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The roles, perspectives and limitations of environmental accounting in higher educational institutions: an emergy synthesis study of the engineering programme at the Paulista University in Brazil

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ABSTRACT

In an era of accelerating change around the globe, the roles of the Higher Educational institutions are an increasingly important part of the debate on the evolution of human society and its position in the biosphere. Emergy synthesis is a methodology that can concomitantly evaluate the integration of sustainability principles into curricula, and the campuses' operations to function with minimal environmental impact. Because of the importance of higher education in mankind's sustainable management of the biosphere, accurate estimates of the emergy of the human knowledge contributing to economic and social activities were performed to quantify the environmental, economic, and social costs and benefits of alternative policies. This study applies emergy synthesis to assess the engineering programme at Paulista University. Results were compared with those obtained from the Pharmacy and Business programmes, and used to visualize the entire system (information and resources), their relationships with the environment, and to evaluate subsystems in order to assist in decision-making for introducing SD concepts into curricula, and establishing targets for greening the campus. Energy and material flows used for construction and use of the campus were evaluated along with the information provided to students. The emergy investment to introduce two courses into the Engineering Programme was quantified and provided valuable information to guide senior university managers in the planning of new curricula that include sustainable development concepts.

1. Introduction

Higher Educational Institutions (HEIs) have increasingly embraced the principles of sustainability as a way to recognize and accept responsibility for their own societal roles. Chapter 36 of Agenda 21 (UN Documents, 1992) focused on three areas: Education, Training and Public Awareness, and stated that "Education is essential for promoting Sustainable Development (SD) and improving the capacity of the people to address environmental and developmental issues". Major efforts to control and articulate what Chapter 36 of Agenda 21 implied for higher education have been addressed through numerous international and national conferences and many reports and declarations, which outlined educational and research needs of various groups in different regions of the planet. The evolution of some initiatives taken in society, education, and higher education to promote sustainable development was published by Lozano et al. (2011). The authors concluded that despite a slow response of some HEIs to society's demands, some institutions of higher education with vision were adopting and integrating the principles of sustainability into their curricula, research, outreach and campus operations.

By helping to educate millions of students, many of whom will become leaders and decision-makers, HEIs play many significant roles in disseminating sustainability concerns, concepts, procedures and relevant technologies, since their primary purpose is to help to prepare them to participate in helping to make societies more sustainable. Thus, for taking the lead in environmental sustainability, HEIs must fully integrate sustainability principles into their curricula, enable their students to work with real problems with interdisciplinary approaches, and perform their teaching, research and campus operations to function with minimal environmental impact. Some articles published in the JCLP documented the increasing attention from academics to reexamine how HEIs are dealing with sustainability. In three recent special issues of the JCLP, titled: "Sustainability in Higher Education: What is Happening?" (Garcia et al., 2006), "The Roles of Academia in Regional

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Sustainability Initiatives" (Zilahy et al., 2009), and "Going beyond the rhetoric: system-wide changes in universities for sustainable societies" (Ferrer-Balas et al., 2010), These special issues included approximately 65 articles, which provided a comprehensive analysis of the critical roles and of progress some universities were making in education to support the transition to sustainable societies. Discussions and analyzes in those issues covered changes in values, attitudes, motives, curricula, social interactions and the impacts of research. Valuable recommendations were provided of ways to promote the progress toward sustainability involving faculties, students, staffs, alumni and other stakeholders outside of the campus boundaries.

Building upon the work referred to in those special issues, the authors of this document applied emergy synthesis as a tool to evaluate the Engineering School of Paulista University accounting for materials, energy, human labor and information. The 'emergy synthesis' tool can be used to quantify the relationship between humans systems and the biosphere. When applied to a HEI, it can be used to quantify not only the resources used in construction, maintenance and operation of the campus, but also the emergy of information carried by students, professors and books. Results are compared to those obtained from the evaluation of the Pharmacy and Business Schools at Paulista University. In particular, emergy accounting offers the following useful attributes:

1. Emergy has a rigorous scientific basis (Odum, 1996). It can determine the actual impact on resource use of HEIs activities on the campuses and the combined expressions of managerial interventions that affect the whole system in different ways.
2. Emergy uses the same unit (solar energy joules) to account for the direct and indirect support required by a system (Odum, 1996). The use of a single unit avoids the step of selecting and classifying variables since scientists designated to select variables, in each institution, may not agree on the nature of the variables to be selected or on the relative importance of one among others (Giannetti et al., 2010).
3. Emergy can help to avoid the difficulty researchers experience in normalizing and aggregating variables having different units to construct indicators. When constructing indicators based on variables (resources, emissions, wastes, information) that are not accounted with the same unit, there is still a need of objective criteria for choosing an appropriate aggregating method to enable international comparability (Giannetti et al., 2006; Almeida et al., 2007).
4. Emergy can provide transparency in evaluating systems, as weighting factors, which are value judgments and can be prone to errors, are not employed.
5. Emergy can account directly or indirectly for the information and for the free ecological services and their contributions to system operation.

2. Contextual literature review

2.1. Some initiatives for greening the campuses

In regard to greening the campuses' operations, many descriptive cases of the different approaches taken by educational institutions have been published. Several papers highlight the potential for HEIs to achieve higher rates of waste diversion and/or energy reduction as well as the challenges that university leaders face in the shift toward a sustainable campus waste management. For example, the use of paper was evaluated at Rhodes University and surrounding areas to reduce the amounts of paper used and to increase the rates of recycling (Amutenya et al., 2009). A waste characterization study created the basis for implementation of a recovery, reduction and recycling waste management program on the Mexicali University Campus in Baja California (de Vega et al., 2008). Following the same approach, the Universidad Autónoma Metropolitana implemented a solid waste management program (Espinosa et al., 2008). In these cases, the amount of solid wastes delivered to municipal collecting services was reduced, and the authors emphasized that the involvement of the community and its interdisciplinary work were decisive in making the progress that was achieved.

Waste characterization studies and environmental programs were also used as the motivating force during the preliminary stages of broader sustainability initiatives. To encourage the adoption of solid waste management programs, researchers of the University of Baja California developed a range of reuse and recycling programs for students (de Vega and Ojeda, 2003). The experience showed that, despite the fact that waste reduction and reuse are far more effective ways to minimize the environmental impact, recycling is the most visible and measurable practice that a campus can use to involve students in seeking to address real problems.

2.2. Initiatives to implement environmental management systems at higher educational institutions

Considering that the environmental pollution caused by universities in the form of energy and material consumption can be substantially reduced by effective uses of organizational and technical measures, the University of Osnabrück developed an environmental management system (EMS) for HEIs built upon Life Cycle Assessment with the aim of providing a procedure example for other institutions (Viebahn, 2002). The University of South Carolina developed the Sustainable Universities Initiative to integrate sustainability into its institution, and into other institutions in the state (Barnes and Jerman, 2002). Koester et al. (2006) institutionalized their 'greening of the campus' efforts at Ball State University, by connecting academic content, administrative policies, and management practices. It is interesting to highlight that these authors reported that not all initiatives attempted led to successful outcomes and, in many of their programs, there was room for improvement. Velazquez et al. (2006) developed a comprehensive managerial framework for a sustainable university with empirical data collected from 80 HEIs around the world. That framework offers an approach whereby people responsible for HEI sustainability initiatives may progress to achieve a more sustainable university. Additionally, a model providing a cost effective strategy for the implementation of an environmental management system was published by Savely et al. (2007a), which was in response to the need for guidance for U.S. colleges and universities. These authors reported on results of a survey that provided a broad overview of the status of implementation of EMS at colleges and universities in the U.S. (Savely et al., 2007b). Alshuwaikhat and Abubakar (2008) provided systematic recommendations for reducing the negative impacts of higher educational institutions by highlighting the importance of integrating the EMS with public participation and social responsibility, and by promoting sustainability in teaching and research.

