UNIVERSIDADE LUSÓFONA

MARA DO CARMO CORREIA MONTEIRO

TRANSITION TO A LOW CARBON ECONOMY IN SCHOOLS: AN EVOLUTIONARY STUDY

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Abstract

Climate change has been one of the major issues facing our time. Achieving greenhouse gas (GHG) reduction targets and reaching carbon neutrality by transitioning to a Low Carbon Economy (LCE) are among many policies adopted to reduce carbon emissions in all areas and mitigate the impacts of climate change.

The Interreg Sudoe ClimACT Project was created to promote and support the transition to a LCE in schools by developing a methodology based on application of technical audits to assess schools' environmental and energy performances; benchmarking of schools based on the implementation of Key Performance Indicators (KPI); and environmental and energy assessment based on scores created by the project. This thesis, developed in the framework of this project, makes an evolutive comparative analysis of the performance of six Portuguese ClimACT schools and assesses if the methodology applied conducted the schools in a pathway to a LCE.

Results show that out of a score of 0 to 5, the average score of all sectors for all six schools was 2.1 and 2.2 before and after implementation of improvement measures, respectively. This mere increase of 0.1 indicates that there is room for more improvements, particularly in mobility and green procurement sectors.

Key words: Greenhouse Gas; Low Carbon Economy; Key Performance Indicators; Environmental and Energy performance; ClimACT.

Resumo

As alterações climáticas têm sido dos principais problemas a enfrentar na atualidade. Alcançar as metas de redução de gases de efeito estufa (GEE) e a neutralidade carbónica por meio da transição para uma Economia de Baixo Carbono (EBC) são apenas das muitas políticas adotadas para reduzir as emissões de carbono em todas as áreas e mitigar os impactos das alterações climáticas.

O Projeto Interreg Sudoe ClimACT foi criado para promover e apoiar a transição para uma EBC nas escolas através do desenvolvimento de uma metodologia baseada na aplicação de auditorias técnicas para avaliar o desempenho ambiental e energético das escolas; através do *benchmarking* de escolas com base na implementação de indicadores-chave de desempenho (KPI); e através da avaliação ambiental e energética com base em pontuações criadas pelo projeto. Esta dissertação, desenvolvida no âmbito deste projeto, faz uma análise comparativa e evolutiva do desempenho de seis escolas portuguesas do ClimACT e avalia se a metodologia aplicada conduziu as escolas a um caminho de uma ECB.

Os resultados mostram que, de uma pontuação de 0 a 5, a pontuação média de todos os setores para as seis escolas foi de 2,1 e 2,2 antes e depois da implementação das medidas de melhoria, respetivamente. Este mero aumento de 0,1 indica que há espaço para mais melhorias, particularmente nos setores da mobilidade e compras verdes.

Palavras chaves: Gases de feito estufa; Economia de Baixo Carbono; Indicadores Chave de Desempenho; Desempenho Ambiental e Energético; ClimACT.

List of Acronyms and Abbreviations

AR4 – Fourth Assessment Report

AR5 – Fifth Assessment Report

ASBEC - Australian Sustainable Built Environment Council

BMS – Building Management System

CFC – Chlorofluorocarbons

CH_4 – Methane

CO – Carbon monoxide

CO_2 – Carbon dioxide

CO_2e - Carbon dioxide equivalent

DCSF – Department for Children, Schools and Families

EDP – Energies of Portugal

EEA – European Environment Agency

EPA – United States Environmental Protection Agency

EU – European Union

FAO – Food and Agriculture Organization of the United Nations

GHG – Greenhouse Gas

GPP – Green Public Procurement

GWP – Global Warming Potential

H_2CO_3 – Carbonic acid

HC - Hydrocarbons

HCFC - Hydrochlorofluorocarbons

HFC – Hydrofluorocarbons

IAQ – Indoor Air Quality

IEA – International Energy Agency

INTOSAI – International Organization of Supreme Audit Institutions

IPBES - Intergovernmental Science Policy Platform on Biodiversity and Ecosystems Services

IPCC – Intergovernmental Panel on Climate Change

IWA – International Water Association

KPIs – Key Performance Indicators

LC – Low Carbon Coordinator

LCB – Low Carbon Brigades

LCC – Low Carbon Committee

LCE – Low Carbon Economy

LED – Light-Emitting Diode

Mt – Metric tons

NASA - National Aeronautics and Space Administration

NCEI – NOAA's National Centers for Environmental Information

NO_x – Nitrous oxides

NOAA – National Oceanic and Atmospheric Administration

NWF – National Wildlife Federation

OCE – Office for Climate Education

OECD - Organization for Economic Co-operation and Development

OHC – Ocean Heat Content

PE – Person Equivalent

PFC – Perfluorocarbons

PwC – PricewaterhouseCoopers

PM – Particular Matter

ppm – Parts per million

PSR – Pressure-State-Response

RNBC – National Low Carbon Roadmap

RSC – Regions for Sustainable Change

SALL – Schools As Living Labs

SDGs – Sustainable Development Goals

SERC – Science Education Resource Center

SF_6 – Sulfur Hexafluoride

SO_x – Sulfur oxides

SOER – The European Environment – Sate and Outlook

SR – Sequestration Rate

UN – United Nations

UNEP – United Nations Environment Programme

UNESCO – United Nations Educational, Scientific and Cultural Organization

UNFCCC – United Nations Framework Convention on Climate Change

UNICEF – United Nations International Children’s Emergency Fund

UniSA – University of Australia

USW – Urban Solid Waste

VOC – Volatile Organic Compound

WHO – World Health Organization

WMO – World Meteorological Organization

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1. INTRODUCTION

1.1 Motivation

Over the years climate change has become a major global issue as overwhelming evidence point to human influence as the primary source. Increase in greenhouse gas emissions from anthropogenic activities has led to the enhancement of the greenhouse effect, causing a rapid rise in global temperatures. As a result, we are seeing a disruption in the earth's climate system that is threatening ecosystems and human health, but despite having identified the problem, atmospheric concentrations of carbon dioxide (CO_2) remain high (Anderson et al., 2016; Pandey et al., 2010).

The world remains on course to exceed the agreed temperature thresholds of either 1.5 °C or 2 °C above pre-industrial levels, objective set by the Paris Climate Accord, increasing the risk of pervasive effects of climate change which could have major environmental, social, and economic impacts (WMO, 2020b). With the goal of achieving the 2030 Climate Target Plan of cutting greenhouse gas emissions by at least 55% by 2030, all sectors of the economy and society can and should contribute to reduction targets (European Commission, 2020a).

The education sector has an important role in reducing emissions and mitigating climate change. Studies have shown that school buildings are essential in reducing carbon emissions as they consume a significant amount of the total energy consumed across Europe (Lizana et al., 2018; Klein-Banai & Theis, 2013). Strategies such as transitioning to a LCE have been taken on by adopting practices and technologies that give emphasis to resource and energy efficiency (Luo et al., 2019; Jossen et al., 2018; RSC, 2011). Schools have an important responsibility in social awareness and show potential in moving towards an energy efficient and low carbon pathway (Lizana et al., 2018).

In this framework, a European initiative - the Interreg Sudoe ClimACT Project – was created to support schools in their transition to a LCE. The project, having international and interdisciplinary collaboration, developed a methodology aimed at contributing to greater effectiveness of policies on GHG emissions (d'Espiney, 2017). In hopes of being part of the solution, this thesis will evaluate the ClimACT methodology which consists of measuring the environmental performance of schools through measurable indicators in the sectors of mobility, green procurement, green spaces, energy, water, and waste (Lizana et al., 2021; d'Espiney, 2017).

By evaluating the impact of the ClimACT methodology, i.e., if the tools provided by the project led to a low carbon pathway, this thesis falls in line with the 17 Sustainable Development Goals (SDGs) proposed in the 2030 Agenda for Sustainable Development, with emphasis on Quality Education, Renewable and Accessible Energies, Sustainable Cities and Communities, and Climate Action (SDGs 4, 7, 11 & 13) (ClimACT, 2019b; UN, 2015).

1.2 Aims and Objectives

The present thesis aims to evaluate six ClimACT schools located in Portugal, regarding their environmental and energy performance. Therefore, this thesis will seek the following objectives:

- assess the behaviour evolution of the school community in question (teachers, students and staff) through the application and analysis of behavioral questionnaires.
- analyze the evolution of schools in terms of environmental and energy performance over the years, through the application of technical audits.

1.3 Thesis Outline

This thesis consists of six main chapters which will be subsequently described in this section.

The first chapter consists of an introduction explaining the motivation behind this thesis by highlighting its relevance and putting into context its purpose, aims and objectives, as well as an outline.

