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Low-Carbon Economy in Schools: Environmental Footprint and Associated Externalities of Five Schools in Southwestern Europe

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Abstract: This study provides an in-depth assessment of the environmental performance of five public schools in the transition towards a low-carbon economy and a more sustainable model of society. Life cycle assessment (LCA) methodology is used to conduct the study. The school system includes several activities and processes clustered in three subsystems: management of the school building, training and learning activities (T&L) and mobility and transport (M&T). A detailed primary data inventory of energy and resources consumption was collected in five schools located in Spain and Portugal. Findings on climate change (CC), water depletion (WD), particular matter (PM), acidification (Ac), and human health (HH), as well as associated external cost (EC), are reported per student in one school year as reference unit, allowing the schools' individual performance comparison and identify the potential improvements. Considering the sample of schools, findings reveal that peculiarities of the schools, such as location, specialization, and level of education, are crucial for the environmental performance. Buildings are a relevant contributor to CC as well as heating and electricity needs, although their relevance is dependent on multiple factors. The M&T subsystem also has relevant weight on the metrics evaluated. Educational activities have a lower impact in absolute terms but, in some schools, it becomes the main contributor to HH due to paper and electricity consumption and manufacturing of equipment. External costs results are in the range of 11 to 38 EUR/student·year mainly caused by heating, electricity and wastes from the building subsystem, and the M&T subsystem.

Keywords: school environmental performance; student footprint; low-carbon economy; life cycle assessment; external costs

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1. Introduction

Current society is called to do the greatest ever cross-sectorial and regional effort in order to achieve the transition to a more sustainable and less carbon intensive model for the next decades [1,2]. The GHG emissions in the European Union (EU) have decreased by 28.3% during the period 1990–2019. Most of the reductions took place in the power sector, mainly due to the increasing share of renewable energies, the consumption of fossil fuels with less carbon emissions, and energy efficiency improvements [3]. However, much greater effort is needed for Europe to become a net-zero carbon economy by 2050 as aimed at in the European Green Deal [4]. In 2020, due to COVID-19 pandemic, there have been significant reductions in GHG emissions due to the significant decrease in transport and economic activity due to lockdowns. Although temporary, these reductions serve to illustrate on the consequences on carbon emissions of human daily activities.

European policies promote the low-carbon economy in all sectors to obtain the emission reduction goals in the years 2030 (40%), 2040 (60%), and 2050 (80%) in comparison with the reference year 1990 [5]. These figures have recently been updated in the provisional agreement between the co-legislators on the European Climate Law, increasing the goal for 2030 until at least a 55% reduction in net emissions and reaching negative emissions after 2050 [6].

Society is increasingly aware of the need to achieve sustainable development. Along these lines, several educational initiatives have been launched with the aim of empowering present and future generations through knowledge and citizen participation, to be able to build a more sustainable world. A relevant example from intergovernmental institutions is the initiative Education for Sustainable Development of UNESCO, a framework linked to the 2030 Agenda for Sustainable Development whose objective is to provide sufficient knowledge to students so that they can take informed and responsible actions aimed at achieving the protection of the environment, which are economically viable and create a just society. Other initiatives include Euronet 50/50 (Interreg EU Programme), which is aimed at promoting energy savings in educative framework at national, regional and local scales; and the ClimACT project (Interreg SUDOE Programme, the ERDF Cooperation Programme Interreg Southwest Europe), which is dedicated to supporting the transition to a low-carbon economy in schools. The concern to conserve the environment for future generations with the participation of the educational community, has also led to the development of schemes from the non-governmental sphere, such as the Eco-schools initiative (The Global Forest Fund) which is targeted to provide tools to the entire educational community through learning and practical experience. Teachers for Future, an NGO, carries out concrete actions to promote sustainability in schools, environmental education, and contact with nature among schoolchildren.

The way to achieve a better environmental profile in schools comprises two main aspects. The first one is a more technical one aimed at reducing energy consumption, as well as improving the energy efficiency and insulation of buildings and the purchase of more sustainable materials. The other aspect, although related to the previous one, has more to do with providing knowledge to the school community and providing tools in order to raise awareness and propitiate changes in attitudes to be able to make responsible decisions. These decisions could include saving water and energy by closing the taps and turning off the lights, selecting more sustainable transport alternatives (walking, use bicycles or public transport), or consuming local food products, among others.

In this context, the mentioned project, the ClimACT project (http://www.climact.net/ (accessed on 18 September 2021)), which is the framework of this research, had a main objective to promote the low-carbon economy in schools through the development of support tools and activities. The project contemplates four lines of action: (i) to design support tools and develop sustainable solutions in schools, (ii) to design educational tools to raise awareness about the impact of climate change; (iii) to raise awareness and establish a thematic network throughout the SUDOE region; and (iv) to create a platform for investment in energy efficiency in schools by contacting the different agents. The project was developed in 35 pilot schools from Spain, France, Portugal, and Gibraltar [7].

In this paper, the results of an environmental footprint analysis applied to a sample of schools from the SUDOE region are presented. Section 2 includes a literature review of the topic. Section 3 describes the methodological framework for environmental impacts and externalities assessment, data collection, and the key data of the school systems studied. Section 4 presents the quantitative results per student considering the different activities identified in schools clustered by the three subsystems: management of the school building, training and learning activities (T&L), and mobility and transport (M&T). Finally, Section 5 discusses the results, influences, and peculiarities found, and provides an exercise of assessment of the potential of selected measures in schools in terms of carbon footprint savings.

2. Literature Review

Recently, abundant literature has been published related to operational energy consumption analysis for educational sector that can be used to find opportunities to improve efficiency in the public sector. Life cycle assessment methodology has been applied to assess sustainability in the schools in order to calculate environmental impacts [8] including quantification of external costs [9]. Other studies open the framework also covering economic sustainability [10]. Integration of energy, water, and environment systems under the umbrella of multidisciplinary concept of sustainability and circular economy has also explored in some investigations [11–13]. The increase in buildings energy efficiency, in both housing and the educational sectors, to reduce energy consumption and CO_2 emissions, including infrastructure and operation and maintenance (O&M) activities, is crucial to decarbonise schools [8,14–18]. Studies on exploring alternatives have been found, such as district heating systems in Mediterranean climate conditions [19], natural ventilation [20], retrofitting of inefficient buildings using decision support applying parametric analysis [21], and the screening of the best thermal energy storage materials for cooling/ heating and zero carbon buildings [22,23].

According to the European Commission, the building sector is responsible for 40% of energy consumption and 36% of GHG emissions [24], which is why it is a key sector to implement solutions. Several works have been developed in buildings with important findings. For instance, Neururer et al. [25] indicates that the operational phase of the building causes among 54% and 83% of the environmental impacts. Gamarra et al. [8,9] found that heating and lighting as a key activities for carbon footprint and energy consumption in the use phase of the educational school building. Most studies are focused on the building, both embodied and operational emissions by using life cycle emission factors [26–28]. Furthermore, top-down estimations based on input–output studies have been used in order to estimate the footprint of educational sector, schools, and students [29].

