J.L.Richards
ENGINEERS · ARCHITECTS · PLANNERS




Wastewater Energy Transfer

City of Ottawa Scoping Study - Findings

Clean Air Partnership Webinar
November 4, 2021

Presented by:
Joan Haysom, Ph.D., P.Eng. J.L Richards & Assoc.
Janice Ashworth City of Ottawa

JLR’s Markets

Municipal

Buildings

Innovative Energy

Environmental

Industrial & Mining

J.L.Richards
ENGINEERS · ARCHITECTS · PLANNERS

JLR Team on this project

Joan Haysom, PEng, PhD
- Energy Market Chief
- Sr Energy Eng & PM

Jarrett Carriere, PEng, MSc, CEM
- **Sr Energy Engineer**
- Heat transfer & geothermal

Sheldon Dattenberger, PEng PMP, FEC
- **Senior Civil Engineer**
- Sewer infrastructure

Mohammad Heidari, PEng, PhD
- **Jr Energy Engineer**
- Geothermal analysis

Jon Milloy, PEng
- **Mechanical Engineer**
- Technology Review, Archetype systems

Adam Frey, EIT
- **Energy EIT**
- Archetype calculations

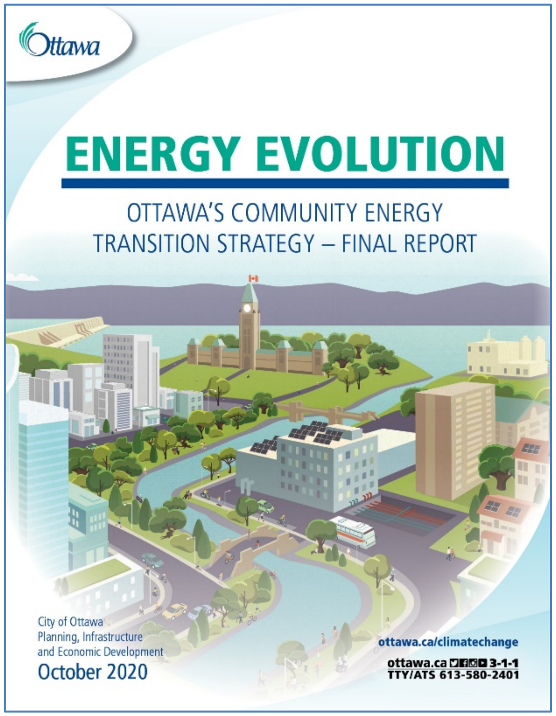
Jurek Wozniak, PEng
- **Sr Mechanical Engineer**
- Peer Review Technology & Archetypes

Kris Kerwin, CTech
- **Sr GIS Technician**
- ArcGIS platform for Wastewater and Geothermal

Eric Dubois, EIT
- **Mechanical EIT**
- Technology Review

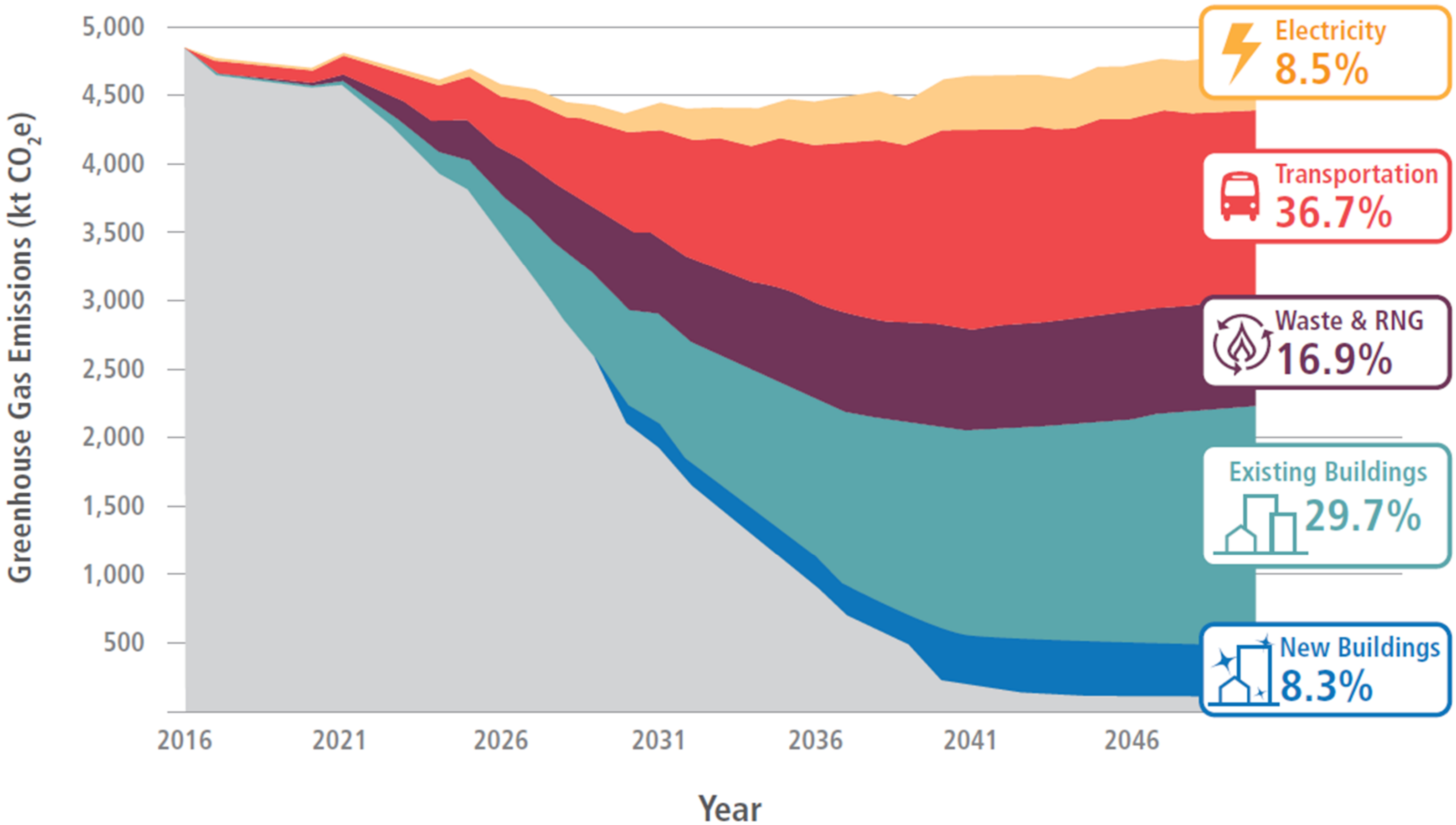
City of Ottawa: Energy Evolution Strategy

- Unanimously received by Council in October 2020
- Sets the framework for how Ottawa can achieve its GHG targets
- 20 projects are to be completed in the short-term (2020-2025) in five areas: Land Use, Buildings, Transportation, Waste and Renewable Natural Gas, and Electricity.



J.L.Richards
ENGINEERS · ARCHITECTS · PLANNERS

What it will take to achieve the targets



Overview

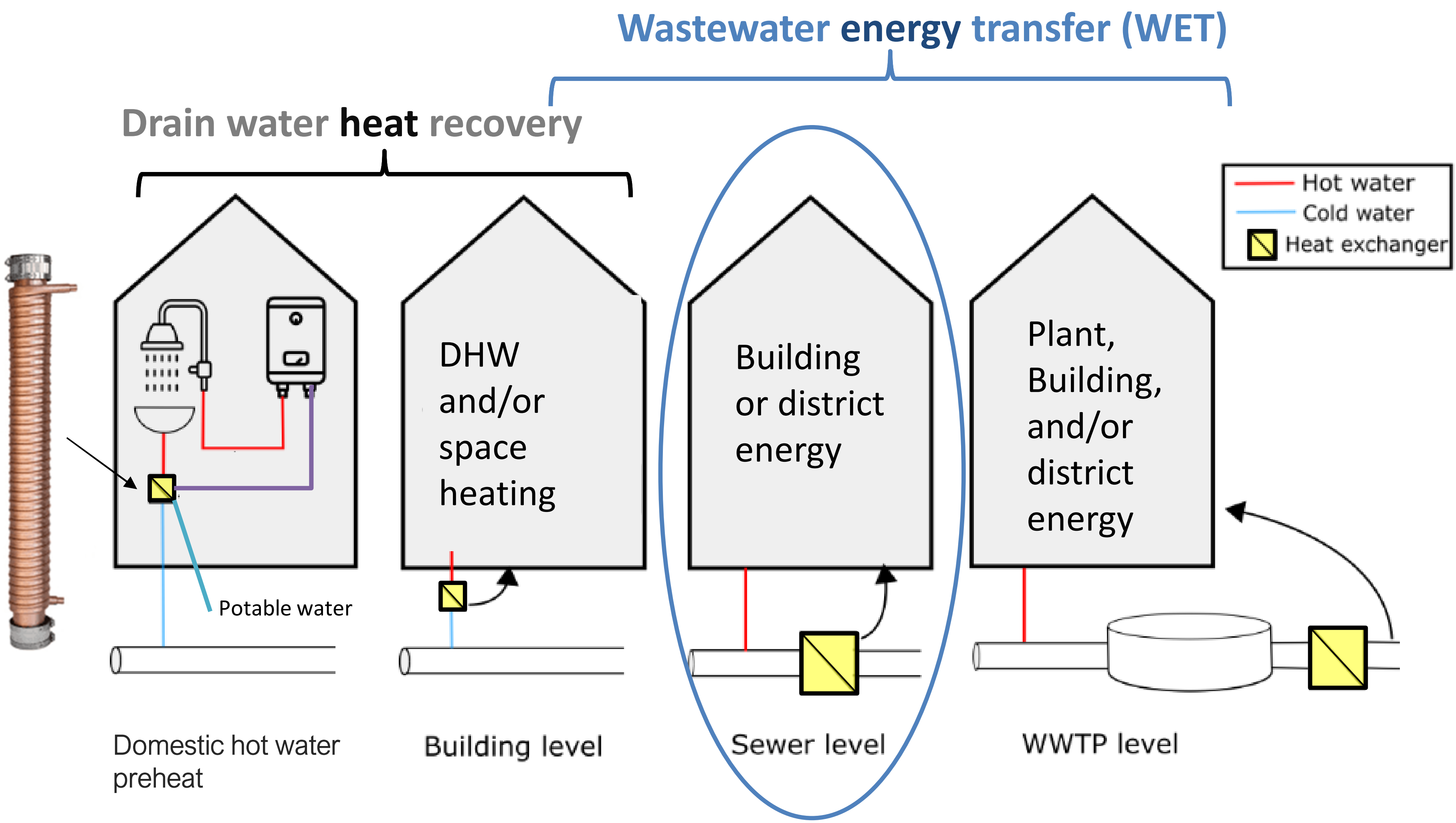
Acknowledgements

FEDERATION OF CANADIAN MUNICIPALITIES

FÉDÉRATION CANADIENNE DES MUNICIPALITÉS

J.L.Richards
ENGINEERS · ARCHITECTS · PLANNERS

Context: Four main types



Adapted from: Heat Recovery from Wastewater—A Review of Available Resource, Nagpal et al, J. Water, Apr 2021

