The Brazilian Educational System: An Analysis of a Hypothetical Full Shift to Distance Teaching

José Hugo de Oliveira and Cecília Maria Villas Bôas de Almeida

Abstract According to statistics published by governmental agencies, 58 million students are currently enrolled in formal education courses available in the Brazilian educational system as a whole. A time series covering the years 2005–2015 reveals a descending number of enrollments in basic traditional school courses and an ascending amount of students attending distance-teaching courses. Distance Teaching has been hailed as an environmentally friendlier alternative to full-time campus activities, in papers with valid statistical data. However, the authors of this work performed the environmental accounting and compared the use of natural resources needed to implement and operate two similar courses, one under traditional classroom conditions, and its distance-teaching version, using the Emergy Accounting method, which allows for different types of energy to be accounted together by using solar energy Joules as a common unit. The results show that implementing and operating the distance-teaching version required 110% more investment in natural resources than the traditional version. This result motivated the analysis, presented in this paper, of the required investment in resources supporting the entire Brazilian educational system, combined with scenarios resulting from a hypothetical full shift from traditional in-class to distance teaching.

Keywords Distance teaching · Emergy accounting · Brazilian education system

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1 Introduction: The Brazilian Education System, and the Paper Limitations

The relevance of the analysis carried out in this work lies on the fact that distance teaching, as a tool for social inclusion, has shown constant growth as a valid alternative to achieve formal education, and this results from the convenience it brings for both the students and the public and the private institutions that offer courses in this mode. On one hand, as distance-learning activities are mostly carried out by teachers, tutors, and students in places other than in school *campi*, a massive adhesion to the distance-teaching mode would imply less campus use. *Campi* would be relegated to periodic or sporadic classroom activities, thus minimizing the impacts caused, among other factors, by the intensive use of electricity to feed computers to support educational activities. On the other hand, the increasing adhesion to distance teaching simply results in dislocating resource use from school the school environment, rather than mitigating it, as the impacts will show elsewhere. Hence, the use of a method capable of analyzing the use of environmental resources to support systems, including in-class or distance teaching education systems, can provide a wider, extra-financial/profit-seeking/managerial panorama of the pros and cons of adopting either mode, thus allowing for comparisons. Emergy evaluation of educational systems have been carried out by a number of authors. Meillaud et al. (2005) evaluated energy savings from solar panels on the façade of a building at the Swiss Federal Institute of Technology, in Lausanne, by using the emergy accounting method; High School and undergraduate students' contributed flows of information into the system. Campbell and Lu (2014) calculated the emergy basis for the formal education system of the United States, from 1870 to 2011, and concluded that, for every unit of emergy invested in the system, a tenfold return was obtained in benefits by the society, from the emergy of teaching and learning. Almeida et al. (2013) used the emergy method to evaluate the Engineering programme at Universidade Paulista. The results were compared to those obtained for the Pharmacy and Business programmes, and a holistic system view and its relationship with the environment was provided. Subsystems were evaluated to assist in decision making on establishing targets towards campus greening as well as on introducing Sustainable Development concepts into curricula. As far as distance teaching is concerned, Roy et al. (2008) state that distant-learning courses consume 87% less energy, and CO_2 emissions are 85% lower in comparison with full-time campus-based courses, by implying in reduction in energy consumption from student travel and housing, besides saving in campus use. Oliveira et al. (2017) used emergy synthesis to analyze the use of resources required to implement and operate a distance learning course of Technical Management, and compared the results with those obtained for the implementation and operation of an in-class version of the same course. The results showed that the emergy support required to operate the distance learning course with 43 students is 110% higher than the emergy required to operate the in-class course with 34 students. Simulations with higher numbers of students showed that the emergy investment lines of both modes cross at about the 300-students mark, the point from which the distance learning mode becomes more advantageous, in terms of resource use, than in-class learning. This notion implies that, at least from the resource use perspective, and under the emergy accounting, distance teaching is not an immediate solution to minimize resource use, unless a given minimum number of attending students is met.

