Tapping untapped renewable energy

IN WATER DISTRIBUTION networks in South Africa, water 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. 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 (Briggeman 2011):

- 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

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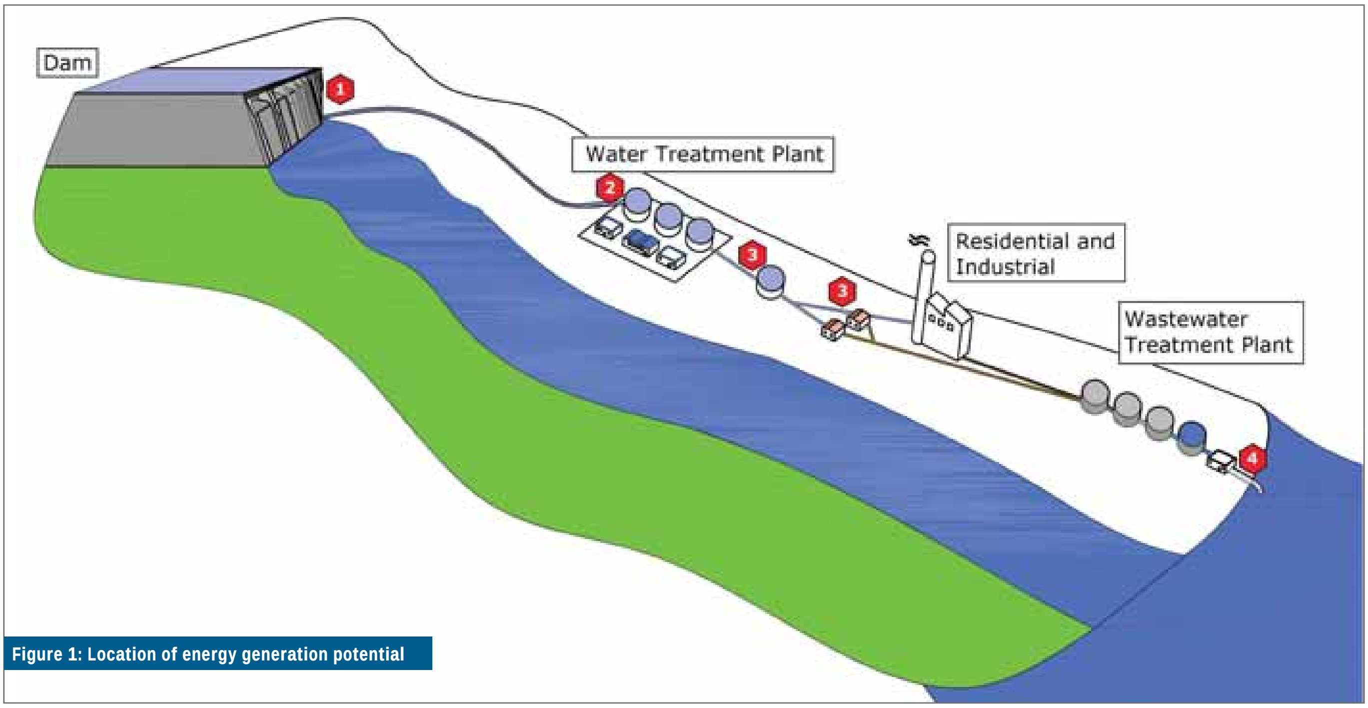

Figure 1: Location of energy generation potential

City of Tshwane, 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 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.

To distinguish the type of hydropower that will be generated it is called "conduit hydropower" (NHA 2011), as shown in Figure 1 at locations 2, 3 and 4.

Hydropower has the following advantages over other forms of energy production in terms of economics, social and environmental impacts (ESHA 2004, USBR 2008):

- **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, 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**, and thus it is essentially inflation proof.
- Hydroelectric energy technology is a **proven technology** that offers high efficiencies, as well as reliable and flexible operation.

Figure 2: Example of Francis turbine installation (Hydrolink 2011)

- Conduit hydropower requires a **small capital investment** and has a **short return on investment period** since existing infrastructure is utilised.

