

Emergy Accounting of the Distance Teaching Version of a Technical Course on Management by IFSULDEMINAS: A Case Study

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ABSTRACT

This paper presents the use of Emergy Synthesis to assess the environmental investment in the distance teaching version of a two-year secondary level course on Management at the Federal Institute of Education, Science and Technology of the South of Minas Gerais state- IFSULDEMINAS- campus in Inconfidentes, MG, Brazil. The study includes the environmental accounting of the construction and usage phases of the Distance Teaching Center (DTC) facilities and equipment, the students' equipment as means to accessing information, and the flows of energy and information within the system. Additionally, a preview of the CO₂ emissions resulting from the operation of the DTC and the students' home computers is included. Computers, books, and concrete make the largest contributions to the emergy of the system, at 9.61×10^{16} sej/2 years, 7.64×10^{16} sej/2 years, and 5.24×10^{16} sej/2 years, respectively.

INTRODUCTION

Distance teaching activities in Brazil date back to the early 1900's, with handwritten material delivered at the student's door by a courier. Radio became a popular medium in the mid-1930's, widening popular adhesion to second-generation distance teaching, long before TV broadcasts began working in the 1970's as a vehicle for elementary and high school education directed at people who could not obtain formal education otherwise. Although the earlier and later distance education generations still co-exist, the earlier ones deliver information to more restricted groups, the computer-based fourth generation predominates today, mainly due to the convenience of the students' ability to deliberate upon their daily study schedule, since once posted, the contents will be available in the virtual learning environment any time within a given term. Thus, aiming at the formation of skilled secondary (high-school) level technicians for the growing labor market, the SETEC (Secretary Office for Technological Teaching) department of the Ministry of Education and Culture of Brazil has strongly invested in the offer of vocational courses especially aimed at students who already hold a high-school certificate, but either cannot afford private schooling or to whom it is difficult or impossible to physically access their intended courses of specialization. Along with the expansion of the federal integrated secondary/technical public education chain - the Federal Institutes of Education, Science and Technology (FI's) - distance teaching has been one of the most convenient and sought after options in promoting citizens' inclusion in the public education system, due to the large variety of courses offered in the modality. The Technical Course of Management, offered by the Distance Teaching Department of the Inconfidentes-MG campus of the Federal Institute of Education, Science and Technology in the south of the state of Minas Gerais (IFSULDEMINAS) under study in this work, is one of many such courses.

LITERATURE REVIEW

Emergy accounting has been used in assessments of buildings and educational systems. Meillaud et al. (2005) used emergy synthesis to assess energy savings obtained from the use of solar energy in the LESO building and the information transmitted to the students at the Swiss Federal Institute of Technology in Lausanne. In that system the inflow of information, represented by the flow due to the undergraduates, graduates and college students account for, approximately, 95% of the required emergy. The emergy representing the knowledge acquired by the graduates by means of interaction with their teachers and classmates was three times higher than that which they had brought into the system from high school. Pulselli et al., (2007) used Emergy Synthesis to explore the construction, maintenance and use phases of a building in Italy. For the construction phase, 50 years was considered as the lifespan of materials, and the emergy in this phase represents 49% of the total emergy, whereas in the maintenance phase the necessary inputs for avoiding depreciation of the built stock were calculated and accounted for 35% of the total emergy. Water, natural gas and electricity consumption subsidized the analysis of the usage phase and the emergy in this case is 15% of the total. Campbell and Lu (2014), used emergy accounting to assess the United States education system from the year of 1870 to 2011. The system was divided into three subsystems: elementary and secondary school, and college. Inputs were determined for every year. The emergy of teaching and learning was quantified as the sum of the emergy gained while information was being transmitted and the emergy brought by the students into the teaching-learning process. Almeida et al. (2013) used emergy synthesis to evaluate the engineering, management and pharmacy schools at Universidade Paulista, in Brazil. Inputs for the implementation and use of the buildings and information flows were calculated. Practice sessions (classes) represented 59% of the emergy received by the students of the engineering unit and 31% of the emergy received by the students of the pharmacy unit during their respective courses. At graduation, the students' transformities had increased 8.7, 4.5, and 1.9 times, as compared to that of a high-school graduate. Campbell et al. (2012) state that the stored emergy of education and experience is delivered to support the economy and society through the work of people in the various occupations. Data on U.S. occupations on the basis of the individual occupations and the occupations aggregated by Standard Occupational Classification Code (SOC) and Job Zone were analyzed and the emergy contributed to the economy of the United States in the work done by the workers of 558 occupations in 2008 was then calculated. The equivalent of the management technician formed at the DTC on that list is most likely the "Bookkeeping, accounting clerks", a Job Zone Three occupation, which contributes $1.390E+18$ sej/ind./yr to the U.S. economy.