From the approximately 5 million people currently subscribed to an online course in Brazil, one and a half million are attaining basic school, college or post-graduation levels via distance learning (ABED 2015). The remaining three and a half million are either receiving corporative training or upgrading skills in an informal area of interest in free courses. The number of students attending basic education in traditional schools, on the other hand, has been experimenting a continual decrease process, from about 56 million in 2005 to about 49 million in 2015 (INEP—Basic Education Synopses, 2005–2015). In the meantime, a growing body of literature on campus greening actions reflect the ongoing discussion among academicians who dedicate their efforts to the general awareness of sustainability by the integration of the topic into university curricula, along with sustainability-oriented management of campus operations. However, with the slow shift from old-standard educational systems into new technology-based approaches, a new concern arises and becomes a topic for discussion, and that is the implicit cost, in terms of natural resources, behind this shift process, and its impact on the environment. This work integrates a wider study of the implicit environmental cost behind the Brazilian educational system as a whole and evolves from one of the leading research questions: what would be the resulting impact of a hypothetical full shift to distance teaching on the use of natural resources? To answer that question, simulations were made based upon the results from previously performed environmental accounting of the natural resources supporting the national educational system in both modes. The limitations of this study, therefore, are in the accuracy of the numbers provided by official statistical agencies and the parameters used to establish a pattern for the accounting of the resources required by every school or DTC unit. The environmental accounting performed accounts for the energy and resources, from raw material state to finished goods and services entering the system. Results show the expected decrease in the use of buildings and in the energy required by the physical facilities to operate. However, the vehicle required for the students' access to the virtual learning environment, and the energy to feed it, have more embodied energy than the vehicle and energy required to transport traditional school students.

2 Methodology: Emergy Accounting and the Calculation Phases

In this work, traditional schools and distance teaching activities in the nation were treated as two distinct energy systems. The relevant energy contributions for the systems functionality were included in an inventory. The data used herein is based on official government statistical publications for year 2015, and this study was developed in the second semester of 2017. The sum of the different forms of energy composing a system is obtainable with the use of Emergy Accounting. Emergy is the available energy of one kind, previously used up directly and indirectly to produce a service or good (Odum 1996). Emergy accounting enables for the analysis of the quantitative/qualitative contributions from the environment and from the economy to a production system, from a donor's perspective. Thus, by using joules of solar energy as a common unit, different forms of energy can be accounted for and compared. Emergy per unit time is calculated as per Eq. (1):

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

where UEV is the Unit Emergy Value calculated based on the emergy required to produce one unit (Joule, gram, cubic meter, or dollar) of a given resource. The UEV of a resource or product derives from all the resources and energy flows that were used to produce it. Previous works featuring the emergy accounting of educational systems (see Oliveira et al. 2017; Almeida et al. 2013; Oliveira and Almeida 2015; Meillaud et al. 2005) analyzed single educational units or institutions; their inventories included items such as water, paper, and plastic material consumption, all of which contributing less than 5% of the total system emergy. Such low rates may be deemed irrelevant to emergy accounting. This work integrates a larger research work in progress that features the emergy accounting of the Brazilian educational system as a whole, and those items have been removed from the inventory. The relevant energy forms entering the system were organized in sections referred to as phases, as described below.

3 Phase 1: Infrastructure of Traditional Schools and Distance Teaching Centers

In this phase, concrete, iron and computers are the relevant emergy contributors. The physical dimensions and numbers of computers vary from school to school. To overcome these limitations and obtain an overall estimate for the dimensions and number of computers, the Ministry of Education and Culture (MEC) guidance stated in the document entitled *Parecer CNE/CEB nº8/2010* (see references) was used. This document sets the norms for the application of item IX of article 4 of Law No. 9.394/96, *on the minimum quality patterns for public basic education.* The description of a functional primary school, as per the document, is adopted herein for every school unit, public or private, that composes the total of working units in a given year, as reported by the *Inep—Instituto Nacional de Estudos e Pesquisas Educacionais Anísio Teixeira* (National Institute of Educational Studies and Research Anísio Teixeira) Statistical Synopses. Institutions offering distance-learning courses offer physical facilities for person-to-person support, called distance-teaching centers