The second chapter contains a literature review which will be crucial in understanding the importance behind this study. The chapter begins with a background in greenhouse gases and how they contribute to climate change and global warming; the effects that global warming has on society and the environment, and how climate change became an emerging issue. It also includes concepts of low carbon economy and the role of the education sector in reducing carbon emissions, following up with a previous study on environmental and energy audits in schools. The chapter continues with a description of the ClimACT Project and discusses the importance of each sector and how they contribute to CO_2 emissions, along with an illustration of calculations of key performance indicators and scores.

The third chapter discusses the applied practical methodology of the case study on which this thesis is based – Portuguese ClimACT Schools – as well as the methodology used for this thesis. It begins with a brief description of the schools in question and describes the method of evaluation used in assessing environmental and energy performances.

The fourth chapter contains an evaluation of the results and a comparative analysis containing the two-year progress.

The fifth chapter concludes this thesis by assessing if the methodology was a success, while highlighting important results and gives recommendations for improvements.

The sixth and final chapter consists of future perspectives.

2. BACKGROUND

2.1 Greenhouse Gases and Global Warming

Until the past 150 years, levels of greenhouse gases and global temperature had varied over time but had been quite constant throughout history. With the industrial revolution, abundances of GHGs increased significantly due to a shift in energy use that progressed from basic forms such as burning of biomass, to burning of fossil fuels - oil, coal, and natural gas (Nunez, 2019; Chatterjee, 1999). As the population increased, fossil fuel energy is what fundamentally drove progress in technological, social and economic development and maintained a dominant role in global energy systems throughout the years (Ritchie & Roser, 2017). Today, fossil fuels are the primary source of carbon emissions and after more than two and a half centuries of use, the Earth's atmospheric concentration of CO_2 has increased from 278 parts per million to almost 414 parts per million (ppm) (figure 1) (Betts, 2020).

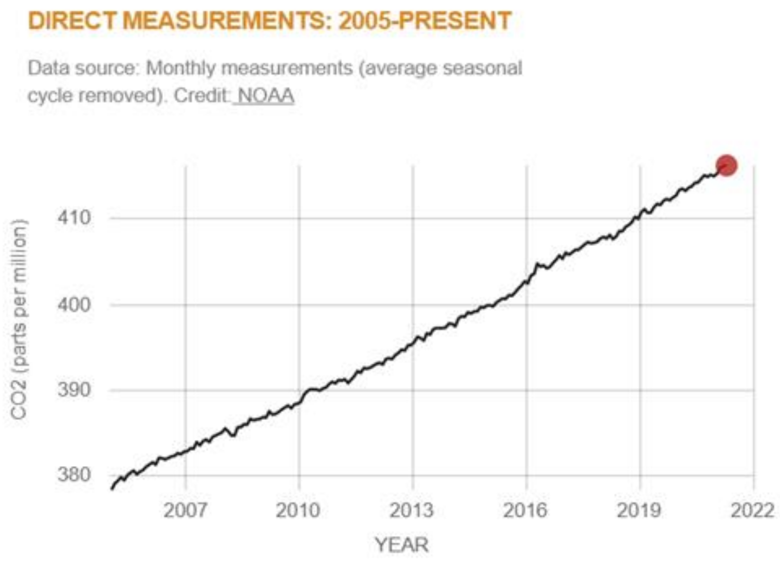

Figure 1 - CO_2 levels measured at Mauna Loa Observatory, Hawaii, in recent years.
source: climate.nasa.gov

As stated in the first Intergovernmental Panel on Climate Change (IPCC) Assessment Report (1990), GHGs such as CO_2, methane (CH_4), water vapor and nitrous oxide (N_2O) occur naturally in the atmosphere and are able to keep the Earth warm so that it is habitable, but by increasing their concentrations and by adding new potent and long-lasting greenhouse gases like fluorocarbons from anthropogenic activities, we are increasing the global-average temperature and changing the climate (NOAA, 2021).

Carbon dioxide is known as the most significant GHG that contributes to emissions mainly from transportation, and production of electricity and heat. It is also emitted through solid waste, soil degradation and through natural processes such as respiration and volcanic eruptions (EPA, 2021). The World Meteorological Organization and Global Atmosphere Watch (2019, p. 3) states that "approximately 40% of methane is emitted into the atmosphere by natural sources (e.g., wetlands and termites) and about 60% comes from anthropogenic sources (e.g., cattle farming, rice agriculture, fossil fuel exploitation, landfills and biomass burning)". It also states that "N_2O is emitted from both natural (about 60%) and anthropogenic sources (approximately 40%), including oceans, soils, biomass burning, fertilizer use and various industrial processes" (The World Meteorological Organization and Global Atmosphere Watch, 2019, p. 6)

Fluorinated gases like chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), and hydrofluorocarbons (HFCs) are produced during the manufacturing of refrigeration and cooling products such as air conditioning equipment (European Commission, 2016). Land-Use and Land-Use Change (LULUCF) such as deforestation is another contributor of global warming and climate change due to its influence on carbon stocks and carbon sequestration, ultimately changing the CO_2 fluxes from and to the atmosphere (Portuguese Environment Agency, 2019a).

Each GHG that has a contribution to the warming effect varies in their ability to absorb energy and can remain in the atmosphere ranging from a few years to thousands of years (EPA, 2020; Durkee, 2006). To better understand the warming impact of each GHG, Vallero (2019, p. 180) explains that the Global Warming Potential (GWP) was developed to compare "(…) the amount of energy the emissions of 1 ton of a gas will absorb over a given time period, usually a 100-year averaging time, compared with the emissions of 1 ton of CO_2". Vallero further clarifies,

> "Because CO_2 has a very long residence time in the atmosphere, its emissions cause increases in atmospheric concentrations of CO_2 that will last thousands of years. Methane's average atmospheric residence time is about a decade. However, its capacity to absorb substantially more energy than CO_2 gives it a GWP ranging from 28 to 36. The GWP also accounts for some indirect effects; for example, CH_4 is a precursor to another greenhouse gas, ozone. The GWP of N_2O is 265–298 times that of CO_2, with an average residence time of 100 years. The CFCs, hydrofluorocarbons, hydrochlorofluorocarbons, perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6) are referred to as high-GWP gases, that is, GWP can be up to tens of thousands. For a given amount of mass, they hold substantially more heat than does CO_2" (2019, p. 180).

Far more CO_2 is being emitted than the Earth's natural physical and biological processes can remove from the atmosphere and although carbon-capturing methods are gaining popularity, their storage capacity falls short of the amount of CO_2 emitted every year (Mulhern, 2020; Lindsey & Gardiner, 2014). According to scientists from NOAA's National Centers for Environmental Information (NCEI) (NOAA, 2020), we have already seen the world's five warmest years all occur since 2015 due to accumulative concentrations of GHGs. Betts (2020) states that "if the build-up of CO_2 continues at current rates, by 2060 it will have passed 560 ppm – more than double the level of pre-industrial times", making it an international issue requiring worldwide studies and responses.

2.1.1 Effects of global warming

As previously mentioned, increase in GHGs is resulting in a warming climate that is having an adverse effect on the planet and population (Fletcher & Smith, 2020). The WMO State of the Global Climate provisional report (2020a) describes and monitors the changing climate by using 7 Global Climate Indicators : global mean surface temperature, extreme events, ocean heat content (OHC), sea level rise, glacial mass, sea ice extent, and ocean acidification. According to the Global Climate Observing System (GCOS) (2018), "the Global Climate Indicators are a set of parameters that describe the changing climate without reducing climate change to only temperature", containing key additional information pertinent to climate change domains.

The effects of warmer temperatures are causing ice sheets and glaciers worldwide to lose mass, causing sea ice cover in the Arctic to decrease and with less snow and ice, more of the sun's energy is absorbed by the ocean and land surface. A warmer atmosphere is also contributing to higher sea levels due to thermal expansion, which can have an impact on the quality and quantity of freshwater supplies due to saltwater intrusion (National Geographic, 2017). The report also states that "as providers of ecosystem services and freshwater supply to millions around the world, glacial loss has significant and direct impacts on both the global climate and sustainable development" (WMO, 2020a). In addition to melting glaciers, the increase in GHGs causes nearly 90% of excess energy to accumulate in the earth's system, threatening marine life and the communities that depend on it (WMO, 2020b).

Ocean acidification is another impact of rising CO_2 concentration. Carbon dioxide is increasing in the ocean at an equal scale to atmospheric levels, but it is accumulating in deep water at a quicker rate, absorbing around 23% of annual emissions, producing carbonic acid (H_2CO_3) and endangering organisms and ecosystem services (Fletcher & Smith, 2020; WMO, 2020b). This compromises food security (fisheries and aquaculture) and weakens coral reefs which shield the coastline, leaving coastal protection vulnerable (WMO, 2020b; National Geographic, 2017).

