FEATURE

Heat-Seeking Sewer Model:

Finding waste heat in sewers and matching it to opportunities

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Courtesy city of Vancouver, B.C.

At the False Creek Energy Centre pumping station, raw municipal sewage is diverted to a screen filter to remove solids and then sent to heat pumps installed in a series-counterflow arrangement to generate 80 C (176 F) water in the district energy loop. The heat pumps run all year long and are complemented with natural gas boilers during peak-load conditions.

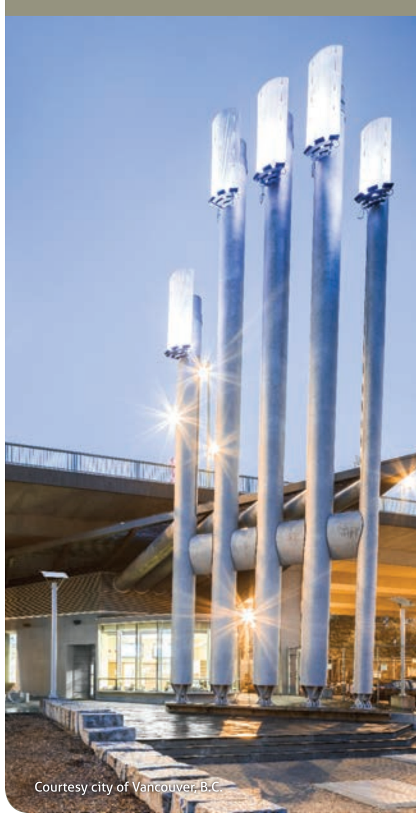
Metro Vancouver is a regional district in British Columbia, Canada, that supports 2.4 million residents and operates 530 km (329 miles) of trunk sewer, 33 regional sewage pump stations and five regional wastewater treatment plants – processing 1 billion liters (264.2 million gal) of sewage each day. A significant amount of renewable heat flows through Metro Vancouver's sanitary sewer system as warm sewage. This excess energy can be recovered and used to heat buildings, and it is an economical means of displacing natural gas and reducing greenhouse gas emissions.

One example of an application of this is North America's first raw sewage heat recovery plant at the Southeast False Creek Neighbourhood Energy Utility, a district energy system located in Vancouver, B.C. The plant was designed to utilize untreated municipal sewage as its main heat source to supply 70 percent of the space heating and domestic hot water requirements for the city's Southeast False Creek community, lowering emissions by more than 50 percent compared to conventional energy sources. Since the completion of the plant in 2010, the interest among Metro Vancouver municipalities and other potential stakeholders in using sewage heat for space heating and cooling has only grown.

THE FRAMEWORK: RULES TO ENABLE VIABLE PROJECTS

As part of its regional Integrated Liquid Waste and Resource Management Plan, Metro Vancouver is

SOUTHEAST FALSE CREEK NEIGHBOURHOOD ENERGY UTILITY



Courtesy city of Vancouver, B.C.

The sustainable community of Southeast False Creek near downtown Vancouver is served by an innovative district energy system that taps waste heat from untreated sewage to supply domestic hot water and space heating to connected buildings. The system's False Creek Energy Centre integrates a municipal pump station where, similar to a geothermal application, heat pumps transfer thermal energy from the sewage to a hot water distribution network.

To learn more, see: City of Vancouver Neighbourhood Energy Utility fact sheet – http://tinyurl.com/nurx2o7

Located under the Cambie Street Bridge, the False Creek Energy Centre features an array of exhaust stacks designed as sculptural public art, topped with LED lights that change color from blue during low energy demand to red during high demand.

enabling communities to build energy systems by establishing clear rules and providing relevant information and decision-making tools so that well-informed choices can be made. Interest in sewage recovery projects has been steadily rising as a result of Metro Vancouver's goal of using waste as a resource, energy price increases and interest in substituting renewable energy sources for fossil fuels to support municipal and provincial climate change and energy objectives. With a number of stakeholders approaching Metro Vancouver about developing sewage heat recovery projects, the district needed guidelines and tools to assess its potential sewage energy capacity, allow agreements between relevant parties to enable such innovative projects, and ensure that these innovations would not have any negative impact on existing sewage treatment processes.

