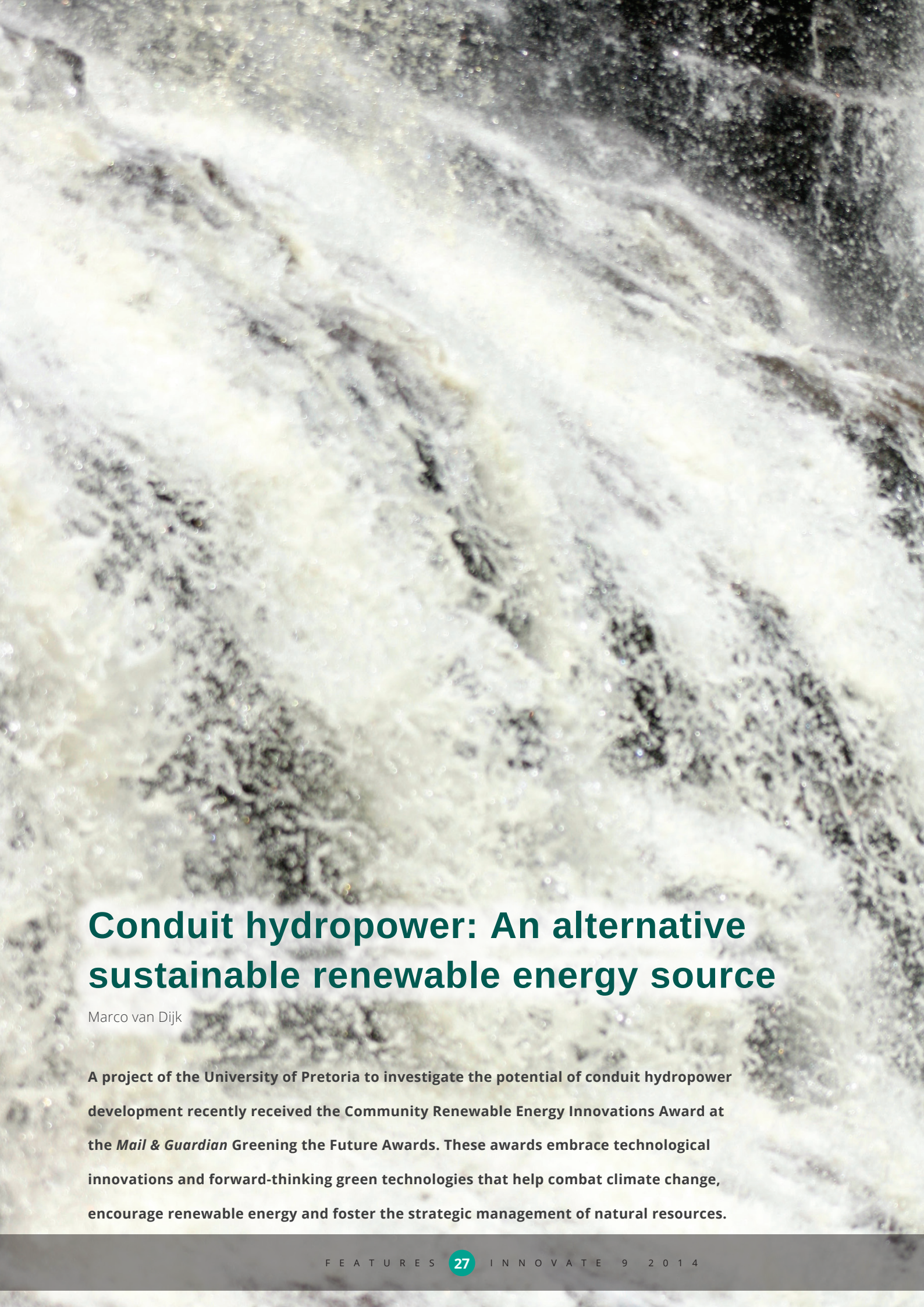

Conduit hydropower: An alternative sustainable renewable energy source

Marco van Dijk

A project of the University of Pretoria to investigate the potential of conduit hydropower development recently received the Community Renewable Energy Innovations Award at the *Mail & Guardian* Greening the Future Awards. These awards embrace technological innovations and forward-thinking green technologies that help combat climate change, encourage renewable energy and foster the strategic management of natural resources.

A few years ago, after it became clear that South Africa is facing critical energy shortages, Prof Fanie van Vuuren and Marco van Dijk, both of the University's Department of Civil Engineering, started to consider ways of harnessing potential energy in water distribution systems. After a scoping study, the Water Research Commission (WRC), with Jay Bhagwan (Executive Manager: Water Use and Waste Management) as the project leader, commissioned the University to test the feasibility of this principle with a pilot project.

"Conduit hydropower" refers to a method of using the mechanical energy of water as part of the water delivery system through man-made conduits to generate electricity. Generally, the conduits are existing water pipelines, such as those in bulk water supply and distribution systems.