FREQUENTLY ASKED QUESTIONS

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 (see Figure 2).

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 are used to generate hydroelectric power.

When is a site feasible?

Feasibility studies aim to objectively and rationally uncover the strengths and weaknesses of the venture, opportunities and threats as presented by the environment; the resources required to carry through; and ultimately the prospects for success. In its simplest term, 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, whilst others have additional value, servicing remote sites with subsequent benefits.

Where can we install conduit hydropower?

An initial scoping investigation (van Vuuren 2010) highlighted the potential hydropower generation at the inlets to storage reservoirs. In South Africa there are 284 municipalities and several water supply utilities all owning and operating gravity water supply distribution systems which 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 (Figure 3) (Kanagy 2011).

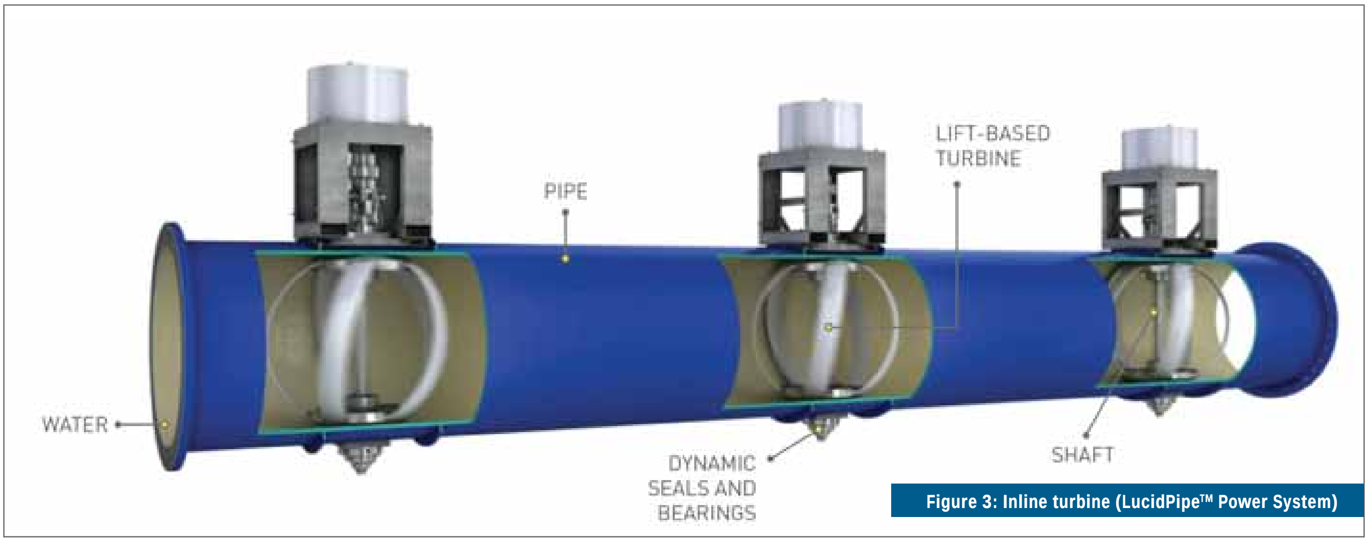

Figure 3: Inline turbine (LucidPipe™ Power System)

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. In some cases electricity can be sold directly to ESKOM.

How are conduit hydropower plants financed?
The feasibility studies conducted thus far 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 and methods for the financing of hydroelectric installations. Currently the municipalities or water boards would utilise their own budgets to finance such projects. Larger-type installation could, however, require other funding mechanisms (DBSA, commercial banks etc).

