FOUR STEPS to recovering heat energy from wastewater

By Chris Johnston, P. Eng., Vice President, Kerr Wood Leidal Associates Ltd.; Erik Lindquist, P. Eng., Senior Mechanical Engineer, DEC Design Mechanical Consultants Ltd.; John Hart, M.A.Sc., P. Eng., Senior Wastewater Process Engineer, Kerr Wood Leidal Associates Ltd.; and Mike Homenuke, P. Eng., Infrastructure Planning Engineer, Kerr Wood Leidal Associates Ltd.

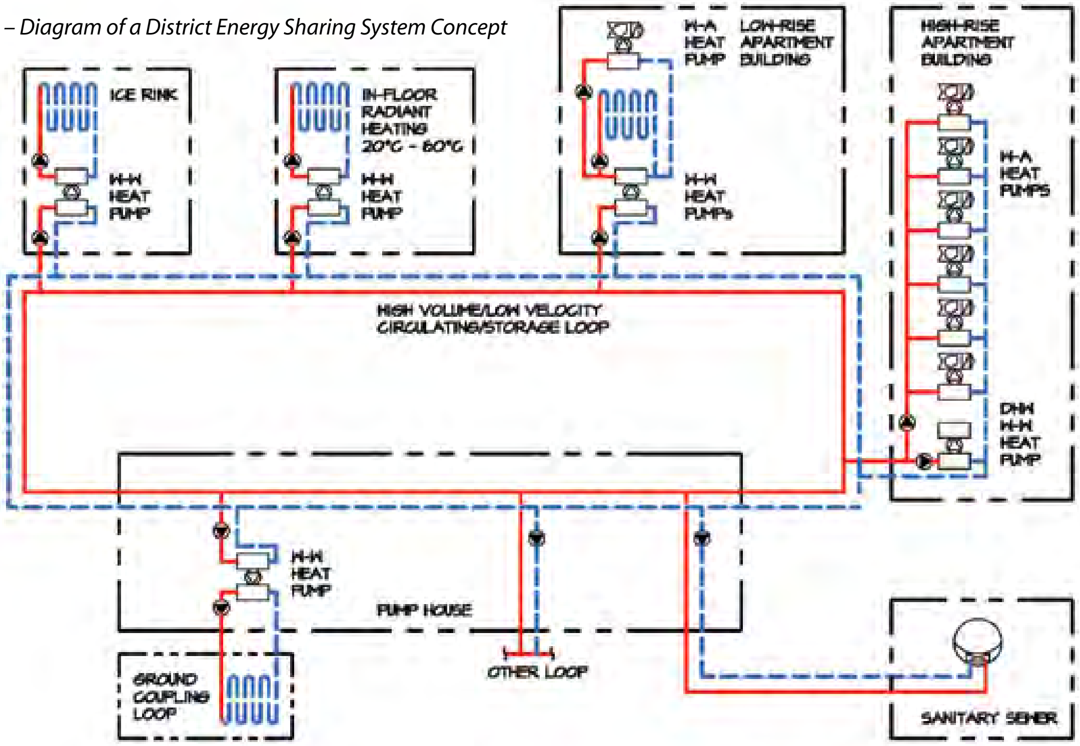
Background

As BC's municipalities work to reduce their carbon emissions, municipal wastewater is gaining attention as a potential new source of energy and reclaimed water. Because virtually every populated area has wastewater collection and treatment systems and wastewater temperatures generally range between 10ºC and 15ºC in the winter and over 20ºC in the summer, heat recovery from wastewater is an attractive option for reducing long-term energy costs and displacing fossil fuels as a heat source in homes and businesses.

Wastewater heat recovery requires a large amount of capital investment when compared with conventional energy sources. Nevertheless, it is possible to realize a payback in less than ten years by reducing natural gas and electricity use. To implement a successful project, several key questions need to be answered:

1) Where are the energy resources, and how much energy is available?
2) Once the heat is recovered, how can it best be used?
3) What kind of systems and infrastructure are required for this project?
4) How much will it cost to implement, and how will it be financed?

Figure 3 – Diagram of a District Energy Sharing System Concept



Click here to return to Table of Contents

How wastewater heat recovery works

There are several ways to extract the heat from wastewater, but generally, a heat pump or heat exchanger transfers heat energy from the wastewater stream to a closed-pipe system containing a carrier fluid, usually water or a refrigerant. This closed-pipe system referred to as a District Energy System (DES) then transports the heat to end users for space or hot water heating. DES have been around for over 100 years, but older high temperature systems tend only to operate on steam or hot water (80°C) and use centralized fossil fuel heat sources.

The amount of heat recovered from raw wastewater and treated effluent is dependent on wastewater temperature, flow rate, heat transfer efficiency, and specific heat capacity. For municipal wastewater, we are primarily interested in dry weather flow conditions to determine the amount of recoverable energy. Wastewater treatment plant influent must be above 10°C so as not to disrupt biological treatment processes, but treated effluent may be cooled to as low as 6°C. These conditions dictate the achievable inlet and outlet temperature differential in a wastewater heat recovery plant.

