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Life Cycle Assessment of Combined Solar System

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Abstract: - Solar combisystems are solar heating installations providing space heating as well as domestic hot water for the inhabitants of the building. Although such a system favours renewable solar energy it causes environmental impacts. For an installed system in Northern Greece we made a Life Cycle Assessment analysis concluding to interesting energy payback periods

Key-Words: - Life Cycle Assessment, solar combisystem, energy payback period

1 Introduction

Although solar energy is considered as a ‘‘clean’’ form of energy, important materials, manufacturing, transportation, utilization and final disposal transactions take place with the environment over the whole solar combisystem’s life cycle. The environmental consequences of these transactions include natural resources depletion, greenhouse gas emissions and acid rain. It is necessary therefore to evaluate solar technology accounting for the indirect environmental impacts caused by the solar combisystems over their whole life cycle.

In this paper, the life cycle assessment (LCA) methodology is applied for the assessment of the environmental impact of a solar combisystem taking into account the principles of ISO 14040 series [1,2,3]. A number of publications applying LCA on Renewable Energy Sources (RES) exist in the literature [4,5,6], but, to our knowledge, noone refers to solar combisystems. We attempt to examine them from an environmental point of view and compare them with other competitive energy transforming systems. The analysis is focused only on atmospheric pollution, and in particular on CO_2, SO_2 and NO_x emissions, caused by energy used in manufacturing and assembling the system. Such a LCA is incomplete however, since no other factor or stage of the product life cycle is accounted for.

Here, the LCA methodology is applied for our developed system in RES Laboratory of TEI of West Macedonia in Greece, but it can be extended to all other configurations examined in last paragraph. With LCA, the environmental impacts associated with the production and utilisation of solar combisystem can be assessed in an objective and scientific way. This can be accomplished by recording the energy and raw materials used in the manufacturing stage and also the air, liquid and solid pollutants emitted over its life cycle. Apart from obtaining a reliable assessment of the total impact, LCA can enable an existing situation to be improved by providing suggestions for modifications or substitutions of materials or manufacturing procedures that have the greatest environmental impact.

2 Methodology

A number of different methodologies for conducting LCA have been developed over the last few years, but none of them covers all the categories of environmental impact. We use the ‘‘Eco-it’’ (Pre-Consultants, www.pre.nl) software, which depends on the methodology and the incorporated database of Eco-indicator ’99 covering a variety of manufacturing procedures and impacts.

The Eco-indicator of a material or process is a number indicating the environmental impact of the material or process, based on data from a life cycle assessment. The higher the indicator, the greater the environmental impact is. The Eco-indicator ’99 methodology used for calculating the standard values conforms well to the ISO 14042, although it may deviate in some details. As a result, many LCA software tools use the database created for the specific methodology.

The standard Eco-indicator ’99 values can be regarded as dimensionless figures, called Eco-indicator points (Pt). One Pt is defined to represent one thousandth of the yearly environmental load of an average European inhabitant [7].

Standard Eco-indicator values have been developed, as such an instrument meant for designers, a tool to be used in the search for more environment-friendly design alternatives. Eco-indicator ’99 includes standard values for [7]:

. Materials. In determining the indicator for the production of materials, all the processes involved are included, from the extraction of the raw materials up to and including the last production stage, resulting in bulk material. Transport processes along this route are also included up to the final process in the production chain.

. Production processes. Treatment and processing of various materials, expressed for each treatment in the unit appropriate to the particular process (e.g. square metres of rolled sheet or kilo of extrude d plastic). The indicators of the production process account for the emissions not only during the manufacturing stage, but also for those resulting from the production of the energy needed.

. Transportation processes. These are mostly expressed in the unit tonne-kilometre. Transportation processes include the impact of emissions caused by the extraction and production of fuels and the fuel consumption during transportation. A loading efficiency for average European conditions is assumed and a possible empty return journey is accounted for.

. Energy generation processes. The energy indicators refer to the extraction and production of fuels and to the energy conversion, using average efficiencies. For the electricity score, the various fuels used in Europe to generate electricity are accounted for. Different Eco-indicators have been determined for high- and low voltage electricity, intended for industrial processes the first and mainly for household and small-scale industries the second.