This paper presents the use of Emergy Synthesis in the calculations of the environmental budget for a two-year term distance teaching version of a secondary level course of Management at the Federal Institute of Education, Science and Technology of the South of Minas Gerais - IFSULDEMINAS-campus in Inconfidentes, MG, Brazil. The study comprises the environmental accounting of the Distance Teaching Center facilities setup and usage phases, including the students' own home computers, which are key pieces in the information transmission process, as well as the flow of information within the system. Additionally, a preliminary estimate of CO₂ emissions resulting from the operation is included.

METHODOLOGY

Data collection on the physical infrastructure was carried out in loco. The Distance Teaching Center (DTC) layout follows SETEC-standardized specifications. The Inconfidentes Campus unit uses four of the rooms in a larger building shared between the Distance Teaching Department and another institutional office. The DTC facilities occupy a 133.29 square meter area. The analysis timeframe was set to two years, which corresponds to the duration of the course. Construction materials lifespan was considered as 25 years. The considered number of working hours by each one of the teachers is the total curricular hours divided by the number of teachers (19 curricular subjects - one subject per teacher). The result is the average number of hours spent by each one in elaborating, organizing, posting contents in

the Virtual Learning Environment (VLE), checking and grading exercises and tests. Online-tutors have a four hours a day/five days a week work contract. Since the building is shared with another department, water and electricity spent by both parts are charged for in the same bills. Thus, the electricity consumption figures used in this work are based on the average time of daily use of the 25 computers and one webserver (accounted for as a computer unit) in the DTC computer room, plus the average time spent by the 43 students logged into the VLE multiplied by the assumed power of all of the 69 computers in the system. Drinking and cleaning water consumption was divided by the number of people who work in both departments sharing the building and multiplied by the number of workers in the DTC, disregarding the insignificant amount consumed by occasional visitors. In this study, the emergy of the access into the VLE has been calculated, as the results are soon to be included in a broader comparative work of a similar course given in a regular (physical) classroom environment that includes the emergy of the access to the physical facilities, via public transportation. The emergy of the information flows was calculated following Odum's (1996) approach.

RESULTS

The total emergy of the system is 3.26×10^{17} sej/2 years. A more detailed view of the accounting results is featured in the division in sub-items, given below.

The Emergy of the Infrastructure

The energy diagram of the Distance Teaching Center, shown in Figure 1 represents the spatial boundaries of the system under study. The timeframe was set to two years, corresponding to the duration of the course, which is divided into 4 semester modules. Solar incidence considered refers to the amount covering the area of the building where the DTC facilities are settled, helping to reduce the cost of lighting and, to a lesser extent, heating inside. Water is used for sanitation and drinking. The depreciation of infrastructure components represents their contribution to the formation of managers, thus, two years-worth of the lifespan of inputs such as the building, library books, furniture, and equipment were accounted for. Twenty-six computers are set up and working in the DTC at the disposal of teachers, tutors, and occasional students, who wish to have a session working the week's posted contents under the standby-tutor's guidance for clarification or are by any chance facing technical problems with their own home computers or connection to the internet.

Inputs to the physical infrastructure construction and usage by staff and students are listed and accounted for in Table 1. As expected, the largest contributions to the infrastructure emergy come from concrete, computers, and labor. The system's high dependence on computers and the internet explains electricity consumption as the highest emergy value, in the usage phase. The total infrastructure building and usage emergy is 2.03×10^{17} sej / 2 years.

Most of the UEV's used in this study were taken from the literature; some UEV's were recalculated to comply with the 15.83×10^{24} sej/year baseline.

The Emergy of the Access to Information

The formation of managers results from the interaction between the students and the infrastructure via the information transmission system, which comprises a stock of digitalized information supplied by the teachers, tutors and books specifically produced for the course – the books are available both in digital form in the VLE and in printed form, which the students are given, free of charge. One dedicated webserver hosts all VLE material and activities. The students' own computers, as well as the units in the DTC computer room integrate the information transmission and interaction system via the internet, and all are assumed to have the same specifications.