2.3. Incorporating sustainability into university courses and curricula

Through a program of active learning, the University of Cape Town in South Africa, introduced students to a series of issues in sustainable development including concepts of societal and financial benefits, engineering economic analysis, entrepreneurship, physical risk in terms of health, safety and environment, stakeholder involvement, cleaner production and cleaner technology, and engineering ethics (von Blottnitz, 2006). The authors reported that, although student success rates were high in the first two years, concern remains as to the actual learning outcomes, particularly in relation to the depth of learning. Teaching participatory backcasting to engineering students as part of the graduate specialization in sustainability was done at Delft University in The Netherlands (Quist et al., 2006). Students working in projects were capable of generating sustainable future visions, and identified cultural, structural, technological changes required to accomplish these visions. The Swansea University, in Wales, started a program for minimizing their overall resource use in order to integrate sustainability into teaching and research activities (Harris and Probert, 2009).

2.4. Diagnosing and evaluating initiatives for greening the campuses and incorporating sustainability into university courses and curricula

With the objective of identifying barriers to include sustainability-related content throughout university curricula, and to develop solutions to eliminate/overcome these barriers, Lidgren et al. (2006) used “Places to intervene in a system” (Meadows, 1999) as a tool to systematically locate these barriers. The intervention places were used for deriving solutions for overcoming the barriers. The authors concluded that “Places to intervene” can be a practical tool toward achieving the organizational purpose of incorporating sustainability into courses and curricula.

In regard to the evaluation/selection of an appropriate environmental management system, the main constraints to the promotion of sustainability were identified in a literature review made by Evangelinos et al. (2009). The major constraints were: (i) the level of participation of the academic community; (ii) the level of provision of information by senior administrative management; (iii) the (non)existence of environmental standards; (iv) the organizational structure of HIEs; and (v) the available funding needed for the implementation of environmental projects. Six different certified and uncertified EMS’s were evaluated by Clarke and Kouri (2009). The authors found that certified EMS’s do not result in greater improvements in environmental performance as compared to uncertified ones, and recommended, as a result of their study, that academic leaders worldwide should continue to reduce their environmental impacts and develop new tools to help them on their journey.

Well-known environmental indicators were applied to evaluate the campuses’ performance in other research as well. For example the use of upstream indicators to examine the extent and content of natural resource use in two university buildings was done in Finland using the ‘*material input per unit of service*’ (MIPS) method (Sinivuoria and Saari, 2006). This study provided valuable information on measures that were useful for reducing the natural resource use of university buildings. The researchers also developed improved information for planning, construction and use of educational buildings.

The environmental performance of the Engineering Campus of the University of Maribor was assessed on a life cycle basis (Lukmana et al., 2009). The results documented that the heating and construction of buildings were responsible for the largest quantity of the environmental impacts. Smyth et al. (2010) determined the amount and composition of waste generated within campuses’ operational areas, and provided recommendations to the senior university council on strategies for improving the overall sustainability of the campus waste management program. Understanding the characteristics of an institution’s solid waste stream is the first step toward enhancing the sustainability of a waste management plan, these authors proposed various educational and policy techniques to be used to develop campus waste minimization in the long term.

Despite extensive literature dealing with integration of environmental disciplines into curricula, the greening of the campuses and the implementation of EMS, most of the papers that present an assessment for decision-making processes and the subsequent actions to be taken, only deal with a part of the problem. However, there are two indicator-based tools that were designed to document, the greening of the campuses and the inclusion of sustainable development into curricula, which include: a. the Graphical Assessment of Sustainability in Universities (GASU) and b. the Emergy Synthesis.

The GASU was developed and tested by Lozano (2006a,b) based upon the Global Reporting Initiative that was applied to HEIs. This tool was designed to facilitate the analysis, longitudinal comparison and benchmarking of universities’ sustainability efforts and achievements. It provides a concise graphical overview of the several indicators used by the GRI. GASU was designed to provide charts by which the user can score all of the indicators of each dimension economic, environmental, social and educational that are or are not incorporated into each course or curriculum. However, according to Leal Filho et al. (2009), although GASU can also be used to focus upon curricula it provides a limited analysis. Lozano also developed the Sustainability Tool for Auditing University Curricula in Higher Education (STAUNCH©) system that assesses the extent to which a university’s curricula contributes to education for SD, and provides consistent and comparable auditing that can be used to compare progress at different institutions (Leal Filho et al., 2009; Lozano, 2010; Lozano and Peattie, 2011).

Emergy synthesis offers a different approach based on thermodynamics and can be used to determine the average ecological burden, through emergy flows, to implement and maintain a campus, and to determine the investment that will be needed to integrate SD into curricula, through the emergy of information flows. According to the emergy theory, the supply of information to a system requires large energy investment for its development and maintenance (Odum, 1996). To evaluate a HEI using emergy synthesis, networks that show components and relationships are diagrammed to show how energy, materials, and information interact. Numerical values for inflows are added; the system’s diagram becomes quantitative and can be used to measure its complex organizational order. The results obtained can be used to compare, on a common basis, the investments required for the student’s education with that for greening the campus. The methodology was first used to evaluate the “Greening” of the University of Florida for the year 1978 (Odum, 1999a). Considering that a large university has a duty to develop new ideas, this research team proposed an environmental policy for the institution, including the implementation of environmental education programs into the undergraduate curricula. More recently, Meillaud et al. (2005), using emergy synthesis, evaluated the energy savings due to installation of solar panels on the building’s facade and the information provided to graduates of the Swiss Federal Institute of Technology Lausanne. The information inputs to the system (represented by undergraduate, graduate and faculty flows) accounted for approximately 95% of the emergy required for the system. The evaluation established that students leaving the institution had an emergy, representing the knowledge gained through interactions with other students and professors, three times higher than what they had when they arrived after graduating from high school.

Campbell and Lu (2009) evaluated the educational system of the United States from 1870 to 2006. The emergy of teaching and learning were measures of the emergy required for copying and transferring information. This was calculated as the sum of the emergy delivered by the education, the experience of the teachers, and the emergy brought to the process of learning by the students. These authors concluded that for one unit of emergy spent on education a return 10 times greater is obtained in terms of the overall benefits gained by society.

3. Emergy synthesis applied to HEIs

By definition, emergy is the available energy that has been used up directly and indirectly to make a product or to provide a service (Odum, 1996). Emergy accounts for quality differences among different forms of energy and can be used to compare the energy involved in information flows with those of energy and materials flows. Emergy per unit time is calculated using:

$$\text{Emergy} = (\text{energy, material or information flow}) \times \text{UEV} \quad (1)$$

where UEV stands for Unit Emergy Values, which are calculated based on the emergy required to produce a given system input (product, service or information). To derive the UEV of a resource or product, it is necessary to draw back through all the resource and energy flows that were used for its production. The emergy per unit of available energy is called Transformity (seJ/J); and the unit emergy value per mass is called specific emergy (seJ/g).