. Disposal scenarios. These are per material unit (kg), subdivided into types of material and waste processing methods (recycling of different materials, incineration, landfill, etc.). Not all products are disposed of in the same manner, therefore the most appropriate waste-processing method must be carefully considered in using indicators. In addition, scenarios have been provided for the incineration, landfill disposal and recycling of products.

3 Analysis

The analysis consists of three stages.

. First, the thermal load covered by our solar combisystem is calculated.

. At the second stage, a life cycle analysis is conducted for the system and the environmental impact is calculated.

. Finally, the environmental impact of the solar combisystem life cycle is compared to the impact of the energy the solar systems cover, and would be covered by heating oil and electricity, which are the predominant energy forms used for the loads under consideration.

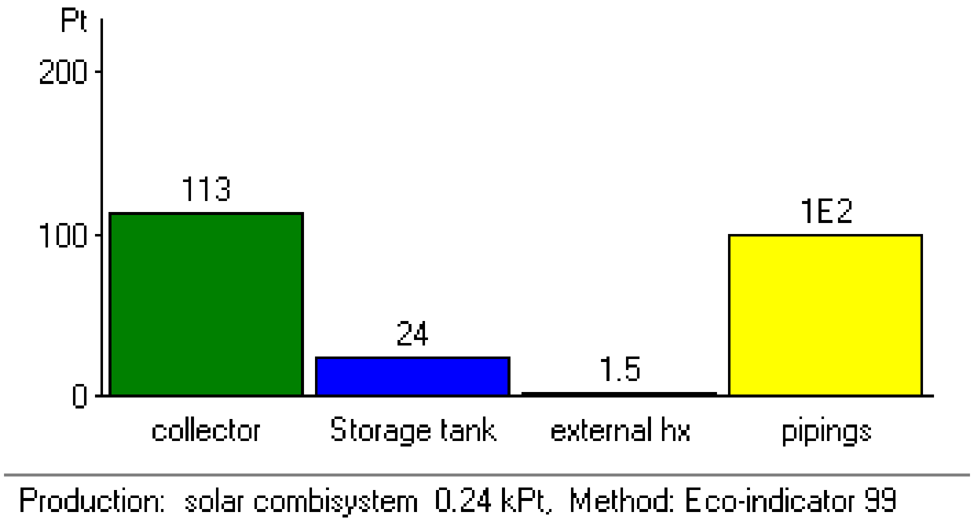

Figure 1 Environmental impacts from solar combisystem production

We have calculated for our solar combisystem in Northern Greece the conventional load (12126 kWh/yr, from which 10573.54 are covered by heating oil and 1372.46 by electricity), the load saved by the combisystem (7677 kWh/yr) and the auxiliary energy needed by the last (4449 kWh/year, from which 3985 are covered by heating oil and 464 by electricity).

Using the ‘‘Eco-it’’ software the total environmental impact of production and transportation for our combisystem can be easily calculated. Assuming no recycling at the end of the systems life cycle, we estimate the environmental impacts 2.54 kPt.

The calculated environmental impacts coming from production is shown in Figure 1, from use of energy in Figure 2 and the total environmental impact in Figure 3.

For the period of 20 years the environmental impacts for the conventional system are as follows:

20 yrs X 10573.54 *3.6 MJ/yr of heating oil X 5.6 mPt/MJ = 4263251.328 mPt

20 yrs X 1372.46 kWh/yr of electricity X 61 mPt/kWh = 1674401.2 mPt

Total environmental impacts for the conventional load = 5.9 kPt

where 5.6 mPt/MJ and 61 mPt/kWh are indicators from the database of Eco-indicator 99 [7].

For the period of 20 years the environmental impacts for the solar combisystem load have been calculated 2.54 kPt