(DTCs), where stand-by tutors and computers are available for teacher, staff, and students use. The DTCs maintained by public schools follow specifications ruled by the MEC. The estimated dimensions, personnel and equipment inventory available in a DTC are based on the work of Oliveira et al. (2017). The emergy contribution from constructions and manufactured stock resources is the number of their lifespan years divided by the timeframe set for the analysis. Stock resources are those that persist in time, i.e. they were part of the system before the initial position and remain in the system after the final position. The considered lifespan for buildings in this work is twenty-five years; personal computers lifespan is five years (Receita Federal do Brasil 2005); the timeframe set for this investigation is one school year.

4 Phase 2: Systems Operation

Electricity consumption is an estimate based on the use of computers and lamps in schools and DTCs. The use of workbooks is based the number of students multiplied by the number of disciplines integrating the curricula for a given year. Lifespan of books is twenty years.

5 Phase 3: Access to Information

The amount of energy required for the students to access the educational environment, be it physical or virtual, makes a relevant contribution to the emergy of an educational system. Said access requires a vehicle, and the energy to feed it. Estimates for diesel and electricity consumption are based upon the work of Oliveira et al. (2017), which compares the energy required for the students of both modes to find themselves in the environment where the interaction with teachers, materials and other students takes place. According to the figures published by INEP, 14% of the students, in average, use public transportation. Because of the lack of data on the use of other transportation modalities, all students have been considered to use 16-seat vans to commute to school. Hence, the accounting considers the amount of steel used to build the buses and an estimate on the total use of diesel. In a similar fashion, it was considered here that the distance teaching mode students' access into the virtual learning environment is achieved by means of personal desktop computers, one unit per student. Other types of device used to access internet services were disregarded. Estimates for electricity consumption by the computers were also calculated.

6 Phase 4: Information Flows Within the System

Intellectual work performed by teachers and students in the teaching-learning process is measured by the metabolic energy dispended during work hours. The quality of the energy dispended by the teachers and students is multiplied by the corresponding UEV. The UEV's for a Joule of human work is the result of the national emergy budget for given year divided by the number of inhabitants in a given education and experience level (Odum 1996), i.e. preschool, basic school, college, and post-graduation levels. Information from books and tutors is also accounted for. The accounting of the information flows integrate the total emergy of a system. However, when analyzed separately, it can be seen as a cost-effectiveness indicator, when one considers the interaction between teachers and students in the teaching-learning process as the end purpose of the investment made in infrastructure and operation of educational systems.

Quantitative student-related data for this work comes from reports published by official entities. The numbers relate to accredited formal education courses. The final results of the surveys for the year 2015 were selected for this study. Traditional school census results are published yearly by the *Inep—Instituto Nacional de Estudos e Pesquisas Educacionais Anísio Teixeira* (National Institute of Educational Studies and Research Anísio Teixeira). An issue containing official numbers for higher education in distance teaching mode is also published yearly. The survey on basic school courses in distance teaching mode used herein were published the *Associação Brasileira de Ensino a Distância—ABED* (Brazilian Association of Distance Teaching) reports. The work of teachers and tutors is calculated from the amount of work hours. Among the limitations of this study is the inaccuracy of the numbers published by ABED, which relies on questionnaires sent to, but not answered by all distance learning schools. The numbers published and used in this work are, therefore, a low estimate of the actual scenario.

