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Emergy Analysis of an English School Located in the South of Minas Gerais, Brazil

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ABSTRACT

An emergy synthesis of an English language school located in Minas Gerais State, Brazil was performed. All the global resources related to building construction and school operation were accounted for in the evaluation. Two approaches were adopted to determine the transformity of the entering students and teachers. The first approach takes into account the educational level of the individual, analogous to Odum's classification. The transformities calculated for entering students and teachers were 4.97E+07 and 18.73 E+07 sej/J, respectively. The transformity obtained for the students after one year of taking classes is 1.17E+08 sej/J. The second approach is supported by the assumption that the teachers acquired their English knowledge in the same school where they are currently teaching. Six years of an intermediate/advanced course was considered the lower limit to acquire the background needed in order to begin teaching activities. Thus, the transformity for the teachers trained in the school was 4.55E+08 sej/J. In this case, students after one year of attending classes have a transformity of 1.69E+08 sej/J.

INTRODUCTION

Few studies have been performed on the emergy analysis of human transformities in Brazil. Many of the papers that use human transformities are not based on a thorough study of the subject. One of the objectives of this paper is to calculate the transformity of human labor by trying to distinguish it from the role of information in an emergy analysis using an English language school located in Ouro Fino - Minas Gerais as the study system.

This was possible using Odum's methodology for calculating the transformity of education levels given in Odum (1996). According to Odum (1996) "Emergy is the available energy of one kind previously used up directly or indirectly to make a service or product. Emergy accounting quantifies the relationship between the human being and the biosphere. Emergy evaluation gives a value to services and products by converting them into equivalents of one form of energy, i.e., solar energy; its unit is the emjoule. The emergy of all the resources is found by multiplying their quantities in mass (kg or g) or energy (J) by a conversion factor, that Odum called the transformity. Extensive work has been performed in the sense of calculating all the transformities of the available energy resources. Odum (1996) started to evaluate the emergy of information, and according to this author, examples of information are the genetic codes of living organisms, the organization of an ecological system, and the cultural information of human societies. He noticed also that information requires some form of energy as a carrier.

The methodology used here will consider the material, energy and human labor in a quantitative way and using a common base to identify and quantify the resources necessary to make an individual proficient in English as a foreign language speaker. All natural and purchased resources needed to make

an individual proficient in the English language were taken into consideration. This includes quantifying the resources corresponding both to implementation (infrastructure, stock of materials that form the building, furniture and so on) and to operation (water, electricity, human labor due to maintenance and teaching). An emergy accounting of the infrastructure of the building that holds the school was performed earlier in a study published in the Proceedings of the 4th International Workshop Advances in Cleaner Production (Lupinacci and Bonilla, 2013). Consequently, in this study we calculated how much an individual has his/her transformity increased after becoming proficient in the English language when studied as a foreign language in Brazil.

METHODS

An emergy analysis was performed on an English school located in a small town in the state of Minas Gerais - Brazil. The first step of the work was to identify all the global resources that were necessary for the school building by defining and diagramming the system. The emergy baseline of 15.83E+24 sej/yr is considered throughout this paper. A Brazilian construction norm that states all the materials used in a typical construction in the country was used to identify all the kinds of resources used in building the school. This was accomplished in a previous study performed by the authors. (Lupinacci and Bonilla, 2013). The total annual emergy required for the construction was 9.02E+15 sej/yr and was calculated from the total emergy divided by a lifespan for the school of 50 years. The system energy diagram is shown in Figure 1.

After performing an emergy analysis of the building that holds the school all the resources used to make the operation of the school possible were identified, including the human work performed by the teachers and secretaries. An energy systems diagram depicting those resources and the way they interact is shown in Figure 2.