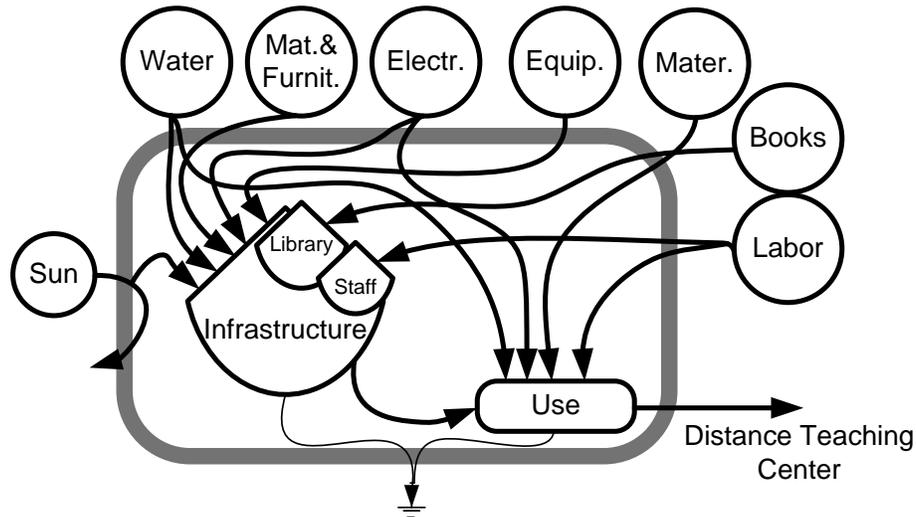


Figure 1. Energy Systems Language diagram of the setup and usage phases of the Distance Teaching Center building at IFSULDEMINAS, Inconfidentes-MG, Brazil.

Table 1. Accounting of the energy inputs to the construction and usage phases of the DTC building.

Item	Description	Unit/yr	Quantity	UEV (sej/unit)	Energy (sej)	%	Ref.
Building construction							
1	Concrete	g	2.03E+07	2.58E+09	5.24E+16	44.38%	a
2	Steel	g	6.30E+05	6.93E+09	4.37E+15	3.70%	a
3	Wood	g	4.73E+04	1.48E+09	7.00E+13	<1	a
4	Plastic	g	4.54E+03	9.83E+09	4.46E+13	<1	a
5	Iron	g	6.85E+04	4.15E+09	2.84E+14	<1	a
6	Ceramics	g	3.77E+05	3.06E+09	1.15E+15	0.98%	a
7	Glass (windows)	g	4.64E+03	3.63E+09	1.68E+13	<1	a
8	Glass (lamp bulbs)	g	2.40E+02	3.63E+09	8.71E+11	<1	a
9	Labor	J	3.01E+09	4.30E+06	1.29E+16	10.97%	b
10	Computer	g	2.89E+04	1.60E+12	4.63E+16	39.25%	c
11	Fan	g	2.88E+03	4.10E+09	1.18E+13	<1	d
12	Book (library stock)	J	1.23E+05	3.45E+09	4.24E+14	<1	h
Subtotal					1.18E+17	100.00%	
Building Usage							
13	Sun	J	5.25E+09	1	5.25E+09	<1	
14	Water (from well)	m3	2.10E+02	7.75E+11	1.63E+14	<1	f
15	Electricity	J	2.86E+10	2.77E+05	7.92E+15	9.37%	e
16	Paper (office)	g	2.80E+03	2.38E+09	6.66E+12	<1	g
17	Paper (towel and toilette)	g	2.70E+03	2.38E+09	6.43E+12	<1	g
18	Plastic (cups)	g	3.70E+03	5.76E+09	2.13E+13	<1	a
19	Workbooks	J	2.96E+09	2.58E+07	7.64E+16	90.39%	h
Subtotal					8.45E+16	100.00%	

References: a-Buranakarn, 1998; b- Coelho et al., 2002; c- Di Salvo and Agostinho, 2014; d-Geber: Björklund, 2001; e- Odum, 1996; f-Buenfil, 2001; g-Meillaud et al., 2005; h- this work

Figure 2 is the Energy Systems Language diagram of the Technical Level Course of Management. It illustrates the energy, materials, and information flows required during the two-year interim, to form a management technician. Environment, the building, and the professors' and tutors' energy, as well as the energy of the necessary equipment to build, manage and transmit information are among the inputs. Shown in the diagram are the students' interactions with the infrastructure and the information received from the information stock containing digital inputs from professors and tutors in the form of digitalized books and text pages, pictures and links to films.