The general methodology for emergy evaluation has been explained in numerous publications (Odum, 1996; Brown and Ulgiati, 1997).

The first step of the emergy evaluation is to create a system energy diagram, which is a way of organizing thoughts and relationships between components and pathways of exchange and resource flows. The next step of the emergy evaluation is to build emergy tables based on the diagrams where each input flow becomes a row in the table to be evaluated. Results can be discussed based on a set of indicators that can be calculated:

- the emergy that indicates the amount of resources and information invested during a course or during the entire series of courses taken by the student during her/his four or five yeast at the university;
- the transformity that can estimate the individual human knowledge increase as a result of the learning process.

3.1. Calculating the emergy of information

Considering that humans learn through an interaction of information, materials and energy inflows, the emergy theory assumes that the information's transformity is equal to the transformity of the fluxes that carry that information. For example, the emergy of a teacher in the United States was calculated by Odum (1996) by dividing the total emergy of the United States by the number of teachers in the country. The transformity was calculated by dividing the teacher's emergy by the metabolic energy of an individual.

The work of professors that is delivered to support the information transfer is primarily a function of their knowledge and experience. To evaluate the different levels of human service, the total national emergy flow in a given year is divided by the number of people in a knowledge and experience category to obtain the emergy per individual in that category. The transformity (sej/J) of an individual's labor could then be determined by dividing the annual metabolic energy (J) of an individual into the emergy (sej) required per individual at a given knowledge level. In the research done for this paper, the emergy of Brazilian professors and students entering the university were calculated by dividing the total emergy of Brazil by the number of Brazilian college professors and students who graduated from high School, respectively (Appendix A).

The emergy of the teaching and the learning processes is that required to increase the total knowledge in the system under evaluation. The emergy of teaching and learning was quantified as the sum of the emergy delivered during the time spent transmitting the information plus the emergy brought to the learning process by the students, who were receiving the information.

To calculate the emergy of the information acquired by the students, the same assumptions made by Odum (1999b) were used, since they have also been used by other authors (Qin et al., 2000, Meillaud et al., 2005). According to these assumptions, the emergy of learning corresponds to 1% of the flow of human services emergy. The exposure time between teachers and students was used to calculate the emergy use in the learning process (Meillaud et al., 2005; Campbell and Lu, 2009). The information carried by the high school students corresponds to 10% of the graduating student's emergy (Meillaud et al., 2005; Campbell and Lu, 2009). The students' knowledge increases as individuals learn more about their fields through the application of what they have learned. Thus, the information that an individual student can contribute grows throughout his academic life and as a result the emergy of his knowledge increases as does the transformity of his work. Both the transformities of teacher's work and high school graduates include parental and societal inputs from zero to six and those supplied by the natural environment and the society to reach each level of education.

The information that students withdraw from books, is considered to be 1% of the book's emergy; this considers not only the materials to fabricate the book, but also the emergy invested to write and make copies (Odum, 1999b). A unique aspect of information is that it is not diminished by use; in fact, it increases as individuals learn more about their fields. Thus, the information that an individual book or other educational materials can contribute remains the same throughout its use.

3.2. Data collection to evaluate the engineering programme at the Paulista University

Data collection was performed in 2007, at the Campus Indianópolis of the Paulista University through documentation and interviews with university officials. The depreciation of school buildings in a given year was used to represent the contribution of the campus infrastructure to the emergy required for the educational process. Infrastructure data were obtained by direct measures and blueprints. The building life-span was considered to be 25 years, which corresponded to its depreciation period (Loiacono and Loiacono, 2005; Meillaud et al., 2005; Campbell and Lu, 2009). Equipment has a life-span that varies from 5 to 10 years, depending upon the equipment (Loiacono and Loiacono, 2005). For textbooks, a useful life of 25 years was considered. The permanence of the staff is 30 years according to the Brazilian labor legislation. Data concerning consumables, such as water, electricity and materials (paper, plastic and others), were obtained though documentation of purchases for the period of one year. All purchases were normalized per department to allow comparisons among courses.

Paulista University offers eight engineering courses: Civil, Mechanical, Mechatronics, Production, Electronics, Electrical, Computer and Aeronautics. Data regarding information considers that, on average, the direct time spent by Brazilian college professors with their students consists of 6 classes of 50 min per day, for five days per week. Preparation time, as well as the time for grading papers were not considered, which means that the contribution of teachers˵ work is underestimated.

In 2007, the number of higher education professors was 305,960 (Sinaes, 2007). The emergy per individual was calculated based on the time that a student remains in School. Students stay in the classroom about 5 h per day, and in 2007, the number of graduates was 6,535,898 (INEP, 2007). Calculations of the transformities of Brazilian college professors and graduated high school students are shown in Appendix A.

4. Results

4.1. Energy systems diagrams

The systems diagram of the Campus Indianópolis building is presented in Fig. 1. The spatial boundaries of this study were set to be the territorial boundaries of the Indianópolis campus. The temporal boundaries of the study were set at five years for the Engineering and Pharmacy programmes and four years for the Business programme.

The main components of the system included the building structure, equipment (computers, projectors, teaching equipment for laboratories of physics, chemistry, mechanics, etc.), furniture, library and the staff. All the external sources were placed in a hierarchical order of quality from left to right: sun, equipment, water, electricity, materials, and the university employees (Fig. 1). Water source represents the water used for sanitary purposes, which is partially obtained from the water supply company of the state and partially form an on-campus artesian well? The solar flux corresponded to the incidence of sunlight into the building, which reduced the use of electricity for lighting in classrooms and hallways, and the use of heaters for indoor climate modification. The depreciation of school buildings represents the contribution of the campus infrastructure to the emergy required for the education process. The product of this system is an Engineering school, ready to be used by the students, and the outputs considered are wastewater and solid waste (paper, plastic). Food preparation and food service were outsourced, and were not included in this analysis.

The diagram of the engineering curriculum is shown in Fig. 2 and shows the flows of energy and building materials, and information flows required for the education of an engineer during the five years. This time window was established because it corresponds to the duration of the curriculum of an engineer. Inputs include the emergy from the environment, the campus, and the information transferred by professors, books and other educational materials for the students and the information brought with them the students when they enrolled in the University.

The diagram shows the interactions among the students, infrastructure and the information transferred by professors and books. The outputs of the system are graduates, dropouts, solid waste (paper, plastic) and water. Dropouts were assumed to have an education equivalent to the 1–3-year degree. Dropouts and students were considered as information receptors, so that the emergy required for the information transferred in a given year would be the sum of the annual emergy inputs required to run the Engineering School.