7 The Hypothetical Full Switch from In-class to Distance Teaching

As the main goal of this work, simulations of resource use in case of a full switch from traditional to distance teaching schools were built, in order to identify the items most likely to cause impact. Moreover, this study aims to analyze the often-neglected environmental cost behind the shift to new trends in general, specifically when involving use of technological novelty resources by using the emergy accounting method, rather than monetary cost. Therefore, comparisons between each one of the phases are provided in separate accounting tables for both modes which favors immediate comparisons and provides information on both positive and negative impacts caused. To obtain the simulated results, the emergy-per-student rate for every item was calculated and then multiplied by the total number of students (DTC students + physical school students). A discussion follows each scenario.

8 Results and Discussion

Data published for the year 2015 was the basis for the emergy accounting of the traditional in-class and distance-teaching formal education systems of Brazil. Table 1 shows the basic numbers in a comparative form.

To base the estimates for infrastructural material inputs, a dimensional and infrastructural standard for the over 180,000 operating traditional-teaching institutions was adopted, based on the directions from the *Parecer CNE/CEB nº8/2010.* The assump-

Table 1 Number of enrollments and operating institutions/DTCs in Brazil in 2015. *Sources* INEP statistical synopses 2015 and ABED distance teaching 2015 yearbook. **a**. Emergy accounting of the inputs required to build and establish the physical facilities of schools in operation in 2015. The UEVs comply with the 15.83 × 10^{25} sej/year baseline. See appendix for UEV references. **b**. Emergy accounting of the inputs required to build and establish the physical facilities of distance teaching centers in operation in 2015. The UEVs comply with the 15.83 × 10^{25} sej/year baseline. See appendix for UEV references

Mode	Enrollments	Number of institutions/DTCs in operation
In-class	56,022,196	186,441
Distance teaching	1,456,348	4,915

a. Building construction—traditional system

Item no	Description	Unit	Qty. 2015	UEV (seJ/unit)	Emergy (seJ/yr)	seJ/student
1	Concrete	g	2.39×10^{13}	2.59×10^{9}	6.19×10^{22}	1.11×10^{15}
2	Steel	g	7.40×10^{11}	6.93×10^{9}	5.13×10^{21}	9.16×10^{13}
3	Computer	g	2.31×10^{10}	8.90×10^{10}	2.05×10^{21}	3.67×10^{13}
	Subtotal				6.91×10^{22}	1.23×10^{15}

b. Building construction—distance teaching system

Item no	Description	Unit	Qty. 2015	UEV (seJ/unit)	Emergy (seJ/yr)	seJ/student	Emergy with migration
1	Concrete	g	7.57×10^{10}	2.59×10^{9}	1.96×10^{20}	1.35×10^{14}	7.73×10^{21}
2	Steel	g	2.39×10^{9}	6.93×10^{9}	1.65×10^{19}	1.14×10^{13}	6.53×10^{20}
3	Computer	g	4.48×10^{8}	8.90×10^{10}	3.99×10^{19}	2.74×10^{13}	1.57×10^{21}
	Subtotal				2.52×10^{20}	1.73×10^{14}	9.96×10^{21}