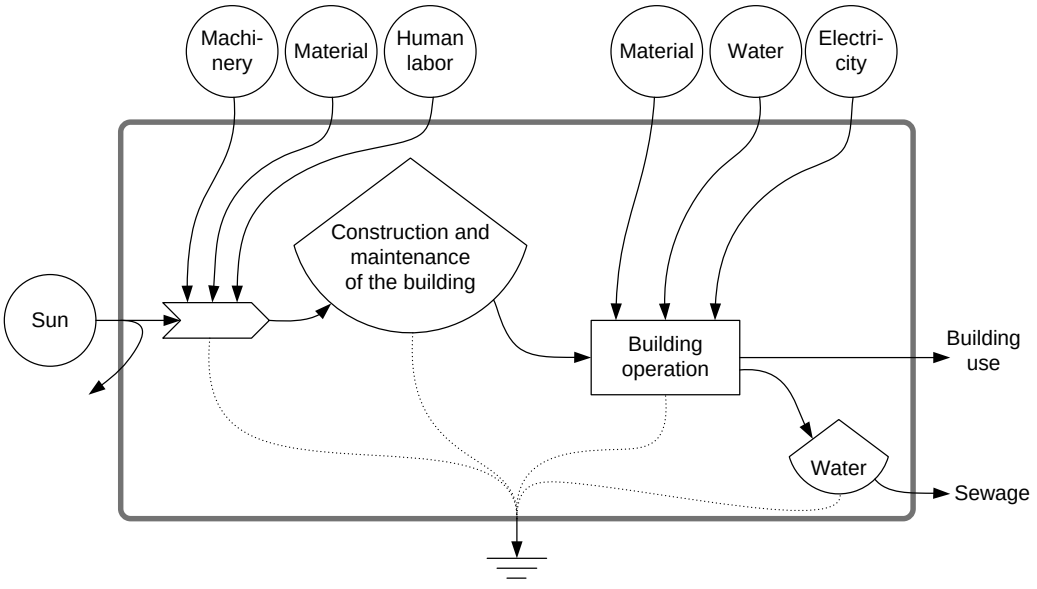

Figure 1. *Energy Systems Language diagram of the school construction (source: Lupinacci and Bonilla, 2013).*

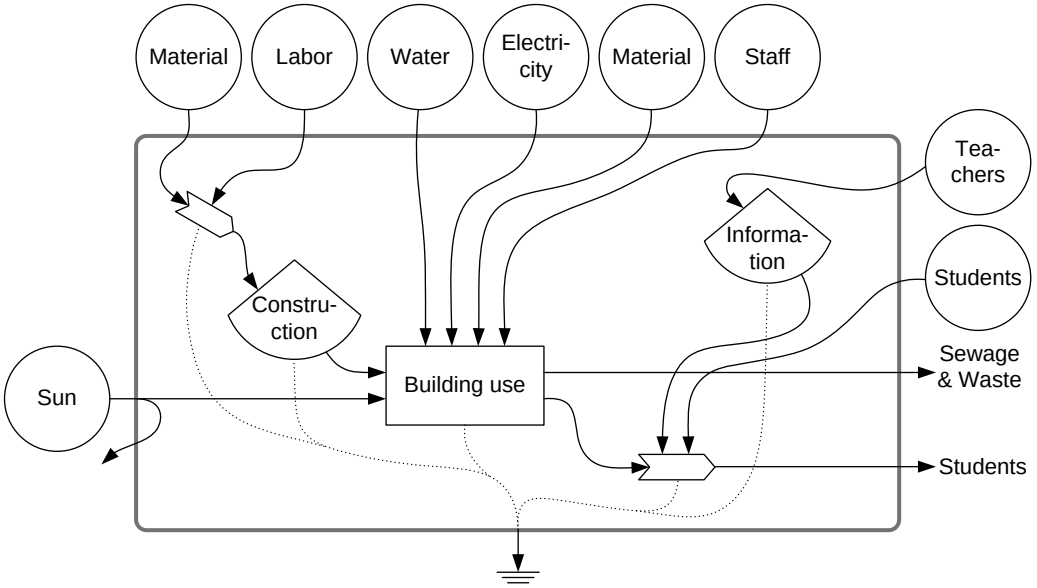

Figure 2. *Energy Systems Language diagram of the English language school*.

