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# Environmental Accounting of a Building Used as an English School in Ouro Fino – Minas Gerais

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**Abstract**

This paper analyses a building used to hold an English school in the city of Ouro Fino – Minas Gerais. This analysis was made only for the construction of the building using a Brazilian norm that states all the material used to build a house in mass unit per km². Using the methodology in emergy accounting developed by Odum (1996) it shows the percentage of the materials used in the building that holds the English school. According to the emergy analysis it is noted that the material that has been used the most in it is the cement (34.78%) of the total emergy, followed by labor (18.16%), copper (17.70%) and the sand (14.16%). When the analyses is performed by mass unit the material that has been used the most is the cement (48.21%), followed by the sand (35.45%) and the ceramic (4.69%).

***Keywords:*** *emergy accounting, transformity, building construction, building maintenance, building use.*

## Introduction

It is well known that English has become the most important language for business, technology, science and communication over the years. It is quite big the number of people that have studied English either as a second language or as a foreign language throughout the world. In Brazil, this is not different. The number of English schools has increased a lot. According to the Brazilian Association of Franchising (ABF) there are more than 35 different types of franchising of English schools in Brazil with more than 6,000 schools nowadays, and this number is increasing.

The increasing number of English schools in Brazil and in the world has caused a certain impact in the environment due to the construction, maintenance as well as operation costs of these establishments. In this sense, the conservation of natural resources is essential to the perpetuation of human beings and it cannot be disassociated from the effects caused by the social and economic developments and their consequences. According to the Brundtland report published in 1987, sustainable development aims to assist the necessities of the current generations without compromising the necessities of the future generations.

The impact in the environment will be analyzed using the Emergy methodology developed by Odum (1996). According to the author "Emergy is the available energy of one kind of previously used up directly and indirectly to make a service or product. Its unit is the emjoule". The methodology used here will consider the material, energy, human labor and information in a quantitative way and in a common base to identify and quantify the necessary resources to make an individual proficient in the English language as a foreign language. The emergy accounting quantifies the relation there is between the human being and the biosphere. When applied to a building it quantifies all the natural resources used in the manufacturing, maintenance and use of it.

The aim of the whole thesis intends to identify and quantify all the natural and purchased resources needed to make an individual proficient in the English language. This includes quantifying theresources corresponding both to implementation (infrastructure, stock of materials that form the building, furniture and so on) and to operation (water, electricity, humam labor due to maintenance and teaching). It is also to verify if there is any quantitative mathematics correlation between the global resources and the English language learning by the students with their scores in the TOEIC (test of English as International Communication. This paper will deal with the first part of the project which is to analyze the building used as an English school in the city of Ouro Fino – Minas Gerais; and it shows the previous emergy necessary to the construction of this building.

## Methods

Odum (1996) developed an environmental accounting method that he called emergy analysis (spelled with an "m"). This analysis is interested in quantifying the relationships between man made systems and the biosphere. Emergy is the available solar energy previously used, directly or indirectly in order to make a service or product. The emergy evaluation gives a value to services and products by converting them into equivalents of one form of energy, solar energy (Pulselli, 2007). This solar energy has *solar emergy joule* (sej) as its unit.

The emergy of different products is obtained by the multiplication of the products' mass quantities (kg or g) or their energy quantities (J) by a conversion factor, that is named transformity when expressed in sej/J or specific emergy when expressed in sej/mass unities. Transformity is the solar emergy required, directly or indirectly, to make 1 J or kilogram of a product or service (Odum, 1996).

When this analysis is used for a building, it quantifies all the natural resources used for building manufacturing, maintenance and use. In this first stage the analyses will be made only for the manufacturing. Inputs are classified according to Odum in renewable energy, nonrenewable energy and purchased resources, R, N and F, respectively. This enables the definition of indexes used to analyze how sustainable the system is.

The standard methods of Emergy Analysis (Odum 1996) were used to evaluate the foreign language acquisition of students learning English in a school located in the southeast of Brazil. The methods used were those appropriate for evaluating a process of production. These methods were applied to all the courses available at this school. The first step in this project was to define the system and draw the diagram of the process of acquisition of knowledge where the inputs are identified and placed in the diagram. The spatial and temporal boundaries of this study were taken into consideration as well. The spatial boundary of this study was set to be the English school located in Ouro Fino, Minas Gerais. The temporal boundary was set to be the years that have taken the students to become proficient in the language.