In consultation with its municipal members, local utilities and other interested parties, Metro Vancouver developed the following set of policies for developing sewage heat recovery projects:

1. **Metro Vancouver's role** – The region's sewage collection system is two-tiered: Municipalities collect sewage from homes and businesses and convey it to larger trunk lines owned by Metro Vancouver, which then collects and treats the sewage. Metro Vancouver will only be involved with projects that extract heat from its own trunk collection system. Municipalities may, however, choose to allow heat extraction from sewage within their own collection systems. If this occurs, municipalities are only required to inform Metro Vancouver of such projects, as they could affect the district's ability to treat sewage. This rule provides clear boundaries of authority and limits Metro Vancouver's role at the municipal level.
2. **Allocation of heat** – Studies have shown that there is plenty of potential heat available within the sewer system (especially given the current technological capabilities of heat recovery systems). So for now, the rule is simple: First come, first served. This policy will be reviewed every three to five years. If sewage heat becomes a scarce resource, then the policy will be changed to reflect this. This rule keeps things simple to support rapid implementation of viable projects.
3. **Sewer heat users** – Any group can make arrangements to gain access to sewer heat from Metro Vancouver, whether a municipality, a public entity or a private developer. This rule keeps the potential pool of users as broad as possible to encourage viable opportunities. Competitive processes will be followed to ensure that arrangements are fair.
4. **Rate setting** – Metro Vancouver will recover costs for establishing a tie-in for access to sewage. Operational costs of the tie-in will be borne by Metro Vancouver. Under the current policy, no fee will be charged for the actual sewage, as raw sewage has no value without further refinement (which costs money). Contracts established under the policy will guarantee this for the life of the contract. The value of the sewage will be reassessed each time the policy is reviewed, and future contracts will reflect any changes made. This rule is intended to provide financial stability for potentially viable projects.
5. **Boundaries of responsibility** – As with other private properties connecting to municipal systems, Metro Vancouver will construct tie-in points to its system, providing access to sewage at its property line (or boundary of right-of-way). The interested party may then extract heat from the sewage and return the sewage to the Metro Vancouver system. This rule keeps things simple legally by tying responsibilities to property ownership.
6. **Project approval criteria** – Before a project is approved, it must meet a number of technical requirements that were established to protect Metro Vancouver's infrastructure and operations as well as confirm project viability. This rule ensures that Metro Vancouver's core wastewater treatment operations are not impaired and also provides a clear process for successfully establishing access.
7. **Greenhouse gas benefits and costs** – Greenhouse gas reduction credit allocation will be established on a case-by-case basis and will depend on a number of criteria, including principally who incurred the financial costs. This rule allocates these benefits to correspond with costs.

These policies were established to ensure that the process for developing a sewage heat recovery project on Metro Vancouver's system was transparent and reasonably paced.

HOW MUCH HEAT CAN SAFELY BE RECOVERED?

With policies in place, the question that still needed to be answered was, How much heat could be safely recovered without endangering the sewage treatment system and processes, both now and in the future? To answer this, Metro Vancouver retained Kerr Wood Leidal Associates Ltd. (KWL) in 2013 to examine the viability and implications of implementing sewage heat recovery projects throughout the region.

Reducing the temperature in the sewage system might at first glance seem harmless enough, but in truth a sewage system and its processes are complex. Temperature reduction in the sewage system could lead to operational issues such as buildup of fat, oil and grease on the walls of sewer pipes, which can cause blockages and increased maintenance costs. Lowering the temperature of sewage can also affect the wastewater treatment plants. Wastewater is treated using microbial processes, which rely on incoming nutrients and warm sewage to keep them active. If the influent temperatures in the treatment plants were to drop significantly, the entire treatment process could be compromised, resulting in lower treatment efficiencies. Although the minimum allowable sewage temperature can differ for individual wastewater treatment plants, 11 degrees C (51.8 F) was used as a minimum allowable temperature of the incoming sewage. Conversely, there are also concerns if sewage is to be used as a heat sink for cooling systems. Heated sewage will tend to have increased microbial activity, leading to odors and corrosion.

THE MODEL

To address these concerns, KWL developed the Heat-Seeking Sewer Model. The model calculates the sewage flow rate and associated sewage temperature at nodes within the sanitary sewer network. The sewage heat capacity throughout the system is calculated by tracking the flows and temperatures of each sewage component separately. This is the first model developed that can calculate these discrete changes for a large sewage network with multiple sewage heat recovery projects and can provide a geographic information system (GIS) interface and mapping capabilities.

THE MODEL IS ABLE TO MAP, QUANTIFY AND ANALYZE SEWAGE HEAT ENERGY CAPACITY THROUGHOUT THE METRO VANCOUVER SYSTEM.

The model (owned by KWL) is able to map, quantify and analyze the sewage heat energy capacity throughout the Metro Vancouver system. The model calculates the sewage flow rate and associated sewage temperature at nodes (i.e., manholes, valves, junctions, grit chambers, wastewater treatment plants, etc.) within the sanitary sewer network. The sewage heat capacity throughout the system is calculated by tracking the flows and temperatures of each component of the sewage separately. These sewage components are

- residential population-based flow;
- industrial-, commercial- and institutional-based flow;
- groundwater infiltration; and
- rainfall-dependent inflow and infiltration.

Each of the above components has a temperature and flow rate associated with it. This data is inputted by the user, and the model calculates the downstream sewage heat characteristics.