Odum (1996) stated that the transformity (sej/J) of an individual's labor could be determined by dividing the total annual solar emergy use of the United States by the number of people in the category and the annual metabolic energy per person (J). He calculated the emergy of the different educational levels of the USA by using this approach. A similar approach was considered here in order to calculate teachers and students' transformities since it was assumed that they belong to different education categories within the Minas Gerais State population. The calculation of the transformities of the teachers and students that enter the system is shown in the Table A, Appendix A.

The emergy of the teaching and learning process is that required to increase the total knowledge in the system under evaluation. The emergy of teaching and learning in the English school was quantified as the sum of the emergy delivered by teachers during the time spent transmitting the information plus the emergy brought to the learning process by the students who were receiving the information. The approach is similar to the one first explored by Campbell and Lu (2009) when they calculated the emergy basis for formal education in the United States and then later adopted by Almeida et al. (2013) when they calculated the emergy of Paulista University students.

A second approach was considered to calculate teachers' transformities. It was assumed that an advanced student after six years education (i.e., equivalent to learning the six books of advanced English content) would be proficient enough to become an English teacher in the school analyzed. It was considered that the transformity of the teacher is six times higher than the transformity of the students, since it would take 6 years (under the assumption considered above) for a student that belongs to the CLASS level to become proficient in the English language. This CLASS level mentioned has a total of 6 books and it is designated for teenagers and adults. The equations used to calculate the transformities of the students, who have completed the English course and who were considered at the threshold level to begin their teaching activities, were developed from calculations using the first approach. Equations are shown in Appendix B.

To calculate the emergy of the system some allocations were made. The number of students taken into consideration for this study is 47, corresponding to the intermediate/advanced English level. They were at the high school level during the evaluation and corresponded to 16% of the total number of students in the English school. Therefore the allocations made were the ones related to water, electricity, paper, plastic cups and cleaning products. In this way, 16% of each of these inputs was considered in the accounting.

DESCRIPTION OF THE SYSTEM

The building under study is approximately 45 years old. It is located in Ouro Fino, Minas Gerais-Brazil and it is used to hold an English language school. It is 114.24 m² in area with five classrooms, a waiting room, a front desk, a bathroom and a teacher's room. There are about 300 students enrolled in the English courses available. The courses are divided according to the student's ages and English proficiency levels. There are four different modalities at this school which are TOTS, KIDS, TEENS and CLASS. This paper focuses on the students who are in the CLASS level.

To make emergy analysis of the school possible two steps were performed in sequence: accounting for 1) the process of constructing the building and 2) the operation of the school (including the teaching-learning process). The first step was developed in a previous work (Lupinacci & Bonilla, 2013) and the results are used here. The second step took into consideration the number of students in the CLASS level, who would take a test to identify their proficiency level in the English language in the near future. The number of students involved in the analysis was 47, which represents 16% of the total students.

RESULTS AND DISCUSSION

To evaluate the teaching and learning process in the English school two approaches to calculate the teachers' and students' transformities were considered. In the first approach the transformities of the students entering the system and the teachers were calculated by dividing the total emergy of Minas Gerais state by the energy used by the total of high school graduates and college graduates in the state, respectively (as shown in Appendix A). With the calculated transformities it was possible to elaborate the emergy table with all the resources used to make an individual proficient in the English language. The results are shown in Table 1.

Table 1. Emergy evaluation table of an English language school (taking into account the number of high school teachers in the state of Minas Gerais

Item	Description	Unit	Quant. (unit/yr)	UEV (sej/unit)	Emergy sej/yr	% (sej/sej)	Reference
Infrastructure							
1	Construction				9.02E+15	2.72	a
Use							
2	Water	m³/yr	4.80E+01	1.30E+12	6.24E+13	<1	b
3	Electricity	J/yr	9.41E+09	4.56E+05	4.29E+15	<1	c
4	Paper	g/yr	2.30E+04	3.99E+09	9.18E+13	<1	d
5	Plastic	g/yr	1.89E+05	9.83E+09	1.86E+15	<1	e
6	Glass	g/yr	6.69E+03	5.39E+09	3.61E+13	<1	e
7	Wood	g/yr	2.74E+04	1.48E+09	4.06E+13	<1	e
8	Iron	g/yr	5.42E+04	6.97E+09	3.78E+14	<1	e
9	Computer	g/yr	3.90E+04	8.90E+10	3.47E+15	1.05	f
10	Secretary	J/yr	1.42E+09	4.97E+07	7.06E+16	21.26	g
11	Students	J/yr	2.83E+09	4.97E+07	1.41E+17	42.36	g
12	Teachers	J/yr	5.43E+08	1.87E+08	1.02E+17	30.58	g
	Total				3.32E+17	100	