However, schools are complex systems and are connected to other sectors, as transport and production of goods and services, and this has to be included in the schools' analysis. Activities related to transport and goods and services production can also take part on the improvement of the environmental performance as a part of the schools' system and students' life. Transport sector and production and manufacture sector, both have themselves their own objectives in terms of decarbonisation. Specifically, the goal for the transport sector is 60% by 2050 [30]. Studies have quantified the footprint of transport and the election of means of transport in the carbon footprint of university students for commuting [31,32]. Others studies around the world include university building performance as well as mobility [33]. However, some researches have been found considering the whole footprint of students of different levels of education considering the consumption of goods for teaching and learning based on participatory methods for data collection [32,34]. Among those, one recent research focused on the consequences of COVID-19 pandemic in the United Kingdom [35] in carbon footprint of university student remarks the potential benefits of online education for the reduction in carbon emissions, but recognised the need of a wider societal context research.

3. Materials and Methods

3.1. Methodology

The main objective of the study is to quantify the relevant environmental impacts of the schools and identify hotspots considering the life cycle approach. That implies assessing the environmental life cycle loads associated with the provision of goods and services for the educational activities during a school year, including the extraction of raw material, the production and manufacturing of materials and energy, the use of these materials and energy in school up to the waste and effluent treatment, and emissions release. The methodology used considers a life cycle approach for the assessment of the environmental impacts and the external costs associated to the educational activity. This methodology combines the life cycle assessment (LCA) methodology and the ExternE methodology. This combined approach was previously applied to the study of the impact associated to students in previous works [9]. First, by following the four phases of the LCA (goal and scope definition, life cycle inventory, environmental assessment and interpretation), according to the LCA guidelines and standards [36,37], a deep knowledge of the environmental performance of the schools system is acquired. LCA allows quantifying the input and output flows (materials, energy, and emissions) and assessing the environmental impacts, i.e., the source of data on emissions required for the externalities impact pathway approach, and thus, for external costs calculation. Second, the external costs calculation provides a way to express the environmental performance of the schools in economic terms, useful for policy planning and decision-taking.

The LCA methodology is defined as holistic methodology conducted in an iterative process in which the study is redefined and redesigns according the findings along the four phases. Thus, the main research questions investigated regard the main environmental impacts associated to one student during one school term in schools in the Southwest Europe, as well as the size of these impacts. Additionally, during the study, other questions arise thanks to advantage of the detailed data collection undertaken and the availability of complete inventories in several schools. First, considering the high quality of primary data due to participation of the schools' community, the study allowed identifying which are the activities and hotspots causing the impacts. Second, from the application to the study cases, it was possible to compare the environmental performance of the different educational centres investigated and to identify the characteristics, behaviours, and activities that cause the main environmental impacts, and therefore how school's communities and decision takers can act to reduce them.

3.1.1. Life Cycle Assessment (LCA)

The scope is the whole school system, including several activities and processes clustered in three subsystems: management of the school building, training and learning activities (T&L), and mobility and transport (M&T). The function considered for this system is the provision of materials and conditions required for the educational activities during a school year.

The second phase of LCA is the life cycle inventory (LCI) analysis, which involves collecting measurable and available data about the inflows and outflows of energy and materials that enter system boundaries. For that, interviews, surveys, monitoring, energy bills, commercial information, and literature were used, as well as specialised LCA software Simapro^{TM} and databases for the common fuels and materials (Ecoinvent, [38,39]).

The third phase concerns the impact assessment by the selected method of impact characterization. Five impacts categories were selected from the set of impact categories recommended by the International Life Cycle Data initiative [40]. References to the methods can be found in Table 1.

Table 1. Impact categories assessed in the study, abbreviates, methods, and unit.

Impact Category		Method	Unit
Climate change	CC	IPCC Method [41]	kg CO_2 eq.
Human toxicity non-cancer + cancer effects	HH	USEtox model Rosenbaum et al. [42]	CTUh eq.
Water depletion	WD	[43]	m^3 eq.
Particular Matter	PM	[44,45]	kg PM2.5
Acidification	Ac	[46,47]	mol H+

The selected impact categories are climate change (CC), human health (HH), particular matter (PM), water depletion (WD), and acidification (Ac). The impact methods selected for these categories are shown in Table 1. Nowadays, the potential to contribute to CC is a widely used indicator relevant for the societal objective of decarbonization as main challenge of the society. HH and PM were selected due to nature of the activity analyzed, where the own student was expected to be the receptor and potentially more affected by the impacts of environmental degradation. Both categories have been previously identified as key in previous works [8,9]. The environmental impact of category water consumption was chosen because of the climatic conditions in the Iberian Peninsula, where many areas suffer high water scarcity levels. Finally, acidification was selected since the pollutants responsible for this impact are released from several sources, causing damages in crops, human health, materials, and biodiversity.

The fourth and final phase is the interpretation, which provides the picture of the system in terms of environmental results, and allows identifying the key processes, activities, and materials that most influence impact results.

3.1.2. External Costs Calculation

The external costs were calculated using the ExternE methodology [48]. This methodology is based on the impact pathway method which considers all the stages that go from the emission and dispersion of pollutants in the environment to the estimation of the affection of receptors (humans, materials, agro, and natural ecosystems). Damage factors considered were those developed in the CASES project [49]. Damage factors are dependent on the country and the year of emission. Therefore, the Spanish and Portuguese values of damage costs per tonne of pollutants were used, and then the currency value to the year of release of pollutants were adjusted. External costs were then obtained by multiplying the damage factors by the amount of pollutants provided by the life cycle inventory of airborne and waterborne emissions obtained from the LCA analysis. The complete list of pollutants considered is provided and their corresponding individual damage factors are shown in the Appendix A in supplementary.

3.2. *School System: Input Data and Study Cases*

The most relevant processes and input and output flows were identified and quantified. For that, first, the school system was characterized, establishing three main subsystems: management of the building, pure teaching and learning activities (T&L), and mobility and transport (M&T).

Figure 1 depicts the LCA scheme of the school system. The student is the core of the school system and the reference unit used in this assessment. Icons represent the different products and services needed for the provision of the necessary conditions for the education of students in every school that are clustered in the three subsystems mentioned. The life cycle of the school system includes the input of material and energy, as well as the output of emissions, effluents, and residues to the environment (input and output arrows) at any stage of the production chain (extraction of raw materials, manufacture, packing, distribution, end of life pathway). Tables 2–4 detail the activities included in the three subsystems considered.