J.L.Richards
ENGINEERS · ARCHITECTS · PLANNERS

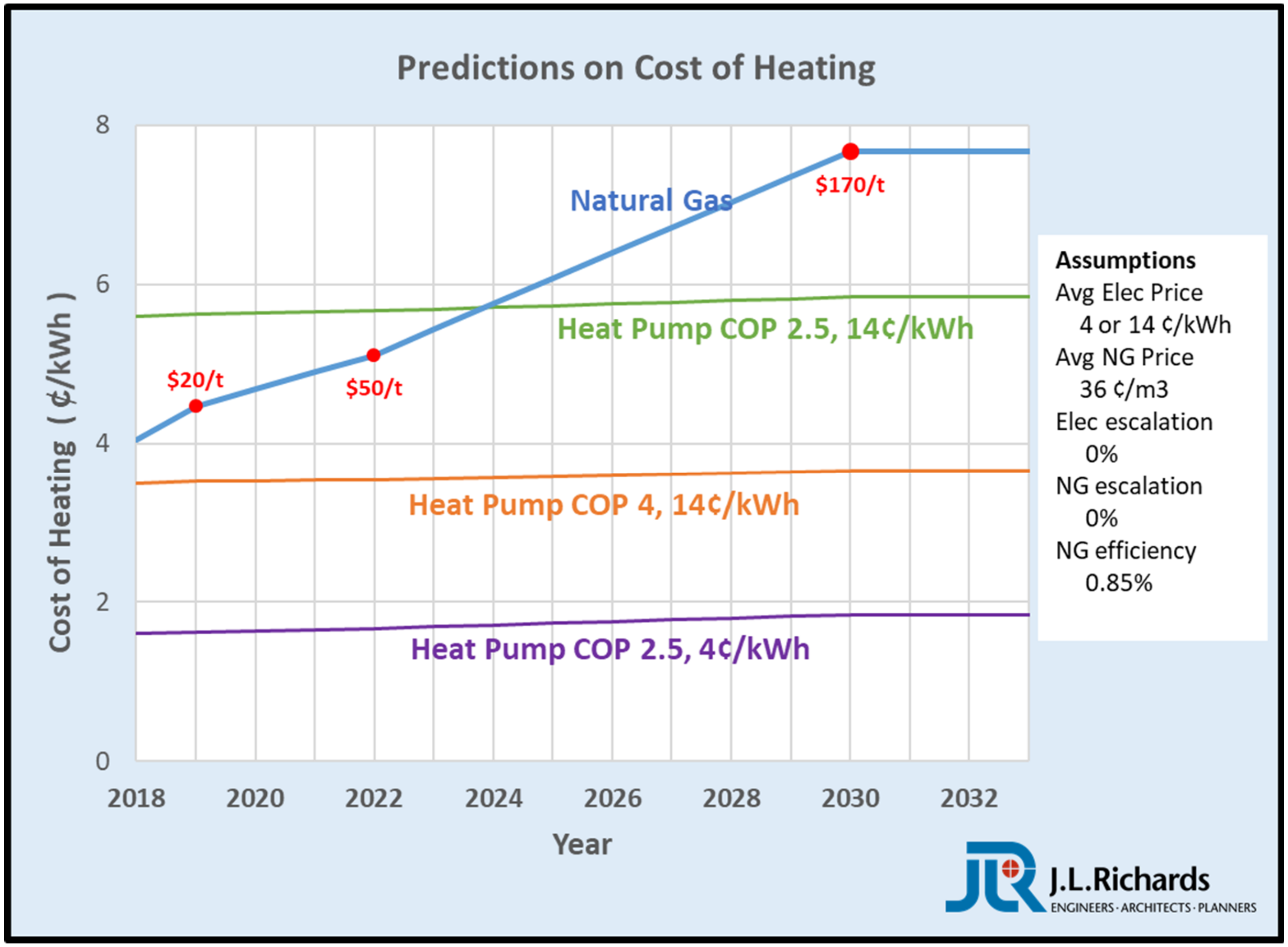
Motivation

- Heat exchange with a flowing liquid is the most efficient, especially when
  - Wastewater is warm in winter (~10°C)
  - Wastewater is cool in summer (~20°C)

⇒ **highest efficiency heat pump for heating & cooling**

- The "resource" is large in the urban core
- Alternative low carbon solutions:
  - Air source heat pump
  - Closed-loop ground source heat pump
  - Open-loop ground source heat pump

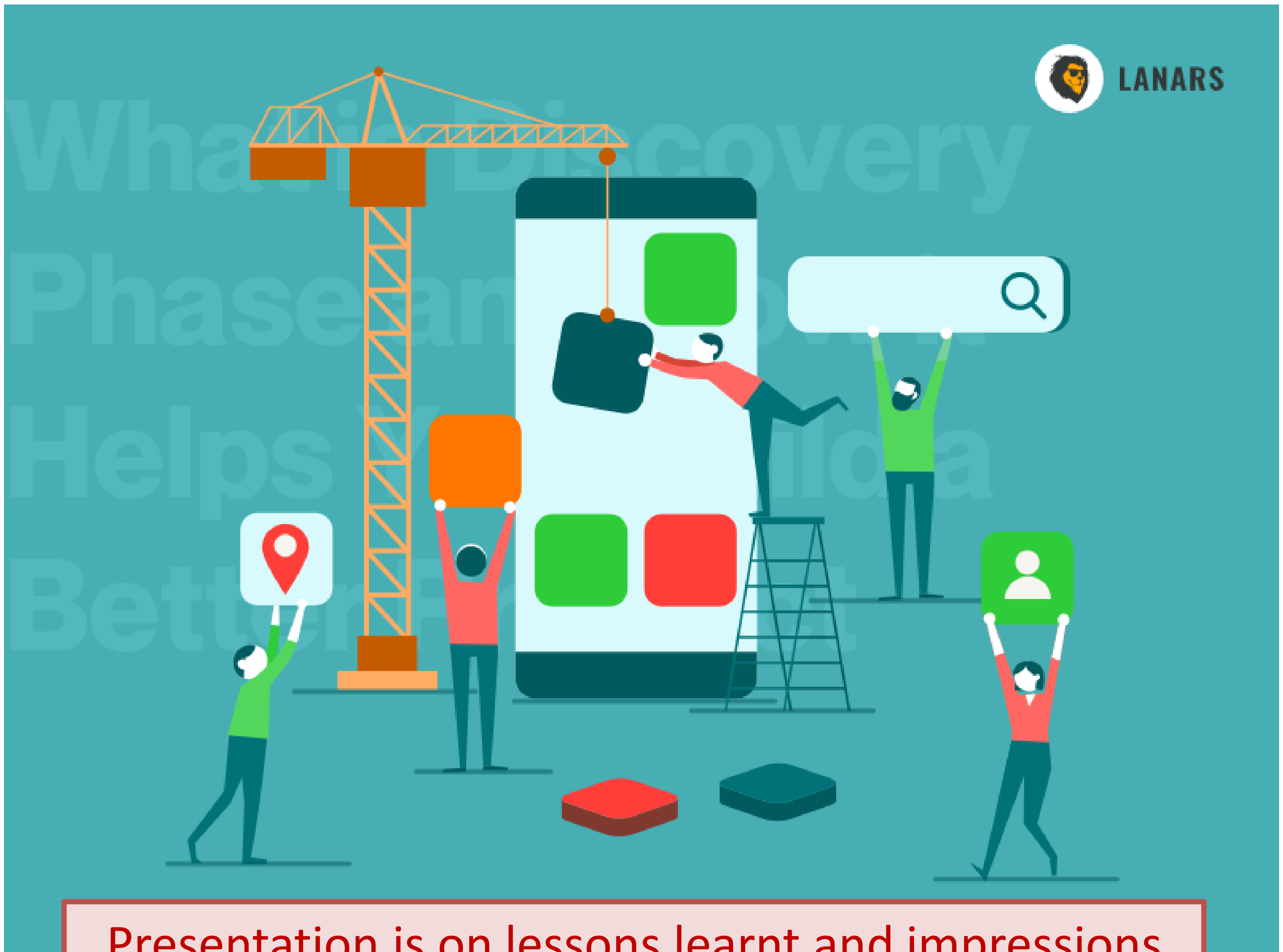
Heating Operational Costs



Outline

1. Technology Overview
2. Wastewater as a Resource
3. WET Implementation Design Concepts
4. Observations, Recommendations, Questions

The Discovery Process



Presentation is on lessons learnt and impressions to date. Understanding may evolve. Others in attendance may know certain items better.