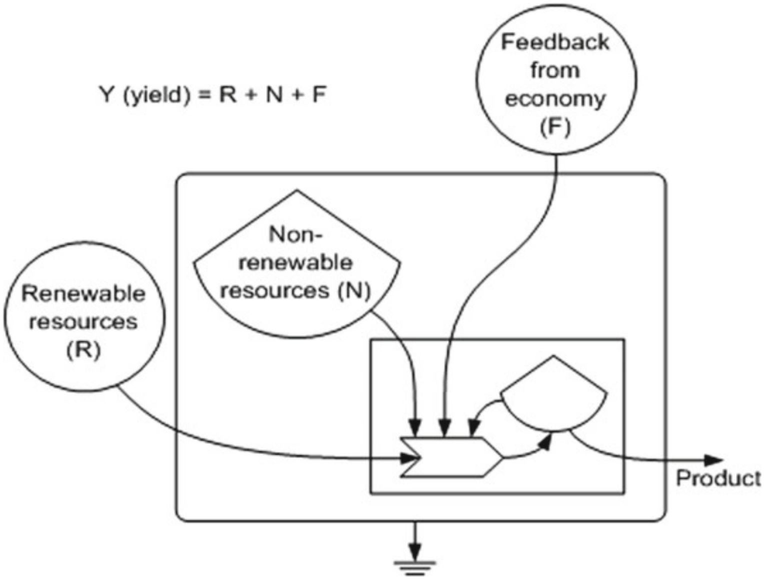

Fig. 1 Energy systems language diagram displaying the positioning of the flows entering the system. Legend: (R) = renewable resources; (N) = non-renewable resources; (F) = feedback from economy; Y (output) is the sum of all flows

tions about the distribution of concrete and steel in interior walls were based upon a two wall-per-room linked to the next room random design, since no official layout for the physical school facilities was provided in the document. The addition of one wall to a number of rooms, nevertheless, does not significantly affect the final emergy figure.

The elaboration of the energy systems language diagram is the first step taken when performing emergy accounting. The diagram provides a general graphic view of the energy flows entering the system, the process of producing a good or service, and the outputs. In this simplified version of the diagram (Fig. 1), only the basic materials and human energy are represented. Money flows from government and private investment have been disregarded, as the aim herein is to analyze the use of natural resources. The general concept of an energy systems language diagram used in emergy accounting, using proper symbols elaborated by Odum (1996) is represented below.

The larger rectangle represents the investigation timeframe; circles indicate the sources and the arrows represent the flows of energy from the sources and the allocation of resources into the system. Renewable sources, i.e. natural renewable resources, are placed on the left side of the diagram; non-renewable resources flow in from the upper-left side of the diagram; resources from the economy, i.e. goods and services that are bought/paid for, are placed on the upper-right, and far right side of the diagram. The smaller rectangle represents the good or service production system under

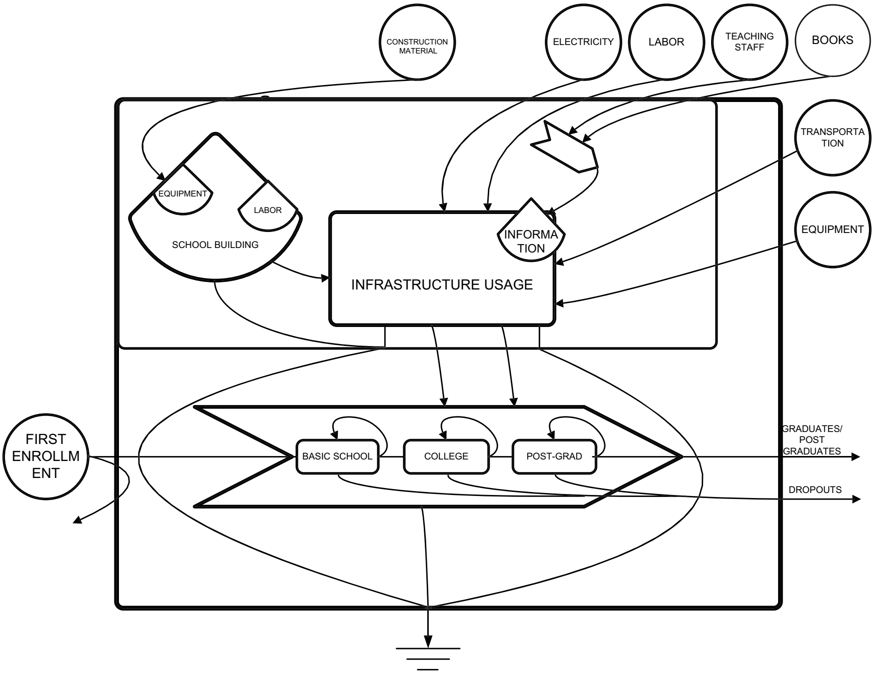

Fig. 2 Energy systems language diagram for the Brazilian educational system. *Source* this work

analysis, as it receives flows of energy both from outside the system and from stocks within the system.