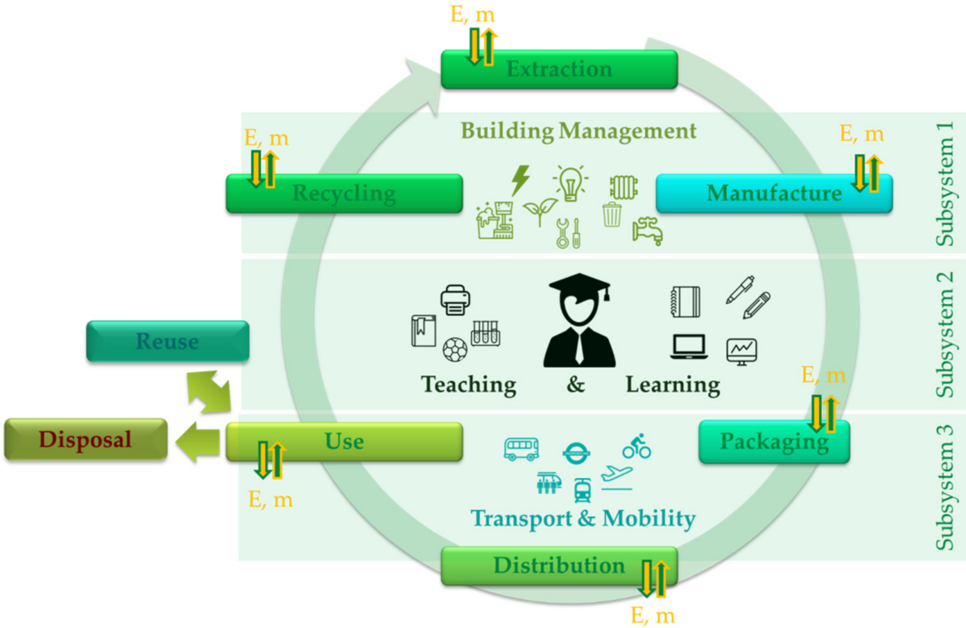

Figure 1. Diagram of the school system under the LCA approach. E: energy; m: materials.

Table 2. Activities included in subsystem 1 (management of the building).

Activity	Inputs and Variables Covered
Water	Tap water consumption
Heating	Boilers fed by light fuel oil in SP/electric radiators in PT
Cooling	Mini-split electricity consumption, refrigerant gas emissions
Lighting	Energy consumption, lamp replacement (different typologies) (fluorescent Tubes, FCL, conventional, halogen, and LED)
Gardening	Water, pesticides and fertilizers, and petrol consumption Water/soil/air emissions and CO_2 captured by plants
Cleaning and Maintenance	Material consumption, wastes production, electricity
Food service	Energy consumption by appliances
Wastes	Waste produced in maintenance
Other electricity consumption	Other electricity consumption not included in the other categories, calculated as the difference with the electricity consumption bill

Table 3. Activities included in Subsystem 2 (Teaching and learning, T&L).

Activity	Inputs and Variables Covered
Student activities	Materials for learning activities provided by the students (pens, pencils, notebooks, etc.) Electricity consumption of appliances and equipment (their own laptops or tablets in class) in the school
Lab	Typical substances in basic laboratory
Library	Books, CDs, DVDs
Gym	Balls, mats, hurdles, frisbi, lockers, Foam mattress
Administrative activities	Materials for teaching and administrative activities provided by the school (paper, folders, printers, computers, etc.)

Table 4. Activities included in Subsystem 3 (Mobility and Transport, M&T).

Activity	Inputs and Variables Covered
Transport	School outings and special trips Mean of transport and place/distance per trip and number of students travelling (pkm)
Mobility	Daily commute to school Means of transport and distance to school Average distance, trips per day, and passengers (pkm)

3.2.1. Input Data Collection

The data collection process was designed combining different techniques (two online surveys filled by students, teachers and workers), planned audits (invoices and bills, inventories, and in situ checking of building, equipment and facilities), as well as interviews with workers. The data collection was carried out during the year 2017, referred to as the 2015–2016 term. The school activity starts in September and ends in June. School buildings work during July only for administration activities. In August, the schools are closed.

The processing and manufacturing information of specific products, such as educational stationary apparels (pencils, pens, paper, etc.) for scenario of product building, were based on commercial information, scientific literature, and LCA databases (Ecoinvent database [50]).

3.2.2. Study Cases: Five Pilot Schools

Five schools (S1, S2, S3, S4, and S5) of different educational levels were chosen to conduct the analysis. The five educational centers are located in the Iberian Peninsula (Spain and Portugal). These schools were participants as pilot schools in the ClimACT project. The sample of schools included in this study is diverse, since it covers different conditions and features regarding climate, urban typology, building features and facilities, level of education, size and specialization (Table 5).

Table 5. Location and technical data of the schools.

Parameter	Unit	S1	S2	S3	S4	S5
Location						
City	-	Alcalá de Henares (ES)	Madrid (ES)	Alcalá de Henares (ES)	Santo António Dos Carvaleiros (PT)	Madrid (ES)
Climate conditions	-	Continental	Continental	Continental	Atlantic-coastal	Continental
Building and facilities						
Number of buildings	N	1	2	2	4	2
Age of the building (s)	Year	s.XVI, 1992	1950	1961, 1987	1970's	1988, 2003
Outdoor and indoor area	m^2	3264	5600	3083	25,221	14,409
Gross building area	m^2	2390	4830	2583	7526	6096
Occupants						
No. students	N	221	410	532	578	907
No. teachers and workers		23	50	59	80	77
Other characteristics						
Level [1]	-	Primary school CEIP	Secondary school IES	Secondary school IES	Primary school EB	Secondary school IES
Specialisation	-	-	Sports, languages, and litarature Technological	Technological	-	Languages and literature

[1] The organizational levels of education are different in Spain and Portugal. The Escola Básica (EB) includes the education between 6 to 15 years old students in Portugal. In Spain, the mandatory education is split in primary (6 to 12 years old) and secondary (13 to 16 years old).

The data of consumption of goods, such as notebooks, pen, pencils etc. (provided by students) and the behavioral data related to mobility, was collected in two surveys. Both surveys were composed by multiple choice questions. Both were answered online, except for primary schools where the surveys were answered with the support of parents and teachers. The first one was designed for the characterization of the student's own material consumption by surveying a sample set (some class groups reaching the 20% of the total students in each school). Results obtained allowed to estimate the material consumption in educational activities provided by households/students, and later was extrapolated to the whole school population multiplying by the number of students. The second one was launched as an online behavioral survey dedicated to detail crucial behaviors of individuals in each school community. Results were considered representative when, at least, the number of responses was equal or higher than the 20% of the school (students and workers).

Input data for the inventory building was included in the Supplementary Information.

4. Results

The results of the assessment include the assessment of the six environmental impact categories and one social impact. The results were analyzed by impact category and pilot school, as well as by subsystem. The contribution of each subsystem to the total impact in each school and for each impact category is shown in Figure 2. Impacts are shown in comparison with those of school S1.