Technology Overview

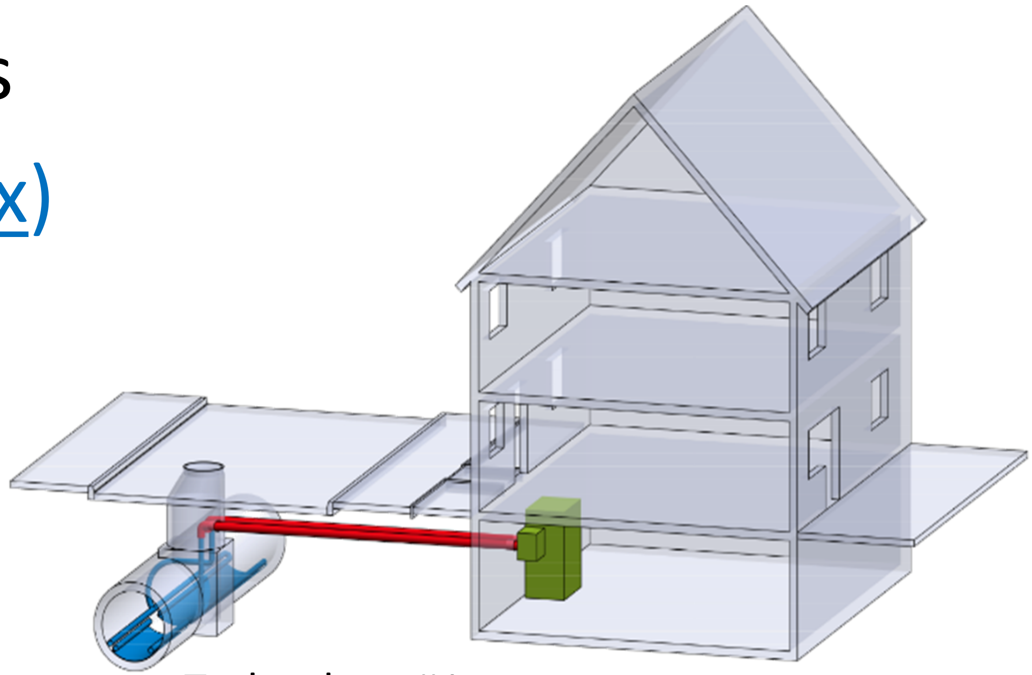
Main Components

Minimum components

- Heat exchanger (Hx)
- Pump
- Connection pipes
- Heat pump (HP)

Some systems have

- Wet well
- Filters, etc

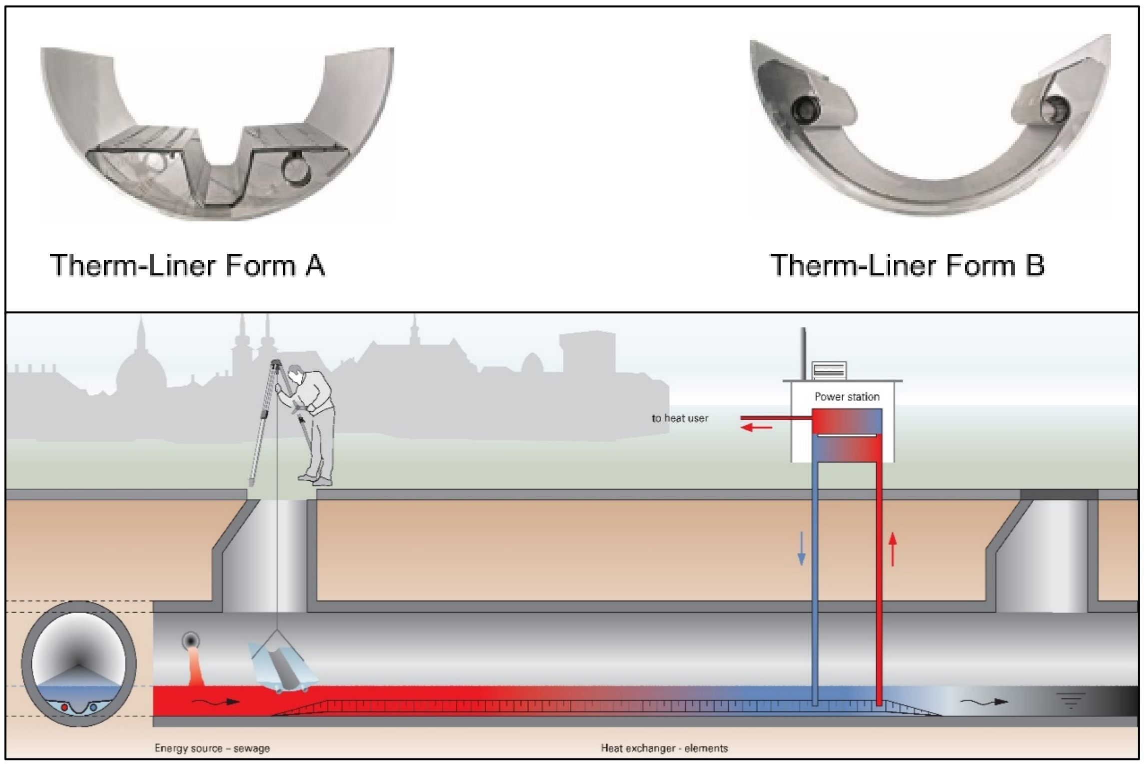

Technology #1

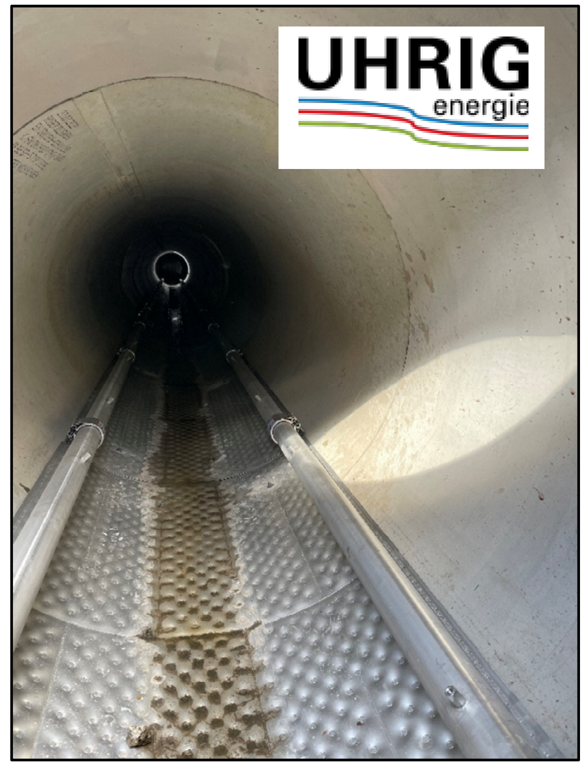
Source: UHRIG

Technology #1 – Hx placed in an existing sewer

- Introducing a new object into the wastewater flow
- Biofouling expected, accounted for in system design, annual clean suggested
- Lowest cost of deployment
- Many deployments in Europe, entering NA

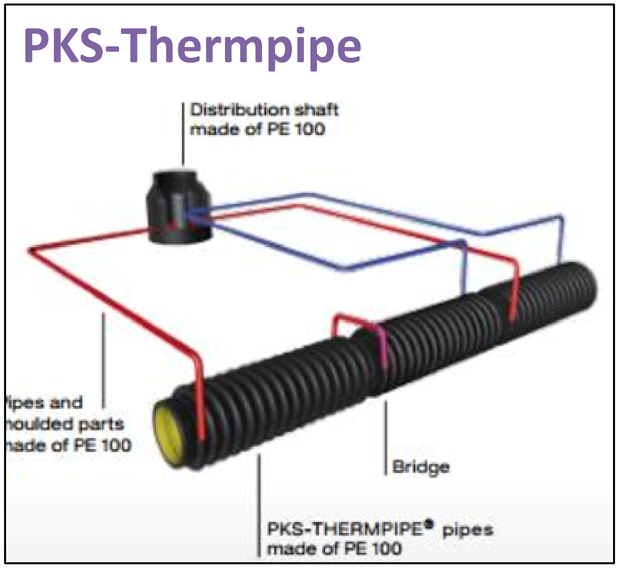
All images care of UHRIG Energie

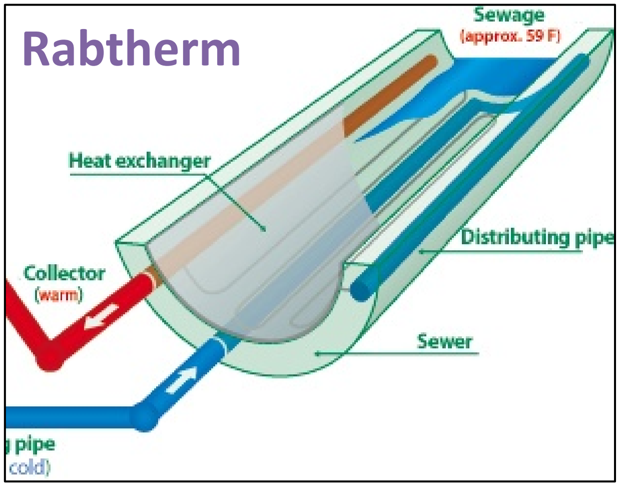




Technology #2 – Hx integrated into pipe

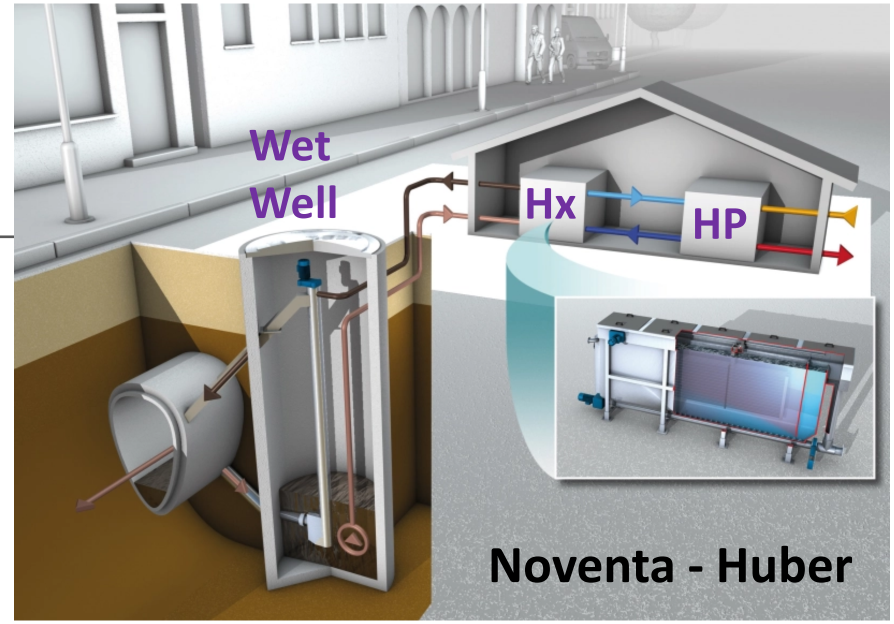
- No direct interaction with sewage
- Very low maintenance
- Will exchange heat with the ground too
- High civil costs *unless* planned
- No known installations in NA



