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School's Low Carbon Economy | Key-Performance Indicators

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ABSTRACT

With society development raises the concern with the climate change and many measures have been taken to build knowledge as well as to provide answers. The Interreg Sudoe ClimACT project, developed in a context of international and interdisciplinary cooperation, emerges with the objective of creating a systematic methodology, with its own tools, that will lead schools in their transition to a Low Carbon Economy (LCE).

The methodology is developed in a research-action project in 39 pilot schools, from several climatic zones, with distinct languages and different levels of education, providing real scenarios for the evaluation, optimization, calibration and validation of its tools. Using key performance indicators (KPI), an initial environmental and energy characterization of schools is being done, which has been defined as a reference for use in benchmarking with other schools. In this work, it is presented the characterization of six schools that had a fundamental role in the calibration of the tools.

The results show a reality with a long journey ahead, where none of the schools exceed 2.6 values, on a scale of 0 to 5. There is room for implementation of measures in the various sectors analysed, with two - residues and energy - attractive for external investment and the rest of the sectors - transport, green space, sustainable demand, water and indoor air quality – can be optimized with the participation of parents and the local community.

1. Introduction

Along the years an increase in the concentrations of a set of gases emitted by human activity has been reported. Since 1988 the Intergovernmental Panel on Climate Change (IPCC)[1], has produced five reports on climate change reflecting on its patterns, warning that the last 40 years had recorded the greatest thermal rise ever and for the consequences that ensue [1].

The most important gases, mentioned to in the Kyoto Protocol[2], are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphurhexafluoride (SF_6)[2].These gases, because they interfere with the normal patterns of radiation exchanges between Earth and outer space, are called Greenhouse Gases (GHG).

CO_2 is known as the main GHG because it accounts for most of the total anthropogenic emissions. This gas is mainly emitted by the burning of fossil fuels in road transport and from the production of electricity and heating. CH_4 is mainly emitted by the enteric fermentation of cattle and by the anaerobic decomposition of residues. The main sector emitting N_2O is agriculture, resulting from microbial activity in soil and water, and a small part is distributed through water treatment, transport and industry sector, among other sectors. F-gases are mostly emitted during the operation of refrigeration and air-conditioning equipment and the second most polluting anthropogenic activity is the use of aerosols [3].

The Low Carbon Economy (LCE), raised in this context of search for answers to the impact that human activities have on the ecosystem and on the public health. Many efforts have been made to find the best procedures in each sector of human

[1] IPCC is an organization dedicated to scientific, technical and socio-economic information for the understanding of climate change, which currently comprises of 195 countries.
[2] Kyoto Protocol to the United Nations Framework Convention on Climate Change was made in 1998 to oblige each country to quantify emissions reduction.

activity and to find the best methodology to evaluate the impacts of each procedure in the performance of the sector in terms of its emissions.

This work intends to be the narrative of the project Interreg Sudoe ClimACT, whose main goal is to develop a systematic methodology, with its own tools, to support the schools in their transition to a LCE. The project is promoted by a European initiative, the Interreg Sudoe program, whose priority is to contribute to a more effective energy efficiency policy in a context of international and interdisciplinary cooperation.

The project's partnership, coordinated by the Centre for Science and Nuclear Technologies of the Instituto Superior Técnico (C^2TN/IST), was designed to bring together the resources and areas of knowledge needed to develop this methodology. The team comprises 45 entities – scientific research teams, local authorities, non-governmental organizations and bodies specializing in audits and cost-benefit analyses – from the four countries of the Sudoe region - Portugal, Spain, France and Gibraltar.

Segregating the school as a system of seven sectors – transports, green spaces, green procurement, indoor air quality, waste, water and energy –, the ClimACT defined sets of Key Performance Indicators (KPIs) that best describe the contribution of each sector to a better performance of schools. At the end, these KPIs allow comparative evaluations between a reference situation characterized in the beginning of the project and the one verified at the end of the project, after the implementation of measures identified during the initial phase.

2. Methodology

The ClimACT project has scheduled its intervention in three major phases: (1) construction of the guides and methodological tools simultaneously with the audits to characterize the reference situation, which should result in a report with improvement measures to be implemented; (2) implementation of measures; (3) project impact assessment and validation of the transition methodology for an LCE. In this dissertation, the initial diagnosis and construction of the methodology will be carried out according to what was foreseen in the first phase of the ClimACT project.