As certain regions become warmer, species are forced to migrate towards cooler environments and may not have enough time to adapt to new conditions. The Intergovernmental Science Policy Platform on Biodiversity and Ecosystems Services (IPBES) global assessment report (2019) says that human actions threaten the extinction of around one million species unless action is taken to reduce the intensity of drivers of biodiversity loss.

Rising temperatures have also contributed to more extreme weather, meaning intense major storms, floods, and heavy snowfall, as well as longer and more frequent droughts, creating agricultural challenges, habitat shifts and diminished water supplies. Along with creating new agricultural challenges, climate change can directly affect people's physical health. In urban areas, the warmer atmosphere creates an environment that traps and increases the amount of smog. This is because smog contains ozone particles which increase rapidly at higher temperatures and exposure to higher levels can cause health problems such as asthma, heart disease and lung cancer (OCE, 2018; Miller, 2017; National Geographic, 2017).

To avoid further consequences, the global temperature must be brought back down to what it was in pre-industrial times and to reach this achievement CO_2 must actively be removed from the atmosphere while promoting low carbon emission sources (IPCC, 2014).

2.2 Climate Change as an Emerging Issue

In the 1970s, environmental degradation and future depletion of resources were becoming a real concern. In response, the European Union (EU) found it necessary to create an environmental policy that can serve as a source of guidance for environmental plans to protect the environment. Two years later, after the United Nations (UN) Conference on the Human Environment, the UN Environment Programme (UNEP) was created, marking a turning point in the development of international environmental politics (UN, 2020; EEA, 2011). Mentions of phenomena such as acid rain, increased air pollution, excessive consumption of non-renewable resources, destruction of the ozone layer, soil contamination, biodiversity loss and extinction of some species gained consistency for more environmental concerns (Portuguese Environmental Engineering Association, 2009).

In the beginning of the 1980s there was a significant rise in temperatures resulting in a global climate shift (University of Plymouth, 2015) and by 1988 the global scientific consensus was that "the predicted changes in climate were significant enough to warrant action to curb greenhouse gases" (Drake, 2000, p. 1; Boehmer-Christiansen, 1993). That same year the IPCC was set up by the WMO and the UNEP to provide regular assessments of the scientific basis of climate change and its impacts and future risks as a basis for informed policy. As global warming became more prevalent, forecast of severe heat waves, droughts and extreme weather events were among possible ramifications predicted by researchers (Oreskes, 2018; IPCC, 2013).

The United Nations Framework Convention on Climate Change (UNFCCC) was adopted in 1992 with the objective of establishing GHG concentrations at a level that would prevent dangerous anthropogenic interference with the climate system. As the importance of sustainable development became more prominent, the UNFCCC created the Kyoto Protocol in 1997. This protocol became the first global agreement to reduce GHGs by committing industrialized countries and economies in transition to limit and reduce GHG emissions in accordance with agreed individual targets (UNFCCC, 2021). Other initiatives such as the Paris Agreement were put in place to strengthen the global response to dealing with the impacts of climate change by keeping a global temperature rise below 2 degrees Celsius above pre-industrial levels and supporting countries in their efforts (European Commission, 2020e).

To date, the IPCC has produced five assessment reports on climate change. The 2007 Fourth Assessment Report (AR4) states that "most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic GHG concentrations" (IPCC, 2007, p. 5). This conclusion was subsequently supported by the Fifth Assessment Report (AR5) released in 2014 (Huisingh et al., 2015).

Although European climate policies have made a significant improvement to the environment in the latest decades, it is still not making enough progress and the prospect for the coming decade is not looking good (EEA, 2019c). Available studies project increases in the frequency, duration, and severity of meteorological and hydrological droughts for most of Europe over the 21st century (Spinoni et al., 2018). It is therefore imperative that individuals, governments and industries support the development of alternatives that do not involve burning fossil fuels (National Geographic, 2011).

2.3 Low Carbon Economy

The concept of a low-carbon economy, also referred to as green economy or a decarbonized economy, emerged as a means for addressing climate change. The term was first published in 2003 in the Energy White Paper for the British Department for Trade and

Industry, «Our Energy Future - Creating a Low Carbon Economy» and was defined as low energy consumption, low environmental pollution, and low carbon emissions in full combination with economic, social, and ecological benefits (Rao et al., 2015; Department of Trade and Industry, 2003). The European environment state and outlook 2015 synthesis report (SOER) explains that,

> "(…) the emergence of resource efficiency and the low-carbon economy as European policy priorities is grounded in a recognition that the prevailing model of economic development based on steadily growing resource use and harmful emissions cannot be sustained in the long term" (EEA, 2015, p. 4).

The decarbonization of the energy sector is at the core of the low carbon solution (Fankhauser, 2012). In 2011 the European Commission set out key elements in the EU Roadmap for moving towards a low carbon economy by 2050, outlining a GHG reduction target of 80% (European Commission, 2011). It stated that energy efficiency will be a key driver in the transition process. In November 2018 the European Commission presented its new long-term strategy to reduce GHG emissions, in which it included eight different pathways to carbon neutrality, two of them reaching net-zero GHG emissions. The first five pathways focus on achieving the 80% GHG reduction target by better understanding how emissions reductions will affect our economic sectors; the sixth pathway integrates the cost-efficient GHG reduction opportunities from the first five pathways, while the seventh and eight pathways assess how climate neutrality can be achieved by focusing on carbon removal technologies and the circular economy, as societies become less carbon intensive (European Commission, 2019).

According to the EEA (2016), the EU will have to depend, in part, on its ability to bring in ample amounts of funding towards sustainable and innovative technology in order to reduce emissions, and that decisions on investments should take into consideration current and future impacts of climate change. It states that by building cities and infrastructures that can manage the impacts of a changing climate, more money can be saved in the future. There is also significant potential in the industry sector to reduce emissions through increased energy efficiency in production processes along with carbon capture and storage (European Commission, 2020a).

Public participation is critical for the implementation of low carbon activities. The IPCC mitigation report states that behaviour, lifestyle, and culture have considerable influence on energy use and associated emissions (IPCC, 2014). Therefore, as the energy consumer, individuals will have to alter their energy-related consumption patterns to be able to transition towards a sharing economy (Büchs et al., 2018; Schanes et al., 2016).

Carbon neutrality is a goal shared by all countries and has the potential to limit the extent of climate change and the associated damage it would cause (Portuguese Environment Agency, 2019b). Currently, it is denoted that policies that were set in place to meet 2020 emissions reductions are not sufficient to reach the 2050 objective. Therefore, there must be a continued progress in the transition (Baranova et al., 2017; EEA, 2015).

2.4 The Contribution of the Education Sector

The role of educational institutions in achieving environmental sustainability is becoming more common. Students are being educated on how their actions can influence the environment, while promoting responsible behaviour and raising awareness of low carbon practices and technologies to reduce their carbon footprint and GHG emissions (Sustainable Development Commission, 2008). The WHO (2008) defines carbon footprint as a measure of the impact of an individual's activities on the amount of CO_2 produced through the burning of fossil fuels and it is an important method of understanding the effect a person's behaviour has on global warming.

According to Rauland et al. (2014), for any school intending to reduce their carbon emissions and improve operational performance, carbon footprinting would be a key starting point and one of the ways reducing a school's carbon footprint can be achieved is through environmental audits. In the 1986 Environmental Auditing Policy Statement, EPA defines environmental auditing as "a systematic, documented, periodic and objective review by regulated entities of facility operations and practices related to meeting environmental requirements" (EPA, 1986, p. 25006). With respect to schools, environmental audits refer to measuring, monitoring and assessing the environmental aspects within the school and provides basis for action plans (NWF, 2019). The audit should show the areas of strengths and weaknesses, how well the schools follow the legislative regulations related to the environment, how it would help solve environmental problems of schools and its surroundings such as waste disposal techniques, potential environmental management constraints and the focus of future audits (Sureshchandra, 2008).

Considering that educational sectors' buildings consume a significant amount of the total energy consumed across Europe, representing more than 12% of the tertiary building sector consumption and that energy bills are commonly one of the largest expenses (ClimACT, 2018a), conducting audits provides the opportunity to address measures that should be improved to increase the schools' energy performance in areas such as lighting, ventilation, heating and cooling, without affecting educational operations. It is also a way to push for sustainable school buildings and contribute to energy efficiency targets (Gamarra et al., 2018; Alfaris et al., 2016).