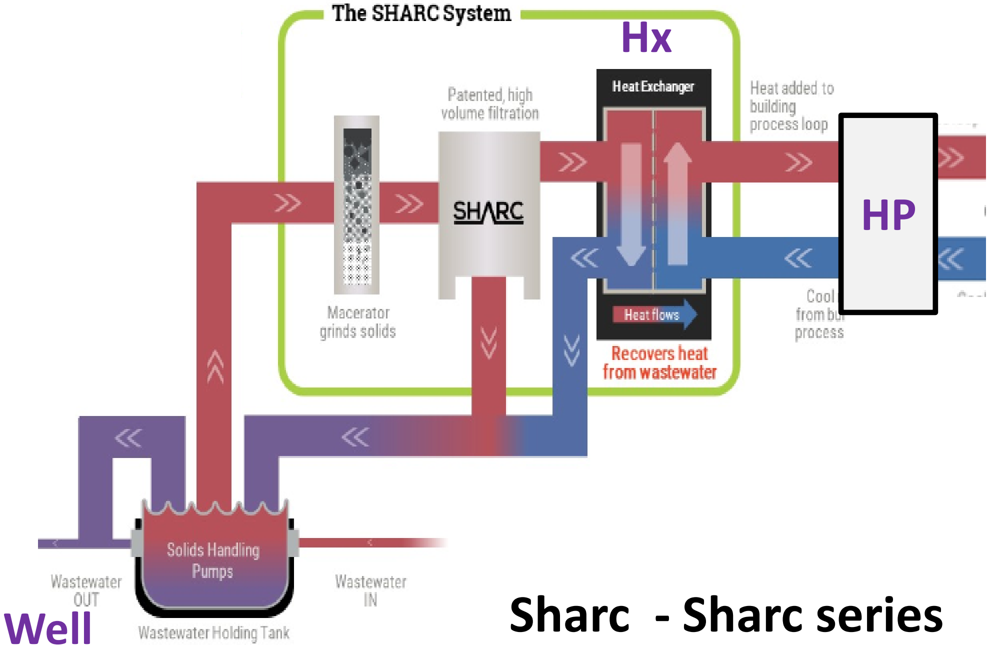


Tech #3 – External Hx

- Sewage is “borrowed" from pipe and pumped to a wet well
- Solids are separated from liquids
- Liquids pass through a proprietary heat exchanger
- Hx have integrated cleaning
- Configuration allows Hx to be optimized for efficiency
- Minimal impact on sewer pipe
- More equipment maintenance, more complexity, higher footprint
- Scalable, generally best for bigger flows, larger heat delivery
- Can integrate with pumping stations and WWTPs



Noventa - Huber



Wet Well

Sharc - Sharc series

Technology #3: Two Canadian Suppliers

- Noventa (Toronto) is exclusive Canadian supplier of German Huber Hx.
  - Will do any part of supply, design, build, finance, own, operate, maintain (spin-out from Enwave)

Toronto Western Hospital
8.5 MW heating, 8.4 MW cooling

- Sharc (Vancouver) Canadian developed technology
  - Primarily a supplier with design support, possibly energy as a service
  - Support through HTS
  - Note they also a building-scale product called Piranha

Vancouver False Creek Neighbourhood Energy Utility
3 MW heating ⇒ 8 M heating

Comparison of Key Parameters

	Tech #1	Tech #3
Sewage Flow	> 10 L/s	> 34 L/s
Sewage Pipe Size	400 mm +	600 mm +
Length in sewer	~ 100 m	n/a
Energy Exchange Potential	< 450 kW	MWs
Mech Room Footprint	< 20 m^2	20 – 60 m^2
Small system costs (80 kW)	$4,600 / kW	n/a
Medium system costs (450 kW)	$2,600 / kW	$3,200 / kW
Large system cost (1.5 MW)	n/a	$1,800 / kW

These are very rough characterizations for guidance only (+ 100%, - 50%). Each project will be different.

Technology #2 is similar to Technology #1

Wastewater as a Resource

Principles

$$\boldsymbol{Heat\ Capacity\ (kW) = Flow\ x\ 4.128\ x\ \Delta T}$$

Flow is flow rate of the wastewater, in L/s

4.128 is the specific heat capacity of the wastewater (assumed to be identical to water), in kJ/kgºC

ΔT is the temperature drop of the wastewater through in the Hx

$$\Delta T = T_{in} - T_{out}$$

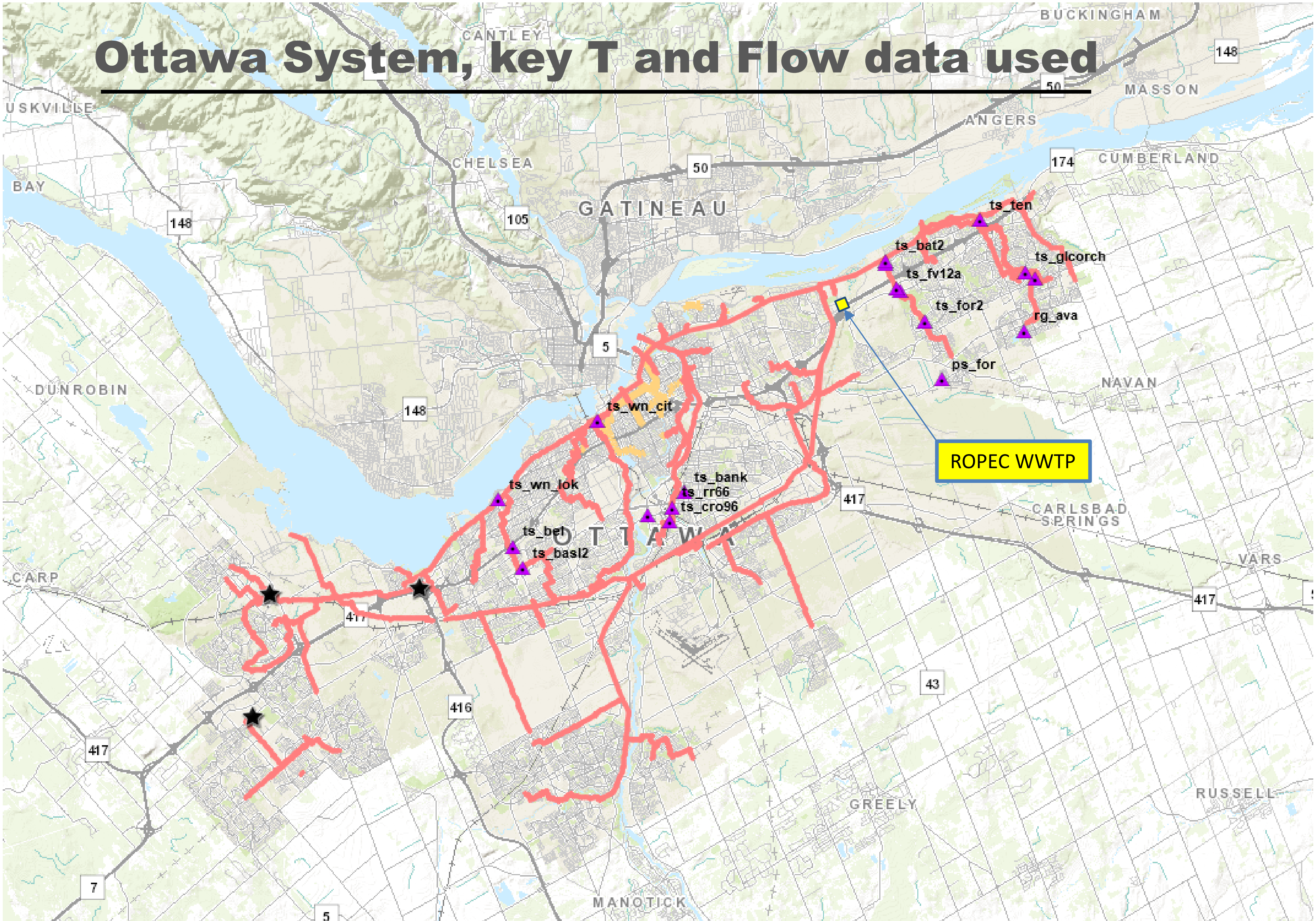
$\Rightarrow$ $\boldsymbol{Flow}$ is the primary determinant of heat capacity of a project.

