Emergy Accounting of a Course of Management at the Federal Institute of Southern Minas Gerais: A Case Study

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Abstract

The aim of this work is to carry out the environmental accounting of a technicians' level programme of Management given by the Federal Institute of Education, Science and Technology of the South of Minas Gerais (IFSULDEMINAS) at an external unit in Jacutinga, MG using the emergy accounting method. This work is an integrating part of a broader case study featuring a comparison between the implicit environmental costs behind this programme and the Distance Teaching version of a similar course carried by the same institution.

Keywords: *emergy, information, CO2.*

1. Introduction

This work integrates a broader study carried out to compare the necessary investment in natural resources behind both a regular classroom and a Distance Teaching version of a course of Management Technicians at the IFSULDEMINAS.

Public schools maintained by the federal government of Brazil have strategically implemented extra-campus units envisaging formation of mid-level technicians in two-year programmes, in an attempt to meet the regional demands for skilled labour. The necessary infrastructure is obtained by means of arrangements between the institutions and the city governments, by which all didactic-related aspects -i.e. pedagogic management, materials and certification- are handled by the teaching institution, whereas the physical structure, along with its maintenance and staff costs are the responsibility of the municipalities; city and federal teachers are assigned, as convenient, to conduct teaching.

Also, Distance Teaching (DT) has been under intense growth nationwide. According to data published by the Annual Brazilian Open and Distance Teaching Statistics in 2007 (ABREAD, 2007) 504,000 students were then engaged in DT courses, which translates into a 36% increase in the number of institutions authorized by the ministry of education and culture (MEC) to carry DT,

consequently increasing the number of graduation courses offered via Universidade Aberta do Brasil (Open University of Brazil) by 74% whereas the number of seats increased by 274%.

The management technician formation course under study here was given at the Federal Institute of Education. Science and Technology of Southern Minas Gerais (IFSULDEMINAS) unit in the town of Jacutinga, MG to thirty-four attending students, from 2012 to 2014. The calculations presented in this work integrate a wider case study which uses emergy accounting to compare the environmental investments required for the formation of management technicians both via classroom and distance teaching and their impact on the environment due to CO2 emissions. Featured here are the calculations of the environmental support behind the classroom programme. The timeframe considered is two years, which corresponds to the duration of the programme.

2. Literature review

Research carried out for this work included studies involving emergy accounting of construction, maintenance and usage of buildings as well as references on emergy information accounting.

Odum (1996) considers information as the most important feature of many systems, and this includes genetic bio-diversity (genetic code of living organisms) and the human knowledge (cultural information acquired). Information requires some form of energy, such as the one in the DNA of seeds (transported so as to give life to a new plant) or in books, which spread information to several locations.

Meillaud et al (2005) used emergy sysnthesis to evaluate energy savings from installing solar panels on the façade of a building at the Swiss Federal Institute of Technology Lausanne. Information flows in the system, represented by High School and undergraduate students' contributions, make up 95% of the total system emergy. By the time a student becomes graduated at the Institute, the emergy of the knowledge he/she acquired from the interaction with teachers and the other students was verified to be three times higher than the emergy of the knowledge he/she brought into the system from his/her previous school experience.

Pulselli et al (2007) use the emergy synthesis to detail the building, maintenance and usage phases of a residential and office building in Italy. Materials related to the building phase which persist through time were accounted for. The flows of energy and materials necessary to the stock maintenance were estimated during the maintenance phase accounting. The building lifespan was set as 25 years and the annual emergy flows were calculated next.

Higher Education institutions play a prominent role in the debate over the evolution of human society and its position in the biosphere. Thus, Almeida et al (2013) used emergy synthesis to assess the programme of Engineering at Universidade Paulista, comparing the results to those obtained for the Pharmacy and Business programmes and used those results to visualize the system holistically and its relationship with the environment. Subsystems were evaluated so as to assist in decision making on introducing Sustainable Development concepts into curricula and establishing targets towards greening the campus.

The emergy of information is the sum of many interacting flows. One's learning is the result of the interaction among information, materials and energy flows. Information transformity is the emergy per unit energy of the information carrier (Odum, 1996). Information requires high emergy and has high transformity.

3. Methodology

Emergy enviromental accounting is the methodology applied in this work. Emergy is the available solar energy previously used, directly or indirectly, to obtain a product or service, including contributions from nature and economy. Its unit is the solar energy Joule (seJ). In this work the methodology is applied to assess the materials, energy, labor and information flows of a course to form management technicians given at the Jacutinga, MG unit of the IFSULDEMINAS, using a common unit – the solar energy Joules. The information brought into the system by students coming from high-school, as well as the energy of the information transmitted by teachers and books both contribute to the students' increase in transformity, therefore those energy flows have also been accounted for.