Along with energy consumption accounting for a substantial amount of a school's carbon emissions, there are several activities inside and outside a school that give rise to emissions (Rauland et al., 2014). According to the Department for Children, Schools and Families (DCSF) (2010), GHG emissions from the school sector are divided into four main sources: (i) the use of energy in school buildings; (ii) pupil and staff travel to and from school, and other commutes undertaken on school business; (iii) emissions produced by companies that supply goods and services to schools; (iv) and emissions from waste produced by schools; all contributing factors in operational performance and environmental impact (Rauland et al., 2014). In addressing these issues, a number of benefits arise, for example lower emissions from school travel means more pupils walking, cycling or taking public transport to schools, with improvements to health and modal shift away from cars; adequate waste management means less waste, more recycling and more composting with less demand for landfill or waste disposal (and potentially lower costs); school green procurement means greater use of suppliers who are equally committed to tackling climate change, helping to stimulate and expand the market for low-carbon goods and services (Sustainable Development Commission, 2008).

Educational institutions may present obstacles in determining their exact contribution to global warming. Issues that prevent schools from calculating and reducing their carbon footprint include lack of available data and tools, difficulty in calculation methods and identifying exact sources of emissions, lack of interest and knowledge by teachers, financial barriers, among others. Nonetheless, they should take action and engage in tackling environmental problems and strive to become part of the solution (National Wildlife Federation 2020; Rauland et al., 2014; Sprangers, 2011; Francois, 2003).

Audits are an opportunity for students to play a key role in reducing emissions through the curriculum. In addressing resource inefficiencies and implementing sustainability and low carbon initiatives, schools can save a great deal on utility bills each year, as well as unnecessary carbon emissions (Rauland et al., 2014). It is an excellent learning experience on how to adapt individual lives as well as ecological, social or economic systems in a changing environment (UNESCO, 2012; Fantini, 1979).

2.4.1 Previous study on environmental and energy audits in schools

Schools and universities around the world are engaging in initiatives involving low-carbon strategies to make schools more sustainable while engaging the school community. This section will detail an example of a successful Low Carbon Schools Program that reduced carbon footprints in several Australian schools. The program resulted in an initiative called ClimateClever, which is an application that helps schools to measure, monitor, compare and reduce their energy consumption and production on waste.

The Low Carbon School's Pilot Program had its start in 2016, lasting a period of two years, involving 10 primary schools and 5 high schools from different areas. The goal was to enable and equip schools with the knowledge, skills and resources to reduce their GHG emissions and utility bills while educating students in becoming more resource efficient.

Rauland et al. (2019) mentions that, according to the Australian Sustainable Built Environment Council (ASBEC) report (2018), the benefits of decarbonizing schools are that they have the most cost-effective carbon abatement opportunities within the building environment, mainly because school buildings are aging and becoming increasingly inefficient. The report also highlights the co-benefits of health improvement and improved academic performance from better, well designed and more sustainable buildings.

The Low Carbon Program consisted of two phases: Phase 1, with workshops to provide information on activities and recommendations on key actions to be implemented; calculating and tracking performance; and creation of action plans. Phase 2 required monthly meetups with all schools to verify if measures were being adequately implemented.

To be able to track the progress, a baseline was set to a year prior to the program - 2015 - where schools' consumptions and costs were obtained for electricity, gas and water and tracked for two years. A carbon calculator template was provided to all schools in order to capture consumption and cost for each resource in order to convert data into carbon emissions. Information about waste did not provide the details necessary for analysis, therefore was excluded from calculations and tracking, however, several schools still considered waste in their action plans.

The schools identified 625 actions with large focus on energy consumption. Half of the actions involved students and nearly half were completed by the actual schools. Actions included i. energy consumption management (switching to light-emitting diode (LED) lights, instalment of a Building Management System (BMS) - a computer-based control system that controls and monitors the building's mechanical and electrical equipment such as ventilation, lighting, power systems, fire systems and security systems, school-wide switch off program for appliances, automatic switch-off program for computers in the evenings and weekends, among others); ii. water consumption management (schools completed a water audit that checked for leaks and inefficiencies, installation of flow restrictors in WCs, faulty urinals were replaced or fixed, etc.); iii. Waste consumption management (improvement of recycling options, introduction of green waste collection such as composting). Although transport was also not included in the process, some schools opted to participate in some transport related initiatives. Occasionally the schools got together to ensure that each one was keeping up with action plans and exchanged their experiences and barriers and how to overcome them.

Once the baseline data had been completed and comparisons between the schools were made, some found they had massive gas bills and gas leaks. They also found two high schools, with similar size and carbon footprints but differentiating in costs. This fact led the school to an investigation on the electricity tariffs and managed to save about 30 000 dollars (25 193,55 euros). One high school changed their BMS and managed to save 8 000 dollars (6 720,68 euros) in each electricity bill. Thirteen out of the fifteen schools planted over 50 000 trees, which were enough to offset all of the schools' emissions of 3800 tons of CO_2 equivalent (CO_2e). These are just some examples of the positive outcomes of the project (Rauland et al., 2019; UniSA, 2019).

Overall results showed that, as previously mentioned, schools identified over 600 initiatives regarding behaviour change. On average, around 70% of the schools that achieved reductions, saved on average 30 dollars (25,20 euros) per student and reduced their carbon emissions by 20%. Due to the successful results, many schools were eager to join the program (UniSA), 2019).

Currently, with the ClimateClever application, schools can insert their data from measurements and audits and be provided with an action plan and recommendations, allowing schools to project-manage their action plans online and exchange their experiences. The application then uses machine-learning and predictive analytics on all the data obtained and recommends solutions to each school (UniSA), 2019).

2.5 ClimACT Project

In efforts to tackle climate change and play a role in reaching carbon neutrality, the ClimACT Project, funded by the Interreg Sudoe Programme, was created to promote the transition to a low carbon economy in schools. The initiative started in 2016 with nine partners from the Sudoe region, coordinated by Centro de Ciências e Tecnologias Nucleares of Instituto Superior Técnico (C^2TN/IST). The goal was to develop a methodology intended to decrease carbon footprints and increase environmental performance of 39 pilot schools located in four countries of the Sudoe region: Portugal, Spain, France and Gibraltar.

To achieve its main goal, the project comprises a decision support tool that would enable schools to increase their energy efficiency, a business model and new energy management strategies for schools, and educational tools for low carbon awareness. In addition, the creation of a thematic network in the Sudoe region was established to sensitize and empower schools in the transition to a LCE.

In the project framework, to better analyze the schools' performance, the school system was segmented into seven sectors, six of which describe environmental performance - mobility, green spaces, green procurement, indoor air quality, water, and waste - and one for energy performance. The performance of each sector in terms of CO_2 contribution will be explained below.

2.5.1 Mobility

According to the EEA (2019d), one quarter of total EU GHG emissions correspond to the transport sector due to its heavy reliance on fossil fuels. In 2017, emissions such as sulphur oxides (SO_x), nitrous oxides (NO_x), carbon monoxide (CO), hydrocarbons (HC), volatile organic compounds (VOC), toxic metals, and particulate matter (PM) accounted for 27 % of total EU-28 GHG emissions from transport and continued to increase in the following years (EEA, 2020b), contributing to air pollution causing cardiovascular, pulmonary and respiratory diseases (Lah, 2015).

Although emissions increased by less than 0.5% in 2019 due to efficiency improvements, the sector is still responsible for 24% of direct CO_2 emissions from fuel combustion (International Energy Agency, 2020). The EEA (2019b) states that road transport, in particular, continues to account for a significant proportion of emissions of all the main air pollutants. In order to reduce environmental and health impacts, there must be a shift to low-carbon transport and reduced transport use.

When transitioning to a LCE, mobility plays an important factor. Transferring from private cars to different modes of public transportation is key and as mentioned before, the challenge lies in user behavior change and infrastructure investment (Portuguese Environment Agency, 2019b; Kopp et al., 2013). More and more cities are creating solutions to emissions, congestion, and air pollution control by creating bicycle and pedestrian lanes to make walking and cycling easier and more pleasant, thus covering components of a «smart citiy» (World Wide Fund for Nature, 2017), which if implemented can reduce energy consumption, water consumption, carbon emissions, transportation requirements, and city waste (Mohanty et al., 2016).

The idea of smart cities consists of infusing technology that make traditional networks and services more efficient and sustainable, while having less impact on the environment (European Commission, 2020f), and in this case, smarter urban transport networks are key. Cities are investing in infrastructure to enhance soft mobility (non-motorized transport), as well as favoring use of electric vehicles (World Wide Fund for Nature, 2017). In achieving low carbon transport in school commutes, the incorporation of soft mobility serves as an incentive towards bolstering change in students' mindsets (Hunken & Krell, 2019 ; EU, 2017).