In order to draw a parallel with the inputs necessary for the students' access to a physical classroom where a similar course is taught, the access to the VLE is considered. In analogy, the virtual system counterparts for the bus, diesel oil and bus driver work are, respectively, the home and/or DTC computers, electricity, and the work done by the VLE supervisor, whose assignments include website management and web-designing, among others. Table 2 shows the inputs required to allow for students' access into the VLE. Electricity feeds both the web-server hosting the data and the computers used by the students, who spend, on average, 1.96 hours a day logged in the VLE. (Oliveira and Almeida, 2013). Over 78% of the total energy required to access information comes from the computers.

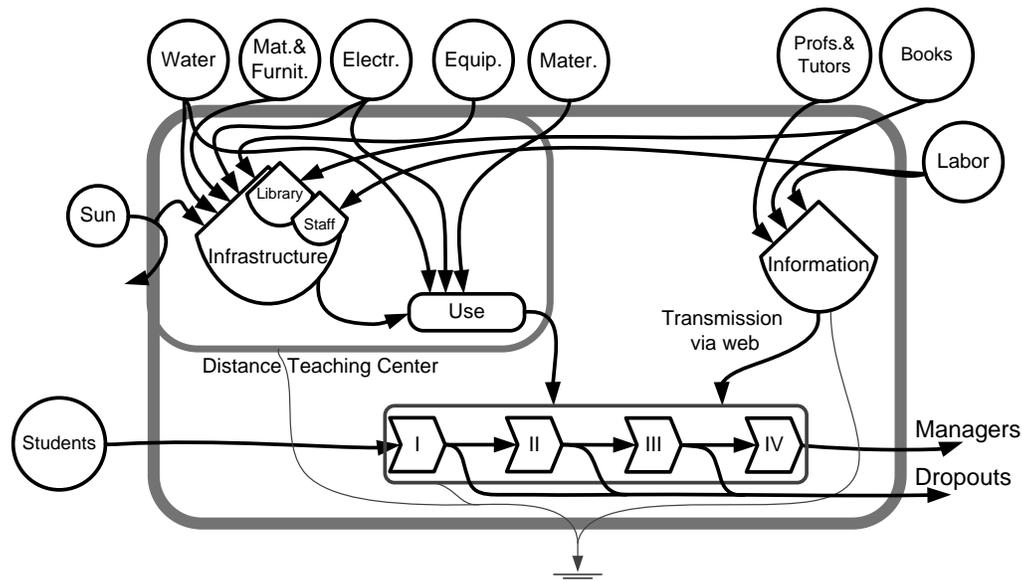


Figure 2. Energy Systems Language diagram of the Distance Teaching Center at IFSULDEMINAS, Inconfidentes-MG, Brazil. Numbers in the inflow circles refer to the input items on Tables 1 and 2.

Table 2. Access to the Virtual Learning Environment. Emergy in sej / 2 years.

Item	Descripton	Unit/yr	Quantity	UEV (sej/unit)	Emergy (sej)	%	Ref.
<u>Access to information</u>							
20	Computer (students')	g	3.11E+04	1.60E+12	4.98E+16	78.49%	c
21	Electricity	J	4.61E+10	2.77E+05	1.28E+16	20.15%	e
22	Labor (VLE supervisor)	J	2.01E+08	4.30E+06	8.64E+14	1.36%	i
Subtotal					6.34E+16	100.00%	

References: a-Buranakarn, 1998; b- Coelho et al., 2002; c- Di Salvo and Agostinho, 2014; d-Geber: Björklund, 2001; e- Odum, 1996; f-Buenfil, 2001; g-Meillaud et al., 2005; h - this work

Most of the UEV's used in this study were taken from the literature; some UEV's were recalculated to comply with the 15.83×10^{24} sej/year baseline.

