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Heat recovery from a decentralized source-separated wastewater treatment plant: A model-based study

Shuoguang Yang

rijksuniversiteit groningen

UMCG

Source-separated wastewater treatment

Blackwater

- Energy (biogas)
- Nutrients (N, P)

Resource recovery

Greywater

- Heat
- Water reuse


A Story about Fire and Water

Research background

Source-separated wastewater treatment plant in Sneek, the Netherlands

Research goal

- Developing an energy-efficient greywater heat recovery system in a source-separated wastewater treatment plant

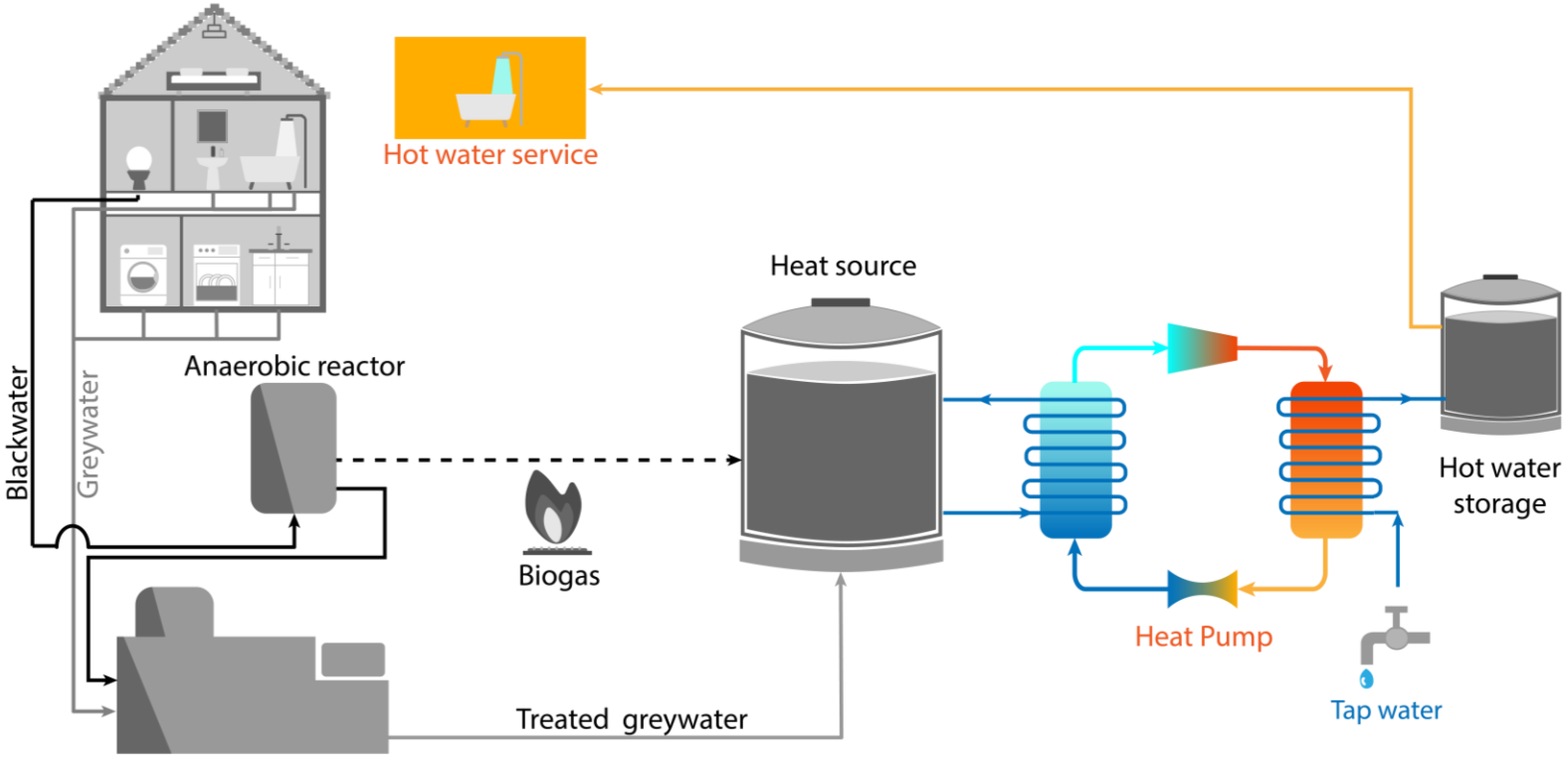
Research method

- Developing different heat recovery settings
- Evaluating the energy efficiency of different settings through a thermodynamic model using real greywater data