2.5.2 Green Procurement

In order to achieve sustainable development, there must be changes in production and consumption patterns (PricewaterhouseCoopers, 2009). One way this can be done is through green procurement, which involves purchasing environment-friendly goods and services that are less harmful to human health, that have reduced environmental impact throughout their life cycle, while contributing to sustainable consumption and production (Pacheco-Blanco & Bastante-Ceca, 2016; European Commission, 2012). Therefore, decision-making purchases have an impact on important environmental issues such as reducing energy-use by acquiring equipment with better efficiency; reducing raw material-use by buying products with recycled content so to reduce extracting raw materials; water-use reduction by purchasing products and technologies designed to consume small amounts of water; using products with fewer toxic ingredients; and using renewable and clean energy technologies.

According to the European Commission (2020c), Green Public Procurement (GPP) is a voluntary instrument. Nevertheless, it has a key role to play in the EU's efforts to become a more resource-efficient economy by helping to stimulate demand for more sustainable goods and services, which in any other case would be difficult to get onto the market. GPP is therefore a great way to stimulate circular economy and eco-innovation.

Through teaching and research, as well as sensitization, and awareness creation, the educational system can significantly impact the attitude and behaviour of students and other stakeholders and facilitate the spread of sustainability thinking.

2.5.3 Green Spaces

Green spaces are important contributors in mitigating climate change impacts via carbon sequestration (Nero et al., 2016), as they reduce environmental health risks associated with urban living (WHO, 2017). They include trees in parks, gardens and along the streets and roads, providing a variety of ecosystem services (Sharma et al., 2021). However, changes in CO_2 sinks are uncertain (Le Quéré et al., 2009) as climate change influences the capacities of land and oceans to act as repositories. Deforestation's rise in recent decades has decreased the total forest carbon stock from 668 billion tons in 1990 to 662 billion tons in 2020 and with faster CO_2 emissions, climate warming accelerates (Mulhern, 2020; Fung et al., 2005).

Urban greenery also adds CO_2 to the atmosphere when vegetation dies and decomposes, increasing total emissions. A recent study by scientists from NOAA, NASA's Jet Propulsion Laboratory and the University of Colorado found that, after measuring the excess carbon of a megacity, one-fifth of emissions was unexpectedly attributed to urban greenery (NASA, 2020). This highlights the importance of green space carbon offsetting and analysis of sequestration and decomposition, along with type of maintenance related to GHG emissions (University of Leeds, 2015).

In general, urban greenery has a higher carbon intake than its release to the atmosphere, but their design can have an important influence on the multitude of benefits to human population and wildlife, and in determining the amount of carbon it can store (University of Leeds, 2015). Tree species, in this case, play an important role in storing carbon and serving as an alternative for improving the greenhouse effect (Unwin & Kriedemann, 2000).

In addressing and minimizing the impacts of climate change, cities' buildings are now being adapted to green rooftops and vertical gardens to improve the sustainability of the built environment (Sheweka & Mohamed, 2012). The incorporation of vegetation to buildings' structures helps to reduce the energy demand for heating and cooling since plants reduce the amount of solar radiation that reaches the wall surface, therefore reducing buildings' carbon footprints (Andric et al., 2020; Deniz & Cig, 2016). Other benefits include improvement of air quality by filtering pollutants in the air, support for biodiversity, and reduction in rainwater run-off (WHO, 2017).

Schools and university campuses play an important role in offsetting the increasing GHG emissions as they provide large space for the development of green space. In return, schools that are surrounded by green space have been shown to experience lower levels of traffic-related pollution in their classrooms and increase in academic performance (Sharma et el., 2021; University of Leeds, 2015).

2.5.4 Water

Climate change is having an effect in our water cycle patterns by making water availability unpredictable, exacerbating water scarcity and contaminating water supplies (UNICEF, 2020). According to the EEA (2018), severe and prolonged droughts have highlighted Europe's vulnerability to this natural hazard and have made governments and operational agencies aware to the many problems of water shortage and the need for drought mitigation measures.

Nevertheless, the water industry is responsible for a number of different carbon emissions. Water typically requires treatment prior to use, and it uses a significant amount of energy when it is pumped and pressurized to reach homes (Reffold et al., 2008). The waste from treatment also has a variety of emissions, and the management of water systems affects land, rivers and reservoirs (Ainger et al., 2009).

According to the International Water Association (IWA) (2015), retrofitting existing systems to more energy efficient designs can improve energy efficiency and reduce emissions associated with river discharge by directing treated effluent to agriculture rather than rivers; it can convert the carbon energy from biosolids into biogas, heat and electricity, covering energy needs if specific wastewater collection and treatment are designed for this type of energy recovery.

In educational buildings, water is used for drinking, cleaning, construction work and irrigation and in order to preserve freshwater supplies, schools must rationalize water-use in the operational processes by installing water-efficient devices and equipment (EL-Nwsany, et al., 2019). In addition, students need to be educated on sustainable water consumption and not only rely on water-saving measures.

A research by Morote et al. (2020) on water consumption and management in schools of southern Spain answered the question if free water helps to promote saving water. The conclusion was that solely encouragement and implementation of water-saving actions and measures did not lead to reduction in consumption. Instead, Morote et al. found that because schools are provided with ‘free’ water, there is no pressure or motivation to engage in water saving measures and that school staff showed lack of interest in the research.

This indicates that for a well successful transition, not only must there be focus on water conservation, but also understand the carbon footprint that comes along with it so that individuals become more environmentally conscious.

2.5.5 Waste

According to the European Commission (2020d), waste is the fourth largest source sector of emissions, accounting for 3% of total greenhouse gas emissions in 2017. The dominant source of urban waste emissions come from landfills due to the production of CH_4 from anaerobic decomposition of organic waste, CO_2 emissions associated with incineration of waste and N_2O emissions related with wastewater treatment (Mohareb & Hoornweg, 2017; Portuguese Environment Agency, 2019a; European Commission, 2014). Along with waste management emissions, there are also emissions from the life cycle steps that include extraction and processing of raw materials, manufacture of products, transportation of materials and products to markets, and consumer use (EPA, 2006).

Statistics have shown that change in waste treatment was brought about through EU legislation, investments in appropriate collection and handling, and financial incentives by focusing on recycling and reducing the disposal of waste as landfill (European Commission, 2020c). It has reduced by more than half over 15 years with the help of composting of solid waste (EEA, 2020c; European Commission, 2020c).

According to the 2019 State of the Environment Report, “(…) the rate of preparation for reuse and recycling of municipal waste was 40%, maintaining the upward trend observed in the last decade” and “disposal of biodegradable municipal waste in landfills increased for the second consecutive year and amounted to 46% in 2018” (Portuguese Environment Agency).

Rada et al. (2016) conducted a study on waste management assessment of a primary and secondary school, as well as a few high schools and found that the amount of waste produced varied depending on the school size and occupancy, students’ ages and the type of activities carried out within the schools. The study also found issues that needed to be improved, such as clear instructions on labelling of recycling bins, lack of correct disposal of waste by teachers and school staff, deficiency of bins for a specific type of waste and so forth.

When managing waste in the education sector, schools have the responsibility of providing and adopting the type of waste disposal least harmful to the environment and the role of teachers is a key factor in setting a good example and achieving good results (Rada et al., 2016).

2.5.6 Energy

As reported by the EEA (2020a), energy represents the largest source of GHG emissions as a result of anthropogenic activities, in which two thirds are associated with the use of fossil fuels for heating, electricity, transportation and industry. In Europe, energy processes are the largest emitter and in 2015 was responsible for 78 % of total EU emissions.

Emissions began increasing due to higher energy consumption resulting from a robust global economy, as well as from weather conditions in some parts of the world that led to increased energy demand for heating and cooling. As energy efficiency became more prominent, CO_2 began to stagnate between 2014 and 2016 even as the global economy continued to expand and as low-carbon technology deployed, the demand for coal started to decline. In 2018, the increase in renewable energy in the power sector avoided 215 metric tons (Mt) of CO_2 emissions (IEA, 2019a).

According to the 2019 State of the Environment Report, in 2018 Portugal had 55.3% of electricity production from renewable sources and in 2017 54.2% share of renewables in the electricity sector, which was the fifth highest in the European Union, confirming the upward trend of the last decade (Portuguese Environment Agency, 2019d). The country is now in the process of closing down all fossil fuel power plants as a part of its decarbonization strategy and is focusing on reaching the 2030 objective of generating more than 90% of electricity from renewable sources such as green hydrogen (EDP, 2018a, 2018b).

