity of the water, instead of pressure head and flow.

In addition, water wheels and hydrokinetic turbines can be installed along sections of concrete-lined canals, if there is a need for electricity nearby. The main drivers to determine suitability of these sites are flow volumes, flow velocities and reliability of flow.



Wastewater treatment plant hydropower opportunities

Four schemes specifically were investigated for their hydropower potential as part of this project, namely the Boegoeberg irrigation scheme, Kakamas irrigation scheme, Lower Fish irrigation scheme and Lower Sundays irrigation scheme. The results of these investigations are discussed in the final report.

Wastewater treatment works

Wastewater treatment works are viable sources of hydropower due to the high volume of water that generally flows from such facilities. The flow rates at these treatment works are fairly constant so that no dam or reservoir is required.

There are two opportunities for hydropower generation at wastewater treatment works: the first is before the treatment plant and the second is at the outflow of the plant.

If a hydropower plant is placed at the inflow of water treatment works, a forebay with trash rack should be included and the hydro plant should be situated as close as possible to the treatment plant to maximise the operational head.

The outflow from water treatment works is usually released into natural streams or manmade channels which transport the water to the river system downstream. These systems convey the water via gravity allowing all of the additional energy to be extracted.

At these outlets a head difference from 1 m can be expected. Some of the analysed outlets have head differences of 8 m which, combined with high flow rates, have large electricity generation potential.

At many of the wastewater treatment plants extensive civil work has been done at the outlets which, in turn, decreases the construction effort needed for a hydropower plant.

The study estimates that about 1.6 MW of exploitable power exists from South African wastewater treatment plants.

Urban stormwater systems

Areas experiencing moderate to high rainfall are possible candidates for low head hydropower. In the hydropower potential formulation head is also a role player. Geographic areas containing small to significant elevation drops will serve to add needed potential.

Some cities in South Africa were forced to build intricate stormwater infrastructure to minimise the probability of damage to the area. Other areas are geographically situated where large volumes of runoff are generated either naturally or due to development. In these areas the foundation for the hydropower plants will already be built, which will decrease the civil works needed.

The most challenging facet will be to account for the irregularity of the stormwater resource. Precipitation can vary from none to large volumes of water, and can result in a low plant capacity factor.

Another challenge is to incorporate the hydropower plant with the existing facility without compromising on the proficiency of the system and keeping the cost to a minimum.

Pipelines

Another WRC study considers in detail the potential and application of hydropower plants in pipelines, specifically at high pressure points and pressure reducing stations in water distribution systems. Similar installations may be possible at

points with excess pressure, albeit lower pressure than investigated during that study. Outlets of pipelines into canals or dams could also have potential for low head hydropower applications, even if pressure reducing measures were not deemed necessary.

Industrial outflows

Many commercial and industrial sites use significant amounts of water for cleaning or processing of materials. These sites may include breweries, dairy producers, vehicle manufacturers and many others. Turbines can potentially be installed at the return flow pipes or canals. Applicable turbines may include Archimedean screws, Kaplan turbines or Steff turbines, depending on the conditions on site.

There could be potential hydropower generation opportunities on the water-supply side as well on the outflows from large water consuming industries.

Certain industries and businesses return a significant portion of their water demand as effluent into the sewerage system. in some cases there could be a head difference between the outflow point and the receiving sewer system. this would then also provide an opportunity to install a low head turbine.

Tidal lagoons and oceans

Hydropower generation using tidal energy is also a growing industry. Low-head turbines and wheels are used to extract energy from unconstrained, reversible water currents, found in oceans and tidal estuaries.

However, ocean energy development is in a total infancy in this country. To date, no significant physical development can be accounted for.

Conclusions

The report concludes that there is significant potential for the development of low-head hydropower in both the perennial streams and within existing water supply (i.e. urban and agricultural schemes) and wastewater treatment infrastructure.

This potential is not necessarily significant with regard to the contribution to the Eskom national grid, but is significant with regard to the potential reduction in electricity demand on the overloaded national power generation capacity.

The potential annual energy output from identified available capacity hidden in existing infrastructure could produce between 35 and 115 GWh thus helping Eskom to deliver coal-fired electricity to other needy users. In implementing determined low-head hydropower potential, various job opportunities will be created in the manufacturing and operation/maintenance economic sectors.

Introducing enhanced in-house energy generation will alleviate to some extent dependency of particularly the water-supply utilities on the already stressed national grid, and keep their energy costs lowered.

The retrofitting of the low-head hydropower at existing infrastructure will to initiate the process of the water supply and wastewater system optimisation and revision of obsolete or insufficient regimes and procedures.

It is believed that this report provides valuable insight into the current state of affairs with regard to available low head hydropower technologies and the potential application of these in South Africa.

Further reading:
To order the report, ***Scoping study: Energy generation using low head hydro technologies*** (**Report No. KV 323/13**) contact Publications at Tel: (012) 330-0340, Email: orders@wrc.org.za or Visit: www.wrc.org.za to download a free copy.

Estimates of the country-wide potential for low-head hydropower development

Low head hydropower location	Estimated potential (MW)	In existing infrastructure (MW)	Estimated potential "greenfield" conditions (MW)
Small (low-head) dams	5.70	5.70	As per new dams installed
Run-of-river schemes	39.50	17.00	22.50+
Measuring weirs	0.30	0.30	As per new weirs installed
Irrigation schemes	5.50	5.50	No new developments envisaged
Wastewater Treatment Works (WWTW)	2.50	2.50	As per new works and rehab/ upgrades
Urban storm water systems	0.10	0.10	Insignificant
Water transfer pipelines and canals	0.65	0.65	As per new transfers and rehab/ upgrade
Industrial outfalls	0.25	0.25	As per new industry installed
Subtotal for inland hydropower	54.50	32.00	22.50+
Tidal lagoons and harbours	26.50	As per further research	26.50
Wave energy systems	Unlimited	None	Unlimited