Mapping of Cities Wastewater Heating/Cooling Capacity

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Abstract. This paper is not a research paper, but is provided as support information for an oral conference presentation. It is intended to provide background information to the topic of using wastewater as a thermal source for heating & cooling buildings and describe innovative work which has been undertaken in New Zealand in mapping the distribution and capacity of thermal energy within wastewater networks. This mapping work is also applicable in Central European cities and so relevant to Sustainable Building.

Approximately 20%-30% of all the energy used in New Zealand households is used in domestic hot water systems. This heat energy then flows ‘down the drain’ and is collected within a city’s wastewater network. So flowing through cities’ sewers, wastewater is a hidden and seldom used source of thermal energy, contained within infrastructure which is already existing. Its flow is constant irrespective of the seasons, and its availability is independent of wind or sun.

There is a very large thermal capacity available, which is currently largely unused. Wastewater can be used for heating and also for cooling of commercial buildings, apartment buildings or district energy schemes. This can allow buildings to stop using fossil fuels and the good thermal characteristics of wastewater offer significant increases in the electrical efficiency of building heating & air conditioning systems, with associated savings in potable water when wet cooling towers are eliminated.

The large thermal capacity available within the wastewater network can be modelled and mapped, to allow cities to start planning to take advantage of this resource and make significant gains in efficiency.

The oral presentation will show examples of cities who have had wastewater network energy mapping done, and a range of case studies of how wastewater heating & cooling energy is being used. An example of the outcomes from these mapping studies from Christchurch City in New Zealand (population 400,000) showed that there is sufficient heat available from the wastewater network to heat approximately 10,000 houses in the city.

1. Introduction
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To become sustainable, cities need to make use of every possibility to become more efficient. In temperate areas of the world including Europe, most buildings need heating for a portion of the year, and this heat energy is normally provided by burning fossil fuels or extracting heat from the atmosphere.
Equally many commercial buildings require mechanical cooling (referred to as Air Conditioning) for a portion of the year to keep the building occupants comfortable. Air conditioning systems account for roughly 40% of the electricity use of commercial buildings [1].

Air conditioning systems not only consume large amounts of electricity, but some also consume large amounts of water in cooling towers and they reject large amounts of heat in the atmosphere, contributing to ‘Urban Heat Island’ effects.

There are significant opportunities for cities to become more energy efficient, reduce their carbon emissions and reduce their water consumption, by moving away from fossil fuels and improving the efficiency of heating and air conditioning systems.

2. **Wastewater As A Thermal Source – Background**

Within New Zealand and Australia approximately 30% of all the energy used in households is consumed in domestic hot water systems [2]. In Europe this figure varies amongst different countries but is typically around 20%. This heat energy then flows ‘down the drain’ and is collected within a city’s wastewater network. So flowing through cities’ sewers, wastewater is a hidden source of thermal energy.

There is a very large thermal capacity available, which is currently largely unused. The energy is contained within infrastructure which is already existing, and its availability is constant, irrespective of the seasons or the availability of wind or sun. Capturing and recycling this thermal energy for use in building heating and air conditioning systems can allow buildings to stop using fossil fuels to generate heat, offering significant opportunities for cities to reduce their carbon emissions.

Since wastewater is a blend of both hot and cold water, its temperature is slightly warm compared to potable water supplies. Wastewater is also very stable and neutral in temperature all year around (refer **Figure 1**). Hence compared to atmospheric temperatures, wastewater is warm in winter and cool in summer. These temperature characteristics mean that it can be used for heating and also for cooling of commercial buildings, apartment buildings or district energy schemes.

![Figure 1. Annual Wastewater Temperatures from various cities. (Sources: Data provided directly from respective city water authorities)](image_url)
The good thermal characteristics of wastewater can offer significant increases in the electrical efficiency of building heating & air conditioning systems. And when used as a cooling source, there can also be associated savings in potable water consumption when wet cooling towers are eliminated.

Recent research [3] from the USA compared the energy consumption of a conventional air conditioning system rejecting heat into the atmosphere, with a system using a neutral temperature water source (in this case ground water). The results after two years of intense monitoring showed that the system using ground water used 44% less electrical energy than the air-based air conditioning system. Since wastewater flows at similar neutral temperatures to ground water, it can be expected that similar gains in efficiency are possible by using wastewater as a thermal energy source.

3. Daily Flow Profiles

The daily flow profiles at any point in a wastewater network are determined by what is occurring upstream of that point. Whilst residential zones within a city typically have a slightly different usage pattern to commercial and industrial zones, the wastewater flows in any network are heavily linked to the times of day when people are active. This wastewater daily flow profile also matches with the times of day when commercial buildings are occupied and hence the times of day when building heating or cooling systems need energy. Refer Figure 2.