Table 1 shows the emergy environmental accounting of the campus infrastructure implemented, at Paulista University, to provide the Engineering programme. The evaluation provides an overview of all materials involved to run the School, and also allows to visualize view the key components required for the operation and maintenance of the campus. The analysis of Table 1 provides the diagnosis of the actual environmental performance of the campus, and can be used, as a baseline, to establish priorities for future actions for Greening the campus. For example, in the study of Meillaud et al. (2005), the heating system was an important component, and the use of electricity for heating corresponded to 9% of the total emergy. For this reason, the installation of solar panels on the building's facade targeting energy savings was considered. In Brazil, there is no need of heating the campus, and fans are used in every classroom for cooling. However, despite the large number of fans, computers and the use of electricity for lighting, the total electricity usage accounts for 6% of the total emergy. The total emergy of the building is 1.65×10^{18} seJ/year. This value indicates how much material and energy were invested annually for the support of students in the Engineering School at this campus. The construction and maintenance of the campus account for 1.48×10^{18} seJ/year (89%) and use for 1.75×10^{17} seJ/year (11%). The main components of the Brazilian campus are concrete, steel and ceramic tiles (contributing together with 62% to

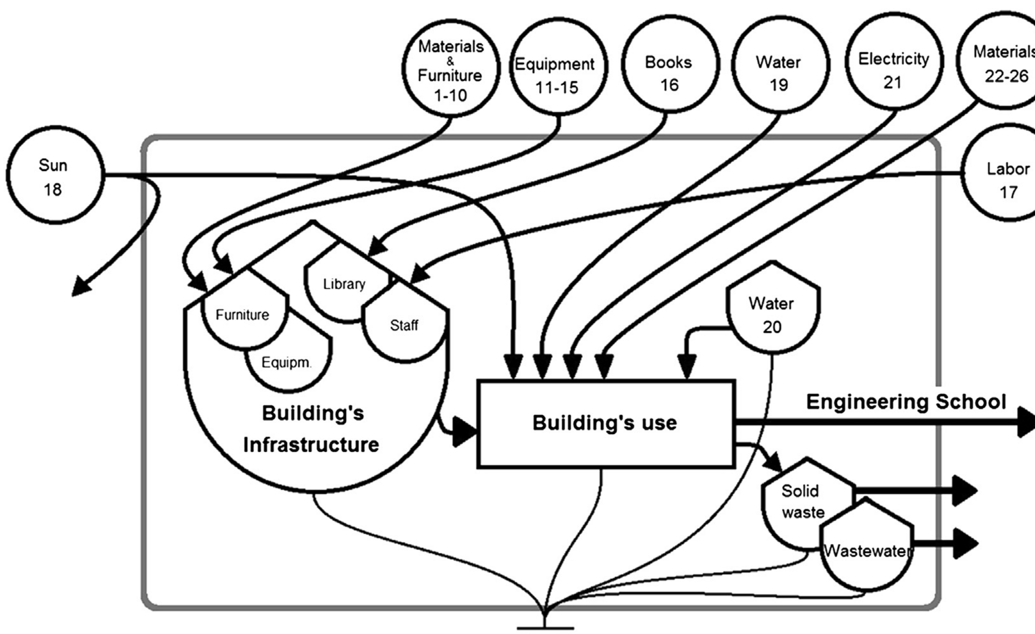

Fig. 1. Energy diagram of the Indianapolis *campus*. The numbers within circles are associated with rows of Table 1. The time period for the evaluation of the campus was one year.

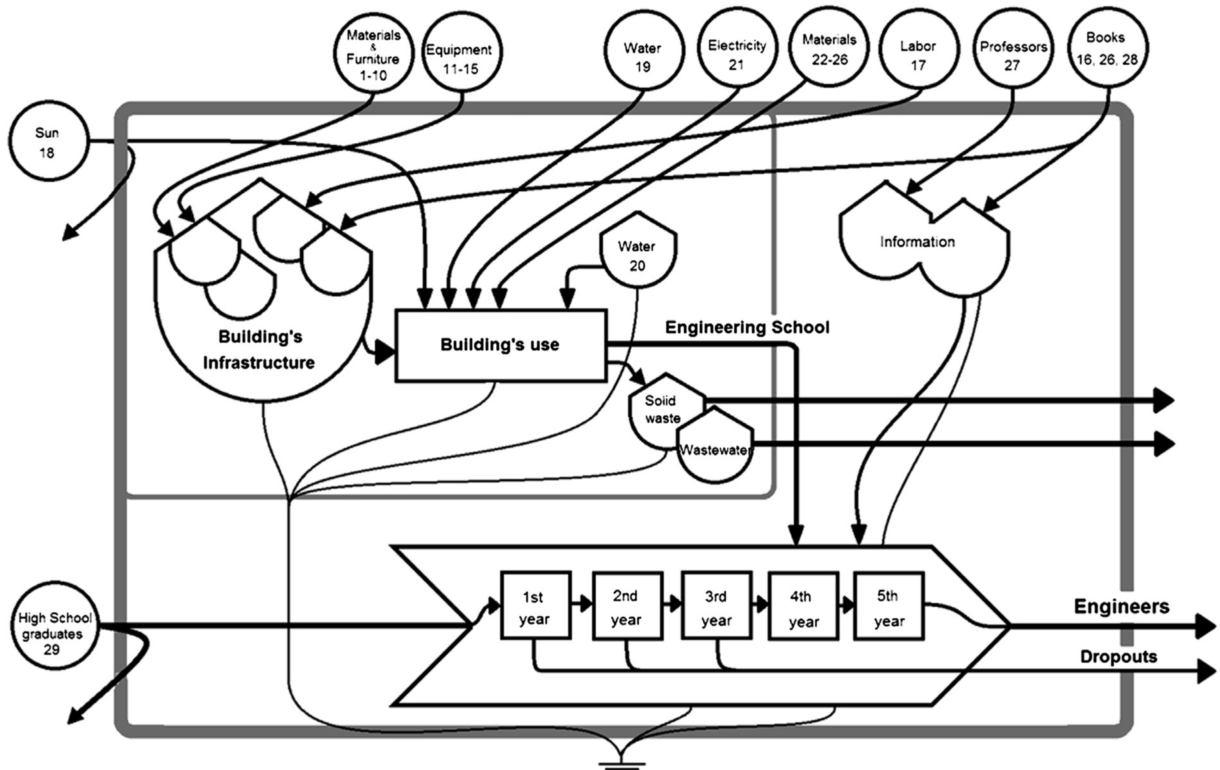

Fig. 2. Energy system diagram of the engineering curriculum at Indianapolis campus. The numbers within circles are associated with rows in Tables 1 and 2.

the total emergy) indicating that need to developing alternative types of facilities in order to reduce the energy needed for campuses' construction and maintenance.

In Table 2, all quantities concerning the infrastructure and use of the campus were multiplied by five to represent the five-year engineering curriculum. The information brought to the university by the high school graduates is the largest contributor to total emergy for engineer training (53%). The second major contribution is the professor's information flow, with 31% of total emergy. The infrastructure for the five year engineering curriculum (Table 1 multiplied by five) contributes 16% seJ/seJ. The emergy of an individual student was calculated as the sum of the emergy per individual for each year of education summed over the time spent at the university. Slow learners and the dropouts (which, despite the fact that they have passed some courses of the engineering programme, may become a sales person or remain unemployed) are also taken into account because they experienced and used the infrastructure and the information supplied by the university during their time on the campus.

Table 3 shows the emergy invested for the three programs evaluated, and the graduates' transformities. Tables and calculations for the Pharmacy and Business Schools are available on Appendix B. The investment and the students' transformities depend on the duration and the number of students that participate in the curriculum during each semester. In comparing the Engineering, Business and Pharmacy curricula, the Business curriculum had the lowest investment, because that curriculum is shorter, and does not offer courses that use laboratories and other complex equipment.

The per student number of professors is also lower in the Business curriculum than that of the Engineering and Pharmacy Schools, because in laboratory classes in Pharmacy and Engineering, students are divided into four classes, which increases the per student number of teachers.