At the beginning of this first phase, the ClimACT project started with the involvement of the school community, which included students, teachers, staff, school administration and local authorities. A sample of 39 pilot schools in the Sudoe region, with different climatic zones, different languages and different levels of education, provided real scenarios for the evaluation, optimization, calibration and, finally, validation of the KPIs. Subsequently, the audits were initiated, which allowed the collection of the necessary data, followed by a comparative evaluation of the schools, through the use of benchmarking practices, resulting in the proposal of a set of measures to implement. In the present work, only six ClimACT schools are evaluated, since the remaining audits are still in progress.

That benchmarking technics (applied within the pilot-schools) allowed the attribution of one score to the KPI obtained by the school, on a scale from zero to five, allowing them to be compared with each other. The classification of zero was attributed to the most unfavourable situation and the classification of five attributed to the most favourable. A margin of 5% was given to ensure improvements in schools that present the best score. Then those scores were used to calculate a final score of the sector, using weighted averages. Finally, an arithmetic mean was calculated using the final scores of each sector, resulting in a final score of the energetic and environmental performance of each school. The sectors and the formulas to calculate the KPIs and their scores are synthetized in Table 1 and 2, respectively.

Table 1 – Calculation formulas for the KPI

Sector	KPI designation	KPI calculation
Transports	Charging stations for electric cars	(1) $KPI_{T1} = \frac{\text{nr of charging stations for eletric cars}}{\text{nr of students}}$
	Parking places for bicycle	(2) $KPI_{T3} = \frac{\text{nr of parking places for bicycle}}{\text{nr of students}}$
	Public Transports	(3) $KPI_{T4} = \frac{\text{nr of public transports within a 1000m radius}}{\text{nr of students}}$
	CO_2 annual emissions	(4) $PE_i = \frac{(\#_{never} \times 0 + \#_{almost\ never} \times 1/3 + \#_{almost\ always} \times 2/3 + \#_{always} \times 1) \times \text{nr of persons of the school}}{\text{nr of persons that answered to the questionnaire}}$ Where: i = transport mean (motorbike; car; boat; tram; train; subway; bus; bicycle; on foot); PE_i = person equivalent of the transport mean i. (5) $CO_{2\ i} Emissions = \sum_i (FE_i \times PE_i) \times \text{daily average distance} \times 22 \times 10$ Where: $CO_{2\ i}$ Emissions = Annual emissions associated to the transport mean i. FE_i = emission factor of the transport mean i [4]. (6) $KPI_{T5} = \frac{\sum_i CO_{2\ i} \text{ Emissions}}{\text{nr of students}}$
Green Spaces	Trees per non-covered area	(7) $KPI_{GS1} = \frac{\text{nr of trees}}{\text{non-covered area}}$
	Trees per student	(8) $KPI_{GS2} = \frac{\text{nr of trees}}{\text{nr of students}}$
	Green area per non-covered area	(9) $KPI_{GS3} = \frac{\text{green area}}{\text{non-covered area}}$
	Green area per student	(10) $KPI_{GS4} = \frac{\text{green area}}{\text{nr of students}}$
	Annual usage of chemicals per green area	(11) $KPI_{GS5} = \frac{\text{quantity of fertilizers and pesticides}}{\text{green area}}$
	Annual CO_2 sequestration per non-covered area	(12) $KPI_{GS6} = \frac{\text{nr of trees} \times SR_{dominant\ species} + \text{lawn area} \times SR_{lawn}}{\text{non-covered area}}$ Where: SR = sequestration rate [5].
	Annual CO_2 emissions per green area	(13) $KPI_{GS7} = \frac{\text{Combustível} \times FE_{fuel} + \text{water} \times FE_{water} + \text{electicity} \times FE_{electricity}}{\text{green area}}$ Where: FE = factor emission [4].
	CO_2 annual emissions	(14) $KPI_{GS8} = \frac{KPI_{EV7} \times \text{green area} - KPI_{EV6} \times \text{non-covered area}}{\text{nr of students}}$
Green Procurement	Equipment efficiency	(15) $KPI_{GP1} = \frac{\text{nr of equipment A+ or higher EU energy label}}{\text{total nr of equipments}}$
	Recycled paper	(16) $KPI_{GP2} = \frac{\text{quantity of recycled paper}}{\text{total quantity of paper}}$
	Biological food	(17) $KPI_{GP3} = \frac{\text{quantity of food with biological certificate}}{\text{total quantity of food}}$
	Eco driving certification	(18) $KPI_{GP4} = \frac{\text{nr of employees with eco-driving certificates}}{\text{total nr of employees}}$
	Training in green procurement	(19) $KPI_{GP5} = \frac{\text{nr of employees with training in green procurement}}{\text{total nr of employees}}$
	Local suppliers	(20) $KPI_{GP6} = \frac{\text{nr of local suppliers}}{\text{total nr of suppliers}}$
IAQ	**Vent**	(21) $KPI_{I_{vent}} = \frac{\sum_i \delta_{CO_2\ i}}{n}$ Where: i = observation 1 to n; n = number of observations; $\delta_{CO_2\ i}$= 1 if $[CO_2]$ > limit value, else $\delta_{CO_2\ i}$= 0 [6]; $0 < KPI_{Vent} < 1$; KPI_{Vent}=0 if there is none transgression to the limit value; KPI_{Vent}=1 if the limit value is exceeded in all observations.
	QAI	(22) $I_p = \frac{C_p - VL_p}{VL_p}$ Where: p = pollutant (CO_2; CO; TCOV; CH_2O; PM; CH_2O; C_6H_6; C_2Cl_4; C_2HCl_3; $C_6H_4Cl_2$; C_2H_4O; C_3H_4O; C_7H_8; C_8H_8; (m+p+o)-$C_6H_4(CH_3)_2$; C_8H_{10}; $C_{10}H_{16}$); I_p = pollutant p; Cp = average concentration of pollutant p; VL_p = limit value of pollutant p [6] [7]. (23) $KPI_{IAQ} = \frac{\sum_p \delta_p}{n}$ Whereby: n = number of pollutants; δ_p = 1 if C_p > VL, else δ_p = 0; $0 < KPI_{QAI} < 1$; KPI_{QAI}=0 se if there is none transgression to the limit value; KPI_{QAI}=1 if the limit value is exceeded in all observations.

