Environmental impact of high temperature industrial heat pumps – from a global warming potential (GWP) perspective

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Abstract

Several factors drive the increased utilisation of heat pumps in industry. Two important factors are the drive to reduce the negative environmental impact of industrial processes and the general trend of electrification ("de-fuelling") of energy systems. Much of the heat demand in the process industry is at temperature levels above 100°C, which is above the temperature achievable with conventional heat pumps. Heat pump manufacturers are developing new heat pump technologies that can meet the demand of high sink temperatures and high temperature lifts. These heat pumps are often referred to as High Temperature Heat Pumps (HTHP) or Very High Temperature Heat pumps (VHTHP). The new heat pump technologies operate under conditions different from conventional heat pumps used for domestic heating, and it is not obvious how to evaluate the environmental impact of the installations. It depends very much on the technology being replaced what the various efficiencies of the heat pump system are (e.g. Coefficient of Performance (COP), system efficiency or exergy efficiency), and what the emissions are from generating the electricity used to drive the heat pump. In this paper we are investigating ways of evaluating the conditions where a heat pump installation will be an improvement and under which conditions it will not, where the focus will be on reducing global warming. We will look at basic thermodynamic considerations and modern thermodynamics tools, e.g. exergy and pinch analysis using data from the European energy systems as practical examples. To give a fuller picture of the impact, a life cycle impact assessment (LCA) is given, comparing a Stirling engine- type VHTHP with more conventional heaters. The paper is also using a current VHTHP installation as an example throughout the paper.

Introduction

Lowering the environmental footprint of industrial heating and cooling utilities resulted in heat pump technology entering this field, as part of a general trend of "de-fuelling" energy systems. Although the maximum temperatures reached with so-called Very High Temperature Heat Pumps (VHTHPs) are in the range 150 - 200°C, significant advantages from the viewpoint of greenhouse gas (and pollutant) emissions follow when electricity from a renewable source is available. An overview of high temperature heat pump development from 2018 can be found in the work by Arpagaus et.al. [1]. As discussed below, analysing the real benefit of VHTHPs must start with the heat generation equipment it replaces, followed by an evaluation of the energy efficiency and environmental footprint of the electricity source. For both, a life cycle assessment (LCA) sheds light on a range of aspects that affect sustainability, besides CO_2 emissions. For optimal implementation of a heat pump it needs to be properly integrated with respect to the heating and cooling demands of the process it