Total avoided environmental impacts = 3.36 kPt

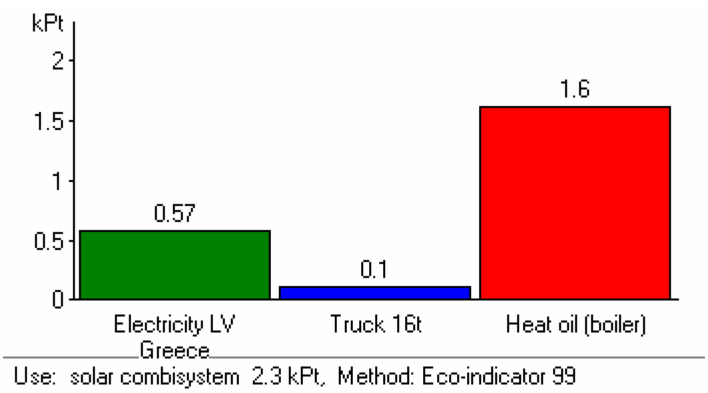

Figure 2 Environmental impacts from solar combisystem energy use over its service life

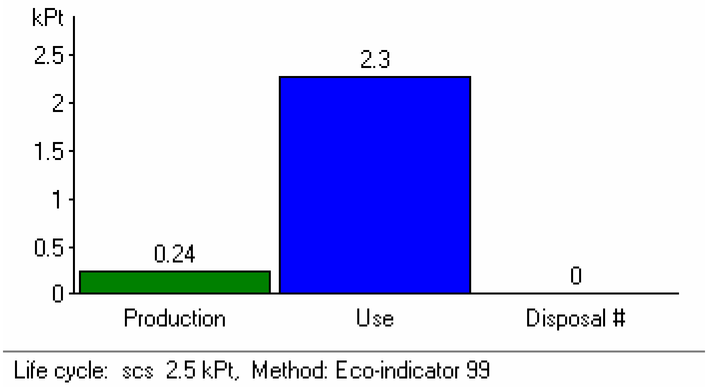

Figure 3 Total environmental impacts from solar combisystem

20 yrs X 10573.54 *3.6 MJ/yr of heating oil X 5.6 mPt/MJ = 4263251.328 mPt

20 yrs X 1372.46 kWh/yr of electricity X 61 mPt/kWh = 1674401.2 mPt

Total environmental impacts for the conventional load = 5.9 kPt

where 5.6 mPt/MJ and 61 mPt/kWh are indicators from the database of Eco-indicator 99 [1].

For the period of 20 years the environmental impacts for the solar combisystem load have been calculated 2.54 kPt

Total avoided environmental impacts = 3.36 kPt

Thus, the production and utilisation of the solar combisystem has a ‘‘net’’ gain of 3.36 kPt of environmental impact, or avoided environmental impacts more than 56.9%, of that caused by the conventional system.

According the above results we can estimate the energy payback time of the system. The energy payback time is the period, the system has to be in operation in order to save the amount of primary energy that has been spent for production, operation and maintenance of the system [8].

Based on an overall consideration a system only contributes to the saving of our resources if it is operated longer than its energy payback time.

If we assume that the energy payback time is x, then we can write:

Environmental impact per year from conventional system * energy payback time = environmental impact form combisystem production + Environmental impact from solar combisystem + Environmental impact per year from combisystem energy use* energy payback time, or:

$$5.9/20 * x = 0.24 + 2.3/20 * x$$

Thus the energy payback time is 1.33 years or 16 months, which is a very good figure. We could also add two months maximum for any impacts not included due to method limitations and possible error of our estimations and conclude to 18 months, which seems a promising figure.

For comparison reasons we would refer to a very recent publication [9], which makes an extensive Life Cycle Assessment for electricity and heating producing systems. This publication makes impact assessment and not energy payback time comparison, however these both are in straight analogy. In this article solar thermal energy (for heating applications) contributes the lowest in global warming (same with biomass), the lowest in acidification (half of the immediate next ranking renewable energy) and the lowest in eutrophication (one eighth of the immediate next ranking renewable energy).

The above calculations do not include the environmental impact from the production of the corresponding heaters, since it is assumed that the solar system is used to substitute part of the electricity or of the heating oil required to cover all or part of the load. In other words, the ‘‘conventional’’ system is assumed to exist in any case, the solar system taking over as much of its duty as possible.

4 Conclusion

The findings of Life Cycle Assessment analysis conclude in an energy payback period of 18 months, meaning that the environmental benefits of the systems balance the imposed environmental burden in that period and during all the next period we eliminate the pollution coming from conventional systems. Even in unfavourable economic conditions this time cannot be more than two years, practically meaning that in energy terms the solution of solar combisystems is far more favourable than conventional methods of domestic hot water and space heating.

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