$\Rightarrow$ T_{in} varies hourly and across the season

$\Rightarrow$ T_{out} should avoid freezing (we have imposed $T_{out} \geq 5°C$)

$\Rightarrow$ Heat pumps have to work harder when T is low, thus T mainly affects efficiency

Ottawa System, key T and Flow data used



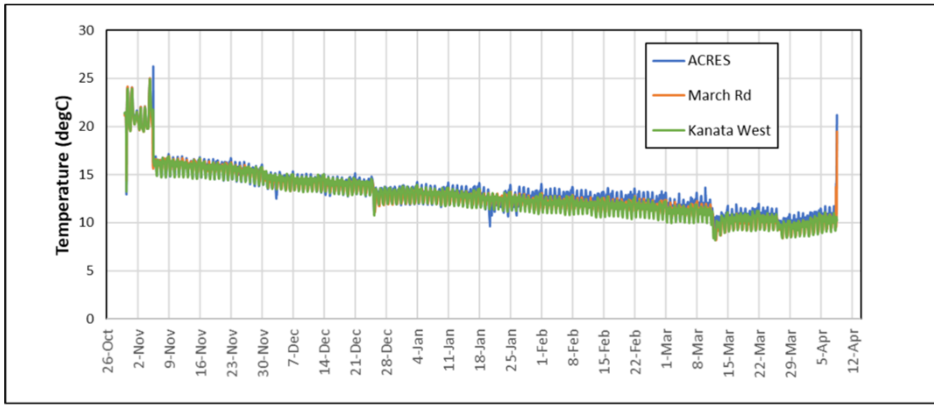
J.L.Richards
ENGINEERS · ARCHITECTS · PLANNERS

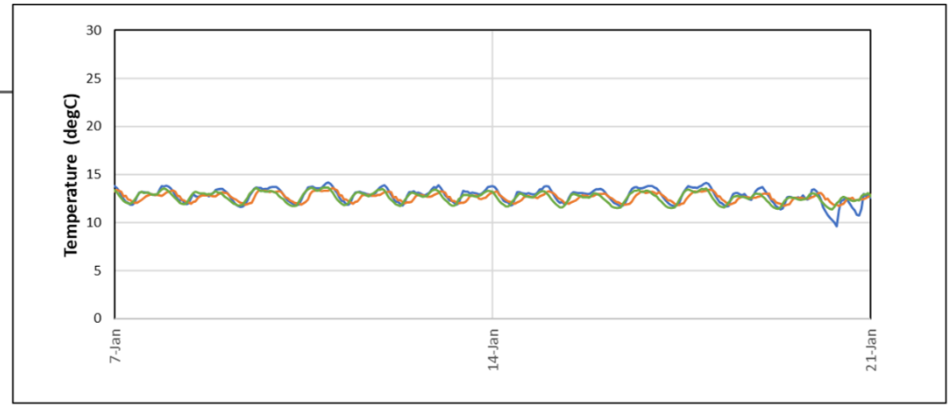
Flow & Temperature Data

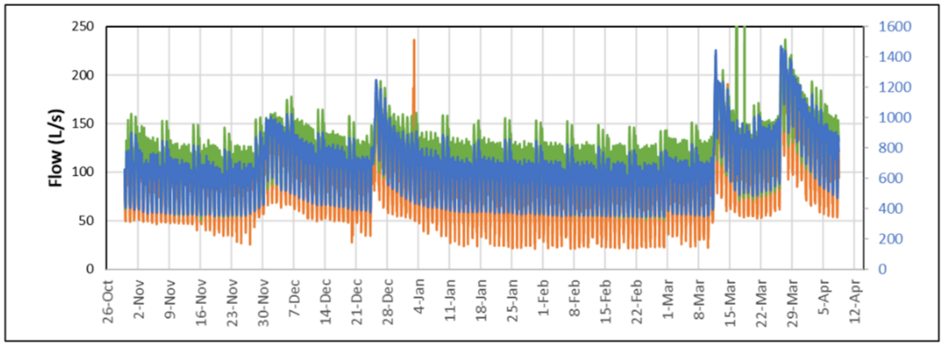
- 3 probes from the *UOttawa-CHEO COVID-19 Wastewater Study* produced golden datasets
  - coincident T and flow measurements
  - spanned the entire winter
  - Used *submersible* T probes

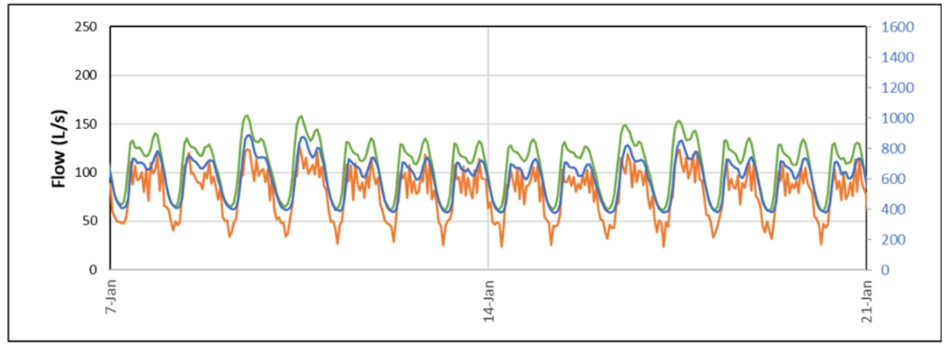
J.L.Richards
ENGINEERS · ARCHITECTS · PLANNERS

Coincident Measured Flow and T data – 1 of 2



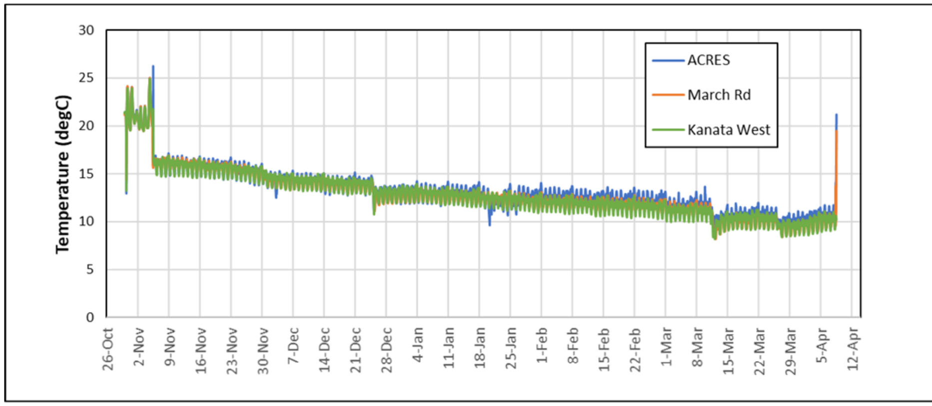


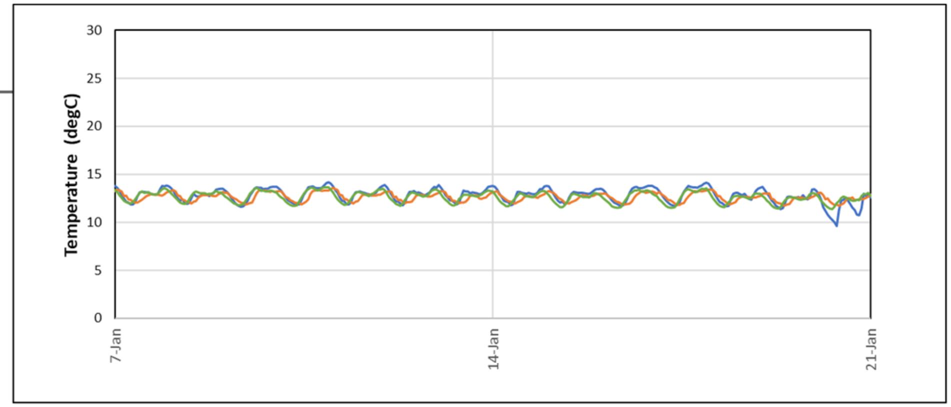


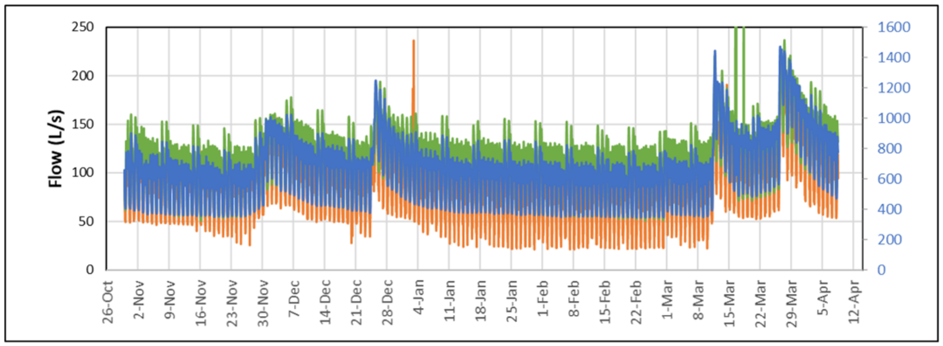


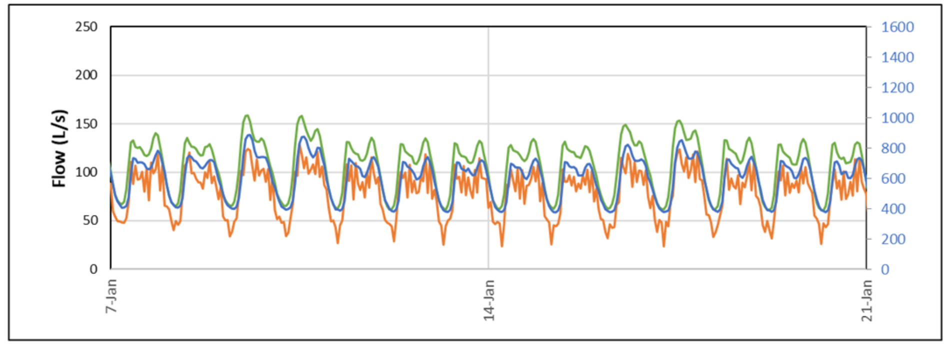
J.L.Richards
ENGINEERS · ARCHITECTS · PLANNERS

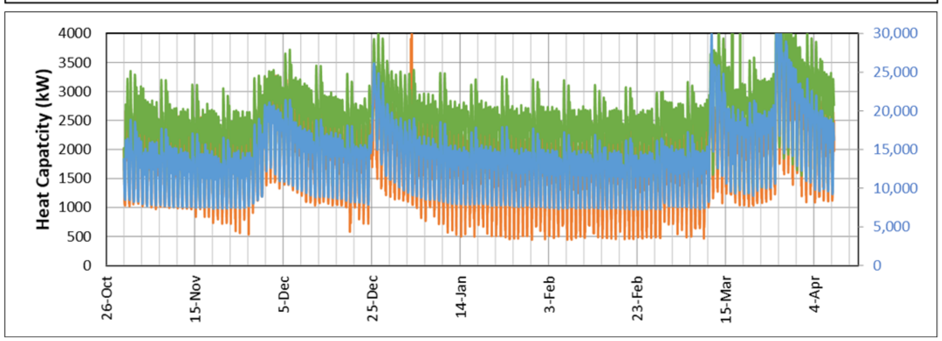
Coincident Measured Flow and T data – 2 of 2