Table 1 – Calculation formulas for the KPI (continuation)

Sector	KPI designation	KPI calculation
Waste	Weekly production of urban solid waste (USW)	(24) $\mathrm{KPI_{R1}} = \frac{\text{weekly production of USW}}{\text{nr of students}}$
	Weekly production of recyclables	(25) $\mathrm{KPI_{R2}} = \frac{\text{weekly production of recyclable waste}}{\text{nr of students}}$
	Weekly production of reusables	(26) $\mathrm{KPI_{R3}} = \frac{\text{weekly production of reusable waste}}{\text{nr of students}}$
	CO_2 annual emissions	(27) $\mathrm{KPI_{R4}} = \frac{\sum_i(\text{weekly production of waste}_i \times \mathrm{FE}_i \times \text{density}_i)}{\text{nr of students}} \times \frac{22\times10}{5}$ whereby: i = type of waste (paper, plastic, undifferentiated, organic); FE_i = emission factor associated to the production of waste i [8] [9] [10] [11].
Water	Water consumption per useful area	(28) $\mathrm{KPI_{W1}} = \frac{\text{annual water consumption}}{\text{useful area}}$
	Water consumption per student	(29) $\mathrm{KPI_{W2}} = \frac{\text{annual water consumption}}{\text{nr of students}}$
	Water costs per useful area	(30) $\mathrm{KPI_{W3}} = \frac{\text{annual water costs}}{\text{useful area}}$
	Water costs per student	(31) $\mathrm{KPI_{W4}} = \frac{\text{annual water costs}}{\text{nr of students}}$
	CO_2 annual emissions	(32) $\mathrm{KPI_{W5}} = \frac{\text{annual water consumption} \times \mathrm{FE}}{\text{nr of students}}$ where: FE = emission factor associated to water consumption [4].
Energy	Energy consumption per useful area	(33) $\mathrm{KPI_{E1}} = \frac{\sum_i \text{annual consumption of eletricidade}_i + \sum_j(\text{annual consumption of fuel}_j \times \text{density}_j \times \mathrm{FC}_j)}{\text{useful area}}$ Where: i = type of electricity (provide by the grid; onsite produced); j = type of fuel (diesel; LPG; natural gas); FC_j = conversion factor to kWh of fuel j [12].
	Energy consumption per student	(34) $\mathrm{KPI_{E2}} = \frac{\sum_i \text{annual consumption of eletricidade}_i + \sum_j(\text{annual consumption of fuel}_j \times \text{density}_j \times \mathrm{FC}_j)}{\text{student}}$ Where: i = type of electricity (provide by the grid; onsite produced); j = type of fuel (diesel; LPG; natural gas); FC_j = conversion factor to kWh of fuel j [12].
	Percentage of renewable energy consumption	(35) $\mathrm{KPI_{E3}} = \frac{\text{annual consumption of grid electicity} \times 0.55 + \text{annual consumption of onsite produced renewable energy}}{\sum_i \text{annual consumption of eletricidade}_i + \sum_j(\text{annual consumption of fuel}_j \times \text{density}_j \times \mathrm{FC}_j)}$ Where: i = type of electricity (provide by the grid; onsite produced); j = type of fuel (diesel; LPG; natural gas); FC_j = conversion factor to kWh of fuel j [12].
	Percentage of onsite produced renewable energy consumption	(36) $\mathrm{KPI_{E4}} = \frac{\text{annual consumption of onsite produced renewable energy}}{\sum_i \text{annual consumption of eletricidade}_i + \sum_j(\text{annual consumption of fuel}_j \times \text{density}_j \times \mathrm{FC}_j)}$ Where: i = type of electricity (provide by the grid; onsite produced); j = type of fuel (diesel; LPG; natural gas); FC_j = conversion factor to kWh of fuel j [12].
	Energy costs per useful area	(37) $\mathrm{KPI_{E5}} = \frac{\text{energy annual costs}}{\text{useful area}}$
	Energy costs per student	(38) $\mathrm{KPI_{E6}} = \frac{\text{energy annual costs}}{\text{nr of studentss}}$
	CO_2 annual emissions	(39) $\mathrm{KPI_{E7}} = \frac{\text{annual electricity consumption} \times \mathrm{FE}_e + \sum_i(\text{annual consumption of fuel}_i \times \text{density}_i \times \mathrm{FC}_i \times \mathrm{FE}_i)}{\text{nr of students}}$ Where: i = type of fuel (diesel; LPG; natural gas); FC_i = conversion factor to kWh of fuel i [12] FE_e = emission factor associated to electrical energy consumption [13]. FE_i = emission factor associated to fuel i [13].