Although the conditions in South Africa do not completely lend themselves to large-scale hydroelectricity plants such as the one at Cahora Bassa, the energy and pressure of water in existing water distribution systems can be harvested to power small plants or perform specific smaller tasks, such as providing power for telemetry, security and flow measurements. Similar to energy saving, every bit of power that does not have to come from the grid will alleviate pressure on the infrastructure and resources needed to generate electricity.

The application of hydropower is divided into four categories, depending on the amount of electricity that can be generated:

- At pico-level, a maximum of 20 kWh is generated, which can be used to supply a few domestic dwellings.
- At micro-level, 20 to 100 kWh can be generated, which can be used to supply a small community with commercial or manufacturing enterprises.
- At mini-level, 100 to 1 000 kWh can be generated, which can supply 1 000 suburban households with reliable electricity.
- At small level, 1 to 10 MW can be generated. This generation is synchronised with the municipal or national grid frequency.

In 2010, a scoping investigation by Prof Van Vuuren indicated considerable potential for power generation at the inlets to storage reservoirs. South Africa has 284 municipalities and several water supply utilities and mines, and all of them own and operate gravity water supply distribution systems that could be considered for small-, mini-, micro- and pico-scale hydropower installations.

The principle according to which conduit hydropower "generation" works is that a turbine (or a pump functioning as a turbine) is installed at the inlet to the reservoir, and because the water is distributed at such a high pressure, the energy already inherent in it generates electricity as the turbine turns. Furthermore, the use of turbines supplements and reduces the requirements for pressure control valves.

Five potential locations for energy extraction in water distribution systems were identified:

- At dam releases into bulk supply lines
- At water treatments works (raw water), where the bulk pipeline from the water source can be tapped
- At inlets to service reservoirs where pressure-reducing stations (PRSs) are used to dissipate the excess energy – potable water
- In the distribution network itself where excess energy is dissipated
- In cases where the treated effluent has potential energy based on its elevation above the discharge point

Pilot projects

Three pilot plants were identified for the development to showcase the application: Pierre van Ryneveld in the City of Tshwane Metropolitan Municipality, Brandkop at Bloemwater, and Newlands 2 reservoir in the eThekwini Municipality. The City of Tshwane Metropolitan Municipality, eThekwini Municipality and Bloemwater were all collaborating organisations and supplied expertise and funding.

Pierre van Ryneveld

The Pierre van Ryneveld conduit hydropower pilot plant was installed on top of a reservoir in the Country Lane Estate, using a cross-flow turbine and synchronous generator. The generated power is used for lighting, alarm systems and communication. Three extensive field tests indicated that there was sufficient pressure and flow to generate power at the pico-level. The estate uses the power generated for the above purposes.

The results of this project indicated that a pico-hydropower plant may be viable for on-site utilisation. Experiencing the advantages of the project at a practical level, the homeowners' association of Country Lane Estate indicated that it would also like to utilise the power for street lighting. On 29 November 2011, the 15 kW Pierre van Ryneveld Conduit Hydropower Plant was launched, and all the site lighting was switched from the conventional municipal grid to the hydropower generated on site.

This project was done in collaboration with the City of Tshwane Metropolitan Municipality, which is committed to developing more renewable energy sources.

Excluding the man hours of the staff and students of the University of Pretoria and the staff of the Tshwane Metropolitan Municipality for the construction of the hydropower plant, the total cost of the plant was R546 000.

Bloemwater

The Bloemwater project, which is the flagship pilot plant of this research

→ *Marco van Dijk at the Bloemwater installation, the flagship project, where research was conducted at the Brandkop Reservoir.*

study, was constructed at the Brandkop Reservoir in Bloemfontein. This is also where Bloemwater's head office is located. A micro-hydropower plant was constructed at ground level this time. A 96 kW Banki cross-flow turbine, imported from Italy, was used.

The turbine has sufficient capacity to supply the entire Bloemwater head office with clean renewable energy, using its own water supply infrastructure. The estimated cost of building the Bloemwater plant is R3 075 000. When Bloemwater's spending on municipal electricity accounts is considered, the project has a payback period of approximately 72 months or six years. This is a relatively short period for a return on this kind of investment. Considering that the installed technology can last for more than 50 years, it is an attractive option.

eThekwini Municipality

The third pilot pico-level hydro-power plant – Pelton turbines – was installed at the Newlands 2 reservoir in Durban, in the eThekwini Municipality. In the case of this particular project, two 1 kW turbines were installed to show the technology, one being a stand-alone unit supplying the site with electricity, and the second feeding the hydro-generated power into the municipal grid. The estimated cost of the project amounted to R282 000, excluding the man hours of the eThekwini Municipality staff to design and construct the plant.

Conduit hydropower

The world is still – to a large extent – dependent on fossil fuels, mainly coal, to generate electricity. South Africa is no exception. In fact, approximately 90% of the country's electricity is generated in coal-fired power stations. Because of the relative abundance, availability and low mining cost of coal in the country, other forms of generating electricity have been largely unfeasible until now. Owing to this, together with the fact that the infrastructure for coal-based electricity generation already exists, it will remain an attractive energy source from a financial perspective.

However, nuclear power stations, hydroelectric schemes, pumped storage schemes, open-cycle gas turbines and wind farms are utilised to generate electricity in South Africa.