The second step was to quantify materials and hours via NBR 12721:2006 and then to calculate the emergy from the raw data by multiplying them by the corresponding "conversion factor". It was necessary to quantify the global resources used in the project which can be of material and labor. The material resources include the infrastructure of the house as well as the maintenance. According to Pulselli there are three phases that need to be taken into consideration when analyzing a building and they need to be assessed separately: (1) building manufacturing process; (2) building maintenance; (3) building use. The building maintenance and the building use will be analyzed in the near future.

The adoption of the norm NBR 12.721/2006 is justified since the building matches the norm considerations in term of construction area and quality.

In figure 1 an energy system diagram of a building drawn by Pulselli (2007) is shown.

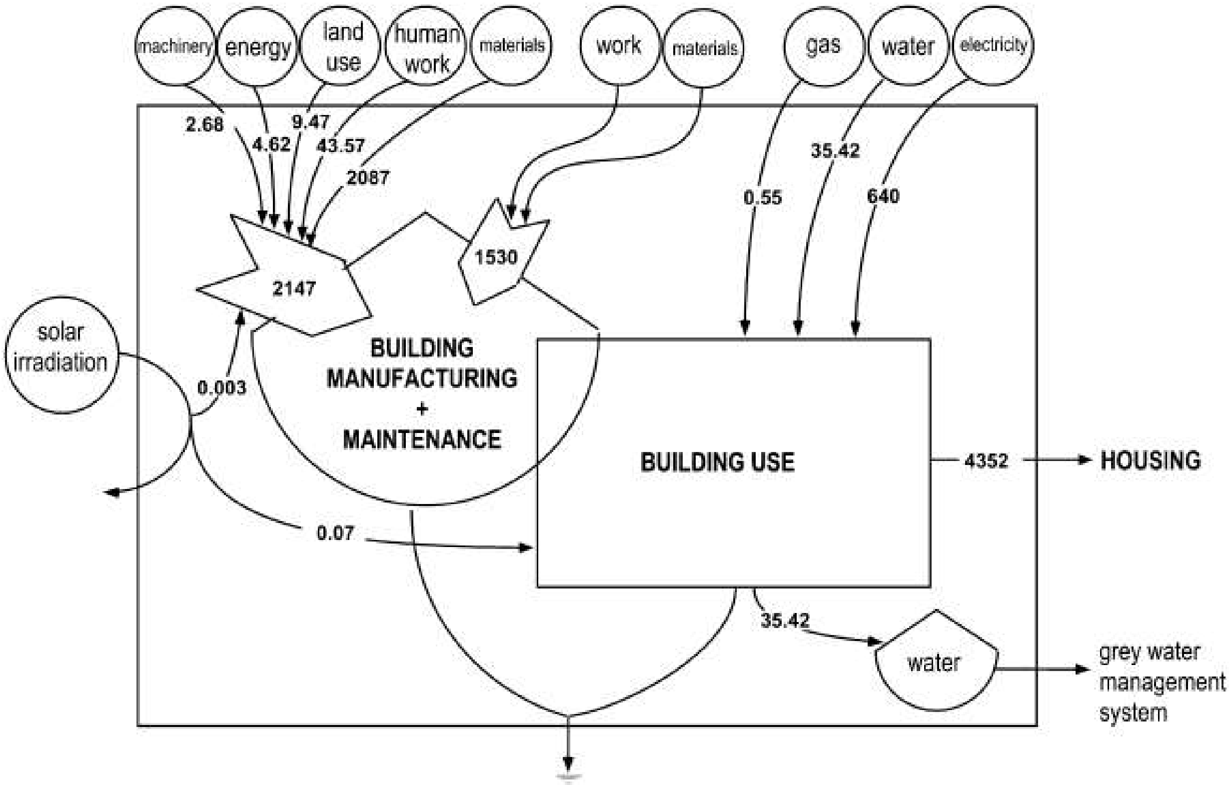


**Fig. 1** – Diagram of energy of systems developed by Pulselli (Pulselli ET al, 2007).

## Description of the System

In this study a building is examined regarding an emergy analysis. This building is approximately 45 years old and it is located in Ouro Fino, Minas Gerais-Brazil and it is used to hold an English school. It has 114,24 m² of construction 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. There are four different modalities at this school which are TOTS, KIDS, TEENS AND CLASS.