Table 2 – Calculation formulas, scenarios and weighting for the scores

Sector	Score designation	Score calculation	Less favourable scenario	More favourable scenario	Weighting for final score
Transports	Charging stations for electric cars	(40) $S_{T1} = \frac{KPI_{T1} \times 5}{1.05 \times \max(KPI_{T1})}$	Without charging stations	Highest KPI_{T2} found plus 5%	$\frac{1}{2}$
	Parking places for bicycle	(41) $S_{T2} = \frac{KPI_{T2} \times 5}{1.05 \times \max(KPI_{T2})}$	Without parking places	Highest KPI_{T3} found plus 5%	$\frac{1}{2}$
	Public Transports	(42) $S_{T3} = \frac{KPI_{T3} \times 5}{1.05 \times \max(KPI_{T3})}$	Without public transports	Highest KPI_{T4} found plus 5%	1
	CO_2 annual emissions	(43) $S_{T4} = = 5 - \frac{\text{school emissions} \times 5}{\text{emissions of 100\% of students going by car}}$	100% of the students go by car	100% of the students go on foot or by bicycle	2
Green Spaces	Trees per non-covered area	(44) $S_{GS1} = \frac{KPI_{GS1} \times 5}{1.05 \times \max(KPI_{GS1})}$	Without trees	Highest KPI_{GS1} found plus 5%	$\frac{1}{2}$
	Green area per non-covered area	(45) $S_{GS2} = \frac{KPI_{GS3} \times 5}{1.05 \times \max(KPI_{GS3})}$	Without green area	Highest KPI_{GS3} found plus 5%	$\frac{1}{2}$
	Annual usage of chemicals per green area	(46) $S_{GS3} = 5 - \frac{KPI_{GS4} \times 5}{\max(KPI_{GS4})}$	Highest KPI_{GS4} found	Without chemicals	1
	Annual CO_2 sequestration per non-covered area	(47) $S_{GS4} = \frac{KPI_{GS5} \times 5}{1.05 \times \max(KPI_{GS5})}$	Without sequestration	Highest KPI_{GS5} found plus 5%	0
	Annual CO_2 emissions per green area	(48) $S_{GS5} = 5 - \frac{KPI_{GS6} \times 5}{\max(KPI_{GS6})}$	Highest KPI_{EV7} found	Without emissions	0
	CO_2 annual emissions	(49) $S_{GS6} = \frac{(\max(KPI_{GS7}) - KPI_{GS7}) \times 5}{\max(KPI_{GS7}) - \min(KPI_{GS7}) \times 1.05}$	Highest KPI_{EV8} found	Lowest KPI_{GS7} found less 5%	1
Green Procurement	Equipment efficiency	(50) $S_{GP1} = KPI_{GP1} \times 5$	Without certified equipment	100% of certified equipment	3
	Recycled paper	(51) $S_{GP2} = KPI_{GP2} \times 5$	Without recycled paper	100% recycled paper	2
	Biological food	(52) $S_{GP3} = KPI_{GP3} \times 5$	Without training	100% trained employees	2
