Challenges of Designing Wastewater Heat Recovery Systems

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Outline

• Wastewater 101

• What resources are available?

• Who is able to use them?

• How do you do it?

• What will it cost?
Wastewater Sources

Homes & Businesses

Industries

Sewers

Wastewater Treatment Plants
Wastewater Components

Water

Organics

Primarily “used food”
Biodegradable

Solids

Fibres, Floatables, Grit

Dissolved Minerals
Heavy Metals
Trace Chemicals

Others

99% of Wastewater
Wastewater Flows

- **Rain**
- **Total Sewage Flow**
- **Domestic Sewage + Groundwater**: 12-18 °C
- **Inflow & Infiltration**: 2-10 °C

Graph showing hourly rainfall, flow, 1hr Avg RDII Flow, 24hr Avg RDII Flow, and DWF.
Typical Dry Weather Flow & Temperature

- Hourly Sanitary Flow (L/s)
- Measured Temperature

Flow vs Measured Temperature chart showing variations in flow and temperature over the course of a day.
Annual Sewage Temperature Profile

- **Heat Gain**
- **Sewage**
- **Drinking Water**

Data for Vancouver
Sewage Heat Estimation

Sensible Heat: $Q = m \cdot c \cdot \Delta T$

- Energy is proportional to flow x “delta T” (temperature drop)
- Consider minimum diurnal sewage flow
- Consider maximum allowable temperature drop
- Usually need a heat pump – add heat of compression
Typical Sewage Energy Profile

Design Load ~1500 kW
## Population and Sewage Heat

<table>
<thead>
<tr>
<th></th>
<th>Produces*</th>
<th>Consumes (avg. annual)</th>
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</thead>
<tbody>
<tr>
<td>1 Single Family Home</td>
<td>0.2 kW</td>
<td>2.3 kW</td>
</tr>
<tr>
<td>1 Apartment Building</td>
<td>16 kW</td>
<td>150 kW</td>
</tr>
<tr>
<td>Town of 10,000</td>
<td>700 kW</td>
<td>9,000 kW</td>
</tr>
<tr>
<td>City of 1 million</td>
<td>70 MW</td>
<td>1,300 MW</td>
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</table>

*5 deg C delta T
Utilizing Sewage as Heat Medium

- Need solids-handling heat equipment and some way to clean it if using raw sewage

- Heat generated from heat pump from 45 °C to 80 °C – return temperature is critical!

- Typical use is for in-building heating or district energy, process uses possible

- Can potentially be used as cooling medium as well
Limitations & Challenges

- Treated effluent is preferred, but usually WWTP is located some distance away from population centre

- Sewage flow varies diurnally and may not be available in sufficient quantities at peak heat demand

- Raw sewage entering WWTP with some biological process needs to be at least 11 °C

- Buildings with high temperature hot water requirements may not be able to effectively utilize sewer heat

- Can be costly and difficult to access trunk sewers and pump stations
On-Site Raw Sewage Applications

• Sewage discharge follows production of hot water for showers, dishwashing

• May need to balance supply and demand using heat reservoirs

• Likely limited to recycling domestic hot water

• Example: Seven35 by Adera in North Vancouver – 35 kW domestic hot water recovery using “Sewage SHARC” technology

Sewage SHARC – seven35 Townhomes
Photo: Mike Homenuke
District Energy Applications

• Hot water district heating or low-temperature/ambient systems

• Requires large flow source such as trunk sewer, major pump station or WWTP

• Examples: Southeast False Creek NEU (raw sewage/hot water), Cheakamus Crossing (treated effluent/ambient)
Process Applications

• Industrial / wastewater processes requiring low-grade heat:
  • Wastewater Treatment Plant
  • Digester Heating
  • Biosolids Drying
  • Process Water Pre-Heating
  • Greenhouses

