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Low-grade waste heat recovery and repurposing to reduce the load on cooling towers

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Abstract. Industrial cooling towers are often ageing infrastructure that is expensive to maintain and operate. A novel approach is introduced in which a heat pump circuit is incorporated to reduce the load upon the towers by extracting low-grade energy from the stream sent to the towers and repurposing in on-site processing operations. To demonstrate the concept, a model was constructed, which uses industrial data on cooling towers linked to a smelter's sulphuric acid plant, to allow direct economic and environmental impact comparison between different heat recovery and repurposing scenarios. The model's results showed that implementing a heat pump system would significantly decrease annual operating costs and achieve a payback period of 3 years. In addition, overall CO_2 emissions could be reduced by 42% (430,000 kg/year) and a 5% heat load reduction on the cooling towers achieved. The concept is significant as the outcomes introduce a new way for energy intensive industrial sectors, such as mineral processing, to reduce energy consumption and improve long-term sustainable performance.

Keywords: low-grade heat recovery; heat pumps; cooling towers; energy repurposing; mineral processing; environmental sustainability

1. Introduction

Industrial low-grade waste heat within process streams, typically classified as below 100°C, is often overlooked, despite representing a source of significant energy that if recovered could enhance overall operational sustainability (Zhang *et al.* 2016, Rubio *et al.* 2020). One such opportunity may lie in cooling towers as for example, a 162 m high wet unit used to remove heat from a 940 MWe generating unit was found to reject approximately 1760 MW of heat while operating at ambient air conditions of 31.7°C (Lee 1979).

Cooling towers use air to cool process water streams through direct contact which transfers heat to the atmosphere through evaporation. The cooled process water can be then cycled back at a reduced temperature (SPX 2016, Afshari and Dehghanpour 2019). There are different types of cooling towers, including cross-flow, where the water flows vertically and the air flows

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$\boldsymbol{k}$	thermal conductivity (W/mK)	T_s	temperature of surface (K)
$\boldsymbol{k_{insulation}}$	thermal conductivity of insulation (W/mK)	$T_{w,in}$	temperature of process water entering heat pump bank (K)
$\boldsymbol{k_{pipe}}$	thermal conductivity of pipe (W/mK)	T_{water}	initial process water temperature leaving cooling towers (K)
$\boldsymbol{K_L}$	minor loss coefficient for pipe components	μ	dynamic viscosity (Ns/m^2)
$\boldsymbol{L}$	length of pipe (m)	u	velocity of fluid flow (m/s)
$\boldsymbol{L_e}$	equivalent length (m)	v	kinematic viscosity (m^2/s)
$\boldsymbol{n}$	number of years	W_{pump}	pumping work (W)