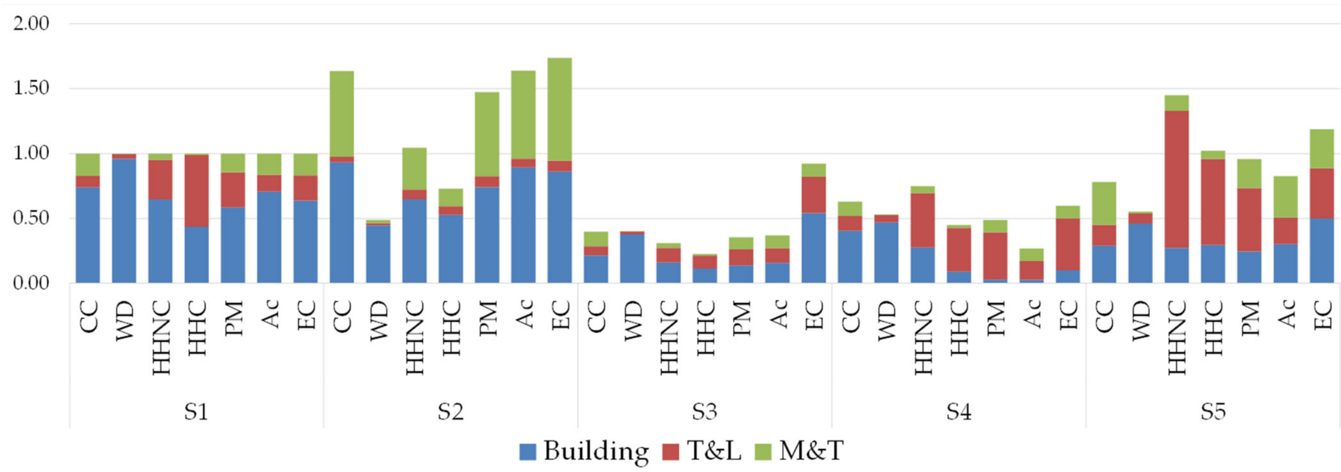

Figure 2. Contribution of subsystems—buildings, training, and learning (T&L), and mobility and transport (M&T) of the sample of schools (S1, S2, S3, S4m and S5) to the results of the assessment of environmental impacts and external costs. CC: climate change; WD: water depletion; HH: human health (HHNC: non-cancer effects and HHC: cancer effects); PM: particulate matter; AC: acidification; EC: external costs. The vertical axis represents the impact result of each school and impact category normalized by the results of School 1 (S1), establishing the proportional size related to this school (S1 = 1).

As shown in the figure, there are notable differences among the schools, both in the magnitude of the impacts and in the relative share of the three considered subsystems. In the following sections, the results of the individual impact categories are presented (environmental impacts in Sections 4.1.1–4.1.5, and external costs in Section 4.2). Figures complementing the results reported in tables are provided in Appendix B in supplementary.

4.1. Environmental Impact Assessment

4.1.1. Climate Change Impact

Results on CC per student are in the range from 127 (S3) to 522 (S2) kg. of CO_2 eq./student·year. The building subsystem is the main contributor to the CC impact in all cases, except in the school S5, in which the main contributor is the M&T subsystem, but closely followed by the building subsystem. Detailed results of CC impacts of the different components of the three considered subsystems, as in shown in Table 6.

Table 6. Climate change impacts results per school, subsystem, and activities.

		S1	S2	S3	S4	S5
Building		236	297	68	129	92
	Other electricity consumption	0.00%	20.81%	0.00%	0.00%	18.53%
	Tap water	0.27%	0.08%	0.39%	1.07%	0.31%
	Heating	60.76%	59.23%	65.94%	4.94%	52.94%
	Water heating	0.00%	0.13%	0.00%	4.31%	0.00%
	Cooling	0.00%	1.21%	9.94%	0.76%	1.48%
	Ventilation	0.00%	0.00%	0.00%	0.00%	0.00%
	Lighting	22.85%	17.05%	20.60%	21.00%	15.41%
	Gardening	−0.04%	−0.04%	−0.09%	−8.11%	−0.36%
	Cleaning and Maintenance	1.50%	1.39%	1.38%	0.45%	2.31%
	Wastes	0.33%	0.13%	1.84%	1.65%	0.23%
	Food services	14.32%	0.00%	0.00%	73.93%	9.16%
T&L		28	14	22	36	51
	Students activity–class	47.15%	12.29%	90.44%	53.25%	50.31%
	Laboratory activity	0.00%	0.00%	0.00%	0.11%	0.02%
	Gym activity	6.74%	2.75%	2.35%	3.87%	0.32%
	Library activity	1.30%	1.79%	7.21%	4.54%	1.45%
	Administrative and school	44.81%	83.17%	0.00%	38.24%	47.90%
M&T		55	211	37	36	106
	Transport-exchanges and outings	27.39%	57.92%	17.30%	15.67%	61.22%
	Mobility	72.61%	42.08%	82.70%	84.33%	38.78%
Total CC (kg CO_2 eq./student·year)		319	522	127	201	249

Within the activities included in the building subsystem, heating is the major contributor (more than 50%), with the only exception of S4, in which heating CC impact is much smaller (4%). This is due to the much lower energy demand for heating consumption in S4 in comparison with the other schools. There are several reasons that could be argued to explain these differences. First, the climate effect. S4 is located in an Atlantic-coastal climate with an annual average temperature of 16 °C (Data from Climate-data.org, https://es.climate-data.org/ and searching "Santo Antonio dos Cavaleiros" (accessed on 20 August 2021)), with an average of minimum temperatures not lower than 11 °C, while the average of the minimum temperatures in the central Iberian Peninsula (where the other schools are located) are lower than 5 °C for a long period. Second, the heating system in the schools S1, S3, and S5 also provides hot water. Therefore, the CC impact attributable to water heating is included in the heating activity. This is why the contribution of water heating is null in all schools but not in school S4 where there is a hot-water system used by the students after sports classes.

The second cause of climate change impacts is lighting in all the schools with an average 19% share of the CC building related impacts. Gardening includes CO_2 sequestration and becomes a net sink of CO_2 when low-intensive gardening works and treatments are implemented. Among the studied schools, S4, the school located in Portugal, achieves the highest CO_2 sequestration.

The CC impact of the T&L subsystem is the lowest and ranges between 22 (S3) and 51 (S5) kg. of CO_2 eq./student·year, mainly due to the regular consumption of learning materials provided by students (books) and by the schools (printed paper, toner) as well as electronic devices and the electricity consumed by them (laptops and tablets). S2 is the exception with a low contribution to the T&L CC impact. In this school, an innovative protocol of teaching based on a computer-implemented educational package is used, which avoids the need to purchase printed books. On the opposite side, S5 shows the highest CC impacts, especially for administrative and school consumption of paper and electricity consumption by devices. The data of the administrative and school consumption of S3 were unavailable in the collection campaign. This is the reason for the relatively low score of this school in this impact category.

The CC associated to M&T is quite relevant in absolute terms in some schools reaching 211 kg. CO_2 eq./student·year in the school S2 and 106 kg of CO_2 eq./student·year in the school S5. These schools provided very detailed data related to international trips to the UK, the USA, and France made by students. These trips were made by plane or private bus with very high GHG emissions. The impact of CC caused by daily commuting to school is very relevant due to the use of private cars.

4.1.2. Water Depletion

Results of water depletion per student are in the range from 3.38 (S3) to 8.41 (S1) m^3 eq./student·year. The building subsystem is the main contributor to the water depletion impact in all cases. Detailed results of water depletion impacts the different components of the three considered subsystems, as shown in Table 7.

Table 7. Water depletion impacts results per school, subsystem, and activities.