The Emergy of Information

Staff in charge of handling information in SETEC-standard distance teaching courses include teachers, who elaborate and post material into the VLE, and two online tutors and one standby tutor per group of 50 students. The tutors' activities are an extension of the teachers' conducting work, as they are in charge of exploiting and reinforcing the contents posted by the teacher via chat sessions, quizzes and exercises. Each online tutor is assigned 25 students at most, while the standby tutor's person-to-person assistance can be required by any of the 50 students, under appointment. Text files, slide presentations and links to external material, such as films, blogs, etc., are prepared by the teacher, stocked into the platform, and then automatically released, at a pre-established day and time, for students to access. A new weekly round of interactive activities among all the actors involved thus begins. Specific text material is also previously sent to the tutors, along with instructions and recommendations. The tutors, both online and stand-by, are available four hours a day, five days a week. Technical/vocational courses offered by governmental institutions envisage formation and supplying of skilled workers to the labor market; therefore, a training stage is mandatory before a student can obtain his/her certificate. A supervisor is in charge of providing guidance to the students during their training stage and checking the reports on their performance sent from the companies where they have been admitted as trainees. Such reports are the basis for performance assessment and grading, by the supervisor. The rate of absorption of the information by the students from books considered here is 10%. Table 3 shows the information flows within the system.

The Total Emergy of the Distance Teaching Version of a Technical Course of Management by IFSULDEMINAS

The sum of the emergy flows supporting the distance teaching course is shown on **Table 4**, which also considers that students who leave the course before completion also benefit from the emergy of the system while they were still attending. By the time they quit, an increase in knowledge and, therefore, in their emergy will have occurred, and that is proportional to the length of time they remain within the system. Figures below refer to the emergy accumulated by dropouts who remain until the end of the module, before declining to continue in the following module.

Table 3. Information flows. Emergy is sej / 2 years.

Item	Descripton	Unit/yr	Quantity	UEV (sej/unit)	Emergy (sej)	%	Ref.
Information (Odum)							
23	Information Teacher --> Student (1%)	J	1.49E+07	7.30E+07	1.09E+15	1.81%	i
24	Information Tutor --> Student (1%)	J	3.01E+07	7.30E+07	2.20E+15	3.67%	i
25	Information from Trainee supervisor	J	1.00E+07	7.30E+07	7.30E+14	1.22%	i
26	Information books --> students (10%)	J	2.96E+08	2.58E+07	7.64E+15	12.75%	h
27	Information brought in by students	J	1.75E+09	2.76E+07	4.83E+16	80.55%	i
Subtotal					5.99E+16	100.00%	

References: a-Buranakarn, 1998; b- Coelho et al., 2002; c- Di Salvo and Agostinho, 2014; d-Geber: Björklund, 2001; e- Odum, 1996; f-Buenfil, 2001; g-Meillaud et al., 2005; h - this work

Most of the UEV's used in this study were taken from the literature; some UEV's were recalculated to comply with the 15.83×10^{24} sej/year baseline.

* Odum (1996) states that the emergy of information is equal to the emergy of the information carriers. The basic academic level requirement for a career as a secondary school teacher or tutor is a college degree. Thus, the UEV for the teaching staff was calculated by dividing the emergy of Brazil (Demétrio, 2010) by the annual metabolic energy consumption of all Brazilians holding a college degree. (INEP, 2010).

** According to Meillaud et al., 2005.

Table 4. Summary of emergy invested in the course of Technical Management and the emergy received by dropout students. Modules last one semester each.

	Emergy	%
Construction and usage of the DTC building	2.03 E+17 sej/2 yrs	62.2
Access to the Virtual Learning Environment	6.34 E+16 sej/2 yrs	19.4
Information flows	5.99 E+16 sej/2 yrs	18.4
Total Emergy	3.26 E+17sej/2 yrs	
Dropouts		
at end of Module I (6 months)	8.16 E+16 sej	
at end of Module II (1 year)	1.63 E+ 17 sej	
at end of Module III (1 year and 6 months)	2.45 E+17 sej	

CO₂ Emissions from the Generation of the Electricity Used in the System

The figures for total electricity consumption provide the basis for calculating the CO₂ emissions by the system. Table 5 shows the total emissions of CO₂ resulting from the generation of the electricity required by the Distance Teaching system, and the CO₂ emission rate per student. With over 45% of its energy coming from renewable sources, the Brazilian energy matrix is among the cleanest in the world. One major benefit is reduced particulate emissions from the use of energy.

The International Energy Agency (IEA) published results from calculations of CO₂ emissions worldwide at <https://www.iea.org/media/statistics/CO2Highlights2012.XLS>; Brazil is featured on the 2012 edition with an 81g/kWh average emission rate from 2008 to 2010. That figure enabled the calculation of a preview of the expected CO₂ emission/student resulting from the generation of the electricity to be consumed by the computers and electric equipment at the DTC, and the students' own computers.