	Eco-driving certification	(53) $S_{GP4} = KPI_{GP4} \times 5$	Without certified employees	100% certified employees	1
	Training in green procurement	(15) $S_{GP5} = KPI_{GP5} \times 5$	Without certified employees	100% certified employees	2
	Local suppliers	(54) $S_{GP6} = KPI_{GP6} \times 5$	Without local suppliers	100% local suppliers	3
IAQ	Vent	(55) $S_{Vent} = 5 - \frac{KPI_{Vent} \times 5}{\max(KPI_{Vent})}$	Highest KPI_{Vent} found	Without exceedance of CO_2 limit value	1
	QAI	(56) $S_{IAQ} = 5 - \frac{KPI_{IAQ} \times 5}{\max(KPI_{IAQ})}$	Highest KPI_{IAQ} found	Without exceedance of limit values	2
Waste	Weekly production of urban solid waste (USW)	(57) $S_{R1} = 5 - \frac{KPI_{R1} \times 5}{\max(KPI_{R1})}$	Highest KPI_{R1} found	Without USW	2
	Weekly production of recyclables	(58) $S_{R2} = \frac{KPI_{R2} \times 5}{\max(KPI_{R2}) \times 1.05}$	Without recyclable waste	Highest KPI_{R2} found plus 5%	1
	Weekly production of reusables	(59) $S_{R3} = \frac{KPI_{R3} \times 5}{\max(KPI_{R3}) \times 1.05}$	Without reusable waste	Highest KPI_{R3} found plus 5%	1
	CO_2 annual emissions	(60) $S_{R4} = \frac{(\max(KPI_{R4}) - KPI_{R4}) \times 5}{\max(KPI_{R4}) - \min(KPI_{R4}) \times 1.05}$	Highest KPI_{R4} found	Lowest KPI_{R4} found plus 5%	1
Water	Water consumption per useful area	(61) $S_{w1} = \frac{(\max(KPI_{w1}) - KPI_{w1}) \times 5}{\max(KPI_{w1}) - \min(KPI_{w1}) \times 0.95}$	Highest KPI_{w1} found	Lowest KPI_{w1} found less 5%	$\frac{1}{2}$
	Water consumption per student	(62) $S_{w2} = \frac{(\max(KPI_{w2}) - KPI_{w2}) \times 5}{\max(KPI_{w2}) - \min(KPI_{w2}) \times 0.95}$	Highest KPI_{w2} found	Lowest KPI_{w2} found less 5%	$\frac{1}{2}$
	Water costs per useful area	(63) $S_{w3} = \frac{(\max(KPI_{w3}) - KPI_{w3}) \times 5}{\max(KPI_{w3}) - \min(KPI_{w3}) \times 0.95}$	Highest KPI_{w3} found	Lowest KPI_{w3} found less 5%	$\frac{1}{2}$
	Water costs per student	(64) $S_{w4} = \frac{(\max(KPI_{w4}) - KPI_{w4}) \times 5}{\max(KPI_{w4}) - \min(KPI_{w4}) \times 0.95}$	Highest KPI_{w4} found	Lowest KPI_{w4} found less 5%	$\frac{1}{2}$
	CO_2 annual emissions	(65) $S_{w5} = \frac{(\max(KPI_{w5}) - KPI_{w5}) \times 5}{\max(KPI_{w5}) - \min(KPI_{w5}) \times 0.95}$	Highest KPI_{w5} found	Lowest KPI_{w5} found less 5%	1