![Average of City Diurnal Factors](image)

**Figure 2.** Wastewater Diurnal Flow Patterns. (Sources: Data provided directly from respective city water authorities)

3.1. Aquatic Centres – A Perfect Match

Aquatic centres are heavy users of low-grade heat. They typically require large amounts of heat all year around, even in summer. Benchmarking undertaken by Applied Energy of 20 aquatic centres from NZ, Australia & UK indicates that on average, aquatic centres consume over 5 times more energy/m² than the average for office/education/retail buildings. Typically 80% of this energy consumed by aquatic centres is low grade heat. However an aquatic centre in Australia that uses wastewater as the heat source uses about 60% less energy than the average of the other aquatic centres. Refer Figure 3.
4. Wastewater Network Heat Mapping
Examples exist of thermal energy mapping projects. These are most prominent in Europe, and include:
- Thermos Project https://www.thermos-project.eu/home/
- UK National Heat Map (now decommissioned) https://www.cse.org.uk/projects/view/1183
- Stratego Project http://stratego-project.eu/

These thermal energy mapping projects are typically demand based, in that they produce maps showing where heat is needed. They also tend to be relatively coarse grained, at minimum grid sizes around 100m x 100m.

To help cities begin to take advantage of the unused energy source within wastewater, mapping the thermal capacity within a city’s wastewater network can be done to show where and how much thermal energy is available within the city, and show this at a fine grain suitable to assess potential projects on a building scale. Applied Energy have undertaken wastewater network heating/cooling mapping studies for three cities within New Zealand. These are listed below:
- Dunedin City – Population 130,000
- Blenheim – Population 30,000
- Christchurch – Population 400,000

The wastewater heating/cooling studies required the gathering & analysis of a range of data such as; hydraulic wastewater flows, temperatures, wastewater network infrastructure, GIS data, land use data, population statistical data, climate data etc. After the data gathering and analysis is complete, a map atlas of the city at 1:10,000 scale is created to show where and how much heating/cooling energy is available within the wastewater network. Refer example in Figure 4.

Most of the work required to undertake these studies can be done remotely, so it is entirely possible to carry out these studies for cities both in Europe and other regions of the world without needing to be located in the particular city concerned. An example of this is the study that was undertaken for Dunedin city. The entire study was successfully completed without the project team needing to visit the city at all.

![Energy Use - Aquatic Centres VS Offices/Education/Retail](image)

**Figure 3.** Aquatic Centre Energy Benchmarking. (Sources: Data provided directly from respective city authorities + Benchmarking Energy and the Indoor Environmental Quality of Aquatic Centres in Victoria [4])
Figure 4. Examples of Deliverables from Wastewater Network Heat Mapping Study

An example of the outcomes from these wastewater heating/cooling mapping studies is shown below from Christchurch. The study showed that there is sufficient heat available from the wastewater network to heat approximately 10,000 houses in the city. In 2018 when Christchurch City Council selected a site for a new aquatic centre and sports facility, they were able to refer to the wastewater network energy maps and identify immediately that there is a suitable heat source from wastewater for the new facility. Refer Figure 5.

Figure 5. Example of How Wastewater Network Heat Maps Used for Urban Planning
5. Conclusions
Flowing through cities’ sewers, wastewater is a hidden and seldom used source of thermal energy, contained within infrastructure which is already existing. Its flow is constant irrespective of the seasons, and its availability is independent of wind or sun. Wastewater can be used for heating and also for cooling of commercial buildings. This can allow buildings to stop using fossil fuels and the good thermal characteristics of wastewater offer significant increases in the electrical efficiency of building heating & air conditioning systems.

Wastewater network energy maps can be fine grained to allow assessment down to a building scale and so can be used by cities when planning of new developments, refurbishment of existing buildings, or energy strategy studies.

6. Examples of Wastewater Energy Projects
There are estimated to be around 1000 working installations of buildings using wastewater are a thermal source for heating and/or cooling. Below are a range of examples.

Figure 6. Hobart Aquatic Centre – Australia
In operation since 1997.
7,500m² Aquatic Centre
~750kW Heating

Figure 7. Levallois-Perret Pool – Paris
In operation since 2010.

Figure 8. MOM Cultural Centre – Budapest, Hungary
In operation since 2011.
1MW thermal capacity
Figure 9. Medical Centre of Hungarian Defence Forces, Budapest
In operation since 2014.
3.8MW thermal capacity system

Figure 10. Straubing – Germany
102 Apartments within 5 Buildings
210kW Heating

Figure 11. Vancouver – Canada
North East False Creek
South East False Creek
NE False Creek is a private district energy scheme currently under development.
SE False Creek is Council owned with 395,000m² floor space in operation and expansion underway.

Figure 12. Ministry of Interior Headquarters – Stuttgart, Germany
In operation since 2012.
500kW thermal capacity.
Figure 13. Winterthur – Switzerland
28 Level Office building
480kW heating & 840kW cooling

References
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