To make the emergy analysis three phases were performed separately: the process of the manufacturing of the house; the maintenance and the use of the house.

The first phase was possible, when the house under study, was adequated to a Brazilian Norm that shows the materials used in the construction and the hours needed to build this house. After doing that, the tranformities and specific emergy values of these materials and labor were found in the literature and the emergy accounting was performed.

The maintenance of the building takes into account the energy and materials inflows that are needed to maintain the building stock constant in time. Pulselli et al (2007) state that "in terms of evolutionary physics this would be the maintaining of a steady state in open dynamic systems." The lifespan of the house and of each material used is considered to be of 50 years old.

## Results and Discussion

According to the NBR 12721/2006 the material used in the construction is listed below in table 1. Due to not having all the materials labeled in the literature when it comes to the emergy accounting it is necessary to adapt them to the materials found. Table 1 shows this adaptation necessary to the emergy evaluation of the house. It has the inputs used in the construction of the house and related material.

**Table 1 –** Material used in the construction according to the NBR 12.721/2006.

| Item | Inputs | Material |
|---|---|---|
| 1 | Laminated plywood sheet 18 mm 2,20 X 1,10 m | Wood |
| 2 | Steel CA - 50 Ø | Steel |
| 3 | Concrete fck = 25 | Cement |
| 4 | Cement CP – 32 II | Cement |
| 5 | Sand | Sand |
| 6 | Gravel n 2 | Granite |
| 7 | Brick 8 holes 9 cm X 19 cm X 19 cm | Brick |
| 8 | Concrete block 19 cm X 19 cm X 39 cm | Cement |
| 9 | Grains Flow Tile 6 mm 2,44 X 1,10 m | Cement |
| 10 | Semi hollow internal door 0,60 X 2,10 m | Wood |
| 11 | Sliding miter natural anodized aluminum | Steel |
| 12 | Sliding window of folded plate 1,20 X 1,20 m | Steel |
| 13 | Iron chromed lock | Steel |
| 14 | White tile 15,0 cm X 15,00 cm | Ceramic |
| 15 | Marble counter top 2,00 m X 0,60 m | Granite |
| 16 | Plasterboard 70 cm X 70 cm | Plaster |
| 17 | Transparent flat glass | Glass |
| 18 | Latex paint | Paint |
| 19 | Asphalt emultion sealer | Asphalt |
| 20 | Anti flame copper wire | Copper |
| 21 | Three pole breaker | Plastic |
| 22 | Toilet basin | Ceramic |
| 23 | Chrome pressure record ø 1/2" | Steel |

| | | |
|---|---|---|
| 24 | Galvanized iron pipe with seam ø 02/12'' | Steel |
| 25 | PVC pipe R drive for enhanced sewage | Plastic |
| | **Labor** | |
| 26 | Bricklayer | Labor |
| 27 | Bricklayer helper | Labor |
| | **Administrative expenses** | |
| 28 | Engineer | Labor |
| | **Equipments** | |
| 29 | Rent of concrete mixer 320 I | Steel |

The emergy per unit used in this project (table 2)are mostly taken from the literature, and are relative to the 15.83E+24 seJ/year baseline (Odum and Odum, 2000).

**Table 2 –** List of the emergy per unit values that will be used in the present work

| Resources | Unit | sej/unit | Reference |
|---|---|---|---|
| Sun | seJ/J | 1,00E+00 | Definition |
| Soil | seJ/J | 1,24E+05 | Odum *et al.*, 2000 |
| Water | seJ/kg | 9,23E+08 | Brown *et al.*, 2000 |
| Brick | seJ/g | 2,52E+09 | Geber e Bjorklund, 2001 |
| Glass | seJ/kg | 1,41E+12 | Odum, 1996 |
| Sand | seJ/kg | 1,68E+12 | Odum, 1996 |
| Wood | seJ/kg | 2,40E+12 | Odum, 1996 |
| Granite | seJ/kg | 2,44E+12 | Pulselli *et al.*, 2006 |
| Cement | seJ/kg | 3,04E+12 | Pulselli *et al.*, 2007 |
| Plaster | seJ/kg | 3,29E+12 | Pulselli *et al.*, 2006 |
| Ceramic | seJ/kg | 4,80E+12 | Brown e Buranakarn, 2003 |
| Steel | seJ/kg | 6,97E+12 | Brown e Buranakarn, 2003 |
| Plastic | seJ/kg | 9,86E+12 | Brown e Buranakarn, 2003 |
| Labor | seJ/h | 1,77E+13 | Demetrio, 2012 |
| Asphalt | seJ/kg | 2,55E+13 | Brown e Buranakarn, 2003 |
| Paint | seJ/kg | 2,55E+13 | Brown e Buranakarn, 2003 |
| Copper | seJ/kg | 1,04E+14 | Pulselli *et al.*, 2006 |

