Tapping untapped renewable energy

Marco van Dijk, Prof Fanie van Vuuren, Jay Bhagwan and Adriaan Kurtz

In water distribution networks in South Africa, water is often fed under gravity from a higher reservoir to another reservoir at a lower level. This provides an opportunity to generate renewable energy by passing the flow through a turbine. The high pressure head at the receiving reservoir is then dissipated through the control valves (altitude valves) or, in some cases, orifice plates. The benefit of this hydropower-generating application is that minimal civil works need to be done, as the control valves are normally inside a control room/valve chamber. No negative environmental or social effects require mitigation and the anticipated lead times should be short.

There are basically four areas where energy generation can occur in the water supply and distribution system as shown in Figure 1:

- Dam releases – conventional hydropower
- At water treatment works (raw water) – the bulk pipeline from the water source can be tapped
- Potable water – at inlets to service reservoirs or in the distribution network itself where excess energy is dissipated, typically with pressure-reducing valves (PRV)
- Treated effluent – cases where the treated effluent has potential energy, based on its elevation above the discharge point

The University of Pretoria, supported by the Water Research Commission (WRC) and collaborating organisations such as the City of Tshwane Metropolitan Municipality, is engaged in a research project to investigate the potential of extracting the available energy from existing and newly installed water supply and distribution systems. The project aims are to enable the owners and administrators of the bulk water supply and distribution systems to install small-scale hydropower systems to generate hydroelectricity for on-site use and in some cases to supply energy to isolated electricity demand clusters or even to the national electricity grid, depending on the location, type and size of installation.

According to the European Small Hydropower Association (ESHA) and the United States Bureau of Reclamation (USBR), hydropower has the following advantages over other forms of energy production in terms of economical, social and environmental impacts:

- It generates clean, renewable and sustainable energy, as it makes use of the energy in water due to flow and available head. It does not emit any atmospheric pollutants such as carbon dioxide, sulphurous oxides or nitrous oxides, or particulates such as ash.
- Hydropower schemes often have very long lifetimes and high efficiency levels. Operation costs per annum can be as low as 1% of the initial investment costs.
- Hydroelectric energy has no fuel cost and low operating and maintenance costs; thus it is essentially inflation-proof.
- Hydroelectric energy technology is a proven technology that offers high efficiencies as well as reliable and flexible operation.
- Conduit hydropower requires a small capital investment and has a short return on investment period, since existing infrastructure is utilised.

The type of hydropower that will be generated is called "conduit hydropower" (National Hydropower Association, 2011), as shown in Figure 1, at locations 2, 3 and 4.

What is conduit hydropower?

Conduit hydropower is when excess energy available in pressurised conduits (pumping or gravity) is transformed into clean, renewable hydroelectric energy by means of a turbine.

How does conduit hydropower work?

Due to demand patterns and component size determination, the water entering the reservoir still has excess energy, which is normally dissipated by means of pressure control valves. By installing a parallel system, a turbine, the flow and head is used to generate hydroelectric power.

When is a site feasible?

Feasibility studies aim to objectively and rationally uncover the strengths, weaknesses, opportunities and threats of the venture as presented by the