Transformity in seJ/J expresses how much energy, materials and information were invested to obtain 1 J of work of the graduate. The work that will be delivered to support economic and social activities is primarily a function of their knowledge and experience, which is based upon the years of parental support, societal inputs, school or other training, while they accumulate enough knowledge to profitably enter the workforce.

5. Discussion

Data gathered in the inventory emergy tables made it possible for the researchers to calculate the indicators that could be used to compare the results with data published in the literature or with other graduate programs of the Paulista University and other universities.

5.1. Evaluation of emergy flows for greening the campus

Emergy synthesis primarily covers the interaction of the whole system with the biosphere, but is also a valuable tool to assess subsystems. Table 1 shows the emergy investment to implement and use the campus. The construction and maintenance of the campus account for 89% of the emergy use, while the use of the campus including the use of consumables for 11%. This result suggests that any action pursuing the greening of this campus by minimizing consumables would cause a small decrease in the value of the total emergy. However, when the annual use of the building is evaluated in separate, it is possible to simulate and prioritize actions and evaluate their implications.

Considering only the campus operations (Table 1,lines 18–26), it is possible to simulate a condition in which the most common inputs were reduced by fifty percent (Fig. 3). Because the campus was already equipped with self-closing valves in all toilets, the results of

Table 1
Emergy evaluation table of the campus Indianópolis, Paulista University. The time period for the evaluation of the campus was one year.

Item	Description	Unit	Quant./(unit/year)	UEV/(seJ/unit)	Emergy/(seJ)	%/(seJ/seJ)	REF[a]
Infrastructure							
1	Concrete	g	5.64×10^8	1.54×10^9	8.69×10^{17}	52	(a)
2	Steel	g	1.65×10^7	4.15×10^9	6.85×10^{16}	4	(a)
3	Ceramic	g	3.35×10^7	3.06×10^9	1.03×10^{17}	6	(a)
4	Wood	g	8.70×10^5	8.79×10^8	7.64×10^{14}	<1	(a)
5	Iron	g	1.13×10^6	4.15×10^9	4.70×10^{15}	<1	(a)
6	Plastic	g	2.58×10^5	5.75×10^9	1.48×10^{15}	<1	(a)
7	Glass (windows)	g	3.67×10^5	2.16×10^9	7.28×10^{14}	<1	(a)
8	Glass (lamps)	g	3.07×10^4	2.16×10^9	6.62×10^{13}	<1	(a)
9	Granite	g	1.51×10^6	8.40×10^8	1.27×10^{15}	<1	(b)
10	Aluminum	g	3.23×10^5	1.27×10^{10}	4.11×10^{15}	<1	(a)
11	Computer[b]	g	1.61×10^6	2.26×10^{11}	3.63×10^{17}	22	(c)
12	Data show	g	4.34×10^3	1.13×10^{11}	4.90×10^{14}	<1	(c)
13	Projector	g	2.18×10^4	1.13×10^{11}	2.47×10^{15}	<1	(c)
14	Fans	g	6.53×10^4	4.10×10^9	2.68×10^{14}	<1	(d)
15	Glassware (laboratory)	g	1.55×10^4	2.16×10^9	3.34×10^{13}	<1	(a)
16	Paper	J	3.82×10^6	3.45×10^9	1.32×10^{16}	<1	(b)
17	Labor	J	1.09×10^{10}	4.30×10^6	4.67×10^{16}	3	(e)
					1.48×10^{18}		
Use							
18	Sun	J	1.61×10^{11}	1	1.61×10^{11}	<1	By definition
19	Water	m^3	2.13×10^3	7.75×10^{11}	1.65×10^{15}	<1	(f)
20	Water (well)	m^3	7.74×10^3	7.75×10^{11}	6.00×10^{15}	<1	(f)
21	Electricity	J	3.49×10^{11}	2.69×10^5	9.37×10^{16}	6	(b)
22	Paper (plain)	g	5.27×10^6	2.38×10^9	1.25×10^{16}	<1	(g)
23	Paper (toilet)	g	2.08×10^7	2.38×10^9	4.94×10^{16}	3	(g)
24	Plastics (cups)	g	8.86×10^5	5.76×10^9	5.10×10^{15}	<1	(a)
25	Chemicals	g	1.00×10^4	6.38×10^8	6.38×10^{12}	<1	(b)
26	Books	J	1.91×10^6	3.45×10^9	6.59×10^{15}	<1	(b)
					1.75×10^{17}		
	Engineering School				1.65×10^{18}	100	

[a] (a) Brown and Buranakarn, 2003; (b) Odum, 1996; (c) Cohen et al., 2006; (d) Geber and Björklund, 2001; (e) Almeida et al., 2010; (f) Buenfil, 2001; (g) Meillaud et al., 2005. The UEVs prior to 2000 were multiplied by 1.68 corresponding to the biosphere baseline 15.83×10^{24} seJ/year (Odum et al., 2000).
[b] UEV for computers was considered twice as large as the combined UEV of other equipment (projector and data show).

seeking for other ways to reduce water consumption by an additional 50% would only reduce the total emergy investment by less than 2%. A fifty percent reduction of plastic usage would reduce the required emergy by 2%, while the reduction of paper use, would save 13% of the emergy required for the campus operation. The reduction in per-year electricity usage can provide the greatest benefits, 27%. Thus, it is possible to establish environmental standards and priorities for future actions.

The reduction of the quantities of sewage and solid wastes leaving the campus (Figs. 1 and 2) is proportional to the reduction of the usage of water, plastic and paper, respectively. Sewage and solid wastes carry much of the energy that was, directly and indirectly, used to produce the inputs of water and materials used in the campus. For reusing or recycling these materials, more energy will be used (for collection, separation, transport, water treatment, etc). Thus, reducing the resources used at the campus would not only avoid the use of more energy to recover or dispose these wastes, but also would make these resources available for other uses in society. The documentation and reporting of the actions taken to reduce wastes and their consequences using indicators are important in improving the motivation of faculty, students and staff with regard to progressive actions toward more sustainable behavior.

Table 2
Emergy evaluation table of the five-year engineering curriculum at Paulista University.

Item	Description	Unit	Quant./(unit/year)	UEV/(seJ/unit)	Emergy/(seJ)	%/(seJ/seJ)	REF[a]
1–26	Engineering School				8.27×10^{18}		Table 1
Information							
27	Information (Professors)	J	9.55×10^8	1.76×10^{10}	1.68×10^{19}	31	This work
28	Information (Books)	J	3.93×10^6	3.45×10^9	1.35×10^{16}	<1	(a)
29	Information (Students)	J	3.53×10^{10}	8.20×10^8	2.89×10^{19}	53	This work
					4.57×10^{19}		
	Engineering programme				5.40×10^{19}		
Outputs							
	Dropouts 1st year	J	9.60×10^9	3.53×10^9	3.39×10^{19}		
	Dropouts 2nd year	J	8.90×10^9	4.37×10^9	3.89×10^{19}		
	Dropouts 3rd year	J	8.23×10^9	5.33×10^9	4.39×10^{19}		
	Engineers[b]	J	8.57×10^9	6.31×10^9	5.40×10^{19}		

[a] (a) Odum, 1996; The UEVs prior to 2000 were multiplied by 1.68 corresponding to the biosphere baseline 15.83×10^{24} seJ/year (Odum et al., 2000).
[b] Resulting from a 3960 h of disciplines distributed in five years.

Table 3
Annual emergy evaluation table for the Engineering, Pharmacy and Business programmes at the Paulista University and graduates' transformities.