Table 3 shows the result of the annual emergy accounting for the building used as an English school.

**Table 3 -** Annual emergy accounting for the building used as an English school.

| Note | Description | Class | Un | Value | UEV (seJ/un) | Life span (years) | Emergy (sej/year) | % |
|---|---|---|---|---|---|---|---|---|
| 1 | Sun | R | J | 5.25E+11 | 1 | 1 | 5.25E+11 | |
| 2 | Kinetic energy of the wind | R | J | 4.66E+09 | 2.45E+03 | 1 | 1.14E+13 | <1% |
| 3 | Soil | N | J | 2.5E+11 | 1.24E+05 | 1 | 3.10E+16 | 70.91% |
| 4 | Electricity | F | J | 7.84E+04 | 2.85E+05 | 50 | 4.47E+08 | <1% |
| 5 | Laminated plywood sheet 18 mm 2.20 X 1.10 m | F | kg | 2.06E+03 | 2.40E+12 | 50 | 9.89E+13 | <1% |
| 6 | Steel CA - 50 Ø | F | kg | 2.03E+03 | 6.97E+12 | 50 | 2.82E+14 | <1% |
| 7 | Concrete | F | kg | 5.85E+04 | 3.04E+12 | 50 | 3.55E+15 | 8.13% |
| 8 | Cement | F | kg | 1.04E+04 | 3.04E+12 | 50 | 6.34E+14 | 1.45% |
| 9 | Sand | F | kg | 5.35E+04 | 1.68E+12 | 50 | 1.80E+15 | 4.11% |
| 10 | Gravel n 2 | F | kg | 1.24E+01 | 2.44E+12 | 50 | 6.07E+11 | <1% |
| 11 | Brick | F | g | 1.08E+07 | 2.52E+09 | 50 | 5.44E+14 | 1.25% |
| 12 | Concrete block | F | kg | 0.00E+00 | 3.04E+12 | 50 | 0.00E+00 | <1% |
| 13 | Grains Flow Tile 6 mm 2,44 X 1,10 m | F | kg | 3.84E+03 | 3.04E+12 | 50 | 2.34E+14 | <1% |
| 14 | Semi hollow internal door | F | kg | 5.61E+02 | 2.40E+12 | 50 | 2.70E+13 | <1% |
| 15 | Sliding miter natural anodized aluminum | F | kg | 2.52E+00 | 6.97E+12 | 50 | 3.51E+11 | <1% |
| 16 | Sliding window of folded plate | F | kg | 5.20E-01 | 6.97E+12 | 50 | 7.25E+10 | <1% |
| 17 | Iron chromed lock | F | kg | 1.60E+01 | 6.97E+12 | 50 | 2.24E+12 | <1% |
| 18 | White tile 15X15 | F | kg | 6.76E+03 | 5.14E+12 | 50 | 6.95E+14 | 1.59% |
| 19 | Marble counter top 2,00 m X 0,60 m | F | kg | 1.23E+02 | 2.44E+12 | 50 | 6.00E+12 | <1% |
| 20 | Plasterboard | F | kg | 0.00E+00 | 3.29E+12 | 50 | 0.00E+00 | <1% |
| 21 | Transparent flat glass 4mm | F | kg | 1.04E+02 | 1.41E+12 | 50 | 2.92E+12 | <1% |
| 22 | Latex paint | F | kg | 3.56E+02 | 2.55E+13 | 50 | 1.82E+14 | <1% |
| 23 | Asphalt emultion sealer | F | kg | 8.13E+01 | 2.55E+13 | 50 | 4.15E+13 | <1% |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 24 | Anti flame copper wire | F | kg | 1.08E+03 | 1.04E+14 | 50 | 2.25E+15 | 5.16% |
| 25 | Three pole breaker | F | kg | 4.16E+00 | 9.86E+12 | 50 | 8.21E+11 | <1% |
| 26 | Toilet basin | F | kg | 2.83E+02 | 4.80E+12 | 50 | 2.71E+13 | <1% |
| 27 | Chrome pressure record ø 1/2" | F | Kg | 5.45E+01 | 6.97E+12 | 50 | 7.60E+12 | <1% |
| 28 | Galvanized iron pipe with seam ø 02/12'' | F | Kg | 1.91E+00 | 6.97E+12 | 50 | 2.66E+11 | <1% |
| 29 | PVC pipe R drive for enhanced sewage | F | Kg | 6.39E+01 | 9.86E+12 | 50 | 1.26E+13 | <1% |
| 30 | Bricklayer | F | H | 3.79E+03 | 1.77E+13 | 50 | 1.34E+15 | 3.07% |
| 31 | Bricklayer helper | F | H | 2.57E+03 | 1.77E+13 | 50 | 9.08E+14 | 2.08% |
| 32 | Engineer | F | H | 1.77E+02 | 1.77E+13 | 50 | 6.28E+13 | <1% |
| 33 | Rent of concret mixer 320 I | F | Kg | 1.58E-01 | 6.97E+12 | 50 | 2.21E+10 | <1% |
| | TOTAL | | | | | | 4.37E+16 | 100.00% |