According to the latest numbers available to the United States Energy Information Administration, South Africa consumed a total of 218.3 billion kWh of electricity in 2011. A report published by Statistics South Africa in 2008 provided the latest breakdown of GWh produced by different electricity-generating technologies as recorded in 2006. It indicated that Eskom produced 95% of the country's electricity, while the remaining 5% was generated by a small group of private individuals for their own use. Eskom has eleven coal-fired power stations, six hydroelectric power stations, two pumped storage schemes, a nuclear power station, a wind farm and four open-cycle gas-fired turbines that are used only for peak supply.

→ *The conduit hydropower plant at the City of Tshwane, which generates power to be used for lighting, alarm systems and communication.*

These statistics would definitely have changed since that time. As was clearly shown by the rolling blackouts in 2008 and again more recently, electricity demand is exceeding the energy supplied by Eskom, and the need to increase supply has become imperative.

Cabinet has approved the Integrated Resource Plan 2010 (IRP 2010), according to which low-carbon options are preferred to align energy supply with the long-term mitigation scenarios to which government aspires. It is anticipated that by 2030, 30% of electricity will be generated from carbon dioxide-free sources. In the meantime, many private concerns and researchers have investigated alternative and renewable sources of energy – solar, biomass, wind and hydropower – and have submitted proposals for these.

There is potential for all forms of hydropower development in South Africa, and although the country has a number of hydroelectric installations, conduit hydropower definitely has a role to play in the overall energy generation and distribution picture of South Africa.

Conduit hydropower has no carbon footprint and can provide electricity relatively inexpensively and easily. A number of requirements that hold for larger and more complex sources of energy will not necessarily have to be met when setting up such a "plant". No water licensing is needed, as this can be seen as a continuation of an existing lawful use (National Water Act, Act 36 of 1998). Because existing infrastructure and resources are used, there is not always a need to conduct environmental impact assessments, and a basic assessment will suffice, as stipulated in the National Environmental Management Act, Act 107 of 1998. In certain cases, the use of the generated electricity is limited to lighting and electric fencing (as in the Pierre van Ryneveld project), which is classified as "own use". This category of use is exempt from licensing by the National Energy Regulator of South Africa (Nersa) in terms of the Energy Regulation Act, Act 4 of 2006.

In the case of the Pierre van Ryneveld project, however, a public participation process should be followed. This entails displaying a noticeboard that meets the requirements of Government Notice 543 of 18 June 2010 on the boundary fence of Country Lane Estate, and holding public hearings if complaints are received.

The way forward

Several water utilities, municipalities and even Eskom are considering conduit hydropower development.

After the pilot project, the City of Tshwane Metropolitan Municipality expressed an interest in further studies to investigate the application of this technology. Consequently, the municipality appointed the University of Pretoria to investigate development possibilities at the top five sites in Pretoria: Garsfontein, Fort Klapperkop, Heights in Valhalla,

→ *Jay Bhagwan, Executive Manager: Water Use and Waste Management of the Water Research Commission (left), joins Marco van Dijk (centre) and Prof Fanie van Vuuren of the Department of Civil Engineering in receiving the Community Renewable Energy Innovations Award at the* Mail & Guardian *Greening the Future Awards.*

Waverley and Akasia/Soshanguve. The principle on which this would function is that electricity generated in the municipality's water distribution systems would be channelled to its grid.

Another application that is being investigated in the City of Tshwane is supplying a reservoir with only the small amount of power that is generated at that reservoir. This can be particularly useful, as everything – such as sensors that indicate water levels – is stripped from reservoirs by criminals. This results in the municipality having to send out three workers at a time (it is unsafe for even two people to go) twice a day to monitor the reservoir. If a turbine can be situated inside the reservoir, together with the necessary recording and sensory devices, the problem of theft would be eliminated and the municipality will have the ability to monitor the conditions at its reservoirs at all times.

eThekwini Municipality also followed up on its project, and several other organisations are conducting studies. Rand Water Services (Pty) Ltd is busy with a project that could potentially generate 15 MW of hydropower electricity.

Furthermore, the University was appointed by the WRC and the Department of Science and Technology (DST) to evaluate the potential of small-scale hydropower development for rural electrification and to create a mini-grid for a few houses. The most important uses for this electricity will be lights, charging cellphones and listening to the radio or watching television in the evening, and perhaps supplying power to a community centre in the day.

An article in the *Journal of the South African Institution of Civil Engineering* and two chapters in an international book have been published on this research, and several postgraduate students have done research on hydropower projects for their dissertations and theses. A postgraduate student, Ione Loots, developed a world-first conduit hydropower development decision support system as part of her studies and has joined the University as a lecturer, further strengthening the Water Division's expertise.

The award by the *Mail & Guardian* created awareness around this project and may stimulate more funding for it. It also provides credibility to this research – it is research with real-life applications that can increase electricity supply in a world in which energy is a scarce commodity.

The next research project will investigate the viability of generating electricity at the point where treated effluent is released at sewerage works. Other possibilities are the reserve environmental flows released by dams and irrigation systems on farms. The comprehensive findings of this research project are published in reports by the WRC.

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