Programme	Years	Emergy/10^{18} (seJ)	Transformity/10^{9} (seJ/J)
Engineering	5	54.0	6.31
Pharmacy	5	42.7	3.65
Business	4	6.4	1.27

5.2. Assessing the investment to produce an engineer and the investment for integrating of sustainable development into curricula

The total emergy of the engineering curriculum was found to be 5.40×10^{19} seJ, which represents the infrastructure, materials, energy and information necessary for the education of one Engineer during the five-year Programme (Fig. 4). The contribution of the information carried by each high school student who enters the university is 53% of the total emergy required to become an engineer. A similar observation was made by Odum (1999a) in a 1978, simplified evaluation of students at the University of Florida. This result highlights the importance of elementary and High School.

Admitting that students' future actions depend on varying levels of education and experience, the emergy required for much of the information accumulated during their education plays a fundamental role in determining the kinds of economic and social activities that they will have during their work-lives. Despite variations in intelligence, dedication to studies, and learning styles, this method makes the plausible argument that all students learn during their time in school, and that the emergy required for a step in learning is proportional to the emergy required to support them during their time in school. The more energy transformations (or the more energy, materials and information that are invested to obtain 1 J of work of the graduates) that contribute to this process, the higher is the students' transformity (Odum, 1996). The transformity of the person who graduated as an engineer from Paulista University is 7.7 times higher than the transformity of the student who graduated from high school (Fig. 5). This increase is associated with the learning programs due to interactions with professors, books, and infrastructure of the buildings provided by the university.

In 2008, Paulista University integrated two courses on sustainable development into the engineering curriculum. The first course was titled, "Development and Sustainability", which introduced concepts related to environmental sustainability, their relations with the productive sector and the influence of energy use in modern societies. By presenting an array of types and perspectives of sustainable development, this course analyzes the ecological and human health impacts of energy consumption and addresses mitigation approaches to reduce those impacts. The second course was titled, "Engineering and Environment", which deals with the relationships, the influences and the impacts of the productive sector on the environment.

It begins with a brief history of the industry–environment interactions, external factors that affect these relationships, reviews projects on environmentally responsible products and processes, and reviews strategies to incorporate concepts of Industrial Ecology and Cleaner Production into productive activities.

The emergy investment to introduce these two courses into the engineering curriculum, including the use of the infrastructure and the information provided, was 5.04×10^{17} seJ/5 years (Table 4), or 0.92% of the total emergy. The emergy increase due to the inclusion of SD courses in the Pharmacy and Business Schools is shown in Table 5, and shows a higher relative increase for the Business School than for Pharmacy or for Engineering, mainly because the Business program is '*leaner*' and the inclusion of new disciplines in the curriculum represents a larger portion of the total emergy of the curriculum.

Although the tools highlighted in the literature review and emergy synthesis cannot measure the effects that such educational curricula will have on particular students' future behaviors and actions, and one can hope that the information, experiences they had before they enrolled in the university, combined with what they learned at the university will contribute in numerous ways, not only to them in their professional careers but also in their lives outside of their work lives. However, such comparative data (Table 5) made it possible to quantify the investment required to provide each student the SD learning opportunities and the

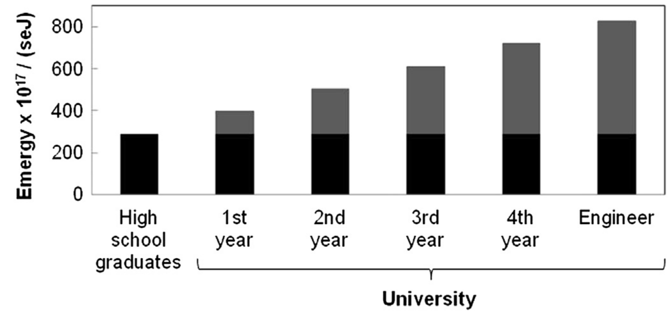

Fig. 4. Increase of the student's emergy along the engineering curriculum as a function of their permanence time at the university. Black: Refers to the emergy relative to the information brought by the high school graduates when they entered the university. Gray: Refers to the emergy acquired at the university.

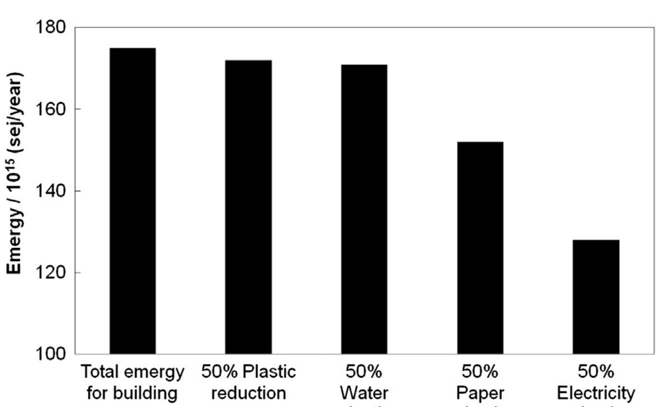

Fig. 3. Simulation of 50% reduction of the most common inputs used by the Indianópolis campus.

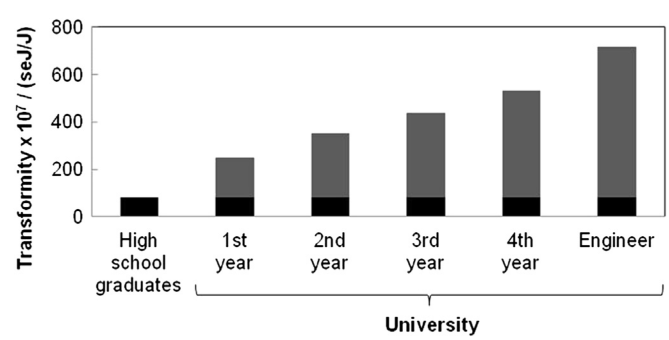

Fig. 5. Increase of the student's transformity along the engineering curriculum as a function of their permanence time at the university. Black: is the transformity relative to the information brought by the high school graduates when they entered the university. Gray: is the transformity acquired by the student at the university.

Table 4
Emergy evaluation table of the engineering curriculum at Paulista University, including courses on sustainable development.

Item	Description	Unit	Quant. (un/5 years)	UEV/(seJ/unit)	Emergy (seJ/5 years)	%/(seJ/seJ)	REF[a]
1–26	Engineering school				8.27×10^{18}		Table 1
Information							
27	Information (Professors)	J	9.55×10^{8}	1.76×10^{10}	1.68×10^{19}	31	This work
27'	SD information	J	$2,87 \times 10^{7}$	1.76×10^{10}	$5,04 \times 10^{17}$	~1	This work
28	Information (Books)	J	3.93×10^{6}	3.45×10^{9}	1.35×10^{16}	<1	(a)
29	Information (Students)	J	3.53×10^{10}	8.20×10^{8}	2.89×10^{19}	53	This work
	Total emergy				5.45×10^{19}		

[a] (a) Odum, 1996.

Table 5
Emergy evaluation table of the Engineering, Pharmacy and Business programmes at Paulista University, including courses for sustainable development.

Programme	Emergy/10^{18} × (seJ/Programme)	Emergy increase/%
Engineering	54.5	0.92
Pharmacy	42.7	1.18
Business	6.0	8.40

relevant information and experiences to catalyze their learning. The results show investment required to supply SD information to the Engineering students (Table 4). It can be used to help to convince senior administrative officials about the needed funding for implementation of environmental courses and related research programmes.