In this work the emergy accounting done in three steps: a- construction of an energy diagram displaying the energy flows into the system studied; b- construction of the table; c- interpretation of results. Four distinct accounting phases were considered: i- building implementation; ii- building usage; iii- students' access to the information environment using public transportation, and iv- information flows within the system.

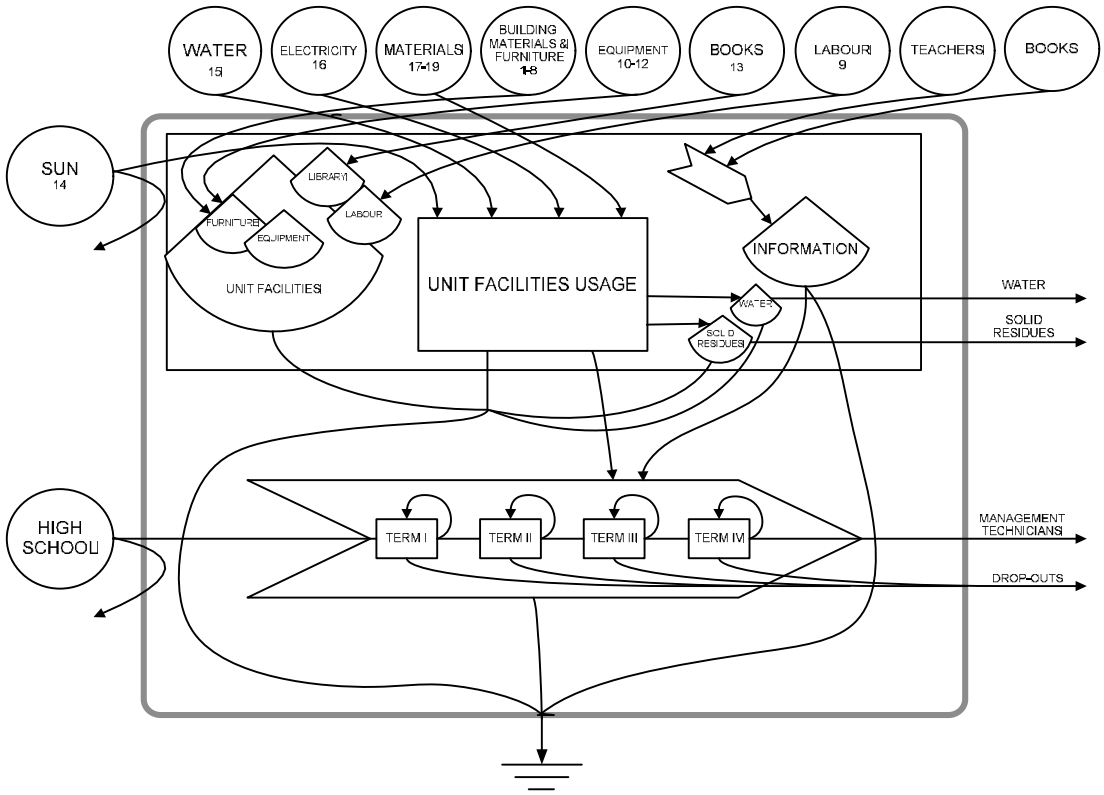
4. Data collection

Data on the necessary material for the implementation of the physical structure were collected *in loco* and comprise documents, interviews and measurements. The unit is located in a public city school campus, therefore only the structure actually used for the course was taken into consideration in this study, which includes a classroom, a video-room, a secretary office and two restrooms. The structure lifespan has been settled to 25 years (Tomson, 2004; Meillaud et al., 2005; Campbell and Lu, 2009). Books lifespan considered here was also 25 years (Odum, 1996). Equipment such as computers, data projectors and fans are replaced every five years. Information flows were calculated second to Odum's (1996) approach, which is based on kilocalories consumption per unit time. Specific transformities for the contributions from teachers and students therein have been calculated based on the work of Demetrio (2011).

5. Results

Figure 1 displays the energy diagram of the implementation and usage phases of the infrastructure of the course, and the interaction of teachers and students with it. This diagram represents the two-year cycle necessary for the completion of the programme. The numbers in the circles refer to the items listed in the tables.

Figure 1. Energy diagram of the course of Management at the Jacutinga-MG unit of IFSULDEMINAS.