In order to unify global emergy budgets, all the UEVs are expressed in the adopted baseline. UEVs on the older baseline were multiplied by 1.68. This procedure was carried out for UEVs extracted from references b, c, d and e.

a- Lupinacci and Bonilla, 2013; b- Buenfil 2001; c- Odum 1996; d- Meillaud et al 2005

e- Brown and Buranakarn 2003; f- Di Salvo and Agostinho 2015; g- Calculated for this paper

Table 2. Emergy evaluation table for the English school using the assumption that the transformity of the teachers is 6 times higher than the transformity of the students after one year of study.

Item	Description	Unit	Quant. (unit/yr)	UEV (sej/unit)	Emergy sej/yr	% (sej/sej)	Reference
Infrastructure							
1	Construction				9.02E+15	1.89	a
Use							
2	Water	m^3/yr	4.80E+01	1.30E+12	6.24E+13	<1	b
3	Electricity	J/yr	9.41E+09	4.56E+05	4.29E+15	<1	c
4	Paper	g/yr	2.30E+04	3.99E+09	9.18E+13	<1	d
5	Plastic	g/yr	1.89E+05	9.83E+09	1.86E+15	<1	e
6	Glass	g/yr	6.69E+03	5.39E+09	3.61E+13	<1	e
7	Wood	g/yr	2.74E+04	1.48E+09	4.06E+13	<1	e
8	Iron	g/yr	5.42E+04	6.97E+09	3.78E+14	<1	e
9	Computer	g/yr	3.90E+04	8.90E+10	3.47E+15	<1	f
10	Secretary	J/yr	1.42E+09	4.97E+07	7.06E+16	14.78	g
11	Students	J/yr	2.83E+09	4.97E+07	1.41E+17	29.45	g
12	Teachers	J/yr	5.43E+08	4.55E+08	2.47E+17	51.74	g
	Total				4.78E+17	100	

In order to unify global emergy budgets, all the UEVs are expressed in the adopted baseline. UEVs on the older baseline were multiplied by 1.68. This procedure was carried out for UEVs extracted from references b, c, d and e.

a- Lupinacci and Bonilla, 2013
b- Buenfil 2001
c- Odum 1996
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The main emergy flows in the table account for human performance in the form of teachers' labor, secretaries' labor and the contribution of students who carry their prior education according to their educational level (in this case considered to be that of the high school level). Approximately 95% of the total emergy corresponds to the presence and functions of humans, teaching, learning and supporting the teaching-learning process. The material inputs have negligible weight on the total emergy flow. Only emergy flows corresponding to computers and construction have a small but at least non negligible weight.

The transformity for the students who leave after one year of attending classes is 1.14E+08 sej/J or around twice as large as their transformity when they entered the CLASS course. The increase in transformity reflects the upgrade in knowledge resulting from the interaction with teachers and colleagues, in addition to the infrastructure needed to support the school.

The total emergy of the school using the second approach to calculate the teachers' transformity is shown in Table 2. The calculation of the teachers' transformity is presented in Appendix B. The second approach assumes that a teacher has graduated in English at the same school in which he/she is learning, currently. The scenario creates an endogenous situation where the teachers not only belong to a specific education level and transformity according to the state population but also have acquired an English knowledge level great enough to begin his/her career in the same school where they originally studied. Of course, this is a preliminary study in order to show an endogenous way to calculate human labor transformities. The period of 6 years at the intermediate and advanced English degree is considered the lower limit to be considered proficient enough to begin the teaching experience with supervision.