6. Concluding remarks

This research was performed considering that humans' actions are dependent on the accumulation of knowledge and experiences, which require multiple information cycles (Odum, 1996) for development and application in real world contexts. These cycles demand energy and materials to help in the experiential learning processes. Thus, the information that an individual HEI's graduate can contribute should continue to increase throughout her/his career and as a result the emergy of his/her knowledge increases as does the transformity of her/his actions. Worldwide higher educational institutions are places where these processes are expected to occur. Evaluation of their effectivity and efficiency must not only include aspects related to dissemination of the concepts of environmental and societal sustainability, but should also effectively incorporate those concepts and approaches into the student's experiences with minimal environmental impact due to the educational experiences.

Initiatives for greening the campuses based upon implementing EMS are crucial for decreasing the demands for energy and materials needed to run a HEI. Additionally, integrating sustainability into university courses and curricula is essential to help to ensure that the students' future actions will support economic and social activities based upon societal sustainability. The results obtained by means of emergy synthesis allowed us to visualize the entire system (information and resources) and its relationships with the environment, but also to evaluate subsystems in order to assist in decision-making:

The evaluation of the campus to estimate the quantity of energy and materials that are required to develop an Engineering school (Table 1) showed that construction and maintenance of the campus accounted for 89% of the emergy use, while the use of the campus was responsible for 11%.

- These results led this research team to reflect on the current structure of the HEIs, which are designed to engage students in their learning activities, while following strict regulations to ensure their comfort and safety. Brazilian universities, in general, do not require heating systems, which makes their operating costs lower due to heating however, they do have substantial cooling costs, especially in some regions of Brazil. However, it has been documented that building design, orientation, materials used and numerous other facets can be integrated to substantially reduce the operational and maintenance costs.
- The quantification of resources used on the campus and the simulation performed showed the amounts of emergy that can be saved with the adoption of an EMS. These results are important to help academic decision-makers to establish priorities, set goals and provide information and leadership for all faculty, staff and students.
- The emergy-based diagnostic approach used in this research to evaluate the initiatives for incorporating sustainability into university courses and curricula documented that the emergy brought to the process of learning by the high school graduates was half of the total emergy required to earn an engineering degree in five years. This finding highlights the importance of elementary and high school, and also points to a new responsibility for HEIs, which is to provide support to basic education in relation to the use of environmental management and the integration of SD concepts into K-12th grade curricula as well as into all university courses and curricula.
- The emergy investment to introduce two courses into the engineering curriculum was calculated, as well as the investment to introduce similar courses into the Pharmacy and Business curricula. The resultant data can be used to provide information for university decision-makers to help them to plan and support the development and implementation of new courses and curricula, which have integrated SD concepts.

Emergy evaluation has the advantage of including parameters usually evaluated for the greening the campuses along with the information needed to integrate sustainability into courses and curricula and the free contributions of nature. In this sense, this evaluation may be considered more comprehensive than traditional or partial assessments commonly performed. It is possible to evaluate the system as a whole in a systematic manner and to weigh the importance of each of its parts independently and collectively. However, some key questions still remain and academic responses to them may require the help of other fields of knowledge:

- The construction of the campus infrastructure accounts for 89% of the total emergy. **In this context, what should be the role of HEIs in the development of new forms of construction, new materials or new types of facilities for teaching and learning that could reduce the energy needed for their construction, operation and maintenance?**

- The use of the campus accounts for 11% of the annual emergy use. It is possible to prioritize greening actions and to quantify the costs and benefits by measuring the reduction of waste production and resource use. **How can HEIs effectively take advantage of cleaner production concepts, approaches and technologies in their facilities to encourage and educate their students in SD concepts? How can they more effectively measure the effectiveness of these actions in the educational processes?**

When the use of energy and materials to provide information to the students is included in the analysis (Table 2), the energy of information accounts for approximately 85% of the total emergy, and this result highlights the importance of incorporating sustainability into university courses and curricula. The information brought by the students when they entered the university was determined to be 53% of the total emergy. This information comes from their educational experiences that are the result of the combination of three main components: school, family and society. **What should/could HEIs do to integrate SD concepts into these three components and to thereby increase the amount of knowledge that high school graduates bring with them when they enter the university?**

- Professor's information transferred to students contributes 31% of the total emergy. **How could/should HEIs prepare university teachers to introduce SD concepts within their disciplines? What are effective ways to make courses, curricula and other educational information and experiences available for educators and '*educators-of-educators*' as well as for the broader society?**
- **Should HEIs integrate SD concepts, values, and tools only into single courses or into all courses in all curricula?**

It was assumed that the information actively acquired during the students' education plays a fundamental role in determining the kinds of economic and social actions that they will be able to take within the society.

- **How long would it take for the SD concepts to be fully integrated into all professionals' minds and actions? This must be emphasized with regard to the responsibilities of HEI's for systematic efforts on providing '*life-long learning*' experiences for all people who want and need such opportunities.**
- **What are the roles and the responsibilities of graduate programs and research in helping to foster sustainable regional development?**
- **What are the roles and the responsibilities of senior academic decision-makers in fostering the transition of their HEIs into being leaders in fostering sustainable regional development?**

This research was designed to focus upon the use of emergy synthesis as a promising tool for understanding and action in a complex problem, presenting an environmental accounting combining both approaches of greening the campuses with the integration of SD concepts into curricula. The authors do not assert that this method fills in all of the limitations of other methods, but rather that it is or can be a potential step in creating systematic approaches that combine a variety of elements found during the evaluation of HEIs, including human learning, energy and materials management.

By providing new information about the role and the weight of information to catalyze learning opportunities and to contribute to student's future careers, this research showed that HEIs environmental accounting still has much room for improvement and that there are still many questions about the effects and the consequences of these initiatives.

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Appendix A

Table A1
Transformity of professors of higher education in Brazil (2007).

	Unit	Calculation	Value
Energy	J/year	305,960 profs × 120 kcal/h × 4186 J/kcal × 5 h/day × 205 days/year	1.57×10^{14}
Emergy of Brazil[a]	seJ/year		2.77×10^{24}
Transformity	seJ/J	$= 2.77 \times 10^{24}$ J/year/ 1.57×10^{14} J/year	1.76×10^{10}

[a] (Demétrio, 2011).

Table A2
Transformity of High School graduates in Brazil (2007).

	Unit	Calculation	Value
Energy	J/year	6,535,898 stds × 120 kcal/h × 4186 J/kcal × 5 h/day × 205 days/year	3.36×10^{15}
Emergy of Brazil[a]	seJ/year		2.77×10^{24}
Transformity	seJ/J	$= 2.77 \times 10^{24}$ J/year/ 3.36×10^{15} J/year	8.20×10^{8}

[a] (Demétrio, 2011).

Appendix B

Table B1
Emergy evaluation table of the Pharmacy programme, Paulista University.