The figures above were calculated to enable a direct comparison with the CO₂ emissions caused by the generation of all the energy required to support the physical classroom version of the technical course on Management. Students' computers are an indispensable part of the information transmission system, completing the process of accessing and staying in the learning environment to receive information, hence their inclusion herein. The analogous situation currently under analysis considers the use of electricity in the facilities where the course is given and the burning of diesel oil by the bus used for daily transportation of students to and from the learning environment. *Oliveira and Almeida (2013)* had previously addressed that topic by calculating the amount of CO₂ emitted by the Distance Teaching system throughout the month of September of 2012.

Table 5. Total CO₂ emission and CO₂ emission per student from the generation of the electricity used in the system, considering 81g/kWh, 43 students, and 500 days in 2 years.

Equipment description	Average power (W)	Average daily activity (h/day)	Consumption (kWh)	CO ₂ emission (kg)
26 DTC Computers	200	1	2,600	
43 Students' Home Computers	200	2	8,600	
Other electric equipment (lamp-bulbs, fans, TV set)	40	4	2,400	
Total consumption			13,600	
Total emissions				1,102
Emissions per student				26

DISCUSSION

The motivation for this work lies in the questioning as to whether or not the governmental efforts to promote social inclusion by means of formal education via distance teaching are justifiable, from an environmental point of view, as compared to the huge investments made lately on the expansion and improvement of the physical infrastructure and staff of federal technical/technological schools and universities, a large group to which IFSULDEMINAS belongs. The ever-growing search for vocational courses via distance teaching may be perceived as an indicator of their efficacy in forming skilled workers for the labor market. Furthermore, the accounting performed in this work should have its significance clarified when eventually compared with the accounting of a similar education course given in a physical environment. This work, therefore, aimed at evaluating the distance-teaching version of the Technical Course of Management at IFSULDEMINAS, i.e. its materials, energy and information inflows by means of emergy accounting. The output is skilled and trained Management Technicians for the labor market.

As opposed to other methodologies such as the Exergy method, by means of which services, information or the environment cannot be accounted for, or LCA (Life Cycle Assessment), which focuses on the quantification of impacts and emissions, Emergy Accounting is the appropriate methodology to be applied in this case, as it can handle the environment, information and service flows as well.

Results obtained here can be compared to those of other works involving emergy accounting of educational institutions.

The transformities for the information flows from teachers, tutors and students were specifically calculated in this work following Odum, 1996-p.232. The calculation procedures for the transformity of the information from books used in table 4 was based upon the approach developed by Campbell and Cai (2007), which includes the energy of information delivered by the author. As a result, the information flows total amounts to 18.36% of the total system emergy. This is a significantly lower contribution rate to the total emergy of an educational system as compared to the 94.6% figure obtained by Meillaud (2003) when assessing the LESO building in Lausanne, or the results in the work of Almeida et al, 2013, who performed the emergy accounting of the Engineering, Pharmacy and Management schools at Paulista University, the information emergy of which corresponded to 87%, 82%, and 91% of the total emergy of the three systems, respectively. Such disparity is mainly due to differences in the number and education level of the students and teachers involved, as well as in the transformity calculation approach. Moreover, the emergy contributed by the time of effective use of 69 computers alone amounted to about 29% of the total system emergy. Without the computers, the contribution of information flows would amount to around 27%. The UEV for a computer adopted here was first presented at the 8th Emergy Research Conference in Gainesville, in 2013, and is still in press.

This study suggests that environmentally-aware decision-making on both the expansion of the SETEC chain of DTC's, as well as the spread of Federal Institute units throughout the region by using third-party facilities could be based mainly on the viability of monetary costs, location, regional demand, social inclusion policies or other relevant variables rather than on infrastructure-related concerns since, in both cases, a significant part of the contribution to the total system emergy comes from the information flows.

We considered the question "Should emissions be taken into account when making decisions on the expansion of an educational system?" A comparison of the rates of CO₂ emissions per student from both the virtual and the physical systems clearly favors the expansion of the chain of DTC's, with a tenfold lower emissions figure and a higher potential to get students enrolled and attending, especially in cities/regions where building a physical school is not possible or viable. Moreover, cost effective expansion of the attendance capacity of a DTC unit can be achieved by increasing the number of courses and groups of students in different neighboring cities using the same online-teachers, and this would only require two extra online-tutors and one standby-tutor for every group of 50 students.

This study highlights the role of information, not only in the education system studied herein, but also in all the published works on emergy accounting of educational systems. At present, one cannot accurately assess or account for information by means of emergy accounting, an issue that should be the subject of inter-disciplinary studies.

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