• Can be done on-site or from a district energy system
Types of Processes

- Building Drains
  - Power Pipe
- In-Line Heat Exchanger
  - Rabtherm /
  - KASAG Gravitytube, Pressurepipe
  - Uhrig Therm-Liner
  - BB Heatliner
- Off-Line Heat Exchanger
  - DDI Cube
  - Sewage SHARC
  - Huber
  - Plate / Frame (Clear Water)
- Direct Heat Pump
  - Friotherm
  - TECSIR
  - Nova Thermal
Typified Sewer Heat Recovery System Design

**Sewage Source:** Gravity or Pressurized Flow? Pipe, Pump Station or WWTP?

**Solids Handling:**
- Grit Removal
- Suspended Solids > 2 mm

**Heat Exchanger (Optional):**
- Wide Gap
- Anti-Fouling / Cleaning System

**Heat Pump:**
- Direct Sewage Exchange
- Or Separated

Temperature Ranges:
- 15-20 deg C
- 12-17 deg C
- 7-12 deg C
- 45-80 deg C
- 35-65 deg C

Return screenings to sewer
Sewage Handling Issues

- Access to sewage
- Hydraulic conditions
- Solids management
- Odour management
Fats, Oils and Grease (FOG)

- Food service establishments are primary source of FOG
- Floats on water surface, will encrust on pipe walls, mechanical equipment
- Major nuisance for sewer systems
- Can heat recovery result in increased FOG precipitation?
Odours

- Sewer odours are mostly H₂S, VOCs
- Transported through airflow in sewer headspace
- Turbulence, siphoning, changes in grade cause odour to escape system
- Solids handling and pump stations are common situations that lead to odour problems
- Need to design sewer heat project so that it does not create a new odour problem!
- Odour control is expensive
Key Project Elements

**Demand Analysis** – Understand nature and size of heating and cooling loads to be served

**Supply Analysis** – Evaluate the sewage heat resource to understand what is available

**Sewage Heat Concept Design** – Specify the right components and processes to suit the size, nature and requirements of the application

**Economic Feasibility Study** – Conduct a lifecycle cost analysis to establish the cost of sewer heat recovery versus other alternatives
Sewer Heat Recovery Lifecycle Costs

- Maintenance Staff
- Overhead
- Consumables
- O&M 20%
- Electricity 40%
- Capital 40%

Sewage Process
- Heat Exchangers
- Heat Pumps
- Mechanical
- Site Work
- Building / Space
- Electrical
- Odour Control

Heat Pumps, Water Pumps, other Equipment
Demand Charge
Commodity Charge

*Plant Only*
## Optimizing Project Economics

<table>
<thead>
<tr>
<th>Capital Costs</th>
<th>Electricity</th>
<th>O&amp;M</th>
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</thead>
<tbody>
<tr>
<td>• Locate to minimize distance between source and loads</td>
<td>• Reduce design supply/return temperatures to heat pump (where possible)</td>
<td>• Automated cleaning system</td>
</tr>
<tr>
<td>• Co-install heat recovery process with sewer infrastructure project</td>
<td>• Use higher-efficiency heat pumps</td>
<td>• Proper sewage pumping design to avoid clogging</td>
</tr>
<tr>
<td>• Treated effluent is less-expensive process than raw sewage, but too far from load density?</td>
<td>• Minimize sewage and hot water pumping by increasing delta T</td>
<td>• Reduce mechanical components</td>
</tr>
<tr>
<td>• Reducing electricity and O&amp;M probably increases capital costs</td>
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2013 Pricing

• Southeast False Creek NEU - $5.81/m²/year + $40/MWh

• Cheakamus Crossing DES - $4.58/m²/year + heat pump electricity

• BC Hydro Step 2 Residential Rate - $103/MWh → $7.21/m²/year for baseboard heating
Summary

• Wastewater heat is everywhere, but best to have concentrated sources and loads

• Wastewater heat recovery potential is about 10% of total heating energy

• Consider practicalities of accessing sewage source

• Select appropriate processes for solids handling and odour management

• New DES projects in BC offer rates near cost of electricity
Thank you!

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