The modeling engine consists of two modules: a hydraulic modeling engine and an advective temperature modeling engine. The hydraulic modeling engine is based on a steady-state hydraulic engine, which calculates the daily average flow at each node in the collection system. The advective temperature modeling engine tracks sewage temperature and available energy by using a mass balance of the sewer flow components. The advective temperature modeling engine also tracks the total energy recovered from the system by sewage heat recovery projects.

Various scenarios and sensitivity analyses can be generated by changing the variables and the loading information. These variables can be adjusted at a nodal level or at a global level. Variables that can be modified include population; size of residential and industrial, commercial and institutional area; industrial equivalent population rate; institutional equivalent population rate; commercial equivalent population rate; base sanitary flow rate per capita; groundwater infiltration rate; rainfall-dependent inflow and infiltration rate; residential sanitary temperature; industrial, commercial and institutional sanitary temperature; rainfall-dependent inflow and infiltration temperature; and groundwater inflow temperature.

Once the Heat-Seeking Sewer Model was developed, KWL ran the model on Metro Vancouver's sanitary sewer system. The results were compared to the flow- and temperature-monitoring data collected at each wastewater treatment plant to confirm their validity. The model results were found to be accurate within 7 percent or better.

The model was run under the following three scenarios:

- **Summer dry weather flow** – This is a period when the sewage temperature tends to be at its highest and thus the period with the most heat availability. It is of interest when considering cooling or supplying domestic hot water loads.
- **Winter dry weather flow** – In this scenario, the cooler ground temperatures lower the temperature of the sewage, lowering its available heat. This is suitable as a design heating condition in most regions.
- **Winter wet weather flow** – In this period, the least amount of sewage heat is available due to the cooler ground temperatures and the cold rainwater or snowmelt that makes its way into the sanitary sewer system. This should be considered in combined sewer systems or locations with high leakage rates as it can temporarily disrupt heat recovery and lower the efficiency and output of the heat recovery system.

Under all modeling scenarios, two temperature constraints were applied. The first was that the sewage temperature, at any given time, could not drop below 6 C (42.8 F), which was assumed as a physical limitation of a "typified" heat recovery process. The second was that the inflow temperature at the wastewater treatment plant was set to a minimum of 11 C (51.8 F).

PLENTY OF SEWAGE HEAT AVAILABLE

The model results show that there is plenty of heat in the sewer system to heat homes, with the average hourly sewage temperature generally above 11 C (51.8 F) year-round. Based on winter dry weather flow, there is a total of around 45 MW of sewage heat that can be recovered to heat buildings in the city of Vancouver and around 100 MW regionwide,

Figure 1. Screenshot From the Heat-Seeking Sewer Model Showing Thermal Energy Potential Along Metro Vancouver's Sewer System in the City of Vancouver, B.C.

Source: Kerr Wood Leidal Associates Ltd.

The Lions Gate Wastewater Treatment Plant is one of the high-potential locations in Metro Vancouver for a heat extraction project, due to the large amounts of sewage converging there as well as the available space for extraction equipment.

which could heat up to 700 high-rise buildings across Metro Vancouver. This would translate to a 200,000-tonne regional reduction of greenhouse gas emissions per year.

Figure 1 shows a screenshot of potential thermal energy extraction capacity at manholes. The potential heat capacity increases as the sewage accumulates through the collection system. The thermal energy shown on the map is the theoretical maximum capacity that is available at each manhole during winter dry weather conditions, assuming the thermal energy is extracted at only that point. The largest amount of heat available is just upstream of the treatment plants, as well as in the major trunk sewers.

Once thermal energy is extracted at any manhole, the downstream capacity is reduced, which is analyzed in the model by recalculating the downstream temperature based on mass balance. The user is then able to assess the cumulative impact of multiple heat recovery projects. For instance, if 30 MW of heat were extracted just ahead of the treatment plant in Vancouver, the model would show there would only be 15 MW remaining that could be allocated to other heat recovery projects in the upstream sewer catchment area.

IMPLICATIONS OF THE MODEL

The Heat-Seeking Sewer Model is an effective tool for Metro Vancouver to use to manage and safeguard the sewage system, enabling it to permit sewage heat recovery projects at locations in the collection system that will not adversely affect sewage collection and treatment processes and to prevent them at locations that will. It has enabled Metro Vancouver to assess the energy capacity of sewage for proposed sewage heat recovery projects and allocate available resources in an effective manner. Because of its mapping capability, the model also enables energy planners to match sewer heat resources to potential development areas, thus optimizing the utilization of sewer heat. The model can be run and rerun to assess and reassess changing conditions in the system. This is crucial to determining the viability and advisability of proposed sewage heat recovery projects.

Although this model was applied to the Metro Vancouver sewage collection system, it could be deployed in any such system. The development of this type of technology will support the broader implementation of viable sewage heat recovery projects and effective management of the underlying sewage collection and treatment systems.

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