Item	Description	Unit	Quant./(unit/year)	UEV/(seJ/unit)	Emergy/(seJ)	Ref[a]
Infrastructure						
1	Concrete	g	5.60×10^{8}	1.54×10^{9}	8.63×10^{17}	(a)
2	Steel	g	1.68×10^{7}	4.15×10^{9}	6.97×10^{16}	(a)
3	Ceramic	g	3.35×10^{7}	3.06×10^{9}	1.02×10^{17}	(a)
4	Wood	g	8.44×10^{5}	8.79×10^{8}	1.26×10^{15}	(a)
5	Iron	g	5.33×10^{5}	4.15×10^{9}	2.21×10^{15}	(a)
6	Plastic	g	1.03×10^{5}	5.75×10^{9}	5.92×10^{14}	(a)
7	Glass (windows)	g	2.57×10^{5}	2.16×10^{9}	5.55×10^{14}	(a)
8	Glass (lamps)	g	2.42×10^{4}	2.16×10^{9}	5.24×10^{13}	(a)

(continued on next page)

Table B1 (*continued*)

Item	Description	Unit	Quant./(unit/year)	UEV/(seJ/unit)	Emergy/(seJ)	Ref[a]
9	Granite	g	1.51×10^{6}	8.40×10^{8}	1.27×10^{15}	(b)
10	Aluminum	g	2.70×10^{5}	1.27×10^{10}	3.42×10^{15}	(a)
11	Computer[b]	g	1.40×10^{5}	2.26×10^{11}	3.17×10^{16}	(c)
12	Data show	g	1.55×10^{3}	1.13×10^{11}	1.75×10^{14}	(c)
13	Projector	g	7.80×10^{3}	1.13×10^{11}	8.81×10^{14}	(c)
14	Fans	g	4.34×10^{4}	4.10×10^{9}	1.78×10^{14}	(d)
15	Glassware (laboratory)	g	6.39×10^{5}	2.16×10^{9}	1.38×10^{15}	(a)
16	Books (library)	J	5.75×10^{6}	3.45×10^{9}	2.64×10^{16}	(b)
17	Labor	J	3.92×10^{9}	4.30×10^{6}	1.68×10^{16}	(e)
Use						
18	Sun	J	8.05×10^{11}	1	8.05×10^{11}	By definition
19	Water	m^3	7.65×10^{2}	7.75×10^{11}	5.93×10^{14}	(f)
20	Water (well)	m^3	2.79×10^{3}	7.75×10^{11}	2.16×10^{15}	(f)
21	Electricity	J	1.97×10^{10}	2.69×10^{5}	5.28×10^{15}	(b)
22	Paper (plain)	g	1.90×10^{6}	2.38×10^{9}	4.51×10^{15}	(g)
23	Paper (toilet)	g	6.22×10^{5}	2.38×10^{9}	1.48×10^{15}	(g)
24	Plastics (cups)	g	3.19×10^{5}	5.76×10^{9}	1.83×10^{15}	(a)
25	Chemicals	g	5.00×10^{4}	6.38×10^{8}	3.19×10^{13}	(b)
26	Books	J	7.65×10^{6}	3.45×10^{9}	2.64×10^{16}	(b)
Information						
27	Information (Professors)	J	9.40×10^{7}	1.76×10^{10}	1.65×10^{18}	This work
28	Information (Books)	J	1.23×10^{6}	3.45×10^{9}	4.23×10^{15}	(a)
29	Information (Students)	J	1.71×10^{9}	8.20×10^{8}	1.40×10^{18}	This work
	Pharmacy programme				4.27×10^{18}	

[a] (a) Brown and Buranakarn, 2003; (b) Odum, 1996; (c) Cohen et al., 2006; (d) Geber and Björklund, 2001; (e) Almeida et al., 2010; (f) Buenfil, 2001; (g) Meillaud et al., 2005. The UEVs prior to 2000 were multiplied by 1.68 corresponding to the biosphere baseline 15.83 × 10^{24} seJ/year (Odum et al., 2000).
[b] UEV for computers was considered twice as large as the combined UEV of other equipment (projector and data show).

Table B2
Emergy evaluation table of the Business programme, Paulista University.

Item	Description	Unit	Quant./(unit/year)	UEV/(seJ/unit)	Emergy/(seJ)	REF[a]
Infrastructure						
1	Concrete	g	1.84×10^{8}	1.54×10^{9}	2.83×10^{17}	(a)
2	Steel	g	5.32×10^{7}	4.15×10^{9}	2.21×10^{16}	(a)
3	Ceramic	g	3.70×10^{6}	3.06×10^{9}	1.13×10^{16}	(a)
4	Wood	g	4.79×10^{5}	8.79×10^{8}	4.21×10^{14}	(a)
5	Iron	g	6.30×10^{5}	4.15×10^{9}	2.61×10^{15}	(a)
6	Plastic	g	1.60×10^{5}	5.75×10^{9}	9.21×10^{14}	(a)
7	Glass (windows)	g	2.36×10^{5}	2.16×10^{9}	5.09×10^{14}	(a)
8	Glass (lamps)	g	1.35×10^{4}	2.16×10^{9}	2.92×10^{13}	(a)
9	Granite	g	6.83×10^{5}	8.40×10^{8}	5.74×10^{14}	(b)
10	Aluminum	g	1.55×10^{5}	1.27×10^{10}	1.97×10^{15}	(a)
11	Computer[b]	g	6.84×10^{5}	2.26×10^{11}	1.55×10^{17}	(c)
12	Data show	g	3.02×10^{3}	1.13×10^{11}	3.42×10^{14}	(c)
13	Projector	g	1.47×10^{4}	1.13×10^{11}	1.66×10^{15}	(c)
14	Fans	g	2.74×10^{4}	4.10×10^{9}	1.12×10^{14}	(d)
15	Books (library)	J	5.75×10^{6}	3.45×10^{9}	2.64×10^{16}	(b)
16	Labor	J	3.92×10^{9}	4.30×10^{6}	1.68×10^{16}	(e)
Use						
17	Sun	J	7.16×10^{10}	1	7.16×10^{10}	By definition
18	Water	m^3	1.46×10^{3}	7.75×10^{11}	1.13×10^{15}	(f)
19	Water (well)	m^3	5.31×10^{3}	7.75×10^{11}	4.11×10^{15}	(f)
20	Electricity	J	3.75×10^{10}	2.69×10^{5}	1.01×10^{16}	(b)
21	Paper (plain)	g	3.61×10^{6}	2.38×10^{9}	8.60×10^{15}	(g)
22	Paper (toilet)	g	1.19×10^{5}	2.38×10^{9}	2.82×10^{15}	(g)
23	Plastics (cups)	g	6.07×10^{5}	5.76×10^{9}	3.50×10^{15}	(a)
24	Books	J	4.60×10^{6}	3.45×10^{9}	1.59×10^{16}	(b)
Information						
25	Information (Professors)	J	1.12×10^{8}	1.76×10^{10}	1.97×10^{18}	This work
26	Information (Books)	J	8.10×10^{5}	3.45×10^{9}	2.80×10^{15}	(a)
27	Information (Students)	J	4.66×10^{9}	8.20×10^{8}	3.82×10^{18}	This work
	Business programme				6.37×10^{18}	

[a] (a) Brown and Buranakarn, 2003; (b) Odum, 1996; (c) Cohen et al., 2006; (d) Geber and Björklund, 2001; (e) Almeida et al., 2010; (f) Buenfil, 2001; (g) Meillaud et al., 2005. The UEVs prior to 2000 were multiplied by 1.68 corresponding to the biosphere baseline 15.83 × 10^{24} seJ/year (Odum et al., 2000).
[b] UEV for computers was considered twice as large as the combined UEV of other equipment (projector and data show).

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