Some differences arise when comparing Table 2 with the results obtained under the first approach. Considerations adopted in order to elaborate the second scenario, led to emergy values corresponding to teachers around twice as large as those found in the first calculation, which only takes into account the education levels in Minas Gerais state. Whereas, in the first calculation entering students present the highest contribution, in the one presented in Table 2, the highest contribution corresponds to the teacher's services. Since this second calculation proposal was only preliminarily addressed, it deserves more work in order to explore it properly. Calculations taking into consideration the weight of teachers' experience on the total emergy flow are in progress.

An important aspect to notice in both approaches is the great contribution of human services when compared to other emergy flows. As stated by Campbell, Lu and Kolb (2011), human service is often engaged to add value to lower quality materials. In this way, the English school would be only structured materials without the presence and contribution of students and teachers involved in the teaching-learning process. Moreover, a high level hierarchical process is occurring.

The transformity for the students leaving after one year of attending classes is 1.69E+08 sej/J, more than twice as large as the one presented when they entered the CLASS course.

CONCLUSION

Emergy studies dealing with human services and labor transformity calculations deserve attention and deep exploration due to the fact that human contributions add value to all production systems. Such systems are qualitatively important and numerically evident in terms of the emergy values calculated in this study. Moreover, when teaching-learning or similar higher level processes are focused on; these calculations are of greater importance, especially because information has been copied or transferred. The two approaches explored here showed that there is not a unified way of taking into account human activities within the systems up to now. The macroscopic point of view, exemplified by Odum's approach to quantifying the educational levels of a nation (or state in our case), deals with average values which may not reflect the real and particular situation of a specific system. To calculate the transformity of English teachers by assuming their endogenous formation within the limits of the system under study was an attempt to contribute to this discussion and is open to debate.

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APPENDICES

Appendix A

Table A. Data necessary for the calculation and the method of calculating transformities of the teachers and students. The value of 2500 kcal/day was considered appropriate for the daily energy expenditures of an individual.

Attainment	Numbers (E+06 indiv.)	Energy per level (E+16 J/yr)	Transformity (E+07 sej/J)
Preschool (Total)	19.36	7.40	1.26
Fundamental school	8.66	3.31	2.81
High-school	4.90	1.87	4.97
College grad.	1.30	0.50	18.73

Transformities were calculated by dividing the total annual solar EMERGY use of the State of Minas Gerais by the number of people in the category and the annual metabolic energy per person. Minas Gerais total solar emergy for the year 2011 is 9.30E+23 sej/year. For the high school level the transformity is: (9.23E+23 sej/year / 4.90E+06 individual x 2.500 kcal/day x 365 days/year x 4186 J/cal) = 4.97E+07 sej/J.

Appendix B

$$E_{Mst\ out2} = E_{Mbuild} + E_{Moperation} + E_{Mst\ out1} = 2 \times (E_{Mbuild} + E_{Moperation}) + E_{Mst\ in1}$$

$$E_{Mst\ outn} = n \times (E_{Mbuild} + E_{Moperation}) + E_{Mst\ in1}$$

Where:
$E_{Mst\ outi}$ corresponds to the emergy value of the output students after i years of study, with i between 1 and 6 in this case. The $E_{Mst\ out\ (i-1)}$ is the entering flows of students of the i year since they have just finished the i-1 year of study;
$E_{Mbuild} + E_{Moperation}$ corresponds to the annual emergy flows of building and operation; the latter includes teachers' and the secretary's labor (according to the first approach considerations for transformity calculations of the latter items), which equals to 1.91E+17 according to Table 1.
$E_{Mst\ in1}$ corresponds to the emergy of students entering the school; the value is equal to the value considered in the first approach. Equals to 1.41E+17 according to Table 1.
For next calculations, the transformity value extracted from the flow of the 6th year course of advanced degree students ($E_{Mst\ out6}$) was adopted for the teachers.
In this way,
$E_{Mst\ out6}$ = 6 x (1.91E+17) + 1.41E+17 = 12.89E+17 sej/yr
So $Tr_{teach} = Tr_{st\ out6}$ = 4.55E+08 sej/J