The diagram above displays the various accounting phases interacting to produce management technicians. The physical facilities are represented by the large stock symbol. The energy from inputs necessary to carry the process flow into the usage phase represented by a rectangle. Teachers and didactic material form a stock of information. Also represented is the interaction among flows of information from teachers, students, materials and the infrastructure, by the large interaction symbol. The outputs from the process include technicians, dropouts, solid and liquid residues.

Table 1 contains the emergy accounting of all the energy inflows necessary for the implementation and usage of the infrastructure represented in the diagram above by the larger stock figure.

Table 1. Emergy accounting of the necessary materials for the implementation of the facilities in the Jacutinga unit used to conduct the course for two years.

Item	Description	Unit/ 2 years	Quantity (unit)	Emergy/unit (seJ/unit)	Emergy (seJ)
	Building implementation				
1	Concrete	g	1.30E+07	1.54E+09	2.00E+16
2	Steel	g	4.03E+05	4.15E+09	1.67E+15
3	Wood	g	1.94E+04	8.79E+08	1.71E+13
4	Plastic	g	4.42E+02	5.75E+09	2.54E+12
5	Iron	g	3.42E+04	4.15E+09	1.42E+14
6	Ceramics	g	2.69E+05	3.06E+09	8.23E+14
7	Glass (windows, doors)	g	1.34E+04	2.16E+09	2.89E+13
8	Glass (lamps)	g	3.52E+02	2.16E+09	7.60E+11
9	Labour	J	2.17E+09	4.30E+06	9.33E+15
10	Computers	g	1.50E+04	8.90E+10	1.34E+15
11	Data projector	g	1.44E+03	1.13E+11	1.63E+14
12	Fan	g	2.88E+03	4.10E+09	1.18E+13
13	Books (library stock)	J	1.23E+05	3.45E+09	4.24E+14
	Total phase emergy				**3.40E+16**

Concrete contributes the highest emergy value in the implementation phase, followed by labor, which is considered as stock, as the staff permanence in the system surpasses the two-year term under study. Table 2 enlists the inflows of materials and energy consumption necessary for the use of the physical structure for two years.

Table 2. Emergy accounting of the necessary materials for the usage of the facilities in the Jacutinga for two years.

Item	Description	Unit/ 2 years	Quantity (unit)	Emergy/unit (seJ/unit)	Emergy (seJ)
	Building usage				
14	Sun	J	5.25E+09	1	5.25E+09
15	Water (from well)	m3	9.52E+01	7.75E+11	7.38E+13
16	Electricity	J	1.17E+10	2.77E+05	3.25E+15
17	Paper	g	1.29E+05	2.38E+09	3.07E+14
18	Paper (towels and toilet)	g	4.23E+04	2.38E+09	1.01E+14
19	Plastic (cups)	g	1.94E+04	5.76E+09	1.12E+14
20	Workbooks (total in 2 years)	J	2.34E+06	3.45E+09	8.07E+15
	Total phase emergy				**1.19E+16**

In the accounting of the usage phase emergy, the workbooks produced and distributed to students have the highest emergy, followed by electricity. With the exception of sunlight, all item flows in this accounting phase are sensitive to the number of attending students. Included here is the accounting of the flows resulting from the use of a bus to transport students from suburban and rural areas to the unit and back (Table 3). Bus mechanical/parts maintenance was not included in the accounting due to the lack of specific data records on the subject.

Table 3. Emergy accounting of the inflows related to the transportation of students by bus.

Item	Description	Unit/ 2 years	Quantity (unit)	Emergy/unit (seJ/unit)	Emergy (seJ)
	Access to information				
21	Bus	g	1.67E+06	4.15E+09	6.92E+15
22	Diesel oil	J	1.89E+11	1.13E+05	2.13E+16
23	Labour (bus driver)	J	4.12E+08	4.30E+06	1.77E+15
	Total phase emergy				**3.00E+16**

A medium-sized city bus weighing 12.500 kilos is used for transporting students, most of its mass being steel. The largest contribution in this phase comes from the consumption of Diesel oil. Calculation of the amount of Diesel oil used in two years is based on a city bus average consumption, of 0,5 l_{diesel}/km, according to the *Anfavea* (National Association of Automobile Manufacturers), *apud* IEMA, 2013. The labor contributed refers to the bus driver's metabolic energy spent on two daily working hours, five days a week, for two years. The inclusion of transportation facilities in the accounting causes an increase of 65% in the emergy value of the course infrastructure. For a clearer overview of the contributions brought into the system by each material and labor inflow subject to managerial actions, table 4 shows their relative percentages.

