1. Project Summary

Utilising secondary heat sources can play a critical role in meeting the UK’s carbon targets.

Renewing waste heat from sewage is an attractive option as it can help UK move towards its climate change targets while decarbonising the heating sector & reducing the reliance on fossil fuels.

In the UK, waste energy has so far been ignored because of the uncertain impacts of lowering sewage temperatures on WWTP efficiency; heat pump operational costs, relatively low cost of natural gas and longer payback period of heat recovery systems.

In fact, along with project lead ICR Ltd. are working on a new design of heat pump.

The work is also supported by Anglian Water and Thames Water, as part of their ongoing innovation work.

It is the aim of ‘Some Energy for tomorrow’ to project explore heat recovery potential in urban water cycle. It will look at how sewer systems (both mains & waste water) can be connected to the heat pump to boost efficiency – turning the water utilities into energy carriers.

This part of HE4T project focuses on assessing the viability of heat recovery systems operating elsewhere in the world. Use of this information to promote this technology in UK’s that emphasises on energy efficiency.

4. Heat Recovery Locations

- The heat recovery can be done either before it reaches WWTP (upstream) or at WWTP (downstream) in the wastewater cycle.
- Below WWTP: Heat recovery can be done close to heat sources i.e. within the premises of the household / building referred as in house. Figure 2(a).
- The wastewater flow from the nearby sewer can be diverted to a custom-made collector / pit / well containing screens and heat exchanger adjacent to the source. Figure 2(b).
- In-sewer, directly installing heat exchanger in the base of sewer pipe by placing heat exchanger plates, panels or installing heat exchanger pipes within the sewer. Also, using internal and external tube heat exchangers within this sewer system. Figure 2(c).
- Alternatively, heat can be recovered after WWTP from the discharge / treated water / effluent, a much cleaner and stable heat carrier. Figure 2(b).

5. Advantages & Disadvantages

- Figure 2(a) - Close to the heat source (Raw wastewater)
  - Proximity is consumers of heat.
  - Sewage temperature is high, more extraction is possible but flow is relatively low & varies.
  - In time required so.
  - Small heat recovery systems may just employ a heat exchanger requiring lower investment to users.
  - Heat exchangers can be modular, can be installed in existing & new premises easily.
  - Fouling of heat exchanger surfaces.

- Figure 2(b) - Adjacent to heat source (Raw wastewater)
  - Sewage temperature & wastewater is cleaner.
  - Construction of storage pit near sewer and equipment installation require space.
  - A sewer at the inlet to the pit is necessary to prevent particle accumulation in the pit.
  - Heat exchanger on the sewer side is also necessary to prevent backflow from the tank to sewer.
  - Sewage accumulation and biofilm growth on screen requires continuous monitoring, periodic maintenance and permitting involving.
  - Can be installed in existing and new developments.

- Figure 2(c) - In sewer / trunklines (Raw wastewater)
  - Higher & stable flowrates but low sewage temperatures due heat lost to the environment.
  - Installation of the heat exchanger may not be possible in all cases e.g. length of straight sewer line.
  - Sewers can be combined sewers and weather / natural events like snow melt, rainfall, flood could alter the sewage flow and temperature can be altered after the sewage treatment significantly.
  - Fouling / biofilm growth on heat exchanger surfaces of varying degree requiring continuous monitoring, periodic maintenance and permitting involving.
  - The effluent temperature is significantly higher than influent with steady and cleaner flow.
  - Since it takes place downstream of WWTP it can be cooled down much more than upstream allowing higher energy potential to new wastewater.
  - This option cannot be used in many locations as WWTPs are located remotely where no heat consumers are available and recovered energy can only be used by WWTP itself.

6. Typical conditions for viability

- Criterion 1 - Flow requirements: Potential in-sewer heat recovery system should be a densely populated area with minimum upstream population rate (5000 – 10000 p) this corresponds to the minimum dry weather flow of 15 to 30 litres per second of wastewater [4,11,42].

- Criterion 2 - Sewer: For new developments sewer pipe, minimum diameter of 400 to 500 mm (d) and for existing sewer pipe minimum diameter 800 mm (d). In-sewer heat exchanger; the water-covered surface at the base of the sewers needs to be at least 0.15 square m (m). [4,11,42]

- Criterion 3 - Short distances: Potential heat recovery system should be in close vicinity to major heat consumers. There should be relatively short distance between sewer charger and heat recovery system, compare. 100 to 300 m (maximum 500 m) [4,11,42].

- Criterion 4 - Heating requirement: Minimum heating load requirement should be 1.5 - 20 MW [4,12].