For illustrative purposes, a sewerage area with an equivalent population of 100,000 would produce about 300,000 GJ of recoverable heat per year, which is enough energy to heat 3,000 single-family homes in Vancouver and up to 5,000 single-family homes in Victoria.[1]

A newer and more progressive concept for a DES is the idea of using a low or 'ambient' temperature system. This concept increases the flexibility of a DES by allowing for a wide range of decentralized energy sources, energy sharing (cooling and heating) between users, and the possibility of a secondary role as a distribution system for reclaimed water from effluent.

Figure 1 shows a schematic of the Whistler Athletes' Village system, which is an ambient-temperature wastewater-sourced DES.

Step 1: District energy master plan

The first stage in assessing wastewater heat recovery options involves a high-level overview of potential heat sources, end users, district energy concepts, and relative costs. Master plans establish goals for district energy, define the relationships among various energy sources and end users, and identify key district energy opportunities.

A good starting point is often to use a sewer network model to estimate heat availability throughout the system. Using modelled sewer flow estimates to calculate the available heat, a detailed spatial profile of heat resources is readily producible. It is also important to consider other sources of waste heat such as large refrigeration units (such as grocery stores, ice arenas, and cold storage warehousing), industrial processes and even greenhouses.

After developing an inventory of energy resources, a profile of potential end users needs to be established. Opportunities to establish a DES arise through building retrofits, redevelopments, and new developments. Early retrofit opportunities are more likely to occur in civic and institutional buildings because of access to lower-cost capital and grant funding. Several new developments, including Dockside Green (Victoria), Westhills (Langford), and both Olympic Athletes' Villages (Vancouver and Whistler), feature heat recovery from wastewater.

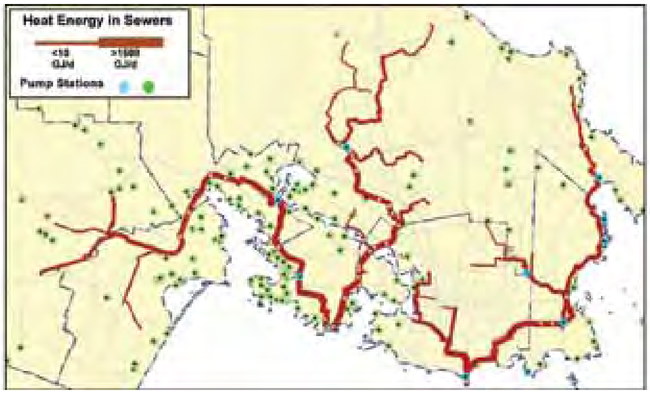


Figure 2 – Wastewater Heat Map for the Capital Regional District. Includes trunk sewers greater than 450 mm diameter.

Using a GIS database to store the energy resource information obtained from the inventory process, is recommended. This provides energy planners with a visual tool to conceptualize district energy plans, and it provides a platform for developing planning toolsets, and determining infrastructure requirements. By ranking opportunities on the unit cost of energy produced, a municipality can identify which projects have a higher likelihood of success. Spatially enabling the entire process allows planners to unlock synergies between potential opportunities.

Figure 2 shows an example of wastewater energy mapping in the Capital Regional District.

Step 2: Evaluate project feasibility

After identifying the most promising opportunities, a detailed feasibility analysis is required for each potential project. Assessing the feasibility of a given project involves considering the individual building envelope and mechanical systems, the DES infrastructure, and various energy sources. It should also include a phasing plan and an assessment of other renewable energy sources such as geoexchange, and solar and wind power.

The ultimate goal of a feasibility study is to identify a DES concept that maximizes benefits and minimizes costs. The primary benefits of a DES are the potential for reducing GHG emissions and providing non-potable, reclaimed water. Maximum GHG reduction occurs when overall reliance on fossil fuel energy input to the DES is reduced. District Energy Sharing Systems (DESS) are one method of achieving a net reduction in energy use while providing a non-potable water distribution system.

A DESS is a two-pipe ambient temperature system that allows users to either extract or contribute energy to the system. For example, a residential building requiring heating during a winter day could be supplied by an office building that requires cooling because of high occupancy and a large number of computers. Net meters in each building track whether a user is contributing or extracting energy from the DESS. A secondary benefit of the DESS approach is provision of a non-potable water system that can supply irrigation and toilet flushing needs (think, '*purple pipes*'). A recent feasibility study by KWL and DEC for the Corporation of Delta indicated that energy use reductions of greater than 80% compared to business-as-usual are possible. KWL and DEC estimate that a system for the Westhills development in Langford, BC may achieve reductions in potable water use greater than 40%, with a similar energy use reduction. Both systems feature wastewater as a primary heat source.

Figure 3 shows the various components of a DESS.

---

[1] Based on published rates by Terasen Gas (BC) Inc.
Typical annual natural gas use for Vancouver = 90 GJ; Victoria = 59 GJ.