Figure 2 is the energy diagram for the Brazilian educational system. The medium-sized rectangle on the upper half of the system diagram displays the inputs required for implementation and operation of the system. The stock symbols represent resources that persist through time. The smaller rectangle represents the system operation, whereas the large arrow, which is the symbol for interaction, represents the full education cycle by means of interaction with teachers, staff, infrastructure, materials, books, and classmates, while providing the job market with skilled laborers and the society with dropouts.

The following step is the construction of the accounting table, based upon the inventory. The set of Table 1a and b include previous calculations of the total emergy of both modes for the year 2015, with a column added, with the functional unit selected for this work, the sej-per-student-per-year (sej/st/yr). One further additional column was added to the distance teaching tables—emergy with migration—containing the emergy that results from the hypothetical full migration of students from the traditional to the distance-teaching mode.

Table 1a and b refer to the Building Implementation phase. As a standard set for this study, it features the most relevant emergy contributors, i.e. higher than 5% per institution unit, their UEVs and total emergy. Every set of tables comprehends all levels of learning, from kindergarten to post graduation.

In both cases, the largest emergy contribution for the implementation phase comes from concrete. The huge difference in concrete totals between both tables is due not only to the number of distance teaching student being considerably smaller, but also for the fact that the physical dimensions of a Distance Teaching Center (DTC) corresponds to a fraction of those of a traditional school. In case of a hypothetic full migration to the distance-teaching mode, a viable assumption as for the increase in number of DTCs is that it could result from multiplying the current average number of 300 students per DTC by the sum of students from both modes. The estimate presented here, however, results from applying the sej-per-student approach based on the current actual numbers. No significant re-dimensioning of distance teaching centers would be necessary, in case of massive migration, as (1) DTCs are physical support facilities equipped to be used by students only in case of necessity, and (2) the total carriage capacity of a DTC is subjective, and schedule-flexibility is one major DTC feature, even in cases where students are obliged to attend activities locally. In these terms, the migration would cause a switch from commuting to large physical school infrastructures, with total emergy of 6.91×10^{22} sej/year, to occasionally attending activities at reduced DTC structures, with an estimated emergy investment of 9.96×10^{21} sej/year. This means only 15% of the material used to build and implement the currently operating institutions would be required. In the Table 2a and b are the calculation results for the energy forms required to operate the infrastructure.

Table 2 **a**. Emergy accounting of the inputs required by physical schools to operate in 2015. The UEVs comply with the 15.83×10^{25} sej/year baseline. See appendix for UEV references. **b**. Emergy accounting of the inputs required by distance teaching centers to operate in 2015. The UEVs comply with the 15.83×10^{25} sej/year baseline. See appendix for UEV references

a. Building usage—traditional system

Item no	Description	Unit	Qty. 2015	UEV (seJ/unit)	Emergy (seJ/yr)	seJ/student
4	Electricity	J	1.43×10^{16}	2.77×10^{5}	3.96×10^{21}	7.07×10^{13}
5	Workbooks	J	6.01×10^{13}	2.24×10^{7}	1.35×10^{21}	2.40×10^{13}
	Subtotal				5.31×10^{21}	9.47×10^{13}

b. Building usage—distance teaching system

Item no	Description	Unit	Qty. 2015	UEV (seJ/unit)	Emergy (seJ/yr)	seJ/student	Emergy with migration
4	Electricity	J	8.27×10^{13}	2.77×10^{5}	2.29×10^{19}	1.57×10^{13}	9.05×10^{20}
5	Workbooks	J	1.61×10^{12}	2.24×10^{7}	3.60×10^{19}	2.47×10^{13}	1.42×10^{21}
	Subtotal				5.89×10^{19}	4.05×10^{13}	2.33×10^{21}