Table 2 – Calculation formulas, scenarios and weighting for the scores (continuation)

Sector	Score designation	Score calculation	Less favourable scenario	More favourable scenario	Weighting for final score
Energy	Energy consumption per useful area	(66) $S_{E1} = \frac{(\max(KPI_{E1}) - KPI_{E1}) \times 5}{\max(KPI_{E1}) - \min(KPI_{E1}) \times 0.95}$	Highest KPI_{E1} found	Lowest KPI_{E1} found less 5%	$\frac{1}{2}$
	Energy consumption per student	(67) $S_{E2} = \frac{(\max(KPI_{E1}) - KPI_{E1}) \times 5}{\max(KPI_{E1}) - \min(KPI_{E1}) \times 0.95}$	Highest KPI_{E2} found	Lowest KPI_{E2} found less 5%	$\frac{1}{2}$
	Percentage of renewable energy consumption	(68) $S_{E3} = KPI_{E3} \times 5$	Highest KPI_{E3} found	100% renewable energy	$\frac{1}{2}$
	Percentage of onsite produced renewable energy consumption	(69) $S_{E4} = KPI_{E4} \times 5$	Highest KPI_{E4} found	100% renewable energy	$\frac{1}{2}$
	Energy costs per useful area	(70) $S_{E5} = \frac{(\max(KPI_{E5}) - KPI_{E5}) \times 5}{\max(KPI_{E5}) - \min(KPI_{E5}) \times 0.95}$	Highest KPI_{E5} found	Lowest KPI_{E5} found less 5%	$\frac{1}{2}$
	Energy costs per student	(71) $S_{E6} = \frac{(\max(KPI_{E6}) - KPI_{E6}) \times 5}{\max(KPI_{E6}) - \min(KPI_{E6}) \times 0.95}$	Highest KPI_{E6} found	Lowest KPI_{E6} found less 5%	$\frac{1}{2}$
	CO_2 annual emissions	(72) $S_{E7} = \frac{(\max(KPI_{E7}) - KPI_{E7}) \times 5}{\max(KPI_{E7}) - \min(KPI_{E7}) \times 0.95}$	Highest KPI_{E7} found	Lowest KPI_{E7} found less 5%	1

Radar graphs were generated for each school to compare the values of each school with the average score of the six schools. In this way, it is possible to have a graphical reading of the performance of each school in relation to the average of the schools. The assessment will be communicated to the school through an audit report where it is possible to observe the distance that each school is from an ideal LCE. The measures to be implemented to improve its performance will be included in the report, as well as the guidelines for their implementation. Furthermore, it will be possible in the future to compare the reference situation of each school with the situation reached after the implementation of the measures identified by the project.

3. Results

According to the targets established by the ClimACT project, one can conclude that the schools have made half of the way to the desired transition to a LCE. Only one school scored 2.6, whereas the others got from 1.8 to 2.2.

Regarding carbon balance among the five sectors whose emissions were accounted (Figure 1), it can be observed that the sources impact is bigger than compensation achieved by the sinks. In E3, E4 and E6, the greatest source of emission is the students' travels, followed by energy consumption. In E1, E2 and E5 the main source of emission is the energy consumption and secondly is the travels.

Also through the carbon balance, it can be concluded that emissions associated with water consumption and waste production are almost negligible and that the most polluting sector varies from school to school, between transport and energy. In this way, it is concluded that schools contribute above all to CO_2 and N_2O, that are the main pollutants emitted by that sector. Once again, attention must be drawn to the fact that the emissions associated with green procurement have not been taken into account, for example, emissions from the cleaning products that are the main sources of F-gases.