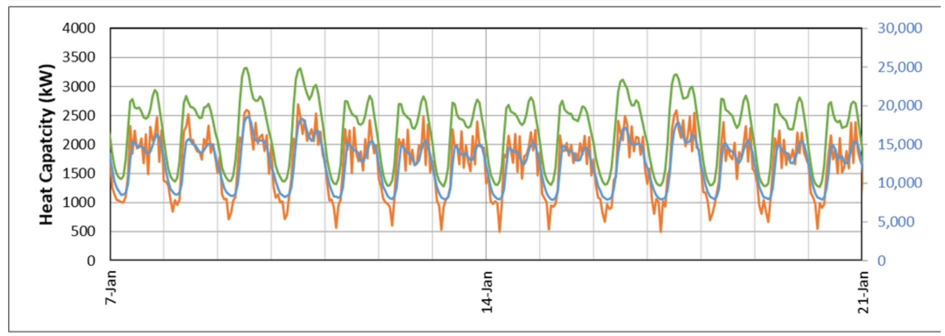




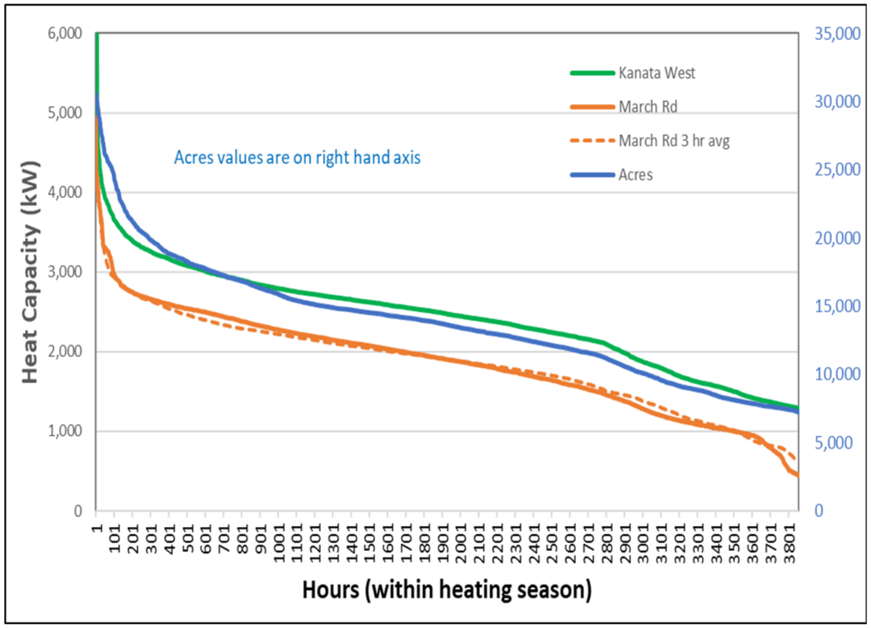








Heat Capacity Curves



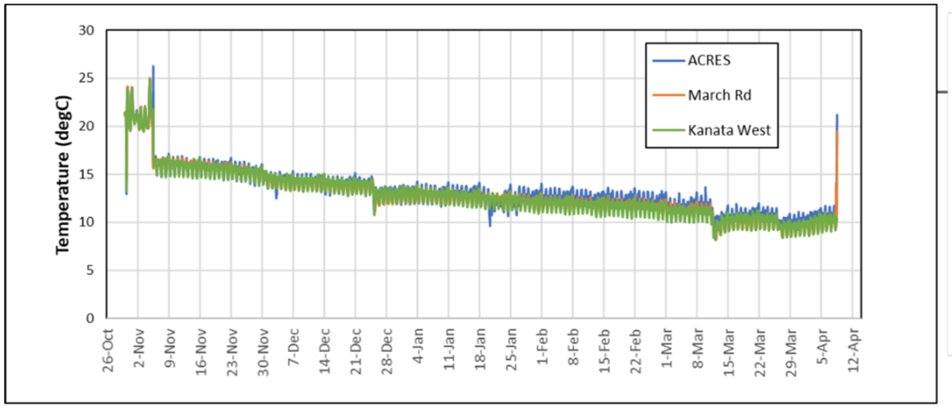
- Re-order hourly data into highest to lowest
- ➢ useful for design work
- ➢ H_{min} and H_{avg}
- ➢ Very different than other heat supplies

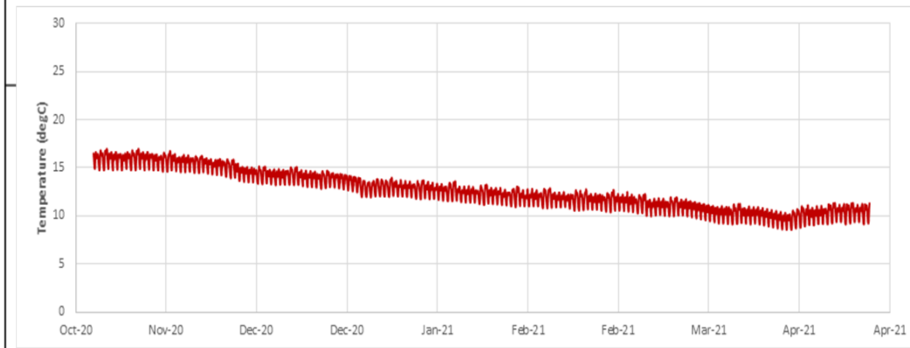
Flow Data

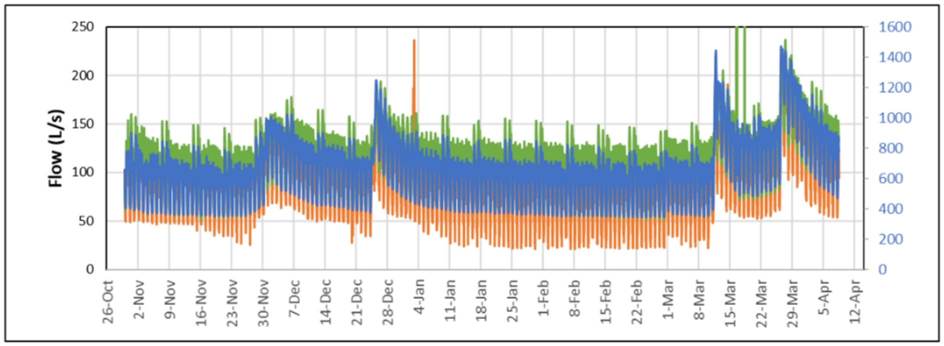
- 600 “ETS” flow measurements across the city
  - But short timespans, mostly spring/summer, sparse, non-coincident
- City uses these to calibrate flow models
  - **We concluded that flow models are typically the most available data for system-wide analysis**
  - **Modeling is *only an* indicative value**
  - We observed different flow values between different models
  - Hourly patterns of flow matter for WET projects
    - But hourly patterns vary dependent on the upstream users
    - Using 16 ETS sites, the minimum flow was found to vary between 20% and 65% of the average daily flow.
  - **Take real measurements during feasibility of a project**

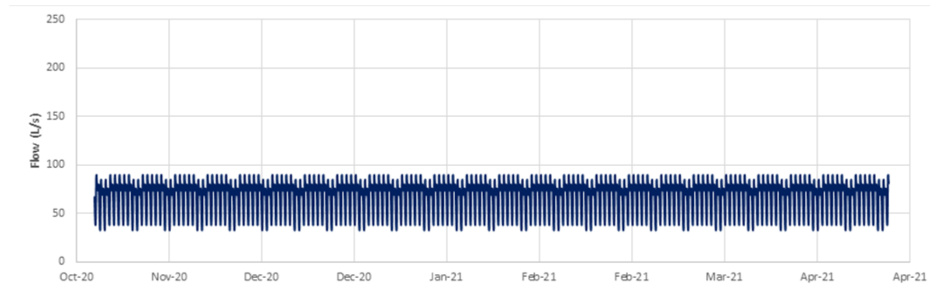
J.L.Richards
ENGINEERS · ARCHITECTS · PLANNERS

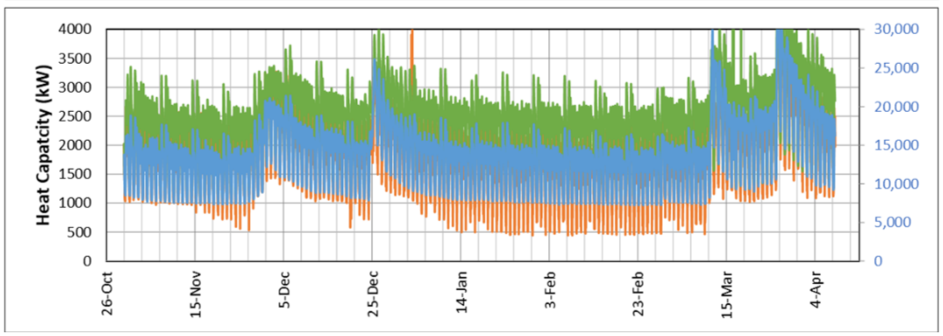
Measured vs Modeled (dry-weather)
(different locations)