Table 3 **a**. Emergy accounting of the inputs required by physical school students to access the learning environment. The UEVs comply with the 15.83 × 10^{25} sej/year baseline. See appendix for UEV references. **b**. Emergy accounting of the inputs required by DT students to access the virtual learning environment. The UEVs comply with the 15.83 × 10^{25} sej/year baseline. See appendix for UEV references

a. Access to information—traditional system

Item no	Description	Unit	Qty. 2015	UEV (seJ/unit)	Emergy (seJ/yr)	seJ/student
6	Vehicle[a]	g	1.02×10^{12}	4.15×10^{9}	4.23×10^{21}	2.91×10^{15}
7	Diesel	J	1.12×10^{17}	1.13×10^{5}	1.27×10^{22}	2.26×10^{14}
	Subtotal				1.69×10^{22}	3.13×10^{15}

b. Access to information—distance teaching system

Item no	Description	Unit	Qty. 2015	UEV (seJ/unit)	Emergy (seJ/yr)	seJ/student	Emergy with migration
6	Computer[b]	g	1.66×10^{10}	8.90×10^{10}	1.47×10^{21}	1.01×10^{15}	5.82×10^{22}
7	Electricity	J	3.19×10^{14}	2.77×10^{5}	8.84×10^{19}	6.07×10^{13}	3.49×10^{21}
	Subtotal				1.56×10^{21}	1.07×10^{15}	6.17×10^{22}

[a] Considering 16-seat vans
[b] Considering one desktop computer per student

The resulting emergy required to operate the DTCs, in case of migration, is less than 50% of the emergy currently required to operate the actual physical schools throughout the nation. As in Table 1a and b, only the most significant emergy inputs were considered.. Electricity is featured due to the amount used and its high UEV, resulting in high emergy contribution to the system. Item 5, workbooks, refers to eight units used per student per school year. The considered lifespan for a book was 20 years. The contribution considered, therefore, corresponds to one-twentieth part of its total emergy.

The emergy required for the students to access the learning environment, where their interaction with teachers, materials, infrastructure and classmates occurs, is also calculated. Results are as shown in the Table 3a and b.

The emergy required for the access of one and a half million distance teaching students into the learning environment via computer is virtually the same as the total emergy required for the access of eight million students—14% from the total—into physical school facilities by using public transportation. It is worth noting that in the case of a full migration, the emergy required to access the virtual learning environment would be forty times higher. This results from considering one computer per student, whereas it is feasible to consider one van for every 16 students. The UEV per gram of computer is higher than the UEV per gram of a van. The emergy of all the electricity used to feed all the computers, however, is lower than the emergy of the diesel used by the school buses. These calculations were based upon the work of Oliveira et al. (2017), which considers a 30-km daily itinerary for the access into physical facilities and 2-h/day access into the VLE by DTC students.

Table 4a and b show the flow of information within the system, which results from the interactive work among teachers, students and materials during class time. It can be sensed as a measure of cost-benefit, as all the necessary inputs previously accounted for constitute the infrastructure implemented and operated with the flows of information as an end-purpose

The calculations for information flows are made upon the metabolic energy required to build or maintain the information carriers. The teacher-to-student information rate at 1% refers to students' capacity to absorb written information, as recommended by Odum (1999), albeit Campbell and Lu (2014) do consider 10% as a reasonable rate. The results show that the sej/student emergy rate for the information flows was higher for the distance-teaching students than for the traditional systems students, in function of the absence of teachers with a high-school level working in distance-teaching, and the higher volume of teacher work in higher education. With the full migration scenario, the total flow of information would increase by 160%.

9 Conclusions

1. The analysis unveils an interesting panorama about the use of the natural resources required to implement and operate the national educational system. The current local discussions about sustainability in universities may benefit from the notion that, apart from the immediate actions towards greening existing *campi*, the implicit cost of implementing these educational systems can, by using robust methods, be analyzed and taken into consideration when implementing a new unit, regardless of its operation mode—in-class, or distance teaching.
2. The calculation procedures taken herein can be adapted and used to analyze any education system. The results are highly influenced by the basic configuration of the infrastructures for both in-class and distance learning courses.
3. In conclusion, the results put the common-sense perception of the distance-teaching mode as an overall cleaner and immediate alternative to traditional "brick-and-mortar" schools into perspective, by considering the environmental cost behind the students' access to formative information and interaction, as shown on Table 3a and b. A contextualized analysis including a comparison between the CO_{2equiv} emissions from mechanical student transportation and electricity production to feed the distance teaching system is encouraged.

