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Heat pump integration in a cheese factory

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ABSTRACT

The aim of process integration is to increase the efficiency and to reduce the energy consumption, operating costs and CO2 emissions of an industrial process. The proposed methodology is applied to a real case study of a cheese factory with non-simultaneous process operations and uses the time average approach combined with restricted matches. This work focuses on appropriate heat pump integration and two different integration strategies are proposed. In the first option, process modifications and direct heat exchange between the process and heat pump streams are not allowed, which means that the integration of heat pumps has to be realized through intermediate heat transfer networks. On the contrary, in the second option, direct heat exchange and process modifications are possible. The results of both options are analyzed and compared for the French and German context. Depending on the industrial constraints and the location, it is shown that the final choice of new heat pump installations may be different. Saving potential in operating costs is higher for option 2 where the cost savings can be higher than 40% for both countries. Furthermore the potential CO_2 emissions and primary energy savings are compared.

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1. Introduction

When studying the energy efficiency of an industrial process, the analysis of heat pump integration has to be considered as part of a complete methodology, beginning from the data collection and modeling of all process unit operations up to the final utility integration. The use of pinch analysis techniques allows identification of heat recovery potential in the process. Opportunities to integrate heat pumps and other utility systems can be identified by analyzing the grand composite curve. The curve shows the enthalpy temperature profile of the heat to be supplied to the process and of the heat excess to be evacuated by a cold utility. Heat pump integration became interesting in the late 80s and the early 90s due to increasing fuel prices. For example, the rules for optimal placements of a heat pump in an industrial process have been introduced by Linnhoff and Townsend [8] in 1983. Later, Wallin and Berntsson [13] demonstrated that, characteristics of both, industrial process and heat pumps, must be taken into account. Kapustenko et al. [5] analyzed heat pump integration based on selected streams of a cheese factory. Also Pavlas et al. [11] analyzed heat pump integration for a gasification process. However, both approaches are limited to ammonia refrigeration cycles. Recently Kapil et al. [4] proposed a methodology for low grade heat recovery, by combining the total site approach with heat recovery models such as heat pumps, ORC–ORC or absorption refrigeration. The main disadvantage of their method is that self-sufficient pockets are not considered and as result not all heat pump opportunities may be identified. More generally, the potential of industrial heat pump integration was demonstrated by Becker et al. [3]: a mixed integer linear programming (MILP) formulation of the heat cascade is used to optimize simultaneously the flow rates in heat pumps and other utility systems.

Two process integration options will be analyzed in this paper: first, process modifications are not allowed and a newly integrated heat pump cannot exchange directly with the process. In the second option, process modifications and direct heat pump process integration are possible. Saving potential becomes higher, but also the complexity of process configurations increases. When utilities (e.g. heat pump in the first option or co-generation unit) cannot exchange heat directly with the process, heat exchange restrictions have to be included and the method proposed by Becker and Maréchal [2] can be applied.

In the food industry, most of the process operations are performed in batch mode. However, consideration of different temperature levels and assumption of heat storage through available hot water tanks, makes the heat recovery between periods possible. The time average approach ([6,7],) can be applied to realize the process integration analysis, where heat loads will be

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