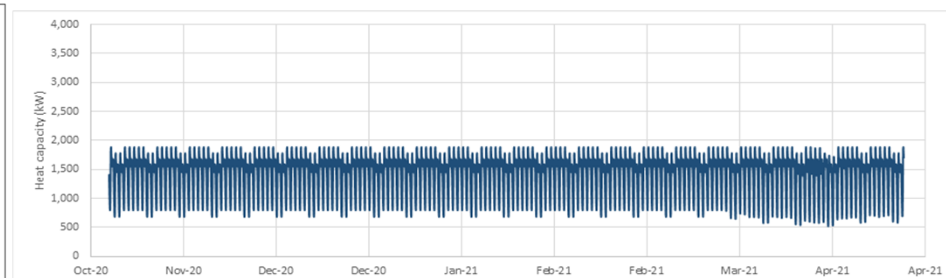








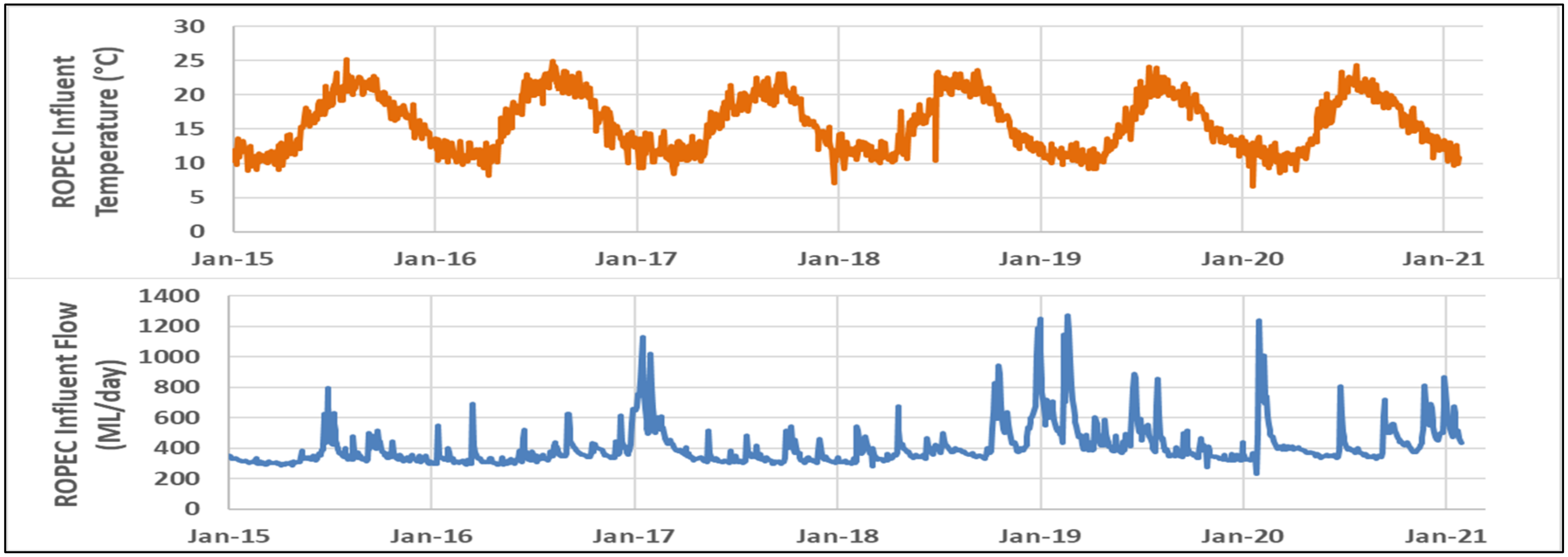




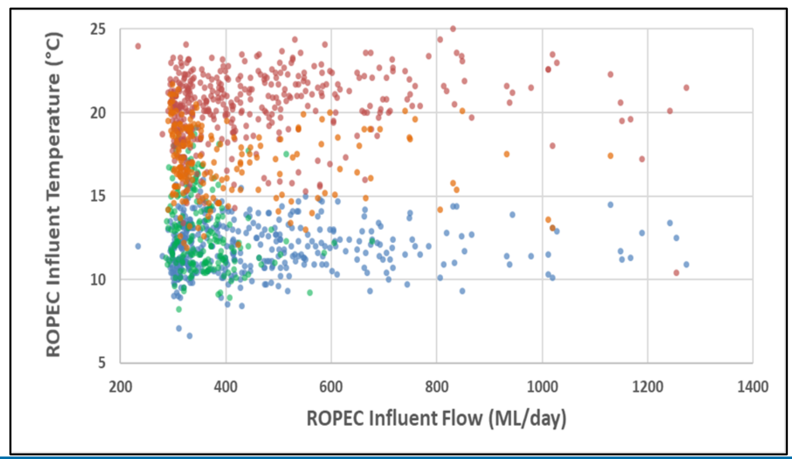
Sewer Types and Temperatures

- Combined pipes should work (using dry-weather flows)
- Heat exchange between the wastewater and the environment seems intuitive
  - Input T influences: potable water T, users, infiltration
  - Heat loss influences: ground (depth), air, pipe type
  - WET suppliers report that sewer T equalizes a few 100 m after the WET system ….
  - Do dense urban areas have higher wastewater T?
- **Needs more study**

Ottawa WWTP (ROPEC) 5 Years of Data

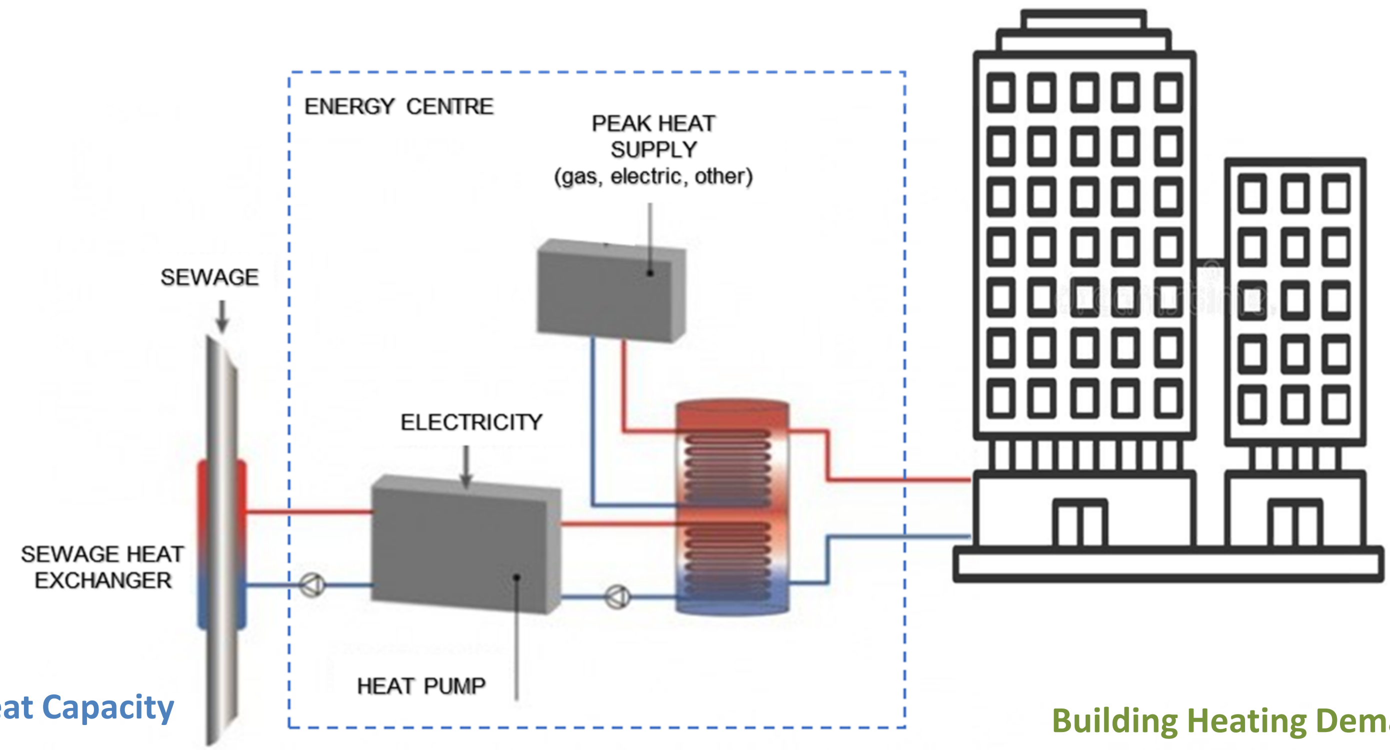


- No correlation between flow and temperature
- General theory is that influent at ROPEC, in particular because of the long travel paths, are equalized with the environment
- More study is warranted

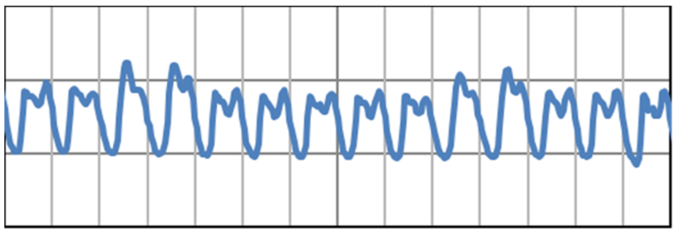


WET Principals of Design

WET System – Principals of Design

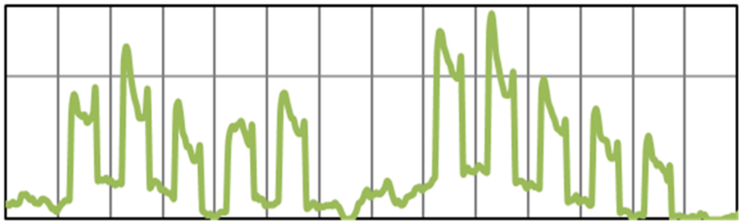


Sewer Heat Capacity



Time (2 week period)

Building Heating Demand



Time (2 week period)

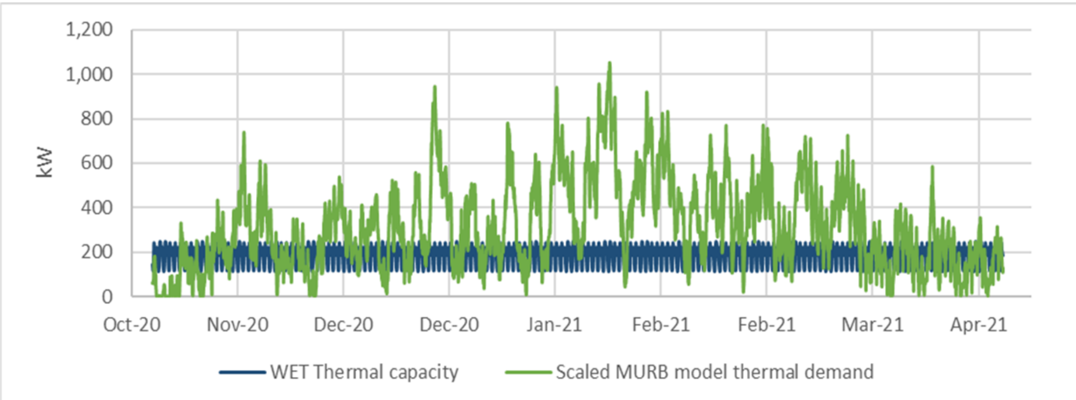
J.L.Richards
ENGINEERS · ARCHITECTS · PLANNERS