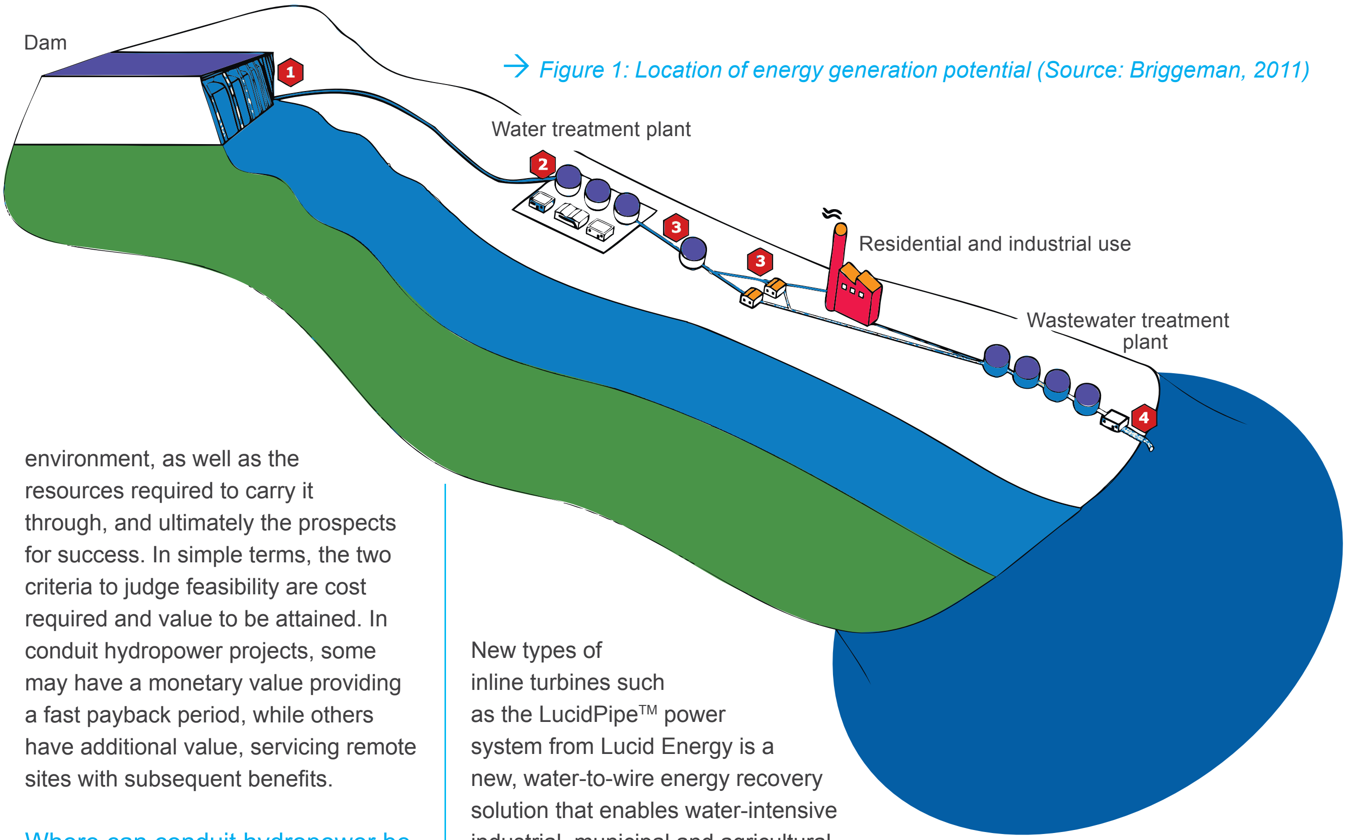


Figure 1: Location of energy generation potential (Source: Briggeman, 2011)

environment, as well as the resources required to carry it through, and ultimately the prospects for success. In simple terms, the two criteria to judge feasibility are cost required and value to be attained. In conduit hydropower projects, some may have a monetary value providing a fast payback period, while others have additional value, servicing remote sites with subsequent benefits.

Where can conduit hydropower be installed?

An initial scoping investigation conducted for the Water Research Commission highlighted the potential hydropower generation at the inlets to storage reservoirs. In South Africa, there are 284 municipalities and several water supply utilities that own and operate gravity water supply distribution systems and have some type of pressure-dissipating system at the downstream end of the supply pipe.

New types of inline turbines such as the LucidPipe™ power system from Lucid Energy is a new, water-to-wire energy recovery solution that enables water-intensive industrial, municipal and agricultural facilities to produce clean, reliable, low-cost electricity from their gravity-fed water pipelines (see Figure 2).

How is the electricity generated by the plant used?

The electricity generated by a plant can be used on site for the lighting, telemetry system, alarm system and electric fence. Larger systems (higher kW output) could be connected to the electrical grid, thus reducing the demand from Eskom.

Example of a Francis turbine installation (Source: Hydrolink, 2011).

In some cases electricity can be sold directly to Eskom.

How are conduit hydropower plants financed?

The feasibility studies conducted thus far have indicated that these types of hydropower installations have a relatively short payback period. The reason for this is the minimum amount of civil works required, compared to conventional hydropower projects. Due to the very low profile of small-scale hydropower development in South Africa during the last two decades, there are no defined approaches or methods for financing hydroelectric installations. Currently the municipalities or water boards would utilise their own budgets to finance such projects. Larger types of installation could, however, require other funding mechanisms, such as the Development Bank of South Africa or commercial banks.

