DISCUSSION PAPER

Capital Regional District
Core Area Wastewater Management Program

Integrated Resource Management Strategy

Discussion Paper – Flow Energy Management and Pressure Energy Recovery
031-DP-4

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1 Objective

This Discussion Paper provides an overview of wastewater flow management strategies that aim to reduce the pumping energy, and associated greenhouse gas emissions associated with supplying the energy required, in conveying wastewater throughout the Capital Regional District (CRD). The paper also provides an overview of technology that can be applied to recover the pressure energy in flowing wastewater / effluent, as well as the regional potential of this energy.

2 Topic Area Overview

2.1 Wastewater Flow Management

Flow energy management focuses on conveying wastewater in a manner that practically minimizes external energy inputs (i.e. pumping) required in its transport. Some design strategies are fairly obvious in this context, for example, siting wastewater treatment facilities at lower elevations in order to reduce the volume of wastewater that needs to be pumped or lifted up to the treatment site. Other strategies are more subtle but can contribute notably to pumping and thus energy reduction. One such example is to maintain high water levels in pump and lift station wet-wells during dry-weather, low wastewater flow periods. This operational strategy utilizes the excess capacity of the upstream sewers and wet-wells during such conditions, in turn minimizing the height that wastewater is lifted and the energy needed by the pumps. Further strategies are less direct and policy centred – implementing low-flow plumbing devices that ultimately contribute to reduced wastewater volumes and flow rates that, in turn, reduce energy associated with wastewater transport.

Although the CRD has much wastewater infrastructure already in the ground, there are several significant opportunities for the District to optimize flow energy management as it develops new facilities and infrastructure. These include siting the new distributed wastewater treatment / resource recovery facilities, both in the near-term and in the future. Other opportunities related to operations and policy can also be pursued.

2.2 Pressure Energy Recovery Technology

Pressure energy recovery in hydraulic systems involves using a turbine or other mechanical device to capture the energy contained in water flow. Traditionally, hydro power generation has focused on large hydroelectric dams and run-of-river projects. In recent years, however, much of the growth in the hydroelectric industry has come in the form of smaller run-of-river and energy recovery projects. Hydroelectric machinery manufacturers have responded to this change by developing new products that are either innovative in arrangement or far simpler to install. A variety of technologies currently exist, their suitability depending on application. While none of the technologies are currently being marketed specifically for municipal wastewater (either raw or treated effluent) at this time (i.e. focus in micro hydro power), they are in commercial production and provide reliable results. A summary of current technologies follows.

Traditional Designs at Reduced Scale

Traditional designs are based on well-proven technology. For the Core Area Wastewater Management Program the same technologies can be applied at a smaller scale. Specifically, axial flow machines could be employed. These machines tend to be specifically designed for an installation and often offer high levels of efficiency over a wide range of flows. The machines are typically complex and are therefore relatively expensive.

Kinetic Devices

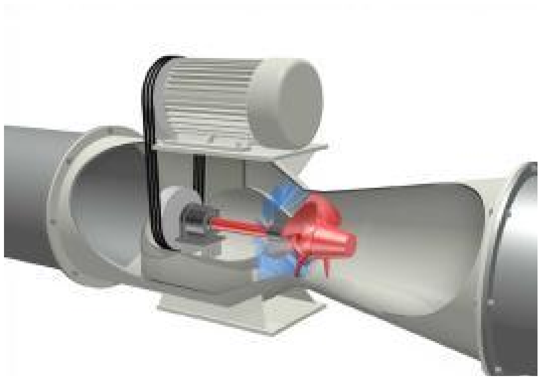
Kinetic devices are turbines that rely on the flow in a stream to convert kinetic energy to electrical energy. The devices have been developed for insertion into creeks or rivers where the intent is to have a minimum of impact on the behaviour of the watercourse. The devices typically only yield a small amount of energy and are best suited to remote sites where battery charging is their principle function, rather than a wastewater / effluent application.

A 300 kW axial turbine installation.
Source: Canyon Industries

In-Pipe Turbines

In-pipe turbines are a relatively new technology that is intended for installation in piping systems. The turbine runner is provided inside the pipe and the generator is installed on the outside. The runner is connected to the generator by a drive belt housed in a dry space in the turbine mounting.

Examples of in-pipe turbines are shown in the following figures, illustrating the internal construction and a typical application, where water is siphoned from a reservoir to the receiving body. The same approach could be utilized in piped water/wastewater, where a pipe including the in-pipe turbine would branch off from the main pipe and reconnect below the turbine.



Internal construction of an in-line turbine.
Source: New Energy Foundation, Japan

A Typical In-Pipe Turbine Installation
Source: Toshiba Corp.

