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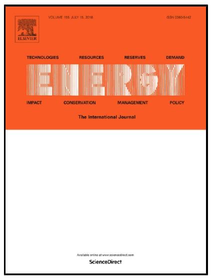

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An integrated approach based on Life Cycle Assessment and Thermoeconomics: application to a water-cooled chiller for an air conditioning plant

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Abstract

A large number of methods for energy systems analysis were developed in the last decades, aimed at acquiring an in-depth understanding of plant performances and enabling analysts to identify optimal design and operating conditions. In this work an integrated approach based on Life Cycle Assessment and Thermoeconomics is proposed as a method for assessing the exergo-environmental profile of energy systems. The procedure combines the capabilities of these two techniques, to account simultaneously for aspects related to thermodynamics of energy conversion processes and to the overall impacts along the plant life cycle related to other phases, i.e. from raw material extraction to the disposal of facilities. The capabilities of the method are illustrated by applying it to a water-cooled vapor compression chiller. After developing an accurate analysis of plant design and bill of materials of the chiller, the exergo-environmental profile was obtained. Then, the method was used as a decision support tool by considering a number of scenarios concerning possible design alternatives, context conditions and levels of maintenance. Results showed that the exergo-environmental performance of the chiller is highly sensitive to the electricity generation mix, which influences the trade-offs between the energo-environmental impacts related with plant operation and construction.

Keywords

Energy systems analysis, Life Cycle Assessment, Thermoeconomics, multi-variable approach, refrigeration plant.

1. Introduction

In the last few decades increasing large efforts have been devoted at developing rigorous techniques for the analysis of energy systems and the optimization of their design, in order to minimize the consumption of non-renewable energy sources and the environmental impacts.
Among these techniques, Thermoeconomics [1] emerged as a promising approach providing useful insights into an efficient and cost-effective design [2] and operation [3] of an energy system by combining exergy analysis with economic principles. In particular, the so-called "exergoeconomic cost accounting" [4] provides rational criteria for allocating costs in multi-product systems such as polygeneration plants [5]. The cost of a product strictly depends on the processes involved in its production. Each sub-process contributes differently to the total cost since it consumes a different amount of resources (measured in either monetary, energetic, exergetic terms) in the so-called *cost formation process* [2]. The exergoeconomic cost accounting is based on a systematic analysis of the cost formation process in energy systems and it clarifies how each sub-process contributes, with its thermodynamic irreversibility, to the consumption of external exergy resources [4]. An interesting example can be found in Verda et

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