Hydrogen can be produced from low carbon technologies, but it is currently extracted primarily from fossil fuels, accounting for 830 million tonnes of CO_2 emissions, according to the IEA (2019b) report. Green hydrogen is the generation of hydrogen through the chemical process electrolysis to produce energy with near zero CO_2 emissions, i.e., it is obtained through renewable sources (Dincer, 2012). This can hopefully reduce reliance on fossil fuels and lower global GHG emissions (Kazi et al., 2020).

Energy activities are ultimately damaging natural ecosystems and the built environment, while having adverse effects on human health. Therefore, there must be a need to consume less energy and transition to clean energy options that are already taking place across Europe (EEA, 2021).

3. METHODOLOGY

3.1 Case Study: Portuguese ClimACT schools

The development of this thesis was based on the ClimACT methodology and aims to evaluate the performance evolution of six ClimACT schools in Portugal. The six Portuguese schools represent different levels of education, from kindergarten to higher education. This range of levels is relevant to the study since the idea of the project is to understand to what extent schools of different levels of education have the potential for low carbon change.

Figure 2 – Location of portuguese ClimACT schools pertaining to this study. Source for image on the right: https://www.istockphoto.com/pt/search/2/image?phrase=portugal%20map

Schools 1 through 4 (S1–S4) are primary schools located in the municipality of Loures, school 5 (S5) is a secondary school also in Loures, while school 6 (S6) is a university located in Lisbon. S1, S3 and S4 comprise students from the second and third cycles, comprising ages 10 to 16; S2 includes students from kindergarten and the first cycle, ages 3 to 10; S5, a secondary school, contains students from ages 16 to 18; and S6 with ages 18+. It is important to highlight that the number of students that was accounted for during the project varied according to the table below.

Table 1 – Number of students per academic year.

	Number of students	
School	**2017-2018**	**2018-2019**
S1	590	585
S2	275	295
S3	722	698
S4	742	750
S5	482	483
S6	1772	1864

The participation of schools in the project brings added value to their commitment and responsibility in enhancing the transition to a low carbon economy through activities and behavior change, while contributing to achieving the goals established in the National Low Carbon Roadmap (RNBC), one of them being reductions of GHG emissions in Portugal by 2050 (ClimACT, 2019b; Portuguese Environment Agency, 2019).

3.2 Method of evaluation

The purpose of the methodology was to assess the environmental performance of schools through characterization of the environmental and energy sectors discussed in section 2.5. In order to achieve this, ClimACT conducted audits and behaviour questionnaires to characterize the school community in question and to assess technical components such as inspections.

A series of guidelines of standard methodologies to conduct energy and environmental audits in schools were provided - which consisted of recommendation of best practices for the pertained audits - along with decision support tools to identify sustainable solutions and assist with the transition to a LCE (ClimACT, 2017a, 2017b). The assessment was made by application of key performance indicators obtained through behaviour questionnaires and technical audits, to which improvement measures were developed and implemented.

The first measurement campaign was conducted during the academic year 2017/2018. One year after implementation of action plans, new audits and behaviour questionnaires were applied in the second campaign of 2018/2019 to measure change in the schools' performance and determine the benefits of the ClimACT methodology towards a LCE. The progress evaluation assessment can be found in chapter 5.

3.2.1 Behaviour Questionnaires

The behaviour questionnaires (annex I) were applied to students, teachers and staff and were intended to analyze the school community and contribute to the implementation of good practices while providing data regarding the use of resources in the selected environmental sectors. The information requested was in regard to transport routines such as frequency of use of mode of transportation during school commutes, and concerning daily habits associated with the environmental areas – if the school community practiced recycling and if so, what type of recyclables; their day-to-day energy-saving behaviours; and if they have participated in any environmental action such as tree planting. Questions were composed of multiple-choice plus 1 open question about what can be done to make the school more environmentally friendly (ClimACT, 2016).

The questionnaires were applied at the beginning of the project to define the baseline for behavior change and once again the following year to assess improvements. They allowed cooperation in identifying areas for improvement and intervention of actions to empower the school community in these areas. It was recommended that the questionnaires be answered by at least 30% of the school population (which was not the case for all of the schools) and that the sample be representative of the different school levels/years (ClimACT, 2016).

Assessing bahaviour questionnaires was the first step in the thesis methodology. This allowed for a baseline characterization of teachers' and students' answers depending on the level of education and different age groups.

3.2.2 Technical Audits

Technical audits were based on checklists (annex II) and inspections to determine building characteristics and resource consumption of school buildings which would serve as a baseline for the work to be carried out (table 2). The audits incorporated 3 stages:

- a pre-audit phase of preparation and information request necessary to conduct the audits (building characteristics, location, equipment, activities, occupation, monthly energy and water bills, etc.);
- an on-site assessment, corresponding to the audit phase, in which consumption equipment were surveyed and characterized;
- analysis of the performance through data processing, breakdown of consumption/production and KPIs (ClimACT, 2017b).

Table 2 – Checklist content for each sector.

Sector	Checklist Content
Energy	Energy production/consumption; heating/cooling; ventilation; equipment; lighting; energy measurement and management.
Water	Monthly bills; water-saving devices; water heating; available water sources.
Green spaces	Water-use in irrigation; energy consumption in gardening activities; use of fertilizers and pesticides.
Green procurement	Electronic equipment labelling; certification; printers; chemicals in detergent; food products and purchase from local suppliers.
Mobility	Parking spaces; characterization of the transport network in proximities.
Waste	Waste separation for recycling; reused paper.

This information was collected to supplement a tool created by the project, functioning as inputs for calculating KPIs and scores in order to evaluate the schools' performance.

3.2.3 Implementation of improvement actions

Based on the first characterization and evaluation of schools regarding their environmental and energy performance carried out in the first year of implementation of the project, a number of improvement measures were implemented, aiming at increasing the schools' performance in each sector. Measures were selected in accordance with objectives defined in each school, based on their initial performance. Such measures are discussed in chapter 4.

In addition to improvement measures, global actions were developed by a low carbon team responsible for local implementation and intervention along with other actions of an educational nature, awareness-raising and training, both for students and teachers. The low carbon team consisted of a Low Carbon Coordinator (LC); a Low Carbon Committee (LCC) comprising teachers, students, staff and municipalities; and a Low Carbon Brigades (LCB) comprising teachers, students, staff and municipalities, contributing towards implementation of the methodology. Much of the measures were training actions promoted by the project team, aimed at teachers and students (workshops, training sessions, seminars, e-learning of ClimACT) and other actions were developed by schools, namely by the LCC and many in partnership with the local municipal council (CMLoures). The low carbon team was established to ensure support from the school community in order to undertake any new initiatives and to allow for the amount of work to be distributed among several participants.

3.2.4 Key Performance Indicators and scores

Each school was evaluated through KPIs created by the project team, taking into account what was considered most important in an assessment of environmental and energy performance in the schools. KPIs measured how well the schools accomplished in reducing their carbon footprint in each sector. Scores are then generated per environmental area ranging from 0 to 5, depicting the margin of evolution. This step in the thesis methodology included analyzing each factor considered in the calculation of KPIs and the effects on corresponding scores.

The performance of each sector is measured on the basis of the Pressure-State-Response (PSR) model (figure 3). The PSR model was created by the Organization for Economic Co-operation and Development (OECD) in an effort to create environmental indicators to link environmental issues with economic and social matters (OECD, 2003).

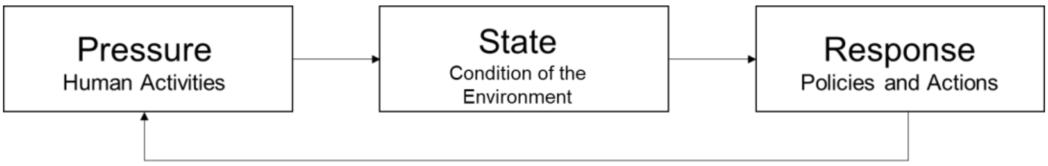

Figure 3 –The Pressure-Sate-Response Framework. Adapted from OECD, 2013.

Pressure indicators refer to actions or activities that impose pressures on the environment. An example of a pressure indicator is CO_2 emissions derived from transport, energy, industry and so forth. State indicators describe the change in quality and quantity of the environment, for example, changes in natural resources such as air or water quality. Response indicators refer to responses by government and society to attempt to reduce or compensate negative impacts on the environment (Levrel et al., 2008; EEA, 1999).

This is important in understanding the results of KPIs presented in chapter 5 and how they influence scores for each sector. All KPIs that represent response indicators will have the same affect in scores, i.e., the higher the environmental performance, the higher the score. In contrast, KPIs that indicate pressure on the environment will reflect the contrary in score results, meaning that the higher the KPI values are, the lower the outcome of scores.