		S1	S2	S3	S4	S5
Building		8.06	3.74	3.16	3.93	3.87
	Other electricity consumption	0.00%	10.98%	0.00%	0.00%	2.92%
	Tap water	90.92%	76.49%	95.78%	99.58%	83.34%
	Heating	0.77%	2.02%	0.61%	0.00%	0.54%
	Water heating	0.00%	0.00%	0.00%	0.00%	0.00%
	Cooling	0.00%	0.25%	0.20%	0.00%	0.06%
	Ventilation	0.00%	0.00%	0.00%	0.00%	0.00%
	Lighting	4.44%	9.00%	2.96%	0.00%	2.43%
	Gardening	0.00%	0.00%	0.00%	0.00%	0.00%
	Cleaning and Maintenance	1.06%	1.23%	0.45%	0.33%	9.24%
	Wastes	0.02%	0.02%	0.01%	0.08%	0.02%
	Food services	2.78%	0.00%	0.00%	0.00%	1.44%
T&L		0.32	0.15	0.20	0.50	0.65
	Students activity-class	59.49%	9.01%	77.89%	6.21%	55.85%
	Laboratory activity	0.00%	0.00%	0.00%	0.05%	0.01%
	Gym activity	1.84%	1.96%	10.36%	3.24%	0.12%
	Library activity	1.64%	2.43%	11.75%	4.38%	1.65%
	Administrative and school	37.03%	86.61%	0.00%	28.13%	42.38%
M&T		0.03	0.21	0.02	0.04	0.12
	Transport-exchanges and outings	23.85%	23.56%	11.67%	6.38%	26.03%
	Mobility	76.15%	76.44%	88.33%	93.62%	73.97%
Total WD (m^3 eq./student per year)		8.41	4.10	3.38	4.46	4.63

The school with the highest water depletion impact per student is S1, overpassing the 8 m^3 of water eq./student·year. The impact of the rest of schools is ranged between 3.2 and 3.9 m^3 eq./student·year. As expected, the WD impact is almost completely caused by direct consumption of tap water in the schools. A small fraction is due to water depletion associated with the production of the electricity consumed in the lighting used in the building subsystem, and also associated with T&L activities related to the production of books and printed paper.

4.1.3. Particular Matter

The results on the potential impact of PM emission associated with schools are shown in Table 8.

Table 8. Particulate matter impacts results per school, subsystem and activities.

		S1	S2	S3	S4	S5
Building		0.07	0.09	0.02	0.003	0.03
	Other electricity consumption	0.00%	34.89%	0.00%	0.00%	28.95%
	Tap water	0.47%	0.15%	0.83%	35.02%	0.49%
	Heating	32.26%	31.29%	43.03%	0.00%	26.05%
	Water heating	0.00%	0.02%	0.00%	6.10%	0.00%
	Cooling	0.00%	1.25%	9.29%	4.78%	1.25%
	Ventilation	0.00%	0.00%	0.00%	0.00%	0.00%
	Lighting	38.52%	28.59%	42.69%	0.00%	24.07%
	Gardening	0.00%	0.00%	0.00%	0.00%	0.20%
	Cleaning and maintenance	4.38%	3.70%	4.31%	26.39%	4.97%
	Wastes	0.23%	0.12%	−0.15%	27.71%	−0.29%
	Food services	24.13%	0.00%	0.00%	0.00%	14.31%
T&L		0.03	0.01	0.02	0.04	0.06
	Students activity-class	62.54%	9.32%	82.35%	65.35%	61.84%
	Laboratory activity	0.00%	0.00%	0.00%	0.06%	0.01%
	Gym activity	4.16%	3.25%	1.14%	1.77%	0.17%
	Library activity	1.72%	3.64%	16.51%	5.47%	1.93%
	Administrative and school	31.58%	83.80%	0.00%	27.36%	36.05%
M&T		0.02	0.08	0.01	0.01	0.03
	Transport-exchanges and outings	37.62%	62.57%	24.88%	21.64%	48.38%
	Mobility	62.38%	37.43%	75.12%	78.36%	51.62%
Total PM (kg PM2.5 eq./student·year)		0.12	0.18	0.04	0.06	0.12

The school S2 with PM emissions of 0.18 kg/student·year) has the highest impact and S3 the lowest (0.04 kg PM2.5 eq./student·year). There is not a clear pattern related to the main sources of PM impacts by subsystem among the sample of schools. For S1, S2, and S3, the main contributor to the PM impact is the building subsystem, while, for schools S4 and S5, T&L is the most contributing subsystem.

Energy consumption, either in the form of heat or power, leads to relevant impacts. For heating supply S1, S2, S3, and S5, the use of fuel oil boilers is much higher than the consumption of fuel per student and year in S1 and S2. The books (purchased by students) and the paper consumption in administrative and teaching activities in the T&L subsystem are the most impacting activities in S4 and S5.

In the case of S2, the M&T subsystem also has a relevant contribution due to the use of road transport in private buses and cars.

4.1.4. Human Health

Similar to the results on PM, the results of HH of the sample of schools make it difficult to find clear patterns on the distribution of the impact between the subsystems. Results on this are shown in Table 9.

The school S5 has the highest impact while S3 has the lowest. There is not a clear pattern related to the main sources of HM impacts by subsystem among the sample of schools. As for the case of PM impacts, for S1, S2, and S3, the main contributor to HH impact is the building subsystem, while, for schools S4 and S5, T&L is the most contributing subsystem. Focusing on this subsystem contribution, the administrative and schools' consumption accounts for more than 50% of the total impact. Books, electricity, and paper consumption, as well as the production of equipment and computers, are relevant contributors to the T&L subsystem. Data on consumptions from administrative and school activities (T&L activities) of S3 were unavailable, so the impact result excludes the contribution of these consumptions and could explain the low value of HH impact in S3. The higher contribution to HH impact of M&T is found in the school S2. Within the T&M, daily commuting to school has the worst effect on HH per student and year in all the schools. This is due to the use of road transport (car and public bus) for commuting, since the human exposition to pollutants is high in streets and roads.

Table 9. Human health (HH) impacts results per school, subsystem, and activities.

		S1	**S2**	**S3**	**S4**	**S5**
Building		2.79×10^{-5}	2.87×10^{-5}	6.94×10^{-6}	1.10×10^{-5}	1.28×10^{-5}
	Other electricity consumption	0.00%	41.08%	0.00%	0.00%	25.39%
	Water	0.54%	0.21%	0.90%	3.23%	0.52%
	Heating	9.24%	11.03%	11.69%	0.00%	6.84%
	Water heating	0.00%	0.00%	0.00%	0.06%	0.00%
	Cooling	0.00%	3.24%	28.14%	2.17%	2.89%
	Ventilation	0.00%	0.00%	0.00%	0.00%	0.00%
	Lighting	36.83%	33.66%	38.74%	0.00%	21.11%
	Gardening	0.00%	0.00%	0.00%	0.00%	0.14%
	Cleaning and Maintenance	12.35%	3.86%	4.64%	1.83%	13.22%
	Wastes	17.97%	6.93%	15.89%	92.71%	17.34%
	Food services	23.07%	0.00%	0.00%	0.00%	12.55%
T&L		1.63×10^{-5}	3.42×10^{-6}	5.05×10^{-6}	1.86×10^{-5}	4.51×10^{-5}
	Students activity-class	32.81%	10.24%	85.15%	45.82%	21.70%
	Laboratory activity	0.00%	0.00%	0.00%	0.04%	0.00%
	Gym activity	21.22%	1.81%	2.02%	1.15%	0.19%
	Library activity	0.90%	2.92%	12.83%	3.38%	0.67%
	Administrative and school	45.06%	85.04%	0.00%	49.61%	77.44%
M&T		1.93×10^{-6}	1.32×10^{-5}	1.53×10^{-6}	2.22×10^{-6}	5.13×10^{-6}
	Transport-exchanges and outings	26.61%	34.11%	14.17%	8.57%	24.06%
	Mobility	73.39%	65.89%	85.83%	91.43%	75.94%
Total HH (CTU eq./student·year)		4.62×10^{-5}	4.53×10^{-5}	1.35×10^{-5}	3.18×10^{-5}	6.30×10^{-5}

4.1.5. Acidification

Results on the impacts of acidification are shown in Table 10, and range from 0.45 (S4) to 2.75 (S2) mol H+ eq./student·year.