Potential in the City of Tshwane water distribution system

The City of Tshwane Metropolitan Municipality (now including Metsweding) receives bulk water from Rand Water, Magalies Water and its own sources, including boreholes,

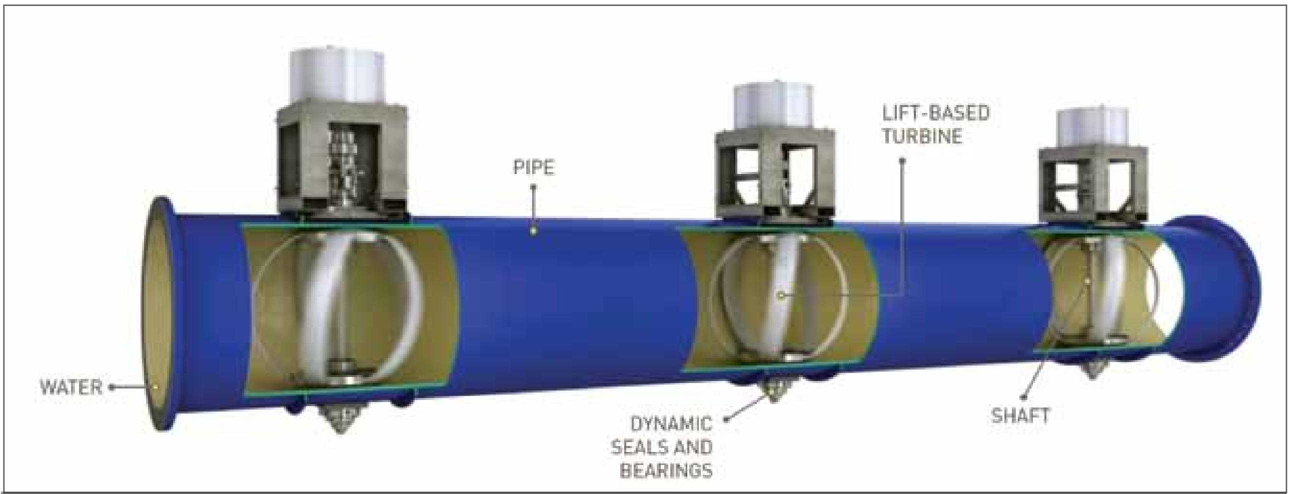


Figure 2: Inline turbine (LucidPipe™ Power System) (Source: Kanagy, 2011)

water purification plants and fountains. Water is then distributed through a large water system that includes 160 reservoirs, 42 water towers, 10 677 km of pipes and more than 260 pressure-reducing installations (PRVs) that operate at pressures up to 250 m. Geographically speaking, the City of Tshwane has a lower elevation than the bulk service reservoirs of Rand Water, which is the main water supply, resulting in high pressures still available in Tshwane.

In a desktop study, the ten reservoirs with the highest potential in the City of Tshwane were identified. The use of the potential energy stored in the pressurised closed-conduit water systems in Tshwane is, however, not limited to these sites. These 10 sites have the potential to generate 10 000 000 kWh per annum.

Case study: Pierre van Ryneveld conduit hydropower plant (PvRCHP)

The first closed-conduit hydropower pilot plant in South Africa was constructed at the Pierre van Ryneveld reservoir, situated in the Country Lane Estate, south of Pretoria. It is a ±15 kW installation that utilises a cross-flow turbine discharging through the roof into the reservoir. A controlled flow is supplied to the turbine from the main supply line into the reservoir.

It is planned to utilise the generated power on site for lighting, as well

Pierre van Ryneveld conduit hydropower plant

Controlled off-take to turbine

as for alarm and communication systems. The Homeowners' Association of the estate have also indicated that they would like to utilise the power for street lighting. Annually, approximately 131 000 kWh could be generated with this unit, which is enough to supply 10 households. As long as people use water, electricity can be generated.

The pilot plant installation has a favourable payback period and upscaling of the plant would result in an even faster payback period.

Payback period

The preliminary cost for the pilot plant totalled R550 000. This was for the turbine and generator, electrical work, pipework, valve chamber, enclosure/plant housing, monitoring system, data logging and communication system. Annual income would be in the order of R78 000 for electricity generated, based on 60 c per kWh. Assuming a discount rate of 10% and a very optimistic energy escalation rate of only 8%, the payback period can be estimated at approximately nine years.

Acknowledgements

This research project was funded by the Water Research Commission, whose support is acknowledged with gratitude.

References

Briggeman, T, Gettinger, B, Araoz, C and Egger, D. 2011. Emerging trend – Water and wastewater utilities embrace small hydro. Hydrovision 2011: Sacramento, California.