Mobility

The ClimACT project chose to create KPIs targeting mobility infrastructure within the schools, transport network nearby and CO_2 emissions generated by students, in order to assess the schools' performance in the mobility sector (table 3). Information collected from audits on parking spaces and transport frequency permitted the calculation of KPI_{M1}, KPI_{M2} and KPI_{M3}. For KPI_{M4}, two factors were taken into consideration in order to calculate CO_2 emissions: Person Equivalent (PE) (annex III) – in this case, the amount of CO_2 emitted per person and per frequent use of mode of transportation - which was determined using questionnaires to find out with which frequency students used each mode of transportation - and the Emission Factor (EF) (annex III) of each mode of transportation which was identified accordingly with the bibliography, then leading to the calculation of KPI_{M4}.

Table 3 – KPI calculations for mobility sector.

Sector	KPI designation	KPI calculation
Mobility	Charging stations for electric cars per student	$\mathrm{KPI_{M1}} = \frac{\text{nr of charging stations for eletric cars}}{\text{nr of students}}$
	Parking places for bicycle per student	$\mathrm{KPI_{M2}} = \frac{\text{nr of parking spaces for bicycles}}{\text{nr of students}}$
	Public Transports per hour	$\mathrm{KPI_{M3}} = \frac{\text{nr of public transport per hour within 1000m radius}}{\text{nr of students}}$
	CO_2 annual emissions per student	$\mathrm{PE}_i = \frac{(\#_{\text{never}}\times 0+\#_{\text{almost never}}\times 1/3+\#_{\text{almost always}}\times 2/3+\#_{\text{always}}\times 1)\times \text{nr of persons of the school}}{\text{nr of persons that answered to the questionnaire}}$ Where: *i* = transport mean (motorbike; car; boat; tram; train; subway; bus; bicycle; on foot); PE_i = person equivalent of the transport mean *i*. $\mathrm{CO_2}_i\text{Emissions} = \sum_i(\mathrm{EF}_i \times \mathrm{PE}_i)\times \text{daily average distance} \times 22 \times 10$ Where: $\mathrm{CO_2}_i$ Emissions = Annual emissions associated to the transport mean *i*. FE_i = emission factor of the mobility mean *i* [1]. $\mathrm{KPI_{M4}} = \frac{\sum_i \mathrm{CO_2}_i\text{ Emissions}}{\text{nr of students}}$

KPIs were subsequently used to calculate intermediate scores shown in table 4, which then led to the calculation of a final score. Each intermediate score ranges from 0, meaning least favourable scenario, to 5 meaning most favourable scenario, and has a weighting in the final score calculation. The attribution of weightings is due to the reason that the areas associated with each KPI were considered to have different impacts or contributions to the total carbon impact.

Table 4 – Calculations, scenarios and weightings of scores for the mobility sector.

Sector	Score designation	Score calculation	Least favourable scenario	Most favourable scenario	Weighting for final score
Mobility	Charging stations for electric cars	$S_{T1} = \frac{KPI_{T1} \times 5}{1.05 \times \max(KPI_{T1})}$	Without charging stations	Highest KPI_{T2} found plus 5%	1
	Parking spaces for bicycles	$S_{T2} = \frac{KPI_{T2} \times 5}{1.05 \times \max(KPI_{T2})}$	Without parking places	Highest KPI_{T3} found plus 5%	1
	Public Transports	$S_{T3} = \frac{KPI_{T3} \times 5}{1.05 \times \max(KPI_{T3})}$	Without public transports	Highest KPI_{T4} found plus 5%	1
	CO_2 annual emissions	$S_{T4} = = 5 - \frac{\text{school emissions} \times 5}{\text{emissions of 100\% of students going by car}}$	100% of the students go by car	100% of the students go on foot or by bicycle	2

The first two intermediate scores calculations for charging stations and parking spaces were added together to form a single score for parking, by an arithmetic mean that had a weighting of 2 in the final score.

Green Procurement

Green procurement evaluates the environmental impact associated with the purchase of products and services by the schools. The assessment was made based on seven KPIs consisting of electronic equipment efficiency, quantity of paper consumption and reused paper, biological food with certification, staff with eco-driving certification and training in green procurement, and purchase of food from local suppliers. All seven KPIs were measured by dividing the number of products and services that reflect green choices by the total number of products and services, as shown in table 5.

Table 5 – KPI calculations for green procurement sector.

Sector	KPI designation	KPI calculation
Green Procurement	Equipment efficiency	$KPI_{GP1} = \frac{\text{nr of equipment A+ or higher EU energy label}}{\text{total nr of equipments}}$
	Paper used per student	$KPI_{GP2} = \frac{\text{total ammount of paper}}{\text{student}}$

	Recycled paper	$\mathrm{KPI_{GP3}} = \frac{\text{quantity of recycled paper}}{\text{total quantity of paper}}$
	Biological food certification	$\mathrm{KPI_{GP4}} = \frac{\text{quantity of food with biological certificate}}{\text{total quantity of food}}$
	Eco driving certification	$\mathrm{KPI_{GP5}} = \frac{\text{nr of employees with eco} - \text{driving certificates}}{\text{total nr of employees}}$
	Training in green procurement	$\mathrm{KPI_{GP6}} = \frac{\text{nr of employees with training in green procurement}}{\text{total nr of employees}}$
	Local suppliers	$\mathrm{KPI_{GP7}} = \frac{\text{nr of local suppliers}}{\text{total nr of suppliers}}$

Table 6 shows calculations for intermediate scores where the most favourable scenario was to have 100% of sustainable products and services as opposed to 0%, representing the least favourable scenario. Calculations of scores for paper used and recycled paper were added together to determine a score for paper consumption, with an added weighting of 2. In the case of green procurement, higher importance was given to aspects of paper consumption.

Table 6 – Calculations, scenarios and weightings of scores for the green procurement sector.

Sector	**Score designation**	**Score calculation**	**Least favourable scenario**	**Most favourable scenario**	**Weighting for final score**
Green Procurement	Equipment efficiency	$\mathrm{S_{GP1}} = \mathrm{KPI_{GP1}} \times 5$	Without certified equipment	100% of certified equipment	1
	Paper used per student	$\mathrm{S_{GP2}} = 5 - \frac{\mathrm{KPI}_{GP2} \times 5}{\max(\mathrm{KPI}_{GP2})}$	Highest $\mathrm{KPI_{GP2}}$ found	Without use	1
	Recycled paper	$\mathrm{S_{GP3}} = \mathrm{KPI_{GP3}} \times 5$	Without recycled paper	100% recycled paper	1
	Biological food	$\mathrm{S_{GP4}} = \mathrm{KPI_{GP4}} \times 5$	Without training	100% trained employees	0.25
	Eco-driving certification	$\mathrm{S_{GP5}} = \mathrm{KPI_{GP5}} \times 5$	Without certified employees	100% certified employees	0.25
	Training in green procurement	$\mathrm{S_{GP6}} = \mathrm{KPI_{GP6}} \times 5$	Without certified employees	100% certified employees	0.25
	Local suppliers	$\mathrm{S_{GP7}} = \mathrm{KPI_{GP7}} \times 5$	Without local suppliers	100% local suppliers	0.25

The final score was determined by calculating the mean of the multiplication of each intermediate score to their weighting.

Green spaces

Green spaces assessment used seven KPIs (table 7). The first two relate to the number of trees per area and per student; the third and fourth to green areas per area and per student; the fifth to use of chemicals during maintenance; the sixth to CO_2 sequestration and CO_2 emissions for the seventh. For determining CO_2 sequestration, the sequestration rate (SR) of species of trees were identified. Carbon sequestration occurrence is the extraction of atmospheric carbon dioxide and its storage in terrestrial ecosystems varies based on the growth rate, age, and species. As for KPI for CO_2 emissions from maintenance activities, factors such as energy, water and fuel consumption were considered.

Table 7 – KPI calculations for green spaces.