Table 10. Acidification impacts results per school, subsystem, and activities.

		S1	**S2**	**S3**	**S4**	**S5**
Building		1.19	1.50	0.26	0.04	0.50
	Other electricity consumption	0.00%	37.52%	0.00%	0.00%	30.71%
	Water	0.48%	0.15%	0.90%	29.09%	0.50%
	Heating	29.21%	28.39%	41.51%	0.00%	23.32%
	Water heating	0.00%	0.02%	0.00%	11.26%	0.00%
	Cooling	0.00%	1.05%	6.16%	2.91%	0.93%
	Ventilation	0.00%	0.00%	0.00%	0.00%	0.00%
	Lighting	41.33%	30.75%	48.80%	0.00%	25.54%
	Gardening	0.00%	0.00%	0.00%	0.00%	0.12%
	Cleaning and Maintenance	2.41%	1.88%	2.60%	11.17%	3.12%
	Wastes	0.68%	0.23%	0.04%	45.58%	0.58%
	Food services	25.89%	0.00%	0.00%	0.00%	15.19%
T&L		0.22	0.11	0.19	0.25	0.35
	Students activity-class	40.82%	13.03%	93.39%	52.49%	48.05%
	Laboratory activity	0.00%	0.00%	0.00%	0.08%	0.01%
	Gym activity	4.02%	1.57%	0.92%	2.87%	0.24%
	Library activity	1.12%	1.46%	5.69%	4.35%	1.45%
	Administrative and school	54.04%	83.95%	0.00%	40.21%	50.25%
M&T		0.27	1.14	0.17	0.16	0.54
	Transport-exchanges and outings	45.88%	67.47%	31.79%	28.90%	64.41%
	Mobility	54.12%	32.53%	68.21%	71.10%	35.59%
Total Ac (mol H+/student·year)		1.68	2.75	0.62	0.45	1.39

Again, for schools S1, S2, and S3, most of the impacts are caused in the building subsystem, while, in schools S4 and S5, T&L and M&T are the most impacting subsystems, respectively.

The contributions of educational activities included in T&L are similar in all the schools. As in the case of CC, the largest contributors to the building subsystem impact are activities consuming energy, such as heating, lighting, and other electricity consumptions. The largest contributors to the M&T are the private bus and plane for outings and the car for commuting.

4.2. Social Impact: External Costs

The results on external costs associated with air and water emissions related to human health, yield of crops, biodiversity, materials degradation, global warming, and radionuclides range from 11 (S4) to 38 (S2) EUR/student per year. The breakdown of the external costs per student of the different activities included in each subsystem is shown in Table 11.

Table 11. External costs impact results per school, subsystem, and activities.

		S1	S2	S3	S4	S5
Building		11.68	15.80	9.92	1.82	9.16
	Other electricity consumption	0.00%	32.57%	0.22%	0.00%	15.45%
	Water	0.00%	0.13%	0.00%	5.00%	0.25%
	Heating	0.00%	34.49%	14.08%	0.00%	16.43%
	HW	0.00%	0.14%	0.00%	14.48%	0.00%
	Cooling	0.00%	0.94%	1.58%	0.18%	0.49%
	Ventilation	0.00%	0.00%	0.00%	0.00%	0.00%
	Lighting	0.00%	26.69%	11.83%	0.20%	12.85%
	Gardening	0.85%	0.00%	0.00%	0.01%	0.10%
	Cleaning and Maintenance	6.89%	1.89%	0.93%	6.96%	2.03%
	Wastes	92.26%	3.19%	71.36%	73.17%	51.40%
	Food services	0.00%	0.00%	0.00%	0.00%	1.00%
T&L		3.60	1.53	5.14	7.36	7.10
	Students activity-class	2.16%	9.40%	98.54%	23.17%	35.57%
	Laboratory activity	0.00%	0.00%	0.00%	2.45%	1.45%
	Gym activity	0.00%	1.91%	0.85%	0.22%	0.15%
	Library activity	0.00%	1.56%	0.61%	1.94%	1.02%
	Administrative and school	97.84%	87.12%	-	72.22%	61.81%
M&T		3.07	14.52	22.67	1.78	5.52
	Transport-exchanges and outings	40.38%	71.01%	27.71%	25.60%	62.18%
	Mobility	59.62%	28.99%	72.29%	74.40%	37.82%
Total EC EUR/student·year)		18.3	31.86	37.73	10.97	21.79

While the building contribution to the EC in the Spanish schools is quite similar (9.2 (S5), 9.9 (S3), 11.7 (S1), 15.8 (S2)) EUR/student·year, it is 1.82 EUR/student·year in the Portuguese School (S4). In S1, waste generation is the main cause of external costs. The data provided by the school S1 related to waste generated in the management, operation, and maintenance of the building indicated that the school replaced the lighting devices in the whole school; thus, the impact of the incandescent bulbs treatment and disposal is a penalty for this school in terms of EC. The damage factor in euros per tonne is huge as the LCI reveals that the disposal of incandescent bulbs releases dioxins. Less relevant is the contribution of wastes to EC in the schools S3, S4, and S5 (71.36%, 73.17%, and 51.40%, respectively). S2 shows a different trend, and the EC contribution is more distributed between activities and mainly linked with the energy consumption (Other electricity consumption, heating, and lighting together cause more than the 90% of the EC associated with the building subsystem).

The external costs of T&L activities ranged from 1.53 (S2) to 7.36 (S4) EUR/student·year. The trend is common between the schools; the administrative and school consumptions for teaching is the main cause, mainly due to the large amount of paper and the electricity consumption by devices and equipment. The lack of data of LCI related to administration and the school consumptions for T&L of the school S3 could be a reason to find the opposite trend.

Regarding the M&T, the use of car for commuting (mobility) and the private bus and plane in outings and exchanges cause the highest external costs.

As shown in Figure 3, the main cause of external costs in all the schools are human health-related impacts followed by global warming related impacts.