POTENTIAL IN THE CITY OF TSHWANE WATER DISTRIBUTION SYSTEM
The City of Tshwane (now including Metsweding) receives bulk water from Rand Water, Magalies Water and its own sources which include boreholes, water purifications plants

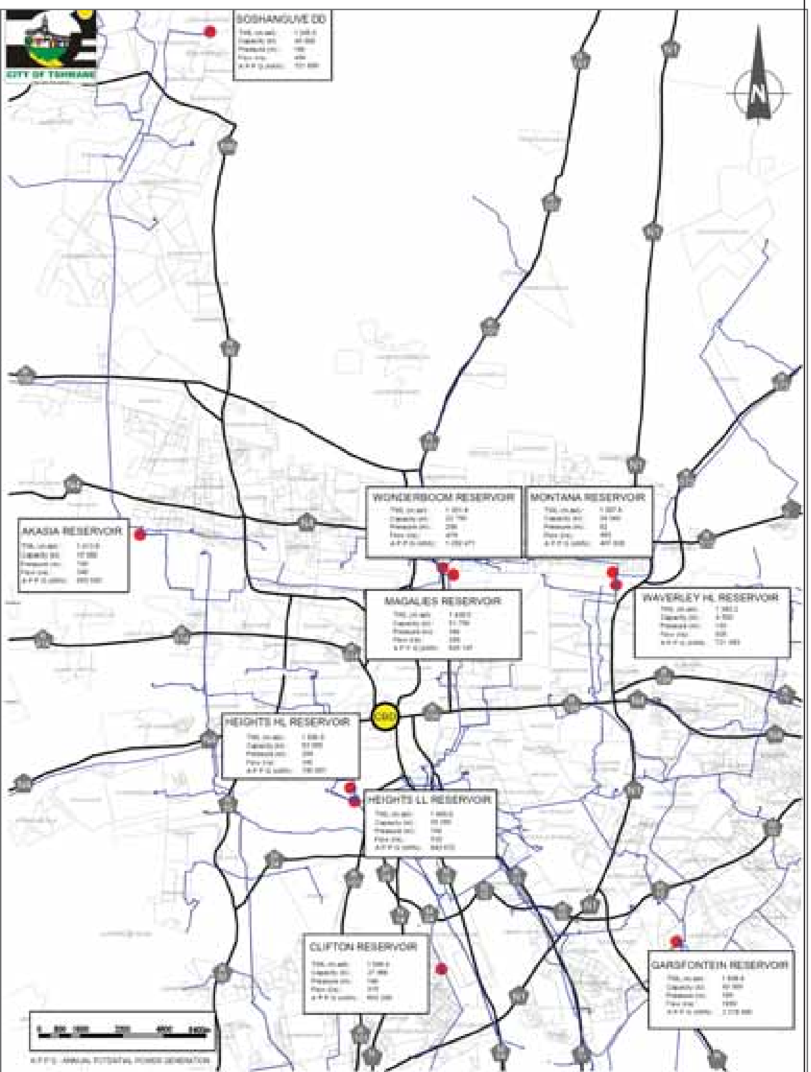

Figure 4: Hydropower potential in the City of Tshwane (ten reservoirs with highest potential)

Figure 5: Pierre van Ryneveld conduit hydropower plant

Figure 6: Controlled off-take to turbine

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)** which 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 (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 (Figure 4). The use of the potential energy stored in the pressurised closed-conduit water systems in Tshwane is, however, not limited to these sites. These ten sites have a potential to generate 10 000 000 kWh/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 utilising a cross-flow turbine discharging through the roof into the reservoir (Figure 5). A controlled flow is supplied to the turbine from the main supply line into the reservoir (Figure 6).

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, and data logging and communication system. Annual income would be in the order of R78 000 for electricity generated, based on 60 c/kwh. Assuming a discount rate of 10% and a very optimistic energy escalation rate of only 8% would result in a **payback period of ±9 years** (**IRR = 23% for 20 year design life**)*

The plan is to utilise the generated power on site for lighting, alarms, communication etc. The members of the home owners association of the Country Lane Estate have also indicated that they would like to utilise the power for street lighting. Annually ±131 000 kWh could be generated with this unit, enough to supply ten households from this pilot plant. *As long as people use water, electricity can be generated!*

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

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