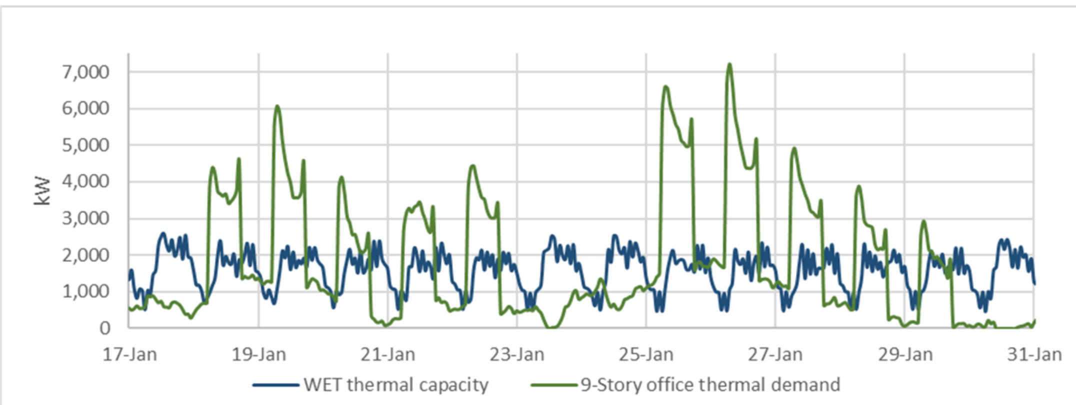
Archetypes – a very small sample size

These are at, and smaller than the bottom recommended flow rates for viability

#	Character of Sewer Line / Load	Study Type	Building Model	Flow Rate	WET size	Outcomes
1	Downtown collector / MURB	Building	A 1990s MURB (11 storey)	12 L/s (675 mm) Modeled	Tech#1 150 kW HP	OK
2	Suburban Pump Station / Office	Building	A 2001 office (9 storey)	21 L/s (1050 mm) Measured	Tech#3 1.4 MW HP	X
3	Medium sized urban collector / possible major new facility	Heat capacity only	n/a	32 – 58 L/s (1050 mm) Modeled	Tech #3 ~ 1.4 MW+	OK
4	Major trunk line / new district energy system	Heat capacity only	n/a	~ 400 L/s (1650 mm) Modeled	Tech #3 17 MW (avg) 7 MW (min)	Wow!

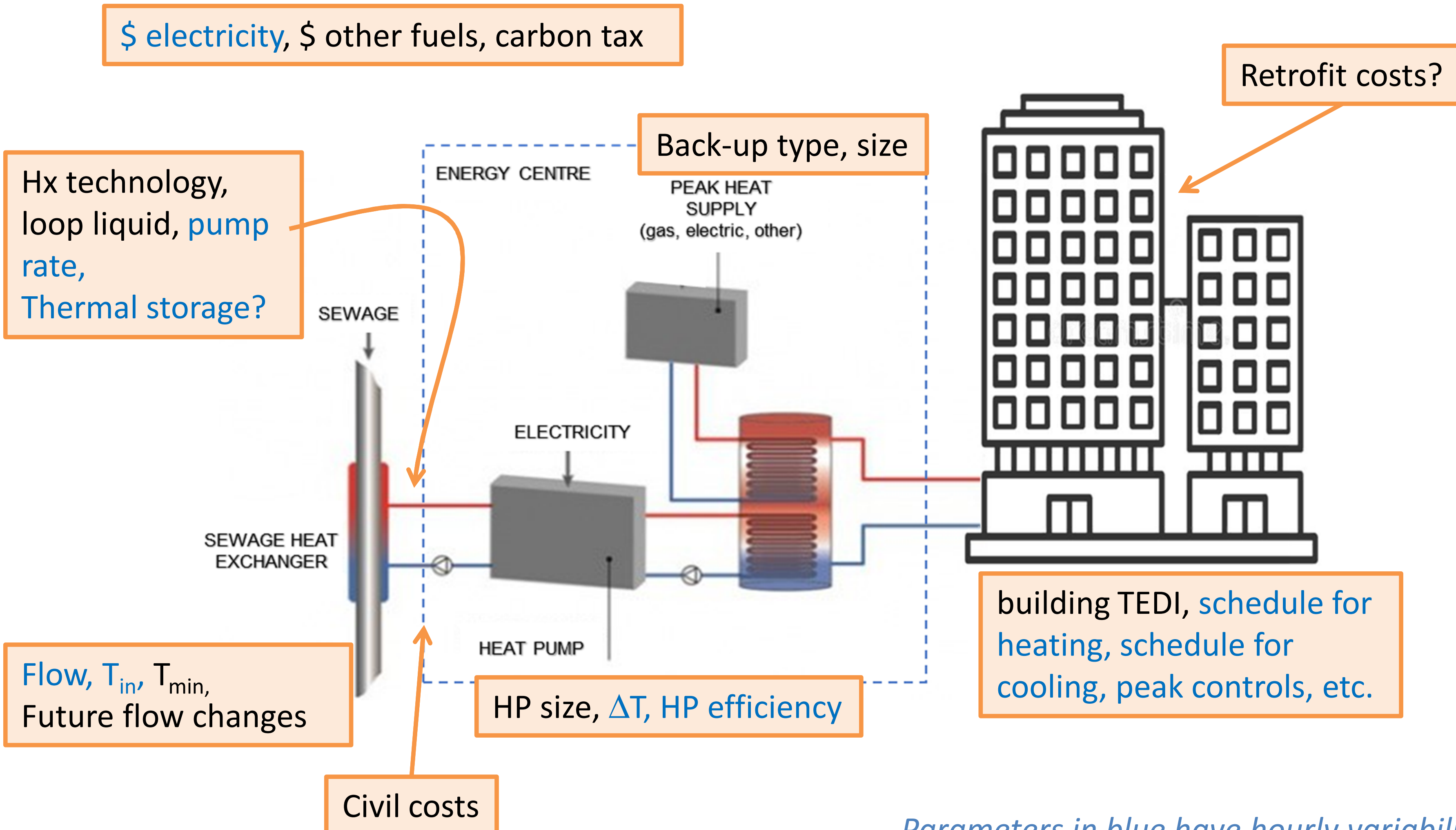
Archetypes - Heat Capacity vs Heat Load





- Older buildings with poor envelopes and peaky heating schedules are harder to support
- Daytime 9-5 occupancy are harder economics
- System economics is complex, dependent on many design factors and boundary definition
- Competitiveness improves with :
  - Inclusion of carbon pricing
  - New buildings
  - Higher flows, larger projects
  - Inclusion of cooling
  - Funding, ACCA, etc…

Complex system design – optimize for economics



Parameters in blue have hourly variability

Contrasting to GSHP

- WET supply may be variable within the day if $H_{cap} = H_{load}$
  - may be mitigated by thermal storage, good envelope
- WET heating/cooling is flexible seasonally
  - any heating : cooling ratio
- WET pairs well with other heat pumps into a hybrid solution

J.L.Richards ENGINEERS · ARCHITECTS · PLANNERS	WET	Closed-Loop GSHP	Open-loop GSHP
Daily variability	Maybe, if project uses full flows	none	none
Seasonal restrictions	~ none	Heating = cooling	~ none
Geographic distribution	Linear along pipes	Nearly anywhere	Local geology dependence
Feasibility assessment	Deploy sensors	~ none	Hydrogeologist consult & drill deep well
Costs	$	higher	$ JH1

Slide 36

JH1 Joan Haysom, 2021-11-04

Observations & Recommendations

Observations & Recommendations

- Wastewater is an underutilized energy source
- WET systems are viable
- Impacts on infrastructure can be low
- A great option for Net-Zero carbon buildings
- ➢ There is significant interest growing (low carbon building developers, MUSH sector, third-party owner, etc.)
- ➢ Cities should develop policies and processes to
  - Support private projects
  - Consider their own corporate buildings
  - Evaluate as part of district energy infrastructure
- ➢ More industry / muni knowledge sharing would *greatly* help
- ➢ FCM should continue to support various grants on the topic

Questions that remain

- Best approaches to quantify the flow?
  - Modeling options, accuracy on hourly profiles
  - Breadth of measurement points
  - Sensitivity to future changes
- Quantification of temperature issues?
  - Heat exchange in next downstream section
  - T profiles on suburban vs dense urban
  - Impacts on WWTP, if any
- Understanding of Project ROI?
  - Full heating and cooling ROI across a number of variables
  - Value to cooling, reduced grid peak demand
  - Share of a complete building design and study
- What Information Should Muni's Provide?
  - Pipe diameter (some are on-line, some are not)
  - Modeled flow (min, avg?, profile?) Modeled Heat Cap.
  - T profiles
  - Anticipatory flow & T measurements of key locations
- Which Municipal Policies Work Best?

(Variables for full heating and cooling ROI:)

System sizes
$H_{sewer}:H_{Load}$ ratio
Building TEDI values
Civic costs
Inclusion of storage
On a combined pipe
Net COP
Hybrid with GHSP
Hybrid with drain water
2 WET projects on 1 line
Ownership structure
Etc.

Ownership models? some thoughts…

- Vancouver False Creek – Municipal Utility
  - WET inside WW pump station, serves a municipal district energy system that provides all heat
- Toronto policy
  - Developer owns all (can be building owner or a third-party energy utility)
- Hybrids?
  - A mixed model is complex, as the value to each building is different
  - could a City own Hx (but not HP)

Thank you!
Looking forward to working with many of you.

Contact Information:
Joan Haysom, Ph.D., P.Eng.
Innovative Energy Market Chief
(343) 804-4402
jhaysom@jlrichards.ca