- Criterion 5 - Legal requirement: Under no condition, activities of WWTPs are to be impaired by upstream heat recovery system, limiting the sewage temperature at WWTP inlet not to be less than 10°C. This is to minimize the negative effects of transformation and biodegradation of pollutants particularly (bio- or bio-chemical processes which may result in high loads of pollutants exiting the WWTP [6] in the effluent) if no further action is taken [5].

- Note that some countries also impose limits on the temperature of discharged sewer and on the temperature of effluent from WWTP to protect habitats in inland waters, estuaries, streams, rivers and sea so that receiving waters stay at natural conditions [5].

8. Best practice examples from around the world

<table>
<thead>
<tr>
<th>City / Country</th>
<th>System Supplier</th>
<th>System Supplier</th>
<th>HP capacity / COP</th>
<th>Purpose</th>
<th>Scale / year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mexico, Mexico, Belgium [4]</td>
<td>HGR Technology</td>
<td>Collector, screened, in-house heat exchanger</td>
<td>1.5 kW</td>
<td>Heating / Hot water</td>
<td>Plant (2010)</td>
</tr>
<tr>
<td>Austria, Belgium, Germany [12]</td>
<td>Germany, France ( piplin project )</td>
<td>Collector, screened, in-house heat exchanger</td>
<td>3 kW</td>
<td>Heating / Cooling</td>
<td>Semi (2012)</td>
</tr>
<tr>
<td>China, China, Germany, France [13]</td>
<td>Germany, China, Canada</td>
<td>Collector, screened, in-house heat exchanger</td>
<td>200 kW &amp; 120 kW</td>
<td>Heating / Cooling</td>
<td>Semi (2013)</td>
</tr>
<tr>
<td>China, China, France, Germany</td>
<td>Collector, screened, in-house heat exchanger</td>
<td>150 kW</td>
<td>Heating / Cooling</td>
<td>Semi (2014)</td>
<td></td>
</tr>
<tr>
<td>China, China, France, Germany</td>
<td>Collector, screened, in-house heat exchanger</td>
<td>150 kW</td>
<td>Heating / Cooling</td>
<td>Semi (2018)</td>
<td></td>
</tr>
<tr>
<td>China, China, France, Germany</td>
<td>Collector, screened, in-house heat exchanger</td>
<td>150 kW</td>
<td>Heating / Cooling</td>
<td>Semi (2019)</td>
<td></td>
</tr>
</tbody>
</table>

9. UK - A future case study

- There is a keen interest in UK to explore this new technology after the successful sewage heat recovery demonstration project at Bordesley, Solihull, Scotland, a joint venture between Scottish Water Horizons and SHARC Energy Systems, utilizing two 400 kW heat pump system (COP ≥ 4.8) that deliver 95% of space heating and hot water requirements of campus. The retrofitted system provides 1.8 GWh of annual heat, saving 150 tonnes of CO2 emissions per annum with no impact on the local sewage network (4).
- With daily discharge of 66 billion litres of sewage in more than 342,000 kilometres of sewer pipes to pass over 5,000 WWTPs across UK - the potential of heat recovery is significant (4). Total sewage temperature in UK sewers vary from 10 to 25°C with a yearly average of 17.5°C (4).
- Theoretically, if above daily discharge is cooled by 3 degrees for heat recovery, it is possible to recover energy to 1710 MWh heat energy annually, enough to heat 1.6 million homes.
- Similarly, considering heat recovery from the effluent of the largest WWTP UK, with daily average DWF of 2207 million litres (5) and cooling by its 3 degrees, the recoverable heat potential would approximately 1.574 TWh heat energy annually, enough to heat more than 100,000 homes.

- Note in practice the total amount of heat is a function of wastewater/effluent flow rates, initial sewage temperatures at WWTP and heat recovery systems. Further, data on the wastewater/effluent efficiencies of the heat exchanger and the heat pump etc. are needed.

- A critical challenge here is to maintain the WTE plant along with significant opportunities for future energy recovery and emissions reduction in the longer term but UK needs to overcome major practical constraints; limited awareness of heat pump technology, lack of cost and a lack of energy networks infrastructure.

10. Next Steps

- Currently the HP is being developed & tested by ICR Ltd. in the laboratory at LSE.
- Thames Water and Anglian Water are performing temperature and flowrates measurements at various potential locations across London and Midlands area.
- Based on the data collected, several heat recovery systems will be developed and various simulation will be performed, estimating potential heat recovery through the sewer pipe released from the WWTP.

References