Click here to return to Table of Contents

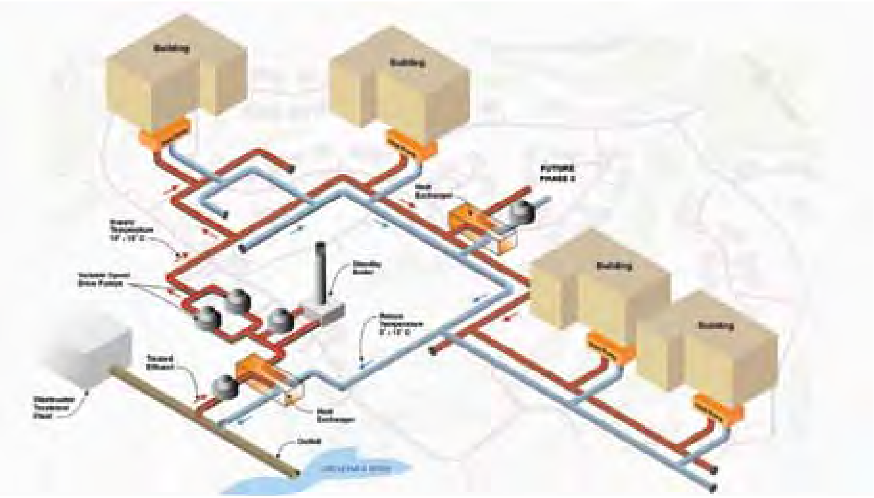


Figure 1

Whistler Athletes' Village District Energy-Sharing System Schematic

Two-pipe closed loop can provide both heating and cooling.

Step 3: Develop business case

The business case for a wastewater heat recovery project must include financing costs and sources, a customer base, and an ownership structure. Ownership and financing are closely linked in most arrangements. Municipalities have access to low-cost financing compared to what would be available for most privately financed projects. Reserve funding and development cost charges are other potential financing options. Private-sector arrangements include P3s and complete outsourcing to a third party. Existing utility companies already have customer service capabilities in place, which may lead to efficiencies where projects include large numbers of customers. Grants, subsidies and rebates from senior governments provide additional sources of funding for renewable energy projects.

Other considerations in developing a business case include how the district energy utility may be regulated, integration of a reclaimed water strategy, and licensing of third-party heat recovery projects. In addition, energy pricing must be attractive enough to pull customers away from conventional energy sources. Based on current energy prices, this means the total cost of providing recovered wastewater heat should be in the $10-$15/GJ range.

Step 4: Design, build and operate

After developing the business case, the challenge of implementing a DES begins. Designers must consider energy load and supply profiles, distribution pipe material, back-up energy sources, and control systems. Generally, a wastewater heat source needs only to provide 60-70% of the peak load condition to meet 95-98% of annual energy requirements in BC. During extreme winter temperatures, it is typical for a DES to rely on a back-up natural gas boiler system to meet peak demands. This arrangement has the dual advantage of increasing the potential customer base and making maximum use of the recoverable energy. The Whistler Athletes' Village DESS is an example of a project where sizing the heat recovery system to the above criteria resulted in a 70% reduction in GHG emissions when compared to a business-as-usual approach.

Wastewater heat may not always be available when required. Peak wastewater temperatures coincide with peak domestic flows that usually occur from 7:00 am until 9:00 am, and from 6:00 pm until 8:00 pm. Space heating and hot water heating, however, are needed a couple of hours prior to these times; therefore, the DESS must be able to store energy – either using tanks or in heat sinks such as soil and groundwater – and also use anticipatory controls to ensure that heat is available when it is demanded. An ambient temperature DESS may also store energy in the distribution piping for a couple of hours to pre-condition the system before peak heating periods.

Conclusions

As climate change and GHG reduction continue to change the way we do business, considering waste streams as resources becomes ever more important. A DES based on heat recovered from wastewater can be a catalyst for larger-scale renewable energy opportunities. With the right combination of technical expertise, capital funding, and champions of the cause, many municipalities can realize wastewater heat recovery at a competitive cost.

Authors:

Chris Johnston, PEng, Vice President, Kerr Wood Leidal Associates Ltd.

Chris has over 20 years experience in the consulting engineering industry, and has been involved in numerous master planning studies including water, sewer and stormwater projects.

Erik Lindquist, PEng, Senior Project Engineer, DEC Mechanical Design Consultants Ltd.

Erik has 18 years experience in mechanical engineering. Most of his recent work has been in the initiation and management of the design and construction of the Westhills District Energy Sharing System.

John Hart, M.A.Sc., PEng, Senior Wastewater Process Engineer, Kerr Wood Leidal Associates Ltd.

John recently joined KWL as a senior wastewater process engineer with a wide range of project management experience from municipal wastewater treatment to contaminated sites.

Mike Homenuke, PEng, Infrastructure Planning Engineer

Mike has worked for KWL for six years, and specializes in integrating GIS solutions into engineering problems, primarily in municipal sewer systems and hydroelectric energy.

Click here to return to Table of Contents