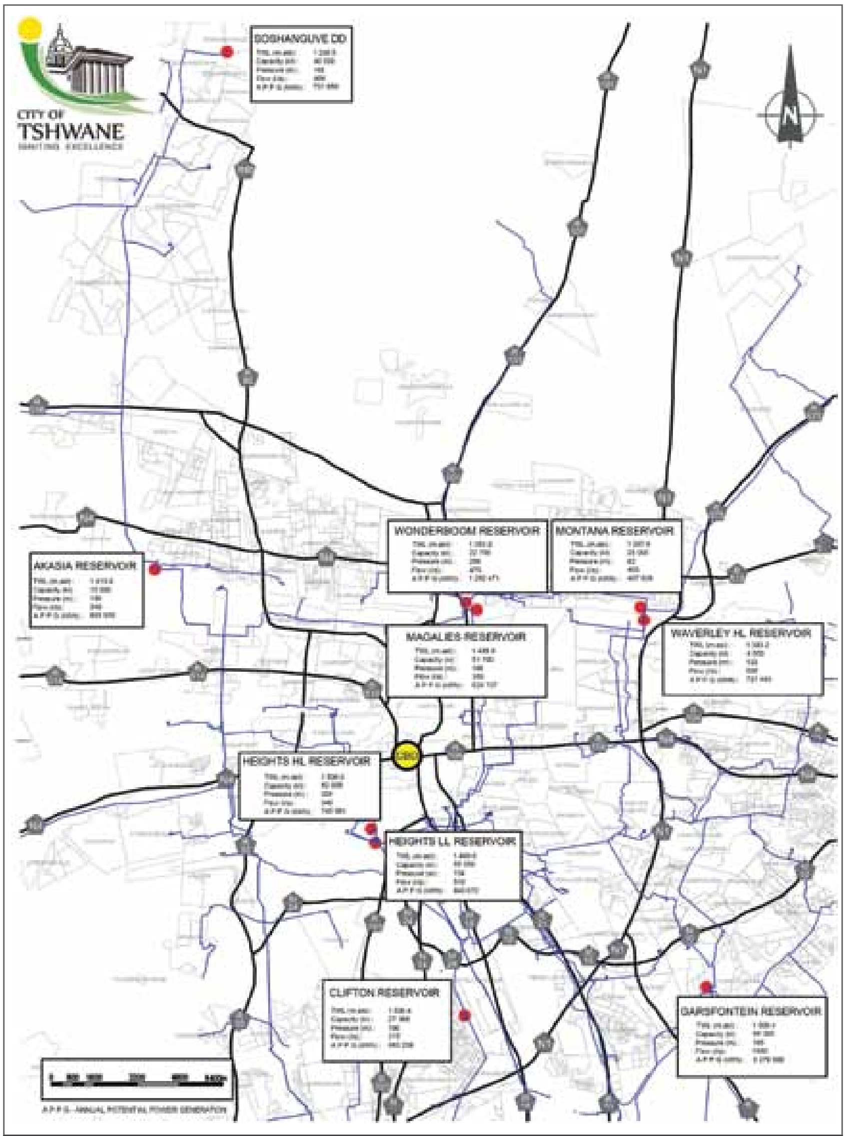
European Small Hydropower Association (ESHA). 2004. *Guide on how to develop a small hydropower plant.* [Online]. Available at: www.esha.be. (accessed on 15 October 2011).

Hydrolink. 2011. *Small hydro power.* [Online]. Available at: www.hydrolink.cz

Kanagy, J. 2011. *Northwest PowerPipe™, an innovative in-conduit power generating technology*. Lucid Energy Technologies, LLP. [Online]. Available at: http://s36.a2zinc.net/clients/pennwell/hydrovision-international2011/Custom/Handout/Speaker9394_Session728_1.pdf. (accessed on 28 October 2011).

National Hydropower Association (NHA). 2011. Rancho Penasquitos Pressure Control and Hydroelectricity Facility. San Diego County Water Authority. [Online]. Available at: www.hydro.org. (accessed on 5 September 2011).

United States Bureau of Reclamation. 2008. *Benefits of hydropower.* [Online]. Available at: www.usbr.gov/uc/ power/hydropwr/. (accessed on 5 September 2011).



Hydropower potential in the City of Tshwane (10 reservoirs with highest potential)

Marco van Dijk *is a lecturer in the Department of Civil Engineering at the University of Pretoria and is a principal researcher for the Water Research Commission research projects.*

Jay Bhagwan *is the Executive Manager: Water Use and Waste Management at the Water Research Commission.*

Prof Fanie van Vuuren *is a professor in the Department of Civil Engineering at the University of Pretoria and Head of the Water Division.*

Adriaan Kurtz *is an engineering consultant at the Tshwane Metro in the Department of Water and Sanitation Planning and Regulation.*