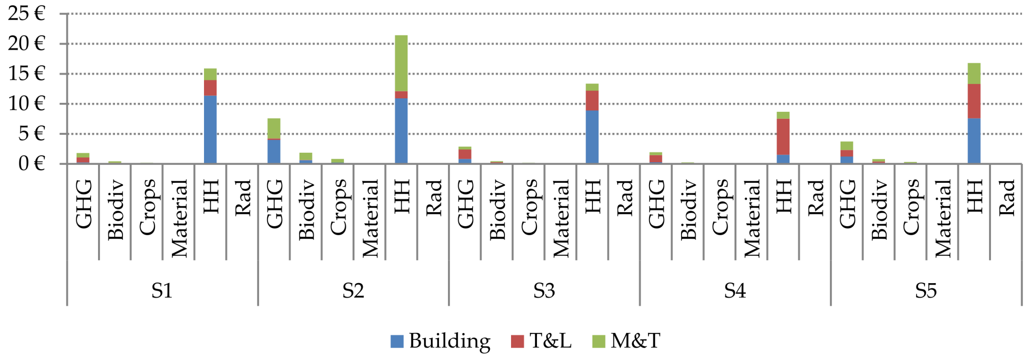

Figure 3. External costs (EC) results whole school (S1, S2, S3, S4, and S5) per student classified by the receptor affected and the damage caused (GHG: greenhouse gases damage; Biodiv: loss of biodiversity; crops: yields affection and deposition over crops; material: materials corrosion and degradation; HH: human health affection; Rad: radionuclides emission).

5. Discussion

Schools are complex systems with a wide range of activities, implying several and diverse consumptions. The results obtained in this work revealed that the specificities on climate, urban typology, building features and facilities, the level of education, the size of the school, innovations on digitalization, and activities for specialization play a key role on the environmental impacts associated with students.

The collaborative approach and work plan developed within the school community was crucial in identifying the relevant flows and in acquiring a deep knowledge of the system study fixed to the peculiarities of each case, which was essential to the interpretation of results. In this sense, the research on sustainability in schools goes beyond the resource use efficiency measurement and environmental performance assessment, since investigation involving educative participation processes in schools promotes cooperative community learning, in turn helping to acquire individual and collective responsibility [51]. Close collaboration between teachers, students, parents, administrative staff personnel, and researchers provides a better understanding about how to act under the principles of sustainability. The role of schools as subjects of study implies the active participation which allowed the collection of primary data, thus reaching a highly detailed and robust analysis. That is one of our remarkable findings.

Therefore, the comparison of schools' performance and presentation of results was carried out by using one student and the annual season as reference unit (student·year). In spite that this reference unit allow a comparison of the performance of schools by their function, it is rarely used. Only a few studies with different goals and scopes [26,32,34] have been found. In the UK [26], the average energy consumption per pupil was estimated (1066 kWh of heating and 223 kWh of electricity per year) and the associated total annual emission was over 260 kg of CO_2 eq. Furthermore, in the UK, the estimation of the educational sector revealed a carbon footprint of 280 kg of CO_2/capita by applying the input–output methodology instead of LCA [29]. Nevertheless, results of the environmental impacts for the building subsystem have also been calculated per square meter, i.e., the unit regularly used by LCA of buildings practitioners in order to compare with the relevant literature. Figure 4 shows the CC impacts of the studied schools' buildings per square meter. The building subsystem activities are responsible for most of the climate change impact of the schools included in this study in all the cases, but the analysis shows a disparity of results in absolute values between the different schools. One key reason is the different area of the school facilities analyzed. This highlights the usefulness of the use of the student·year parameter as the reference unit for the assessment of the performance of the whole school's system.

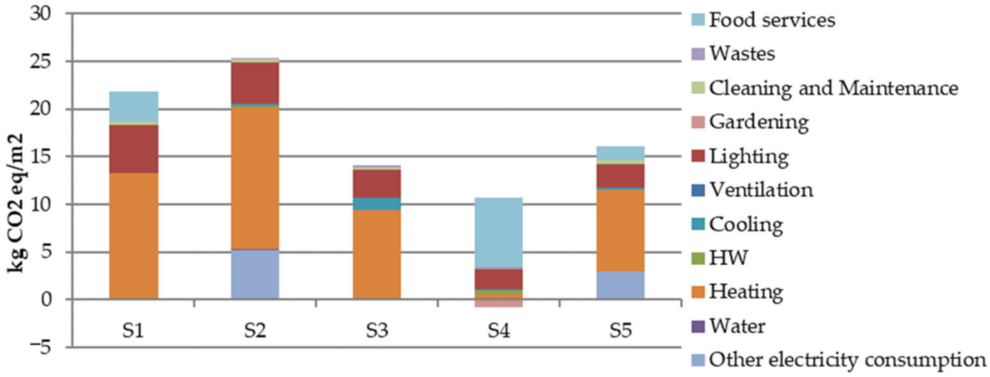

Figure 4. CC impact per m^2 and year, per school, and activity of the building subsystem.

Previous studies on LCA of buildings have found results on CC in the range, as this study results. In 2018, a review, published by the *Joint Research Centre* (JRC) [28], reported a mean value of 23 (ranged between 21.5–26) kg of CO_2 eq./m^2 year in collective buildings and 15 (11–18) kg of CO_2 eq./m^2·year in offices buildings, which were the most similar building typology of use to school buildings. Focusing on schools, the key role of the energy-intensive process in schools, such as heating or lighting, have been found in the literature. [8]. In the study of the carbon footprint of the School of Technical Design and Innovation located in Madrid (Spain), with 1500 undergraduate students, 28 kg CO_2 eq./m^2·year was estimated for the building energy consumptions [32]. Xue et al. [52] conducted a LCA of an university building in China and obtained that the electricity consumption is responsible for more than 90% of the impact in five environmental impact categories in the operational phase, including CC and AC, but also eutrophication and photochemical oxidation creation potential. The main reason is the coal-fired power generation dominant in this country. Buildings' design models support the research and optimization of energy use. For example, the modelling of a net-zero building school in Italy [27] reaches an estimated value of CC of 0.183 kg CO_2 eq./m^2·year, much lower than the found in literature or the obtained in this study.

The constructive characteristics of the buildings and the type of activities performed in the schools also play a relevant role on the size of the impacts. Focusing on the contribution to climate change, the highest CC reached is 522 kg CO_2 eq./student·year by the school S2. This is a school located in Madrid whose building was constructed in 1950 which keeps several international exchanges of students travelling by private bus or plane. Opposite to this, the same school S2 presents the lowest CC on T&L activities due to a lower consumption of books and printing paper, associated with the innovative teaching solution based on the IT-based educational package of materials and resources.

Climatic conditions are also a relevant parameter which determine the use and characteristics of buildings and demands [53]. The lowest CC associated with heating was found in the school S4 (Portugal), in which individual electric heaters are only occasionally used in cold days. Therefore, the low CC associated with S4 building is likely attributable to the climatic conditions. In spite of similar latitude, climatic condition makes great difference. According to Gervasio et al. [28], the values for the operational carbon have a much higher variation within each climatic area, and it is higher in the Northern Europe than in the South. Furthermore, it is found that the green spaces play a role, with a contribution of gardening (negative CC because the sequestration of CO_2 by trees). Other building features that could affect the building's energy consumption, such as the windows frame, building insulation, or exposition, were not characterized, which is a limitation of this study.