Pumps as Turbines

Pumps as turbines (PATs) are a recognized technology for providing inexpensive pressure energy recovery. In a PAT the pump is operated in reverse to drive a generator. Pumps are less expensive than turbines and are readily available. The efficiency of a PAT is generally less than a turbine but this is often a minor consideration when considering energy recovery. The other consideration is that the flow rate must be relatively constant for pumps versus turbines (Williams, et al., 1998).

A typical small-scale PAT installation.
Source: Associated Engineering

2.3 Raw Wastewater Application

Pressure energy recovery from piped wastewater is an attractive option provided there are sufficiently high flow rates and/or differences in elevation to sustain a turbine. Applications involving raw wastewater, however, musts address such issues of self-cleaning screens, and maintenance and service of the turbines in light of the solids and other constituents present in untreated wastewater. That being said, the same screening that is used in wastewater heat recovery applications (to 2 mm) would be sufficient for the requirements of turbines used in pressure energy recovery. Secondly, raw wastewater flows are typically gravity-conducted and not in full pipes (i.e. not under pressure). This may present a feasibility issue as turbines operate under conditions of pressurized flows, although it is conceivable that local system configuration changes could be made to accommodate a turbine. Our literature review did not reveal any examples of pressure energy recovery from raw wastewater.

2.4 Effluent Application

The application pressure energy recovery to effluent is very promising, especially at outfalls to watercourses, where there is some significant drop in elevation between the treatment facility and receiving water body. Given its characteristics effluent does not present the same issues as were discussed with raw wastewater. While few examples of pressure energy recovery from wastewater treatment plants could be found in a fairly extensive literature review, there are some examples of existing and planned projects for related applications.

Pressure energy recovery from desalination plant effluent (which operates under higher pressures to facilitate reverse osmosis processes) is an established market where the technology helps to reduce energy intensity in the desalination.

More closely related to the proposed application in this case is energy recovery from transmission pipelines around a water treatment plant. Generally, where excess pressure builds up due to drops in elevation, it is typically dissipated by pressure reducing valves, but in fact, most of the dissipated energy can be recovered by the use of some of the aforementioned technologies. Generally speaking, PAT solutions require greater head, whereas in-pipe turbines require greater flow rates.

Williams, et al. (1998) note an example of a PAT for energy recovery that was installed above an intermediate reservoir at the Barnacre water treatment facility in the Blackpool area, UK. The City of Sault Ste. Marie, ON is set to install a 45 kW Francis turbine at their facility, capturing energy from raw surface water destined for the treatment facility. They expect to capture 330,000 kWh/yr from a flow rate of roughly 40,000 m^3/day and a difference in elevation of 30.5 m (PUC, 2007). The only installed example of an energy recovery project from a wastewater outfall, identified in our literature review, is a demonstration project in Nyon, Switzerland. Built in 1993, the plant uses a PAT to produce up to 210 kW from a wastewater outfall (Chenal, 1995).

3 Energy Recovery Potential

3.1 Unit Basis

The unit potential pressure energy is 9.8 kW per m^3/s-m of head, which is reduced to approximately 3.9 kW per m^3/s-m once efficiencies are taken into account. This is based on the most applicable technology and average reduction factors that take into account turbine efficiency, pipeline loses, and discharge capacity. The potential for energy recovery has been calculated based on a capacity factor of 80% and with combined pump efficiency and line losses of 50%. Therefore, of the potential energy in the system, only 40% is estimated to be recoverable with the technologies described above.

3.2 Regional Potential

The total amount of pressure energy that could be recovered from flowing wastewater / effluent within the CRD is a function of individual “extraction” locations and the attributes (i.e. flow rate, elevations) of these locations. For the purposes of illustration, assuming a large wastewater treatment facility in the Macaulay/McLaughlin area and two smaller distributed facilities in the Westshore and Saanich East areas, and the recoverable unit potential pressure energy discussed above, approximately 35 kW of pressure power could be recovered from effluent at these facilities under current average dry weather flow rates. The potential increases to about 62 kW for the Year 2065 scenario.

In terms of annual energy production, these values equate to about 305 MWh per year and 540 MWh per year for existing and Year 2065 wastewater flow rates, respectively. With typical households in British Columbia currently consuming approximately 10 MWh of electricity per year (British Columbia, 2007), this energy could supply between 30 and 50 households.

4 Summary

The CRD has significant opportunity to manage wastewater flow and its conveyance in a manner that minimizes energy consumption. Siting the distributed wastewater treatment / resource recovery facilities at low elevations and implementing operational and policy strategies can contribute to notably reduced energy requirements.

Although a relatively new technology application, the recovery of pressure energy from flowing wastewater / effluent is technically feasible within the CRD's planned wastewater infrastructure. With currently available technology, and at existing household electricity consumption rates, the relative amount of recoverable pressure energy is minimal. However, as technology and associated recovery efficiency improves, and in combination with a decreasing trend in household electricity consumption, some gains in the relative significance of recovered energy will be achieved.

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