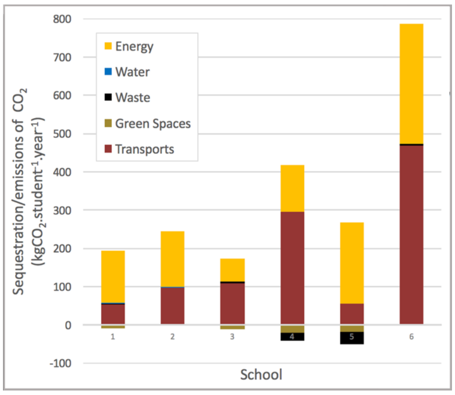

Figure 1 – Carbon balance.

The radar graphs generated for the scores obtained for the various sectors in each school and for the average of the six schools are presented in Figure 2.

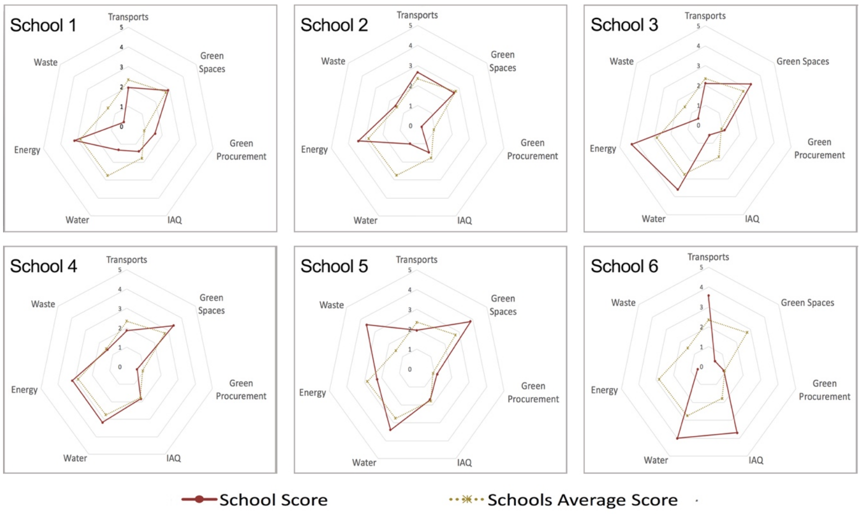

Figure 2 – Score discriminated by sector and benchmarking.

School 1 is significantly below the average in water and waste sectors and slightly below in transports and IAQ. In School 2 the water sector and green procurement are lower than the average. In School 3 it is possible to see IAQ and waste sectors below the average. School 4 and School 5 are the ones that present the best results, with School 4 presenting only two sectors slightly lower (transports and green procurement), and School 5 with two sectors slightly below (transports and energy) and with one sector much higher than the average (waste). School 6 appears with the green spaces and energy sectors below the average and for the residues no comparison is made since data were not available yet.

Regarding the general characterization of each sector some results must also be pointed out.

For the transports sector, it should be mentioned that although many students travel by car (24%), the pedestrians and bikers represent a big percentage of the students (45%). The results also show that the choice of the mean of transportation happens regardless of the offer of public transports. Nevertheless, it can be influenced by precarious conditions offered to pedestrians and bikers and by the risk perception that parents have concerning the travel mode used by their children.

With regards to green spaces, a very low efficiency of the management of the non-covered area (the total area without the buildings) must be pointed out, both in terms of its vegetation density and in terms of its sequestration rate. Only two schools have pedagogical gardens and in the remaining ones only one member of the staff takes care of the green spaces.

In the green procurement sector, it was not possible to find the energetic classification of much of the electronic equipment, the sources of many purchases are completely unknown and there is no training among staff concerning this issue.

The indoor air quality (IAQ) results show, in general, a bad quality with only School 6 presenting a better result due to its mechanic ventilation system. In fact, the natural ventilation system is not enough to remove the pollutants and the cleaning and classroom timetable do not promote the best IAQ, even in School 6. The pollutants with a higher exceedance to the limit value are the CO_2, the total volatile organic compounds (TVOC) and the particulate matter (PM).

Since 2014 a contest of recyclables had been promoted by the local waste company and the local authority, which already started to lead the waste sector into a LCE. Nevertheless, there are no curricular projects that aim to reuse the waste in some kind of activity or good. The only exceptions happen in two schools where the organic waste is used as compost in their agriculture experiences and gardening clubs.

