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Life cycle assessment of a solar thermal collector: sensitivity analysis, energy and environmental balances

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Abstract

Starting from the results of a life cycle assessment of solar thermal collector for sanitary warm water, an energy balance between the employed energy during the collector life cycle and the energy saved thanks to the collector use has been investigated. A sensitivity analysis for estimating the effects of the chosen methods and data on the outcome of the study was carried out. Uncertainties due to the eco-profile of input materials and the initial assumptions have been analysed.

Since the study is concerned with a renewable energy system, attention has been focused on the energy indexes and in particular the "global energy consumption". Following the principles of Kyoto Protocol, the variations of CO_2 emissions have also been studied.

Keywords: Life cycle assessment (LCA); Solar thermal collector; Energy payback time; Sensitivity analysis

1. Introduction

The life cycle assessment (LCA) is a useful tool to estimate the effective energy and environmental impacts related to products or services. However, the results of LCA do not represent "exact" and "precise" data, but are affected by a multitude of uncertainty sources.

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The reliability of LCAs strictly depends on complete and sharp data that unfortunately are not always available [1]. ISO 14040 recommends to investigate all those parameters that could heavily influence the final eco-profile [2]. Because Life Cycle Inventory (LCI) results are generally used for comparative purposes, the quality of data is essential to state whether results are valid or not [3–5]. Regarding data quality, LCA studies should include: time-related coverage, geographical coverage, technology coverage, precision, completeness and representativeness of data consistency and reproducibility of methods used throughout the LCA, sources of the data and their representativeness, uncertainty of the information [2].

The international standards give little practical guidance on how to manage such information. In addition to previously listed parameters, other sources of uncertainty are [6]:

- Data inaccuracy (due to errors and imperfection in the measurements);
- Data gaps or not representative data;
- Structure of the model (as simplified model to represent the functional relationships);
- Different choices and assumptions;
- System boundaries definition;
- Characterisation factors and weights (as those used in the calculation of potential environmental impacts);
- Mistakes (unavoidable in every step of LCA).

Furthermore, the global environmental balance of a product is strictly related to the service life ("*Period of time after installation during which all essential properties of an item meet or exceed the required performance*" [7]) and durability ("*Capability of an item to perform its required function over a period of time*" [7]) concepts. The durability is certainly a key element since LCA takes the life cycle of the material into account, which includes its use over a number of years: by increasing the length of the service life, the use of resources is improved as much as specific impacts are reduced. Design concepts, aiming to improve the environmental performance of a product, should include the design for durability and the design for longevity including, for example, concepts of reparability, maintainability and upgradability [8,9]. However, even the durability assessment implies many problems and uncertainties as: non-reproducibility and traceability of field tracking studies, subjectivity of expert opinion, length of accelerated tests and natural weathering, relevance of stress test, required quality and quantity of knowledge for modelling [10].

Moreover, the study of uncertainty sources is itself affected by uncertainty. It is necessary to distinguish uncertainty, which arises due to the lack of the knowledge about the true value of a quantity, from variability that is attributable to the natural heterogeneity of values [6]. Uncertainty could be reduced by more precise and accurate measurements while variability is entailed into processes. Details contained in the normal LCI study do not often allow distinguishing uncertainty from variability. Consequently, in this study, they will be jointly considered.