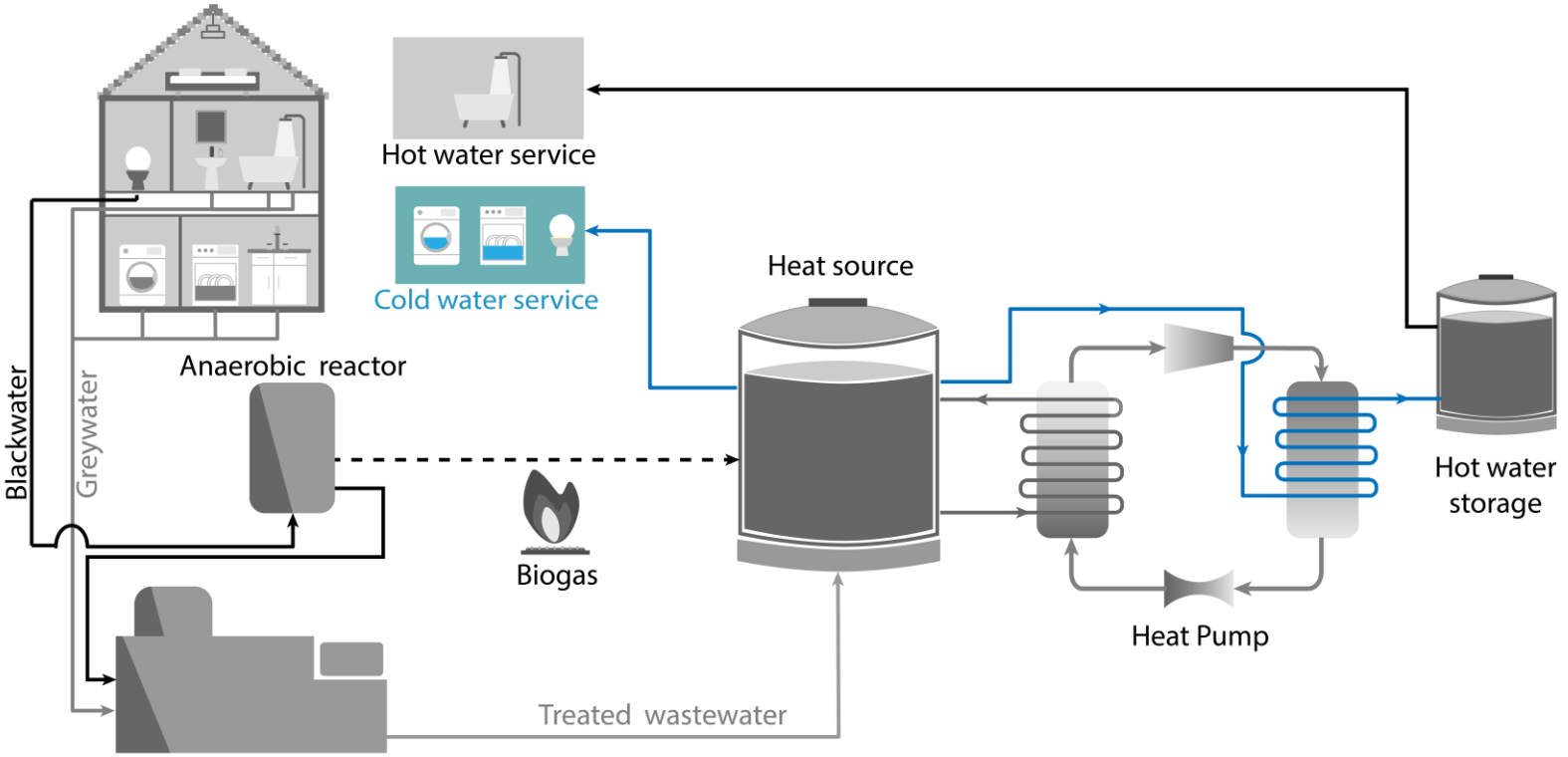
Four heat recovery system settings

Setting	Element included
0	Source-separated WWTP (current status)
1	Source-separated WWTP + heat recovery for shower (40 ºC hot water)
2	Source-separated WWTP + heat recovery for shower (40 ºC hot water) + greywater reuse
3	Source-separated WWTP + heat recovery for shower (60 ºC hot water)

Setting with heat recovery only



Setting with heat recovery and water reuse



CO_2 heat pump

- Reasons of using CO_2 heat pump:

  - Natural refrigerants, non-flammable, and non-toxic

  - GWP = 1

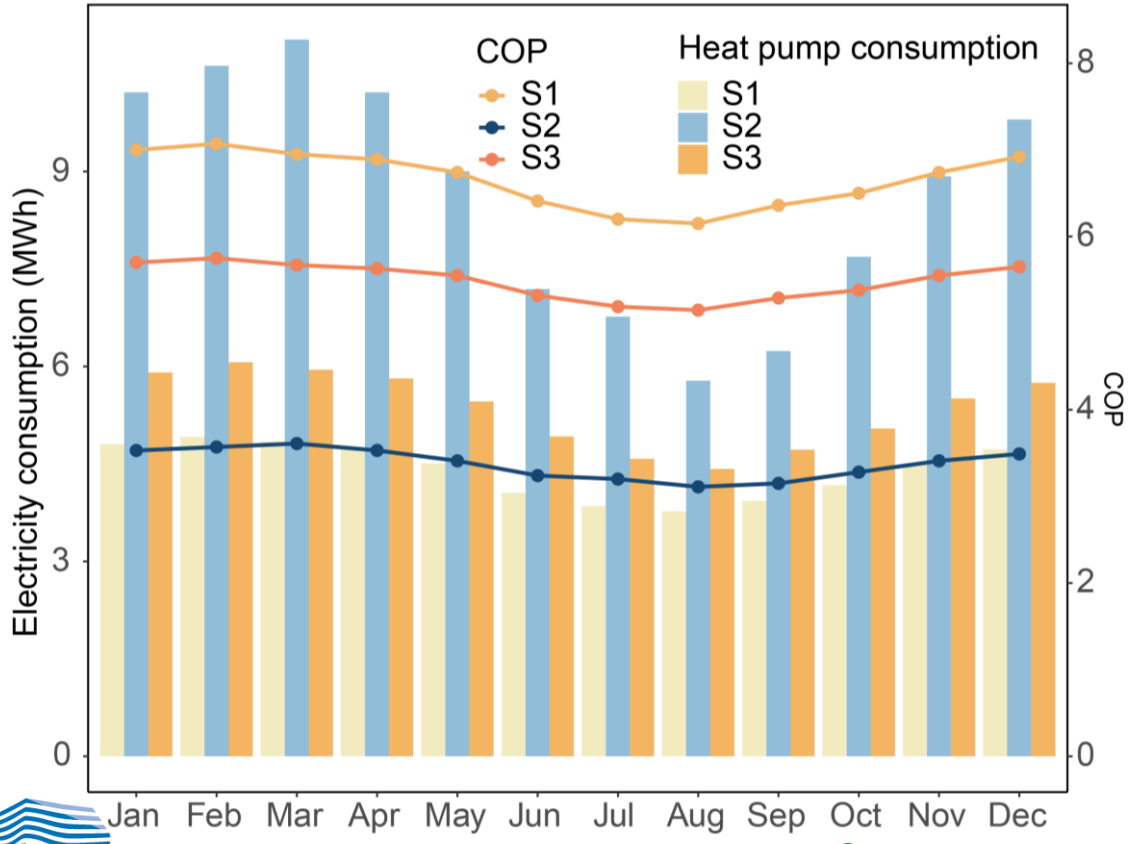
  - High performance in substantial temperature lift applications

- CO_2 refrigerant cycle calculation:

$$\frac{P_r V_r}{T_r} = 1 + \frac{B}{V_r} + \frac{C}{V_r^2} + \frac{D}{V_r^5} + \frac{c_4}{T_r^3 V_r^2}\left(\beta + \frac{\gamma}{V_r^2}\right)\exp\left(\frac{-\gamma}{V_r^2}\right)$$

- Lee-Kesler EoS

Heat pump performance in different settings



S1: Heat recovery for 40 ºC shower water

S2: Heat recovery for 40 ºC shower water + greywater reuse

S3: Heat recovery for 60 ºC shower water

The microbiological safety of reusing treated greywater

Figure: DAPI staining with fluorescence microscope

Take home message

- The heat recovery system within a source-separated WWTP can save ca. 20% of the domestic hot water energy demand.
- In the design of a greywater heat recovery system, introducing treated greywater reuse for showering may decrease the overall energy efficiency.
- CO_2 heat pumps can deliver high performance in generating high-temperature hot water (60 ºC) using greywater as a low-grade energy source.


Thanks for your attention!