Description	Emergy	% from total emergy
Sunlight	2.25E+09	<1%
Glass (lamp bulbs)	7.60E+11	<1%
Plastic	2.54E+12	<1%
Fan	1.18E+13	<1%
Wood	1.71E+13	<1%
Glass (doors/windows)	2.89E+13	<1%
Water (from well)	7.38E+13	<1%
Paper (toilet and towels)	1.01E+14	<1%
Plastic (cups)	1.12E+14	<1%
Iron	1.42E+14	<1%
Data projector	1.63E+14	<1%
Paper (office and classroom)	3.07E+14	<1%
Books (library stock)	4.24E+14	<1%
Ceramics	8.23E+14	1.1%
Computers	1.34E+15	1.8%
Steel	1.67E+15	2.2%
Labour (bus driver)	1.77E+15	2.3%
Electricity	3.25E+15	4.3%
Bus	6.92E+15	9.1%
Workbooks	8.07E+15	10.6%
Labour	9.33E+15	12.3%
Concrete	2.00E+16	26.4%
Diesel oil	2.13E+16	28.1%
	7.59E+16	**100.00%**

Emergy accounting has been used previously by several authors to analyze educational systems. Besides providing financial managers of environmentally-aware teaching institutions with important data on the intrinsic, albeit not usually considered use of natural resources behind financial investments in school infrastructure, a type of cost-benefit relationship can be drawn from the accounting of the information flows within a working system. Although dependent on the number of attending students and the number of staff teachers, the analysis goes beyond the mere attending students per hired teachers rate or average students' grades. The interaction with each other group and with the infrastructure is measured in terms of metabolic energy spent per time in interaction, thus resulting in students' gradual transformity value increase, also allowing for comparisons with similar systems. As noted by Odum (1996), information can be the most important feature of some systems, and its transformities are very high, which can cause the emergy of simple infrastructures seem close to non-significant when information and infrastructure are included in the same accounting table. Table 4 shows the accounting of the information flows within the system.

Table 4. Emergy accounting of the information flows resulting from the interaction among students, teachers, and the infrastructure.

Item	Description	Unit/ 2 years	Quantity (unit)	Emergy/unit (seJ/unit)	Emergy (seJ)
	Information (Odum)				
24	Information transmitted by teachers	J	1.48E+07	2.08E+11	3.08E+18
25	Information transmitted by books (1%)	J	2.46E+04	3.45E+09	8.49E+13
26	Students' previous information - (10%)	J	1.37E+09	1.80E+09	2.46E+18
	Total phase emergy				**5.54E+18**

The emergy subtotals shown in the summary below (table 5) evidences that the environmental investment in transportation reaches close to 90% of the total emergy of the building used, in comparison. On the other hand, information flows make up 99% of the total emergy value of the entire system.

Table 5. Emergy per phase summary.

Phase	seJ
Building implementation	3.40E+16
Building usage	1.19E+16
Access to information	3.00E+16
Information	5.54E+18
Total	**5.63E+18**

5. Conclusions

Being part of a broader work of research originally designed to serve as a reference for the environmentally aware school directors, financial directors and decision makers, this study features calculations that are representative of the investment in natural resources necessary to train a group of skilled management technicians at the Jacutinga unit of the IFSULDEMINAS. The investment in natural resources backing the infrastructure increases 65% with the inclusion of the environmental costs related to the students' transportation, an input not considered in other authors' works on educational systems. Nonetheless, due to its high transformity value, most of the system emergy derives from the information flows. For those not familiar with the methodology, the flows corresponding percentage values may better explain nature's contribution to the system as a whole.

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APPENDIX

List of transformities and UEVs used in this work.

Flow	UEV (sej/unit)	Reference
Sunlight	1	By definition
Electricity	2.69E+05	Odum page 305
Labour	4.30E+06	Coelho et al, 2002
Services	4.30E+06	This work
Wood	8.79E+08	Buranakarn, 2003
Concrete	1.54E+09	Buranakarn, 2003
Students' previous information - (10%)	1.80E+09	This work
Glass	2.16E+09	Buranakarn, 2003
Paper	2.38E+09	Meillaud et al., 2005
Ceramics	3.06E+09	Buranakarn, 2003
Books	3.45E+09	Odum, 1996
Information book --> student (1%)	3.45E+09	Odum, 1996
Fan	4.10E+09	Geber: Björklund, 2001
Steel	4.15E+09	Buranakarn, 2003
Iron	4.15E+09	Buranakarn, 2003
Plastic	5.75E+09	Buranakarn, 2003
Information tutor --> student - (1%)	2.86E+10	This work
Computer	8.90E+10	Di Salvo and Agostinho, under review
Datashow projector	1.13E+11	Cohen et al., 2006
Information online teacher --> student	2.08E+11	This work
Water (from well)	7.75E+11	Buenfil, 2001