In terms of CC, transport election for commuting to school (mobility) and the long-distance outings and international exchanges (transport) are quite relevant. Schools S1 (55 kg. CO_2 eq./student·year), S3 (37 kg. CO_2 eq./student·year), and S4 (36 kg. CO_2 eq./student·year) have a low CC impact associated with M&T, while S2 (211 kg. CO_2 eq./student·year) and S5 (106 kg. CO_2 eq./student·year) reach very high scores for this impact due to taking long trips. Solutions based on digitalization and environmental criteria consideration, when deciding the destination of trips and the mode of transport, could be proposed to mitigate these impacts. Additionally, S2 and S5 have the highest CC on commuting activities too. This is due to the lower rates on commuting by walking, and a high (19%) share of the school community going to school by car. Furthermore, the external costs assessment reveals that, in addition to the remarkable external costs of transport and mobility as a consequence of GHG emissions, the damages caused by the affection of pollutants to human health is the largest in all schools. Local policies fostering the improvement of walking and bicycle networks towards achieving zero- or low-carbon mobility, and healthier air quality on cities are essential for the transition to a sustainable life in schools of the urban areas.

A survey-based study carried out in a Chinese university [34] found that the average annual carbon footprint was 3.84 tons of CO_2 eq. per student and year, with 65% attributable to daily life (a wide range of activities including, dining, showering, etc.), 20% to transportation, and 15% to academic tasks. Specifically related to the school system scope (as defined in this research), they found a mean CC impact of 240 kg CO_2 eq./student·year for daily commuting; 100 kg CO_2 eq./student·year for library and classroom; and 410 kg CO_2 eq./student·year attributable to computer use, scanning, and printing. As previously discussed, results of CC impact are closely linked to energy consumption and the characteristics of the Chinese system (coal-fired and power-based).

In the present study, regarding to the pure educational activities needed for teaching and learning, the innovative technological alternative to avoid printed books undertaken in the school S2 have proved to be a powerful tool in reducing CC impacts associated with student activity.

The analysis carried out has the ultimate objective of identifying the key activities that influence the environmental performance of schools to focus efforts that can achieve low-carbon economy goals and reduce negative environmental impacts and costs. Based on the results obtained in this work, several measures have been identified with the potential to reduce environmental impacts. These measures are as follows:

- PV electricity: substitution of grid power by the installation of photovoltaic panels for electricity production in the schools
- Reduction in paper use and increase in recycling: this measure is aligned with the minimization in material consumption, reduction in paper consumption for teaching and administrative issues, and increase in the use of recycled paper
- Changes on mobility: substitution of daily commuting by car and motorbike, used by teachers and students, by public transport
- Correct electronic waste management, especially when substituting luminaires.
- Select low-carbon transport means for school outings
- Substitution of heating boilers with electric heat pumps
- Building retrofitting solutions [54,55] to reduce energy demand
- Replacement of luminaires with LED [55]
- Reusing books or adopting IT devices use to foster paperless education.

Limitations and assumptions made in the study, mainly related to methodological uncertainties and the complexity of the system, has to be taken into account when interpreting these results. For instance, this study excludes the impact of the food production because there was a lack of quality data in schools. In addition, this study deeply considers the social and economic context of development as a parameter for explaining patterns given that public schools in Spain and Portugal have similar levels; however, studies have found existing relationship between energy consumption and level of wealth [56], as well as differences in the consumption patterns (for instance, lighting energy consumption is a higher contributor in poor schools than in affluence schools). The measures implementation must be joined to the awareness, participation, and learning. Gained knowledge can help in selecting the best environmental measures to implement in the specific educative center according to climate and economic context [51].

Although the results of the study are framed within the Spain and Portugal conditions (climate, buildings structure, energy consumption, mobility type, etc.), and therefore the associated environmental impacts are greatly influenced by them, some of the outcomes can be generalized and be useful for other countries, taking into account the variability in all these variables. In the same way, measures to be applied to advance in the path towards low-carbon schools present a wide range of possibilities to be implemented in the different educational contexts around the world. Beyond the direct potential benefits of the implementation of measures that lead to a reduction in the environmental impact in schools, other economic and social implications associated with the transition to a new global model could arise. This is even more relevant when public investment in low-carbon solutions are proposed, given the interrelation along the value chain between green financial behavior, climate change mitigation, and environmental energy sustainability [57]. There is a positive impact on environment improving, but also a risk related to the different access to improvements or inequities regarding environmental quality for heterogeneous levels of economic development [58].

The COVID-19 crisis has led to new alternatives on digitization and a higher use of resources in schools, on mobility and transportation, and on new modes of teaching and learning. In this period, the demands in situ in schools have changed substantially. Some of these changes may be sustained over time. Future lines of research in the field of evaluating the environmental implications of schools and students could be devoted to evaluating the advantages and disadvantages for environmental performance of the changes induced by the pandemic.

6. Conclusions

This paper has contributed to deepen the knowledge of the environmental impacts of schools as complex systems involving a wide range of activities. Various environmental impacts were calculated, and associated external costs, the relative relevance of school buildings, teaching activities, and transportation activities were also identified.

This assessment was performed in five very different schools of the Iberian Peninsula, in the Southwestern Europe. The active participation of school agents as primary data providers was crucial in completing the inventory of all incoming and outgoing energy and material flows that cross the boundaries of the school system.

Results have shown that differences in climatic conditions may have a very important effect on the size of the impacts, mainly due to differences in heating requirements. Differences in teaching methods are also an important parameter. Alternative teaching techniques based on the use of IT devices have revealed a very powerful tool in reducing the environmental impact of school activities. Furthermore, the use of toner in printers and the manufacturing of electronic equipment are also important aspects in human-health-related impacts. Transport activities in daily commuting and school outings can be responsible for a high share of the impacts, especially if commuting is made by car and schools outings involve the use of long-distance flights. The management of wastes related to luminaire replacement is also a point of concern since an improper treatment could lead to high environmental costs.

These results have served to identify some potential mitigation measures that involve the use of renewables, the substitution of heating equipment and luminaires, the retrofitting of school buildings, changes in educational practices towards the reduction in the use of paper, the use of printers and books, and changes in mobility patterns towards the use of a more sustainable means of transport.

The external environmental costs caused by each student in an academic year have been quantified at an average value of EUR 20. This seemingly small amount serves to point out the fact that student activities are not without harm to the environment. Proper communication of these findings to the involved educational communities could drive the necessary behavioural changes toward a more sustainable educational system.

However, this research is not without its limitations. LCA studies depend on system definition and boundaries and model the real world by undertaking assumptions, using databases, scenarios and methods of quantification. As a consequence, there could be an important degree of uncertainty in the results. To this extent, we have ensured good-quality data collection and a detailed characterization of the system to address this limitation. These limitations must be taken into account when interpreting these results.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/en14196238/s1, those are excels files which consist of the input data collected for the inventory building. Appendix A consists of the list of pollutants considered for EC calculation, as well as the corresponding individual damage factors in monetary units. In the Appendix B the environmental and social results by the school' subsystems and activities are presented in graphs in order to complement the tables stated in the Results section with the aim of complement those and facilitate the interpretation.

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Institutional Review Board Statement: All representatives of schools gave their informed consent for inclusion before they participated in the study. Behavioral data of schools community participants was collected by using non-interventional methods (surveys, questionnaires, etc.) assuring anonymity. The study was conducted in accordance with the protocol of data collection and according to the Ethics Management Plan included in the Quality management plan of the (ET93.3.1) of the Climact Project (SOE1/P3/P0429).

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