The total emergy necessary for the construction of the house is 4.37E+16 sej/year; the soil is responsible for more than 70% of this total.

**Table 4 -** Material used in the process of production.

| Material | Mass Unit kg | Fraction of total mass | Emergy sej/year | Fraction of total emergy |
|---|---|---|---|---|
| Wood | 2.621E+03 | 1.75% | 12.59E+13 | 0.99% |
| Steel | 2.10E+03 | 1.39% | 2.93E+14 | 2.30% |
| Cement | 7.28E+04 | 48.21% | 4.42E+15 | 34.78% |
| Sand | 5.35E+04 | 35.45% | 1.80E+15 | 14.16% |
| Granite | 1.354E+02 | 0.10% | 6.607E+12 | 0.05% |
| Brick | 1.08E+04 | 7.18% | 5.44E+14 | 4.28% |
| Ceramic | 7.04E+03 | 4.69% | 7.22E+14 | 5.68% |
| Glass | 1.04E+02 | 0.08% | 2.92E+12 | 0.02% |
| Paint | 3.56E+02 | 0.15% | 1.82E+14 | 1.43% |
| Asphalt | 3.56E+01 | 0.25% | 4.15E+13 | 0.33% |
| Copper | 1.08E+03 | 0.74% | 2.25E+15 | 17.70% |
| Plastic | 4.16E00 | 0.01% | 1.34E+13 | 0.11% |
| Labor | | | 2.31E+15 | 18.16% |
| Sum | 1.51E+05 | 100% | 12.712E+15 | 100% |

According to table 4 the material that has been used the most in the emergy analyses is the cement (34.78%) of the total emergy, followed by labor (18.16%), copper (17.70%) and the sand (14.16%).

But when the analyses is performed by mass unit the material that has been used the most is the cement (48.21%), followed by the sand (35.45%) and the ceramic (4.69%).

If the results are compared with the results found in a study performed for an evaluation of the LESO building (Solar Energy and Building Physics Laboratory), situated on the campus of the Swiss Federal Institute of Technology (EPFL) in Lausanne, Switzerland, it is noted that the materials that accounted for the most emergy use were concrete (31.75%), cement (22.92%) and labor (27.18%) respectively.

## Conclusion

This paper deals with the first part of the whole thesis which is to quantify all the global and purchased resources necessary to make an individual proficient in the English language. This first step is important because it shows the resources needed for the building used. After analyzing the building it is necessary to quantify all the global and purchased resources used in the whole school. The analyses will be made using the emergy methodology developed by Odum (1996). This will show how the environment is affected by the school. This will be important because some actions could be taken so as to improve the school's system. This is a small school that belongs to a bigger chain of franchising with more than 1,300 schools throughout the world.

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