Table 4 **a** Emergy accounting of the emergy flows in the traditional school system. The UEVs comply with the 15.83 × 10^{25} sej/year baseline. See appendix for UEV references. Information refers to the emergy required to maintain the teaching staff. Item 8 refers to information from teachers with high school formation; item 9 refers to teachers with college formation; item 9 refers to post-graduated teachers; item 13 refers to basic school students' previous information load; item 14 refers to college students' previous information load; item 15 refers to post-graduation program students previous information load. **b** Emergy accounting of the emergy flows in the distance teaching system. The UEVs comply with the 15.83 × 10^{25} sej/year baseline. See appendix for UEV references. Information refers to the emergy required to maintain the teaching staff. Item 9 refers to teachers with college formation; item 9 refers to post-graduated teachers; item 13 refers to basic school students' previous information load; item 14 refers to college students' previous information load; item 15 refers to post-graduation program students previous information load

a. Information flows—traditional system

Item no	Description	Unit	Qty. 2015	UEV (seJ/unit)	Emergy (seJ/yr)	seJ/student
8	Info. teacher (1) → student (1%)	J	4.38×10^{12}	4.44×10^{7}	1.95×10^{20}	3.47×10^{12}
9	Info. teacher (2) → student (1%)	J	4.41×10^{12}	1.34×10^{8}	5.91×10^{20}	1.05×10^{13}
11	Info. teacher (3) → student (1%)	J	5.15×10^{11}	2.87×10^{9}	1.48×10^{21}	2.64×10^{13}
12	Info. books → students (10%)	J	6.98×10^{11}	$2. \times 10^{7}$	1.56×10^{19}	$2. \times 10^{11}$
13	Info. from students (1) (10%)	J	1.92×10^{15}	1.57×10^{7}	3.01×10^{22}	5.38×10^{14}
14	Info. from students (2) (10%)	J	2.67×10^{14}	4.44×10^{7}	1.19×10^{22}	2.12×10^{14}
15	Info. from students (3) (10%)	J	7.44×10^{12}	1.34×10^{8}	9.97×10^{20}	1.78×10^{13}
	Subtotal				4.53×10^{22}	8.08×10^{14}

b. Information flows—distance teaching system

Item no	Description	Unit	Qty. 2015	UEV (seJ/unit)	Emergy (seJ/yr)	seJ/student	Emergy with migration
9	Info. teacher (2) → student (1%)	J	7.00×10^{9}	1.34×10^{8}	9.38×10^{17}	6.44×10^{11}	3.70×10^{19}

(continued)

Table 4 (continued)

b. Information flows—distance teaching system							
11	Info. teacher (3) → student (1%)	J	5.16×10^{9}	2.87×10^{9}	1.48×10^{19}	1.02×10^{13}	5.84×10^{20}
12	Info. books → student (10%)	J	2.22×10^{8}	2.24×10^{7}	4.97×10^{15}	3.41×10^{9}	1.96×10^{17}
13	Info. from students (1) (10%)	J	4.60×10^{12}	1.57×10^{7}	7.22×10^{19}	4.96×10^{13}	2.85×10^{21}
14	Info. from students (2) (10%)	J	4.88×10^{13}	4.44×10^{7}	2.17×10^{21}	1.49×10^{15}	8.55×10^{22}
15	Info. from students (3) (10%)	J	5.13×10^{12}	1.34×10^{8}	6.88×10^{20}	4.72×10^{14}	2.71×10^{22}
	Subtotal				2.94×10^{21}	2.02×10^{15}	1.16×10^{23}

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