The water distribution network did not present any kind of saving or appliances in five of the schools analysed and one have devices for tap water saving and bottles inside flushing systems. None of the schools have retention devices for rain water installed. Despite that, the water sector obtained the best scores and its emissions are almost negligible comparing to the other sectors.

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The energy sector also presents a low effort in procedures to achieve a LCE. There is no renewable energy produced onsite except from the case of one school that uses renewables to heat the water. The heating and cooling systems are not according to the occupants needs and the illumination is not according to a LCE, since there are no movement sensors or other saving procedures. The energy consumption during the month that schools are closed suggests that plug load equipment has been left in hibernation mode, revealing bad habits in what concern a better LCE.

From the analysis of the results it is possible to conclude that there is room for implementation of measures in the various sectors of the schools analysed.

1. Improvement measures

The improvement measures can be grouped in two categories: one that promotes better conditions of the infrastructures and another that aims to disseminate a LCE among the school community.

Regarding the infrastructures: i) in the transports sector the mobility conditions for pedestrians and bikers and safety routes for students must be incremented and planned with parents; ii) in the green area sector the potential for green areas of the non-covered area must be monitored, having in mind carbon sequestration rates of the vegetation; iii) staff training must occur and control systems for suppliers should be implemented; iv) the HVAC systems should have maintenance and different type of temperature regulation systems should be pursued; v) the waste collection must be extended in terms of the type of wastes collected (light bulbs and waste of electric and electronic equipment (WEEE)) and in terms of users (habitants and local commerce); and finally vi) saving devices should be installed in both water and energy sector, as well as retention water systems and renewable energy production systems.

All these measures will not succeed without proper dissemination of correct procedures in a LCE. A process of transition conducted without the involvement of the parents may never achieve the desired LCE. It is necessary to create new habits, through dynamic and appealing platforms and events to attract young people and their parents, where all can contribute to the design of the LCE procedures in the several sectors. That can be made by planning safety routes with them, by planting trees offered by them, or through the promotion of training courses and events organized for or by them, regarding those procedures.

Also, these many sectors can be managed taking advantage of their potential as pedagogical tool. Thus, in science classes they can make furnaces or solar cars and small renewable energy production systems, identify the phases of water (solid, liquid and gaseous), identify sequestration rates of plants and impacts that the different sectors have on the ecosystems and natural resources, investigate the role of micro-organisms and the composting capacity of different materials. In mathematics classes the students can calculate the volumes and weight of waste production or energy and water consumed in their schools and homes and in language classes they can search for articles of good practices or write essays to express the opinion about the importance of implementation of a LCE.

Some sectors are attractive for external investment measures, mainly waste and energy sectors, where the right to explore commercially the energy produced onsite can be granted to the companies that make an initial investment in one system for the school.

2. Conclusion

Concerning the methodology, it must be said that this sample of schools served as a calibration of the KPIs calculation tool allowing to identify some aspects to improve. This is the case of KPIs in which a negative result was obtained leading to an adjustment in the calculations of their scores. With the total sample of 39 schools involved in the ClimACT project, new weaknesses can be identified, so that the tool can only be validated after calibration with the other schools.

It is also worth pointing out that for most of the scores the most favourable scenario corresponds to the KPI observed in the school that presented the best performance for the considerer sector increased forplus 5%. When other schools are included, the most favourable scenario can change and the values could be lower than the ones here presented.

Still regarding methodology, the conclusions are restricted to the universe of the sample studied (since the sample of this work consists of only six schools, it is not representative of the total universe of the schools), as well as the conclusions about the carbon balance are restricted to the five sectors in which emissions were accounted.

Regarding the schools analysed it can be said that there is an acceptance from the members of the school community involved - students, teachers and employees - to embrace the transition towards a LCE. All schools had some kind of environmental policy or got engaged in initiatives that led them to management improvements of certain sectors, but there is still a long way ahead to achieve the intended compromise.

Also, the parents and other scholar community members, such as suppliers, local authorities and gardening and catering companies, should be included in this transition. Not only does the LCE benefit from the engagement of the local community, but so will the community benefit from the ‘spillover’ effect that occurs with the procedures dissemination. The practices shared during awareness actions provide LCE tools to be used beyond the borders of the school.

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