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Evaluation of a building using the emergy method

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Abstract

Emergy (spelled with an m) is the energy of one kind, usually solar energy, which is required to make a service or product. The yearly emergy consumption/production of a building is evaluated considering the Solar Energy Laboratory (LESO) building on the campus of the Swiss Federal Institute of Technology of Lausanne (Switzerland). This experimental building was constructed according to special environmental considerations, such as important the use of passive gains (heat emitted from solar radiations, electric appliances and building users). It is therefore characterized by a very low energy consumption, equal to 232 MJ/m^2 year. The LESO building is occupied by faculty and students. Undergraduate and graduate students as well as faculty represent information inputs to the system with their emergy accounting for 94.6% of the emergy inputs to the building, equal to 3.3E18 sej/year (solar emjoules per year).

"Educated students" (students who have completed a semester project, master's or PhD research in the laboratory), publications, courses and services are the main outputs of the system. The four outputs are considered as co-outputs, as such the total emergy associated to the operation of the building as a structure is entirely assigned to each of them. The evaluation established that a student leaving the LESO building has a transformity (emergy per unit energy) equal to 2.4E8 sej/J, which is about three times higher than the one which he/she had upon arrival, representing the knowledge gained through conferences and interactions with other students and professors.

Considering only energy and materials inputs, electricity was established to be the largest input to the system (2.7E16 sej/year). The total emergy of the material inflows was determined to equal 1.7E16 sej/year, paper being the largest material input (5.7E15 sej/year). The specific emergy (per mass) of some common building materials was also evaluated and compared to NRE (non-renewable energy).

Finally, the question of uncertainties related to the determination and use of average transformities and emergy per mass values is addressed, and advantages and drawbacks of the emergy method are discussed in relation to other common evaluation methodology (exergy, embodied energy, life-cycle analysis).

Keywords: Emergy evaluation; Building; Information production

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Nomenclature

J_{em}	emergy per unit time (sej/year, solar emjoules per year), Eq. (1)	J_i	energy flow (J/year), Eq. (1)
		Tr_i	transformity (sej/J), Eq. (1)

1. Introduction

1.1. LESO building

The experimental LESO building is three-stories containing faculty and students offices and a workshop. A photovoltaic (PV) installation is situated on the roof. The building was constructed in 1981 with different solar facades that could be individually analyzed. A homogenous south facade, replacing these units, was built in 1999 in accordance with sustainable development strategies and a drastic reduction of the use of non-renewable energy, as described in (Altherr and Gay, 2002), see Fig. 1. The LESO building energy consumption, 232 MJ/m^2 year, is subdivided as follows: 156 MJ/m^2 year for electricity and 76 MJ/m^2 year for heat, for a treated floor area (area that is heated and lighted) of 765 m^2. Seventy-five percent of the electricity consumption is associated with the presence of data-processing equipment and machines (Altherr and Gay, 2002). The PV installation covers approximately nine percent of the electricity requirements of the building. The heat consumption is very low, as gains by windows (solar gains), electric appliances and presence of people cover 75% of the total heat requirements.

1.2. Emergy definitions

By definition, emergy is the available energy of one kind that has been used up directly and indirectly to make a product or service (Odum, 1996). It may also be considered as a measure of the entropy that has been produced over the transformation process (Lloyd and Pagel, 1988). The term emergy was first introduced in 1987 as the "memory of energy" (Scienceman, 1987). Studies about the relationship between society and environment had then already been done for more than 10 years by H.T. Odum, (see for example Odum, 1971). A crucial concept that has occupied emergy theory during its evolution has been the notion of energy quality. Indeed, different forms of energy have different abilities to do work, and it is necessary to account for these different abilities if energies are to be estimated correctly. Some evaluations consider each flow in an "oil equivalent amount" before comparing them, whereas emergy evaluation expresses all flows using the common measure of solar energy. Emergy therefore accounts for quality differences among distinct forms of energy and allows for the inclusion of information and monetary flows to those of energy and materials.

Emergy per unit time is calculated using:

$$J_{em} = \sum (J_1 \cdot Tr_1 + J_2 \cdot Tr_2 + \cdots + J_i \cdot Tr_i) \quad (1)$$

where J_{em} is the emergy per unit time, for example year, and is expressed in sej/year (solar emjoules per year), J_i is an energy flow in J/year and Tr_i the corresponding transformity in sej/J.

Fig. 1. View of the south facade and photovolatic installation of the LESO building.