Sector	KPI designation	KPI calculation
Green Spaces	Trees per non-covered area	$\mathrm{KPI_{GS1}} = \frac{\text{nr of trees}}{\text{non−covered area}}$
	Trees per student	$\mathrm{KPI_{GS2}} = \frac{\text{nr of trees}}{\text{nr of students}}$
	Green area per non-covered area	$\mathrm{KPI_{GS3}} = \frac{\text{green area}}{\text{non} - \text{covered area}} \text{ x } 100$
	Green area per student	$\mathrm{KPI_{GS4}} = \frac{\text{green area}}{\text{nr of students}}$
	Annual usage of chemicals per green area	$\mathrm{KPI_{GS5}} = \frac{\text{quantity of fertilizers and pesticides}}{\text{green area}}$
	Annual CO_2 sequestration per non-covered area	$\mathrm{KPI_{GS6}} = \frac{\text{nr of trees} \times \mathrm{SR_{dominant\ species}} + \text{lawn area} \times \mathrm{SR_{lawn}}}{\text{non} - \text{covered area}}$ Where: SR = sequestration rate
	Annual CO_2 emissions per non-covered area	$\mathrm{KPI_{GS7}} = \frac{\text{Combustível} \times \mathrm{FE_{fuel}} + \text{water} \times \mathrm{FE_{water}} + \text{electicity} \times \mathrm{FE_{electricity}}}{\text{non} - \text{covered area}}$ Where: FE = factor emission

From seven KPIs, four intermediate scores were generated (table 8) where the first two were combined together to create an intermediate score for green areas with a weighting of 1. Scenarios ranged from most favourable to least favourable plus 5% to give schools room for improvement.

Table 8 – Calculations, scenarios and weightings of scores for green spaces sector.

Sector	Score designation	Score calculation	Least favourable scenario	Most favourable scenario	Weighting for final score
Green Spaces	Trees per non-covered area	$S_{GS1} = \frac{KPI_{GS1} \times 5}{1.05 \times \max(KPI_{GS1})}$	Without trees	Highest KPI_{GS1} found plus 5%	0.5
	Green area per non-covered area	$S_{GS2} = \frac{KPI_{GS3} \times 5}{1.05 \times \max(KPI_{GS3})}$	Without green area	Highest KPI_{GS3} found plus 5%	0.5
	Annual usage of chemicals per green area	$S_{GS3} = 5 - \frac{KPI_{GS4} \times 5}{\max(KPI_{GS4})}$	Highest KPI_{GS4} found	Without chemicals	1
	Annual CO_2 sequestration per non-covered area	$S_{GS4} = \frac{KPI_{GS5} \times 5}{1.05 \times \max(KPI_{GS5})}$	Without sequestration	Highest KPI_{GS5} found plus 5%	1
	Annual CO_2 emissions per green area	$S_{GS5} = 5 - \frac{KPI_{GS6} \times 5}{\max(KPI_{GS6})}$	Highest KPI_{EV7} found	Without emissions	1

The final score was determined by calculating the mean of the multiplication of each intermediate score to their weighting.

Water

The water sector consists of four KPIs: two for consumption and two related to costs (table 9). Consumption was determined by considering the different domestic hot water (DHW) equipment measured, thus allowing to identify how much DHW is consumed by sector and by use. Calculations were made based on yearly water consumption and costs from water bills divided between DHW consumed in the kitchen, in the sports pavilion and between water consumed cold (ClimACT, 2017b).

Table 9 – KPI calculations for the water sector.

Sector	KPI designation	KPI calculation
Water	Water consumption per useful area	$KPI_{W1} = \frac{\text{annual water consumption}}{\text{useful area}}$
	Water consumption per student	$KPI_{W2} = \frac{\text{annual water consumption}}{\text{nr of students}}$
	Water costs per useful area	$KPI_{W3} = \frac{\text{annual water costs}}{\text{useful area}}$
	Water costs per student	$KPI_{W4} = \frac{\text{annual water costs}}{\text{nr of students}}$

Intermediate scores were calculated for each KPI, using the scenarios and weightings illustrated in table 10. In the case of the water sector, the higher the KPI, the lower the score, meaning that the indicator has a negative impact on the score. The final score consists of an average of the intermediate scores.

Table 10 – Calculations, scenarios and weightings of scores for the water sector.

Sector	Score designation	Score calculation	Least favourable scenario	Most favourable scenario	Weighting for final score
Water	Water consumption per useful area	$S_{w1} = \frac{(\max(KPI_{w1}) - KPI_{w1}) \times 5}{\max(KPI_{w1}) - \min(KPI_{w1}) \times 0.95}$	Highest KPI_{w1} found	Lowest KPI_{w1} found less 5%	0.5
	Water consumption per student	$S_{w2} = \frac{(\max(KPI_{w2}) - KPI_{w2}) \times 5}{\max(KPI_{w2}) - \min(KPI_{w2}) \times 0.95}$	Highest KPI_{w2} found	Lowest KPI_{w2} found less 5%	0.5
	Water costs per useful area	$S_{w3} = \frac{(\max(KPI_{w3}) - KPI_{w3}) \times 5}{\max(KPI_{w3}) - \min(KPI_{w3}) \times 0.95}$	Highest KPI_{w3} found	Lowest KPI_{w3} found less 5%	0.5
	Water costs per student	$S_{w4} = \frac{(\max(KPI_{w4}) - KPI_{w4}) \times 5}{\max(KPI_{w4}) - \min(KPI_{w4}) \times 0.95}$	Highest KPI_{w4} found	Lowest KPI_{w4} found less 5%	0.5

Waste

Assessment of the waste sector was done through three KPIs: the first for waste produced per student, the second for waste recycled per student and the third for waste reused per student (table 11). Data collection was obtained during a two-week site assessment on the quantity of waste to be disposed (undifferentiated), composted (organic), reused and recycled (plastic, metals, glass, paper).

Table 11 – KPI calculations for the waste sector.

Sector	KPI designation	KPI calculation
Waste	Weekly production of urban solid waste (USW) per student	$KPI_{R1} = \frac{\text{weekly production of USW}}{\text{nr of students}}$
	Weekly production of recyclables per student	$KPI_{R2} = \frac{\text{weekly production of recyclable waste}}{\text{nr of students}}$
	Weekly production of reusables per student	$KPI_{R3} = \frac{\text{weekly production of reusable waste}}{\text{nr of students}}$

The KPIs above led to three intermediate scores presented in table 12, which were subsequently used to calculate a final score in which waste produced had the highest weighting.

Table 12 – Calculations, scenarios and weightings of scores for the waste sector.

Sector	Score designation	Score calculation	Least favourable scenario	Most favourable scenario	Weighting for final score
Waste	Weekly production of urban solid waste (USW)	$S_{R1} = \frac{(\max(KPI_{R1}) - KPI_{R1}) \times 5}{\max(KPI_{R1}) - \min(KPI_{R1}) \times 0.95}$	Highest KPI_{R1} found	Lowest KPI_{R1} found less 5%	2
	Weekly production of recyclables	$S_{R2} = \frac{KPI_{R2} \times 5}{\max(KPI_{R2}) \times 1.05}$	Without recyclable waste	Highest KPI_{R2} found plus 5%	1
	Weekly production of reusables	$S_{R3} = \frac{KPI_{R3} \times 5}{\max(KPI_{R3}) \times 1.05}$	Without reusable waste	Highest KPI_{R3} found plus 5%	1

Energy

In assessing the energy sector, energy bills allowed for the calculation of six KPIs: two for consumption (per area and per student), two for costs (per area and per student), one for renewable energy production and the last for CO_2 emissions, resulting in students' carbon footprints (table 13). Consumption was evaluated through the different energy sources, uses and sectors. This breakdown permitted for the quantification of energy used for lighting, heating/cooling and other equipment.

Table 13 – KPI calculations for the energy sector.

Sector	KPI designation	KPI calculation
Energy	Energy consumption per useful area	$\mathrm{KPI_{E1}} = \frac{\sum_i \text{annual consumption of eletricidade}_i + \sum_j (\text{annual consumption of fuel}_j \times \text{density}_j \times CF_j)}{\text{useful area}}$ Where: *i* = type of electricity (provide by the grid; onsite produced); *j* = type of fuel (diesel; LPG; natural gas); CF_j = conversion factor to kWh of fuel *j*.
	Energy consumption per student	$\mathrm{KPI_{E2}} = \frac{\sum_i \text{annual consumption of eletricidade}_i + \sum_j (\text{annual consumption of fuel}_j \times \text{density}_j \times CF_j)}{\text{nr of students}}$ Where: *i* = type of electricity (provide by the grid; onsite produced); *j* = type of fuel (diesel; LPG; natural gas); CF_j = conversion factor to kWh of fuel *j*.
	Percentage of onsite produced renewable energy	$\mathrm{KPI_{E4}} = \frac{\text{annual consumption of onsite produced renewable energy}}{\sum_i \text{annual consumption of eletricidade}_i + \sum_j (\text{annual consumption of fuel}_j \times \text{density}_j \times CF_j)}$ Where: *i* = type of electricity (provide by the grid; onsite produced); *j* = type of fuel (diesel; LPG; natural gas); CF_j = conversion factor to kWh of fuel *j* [9].
	Energy costs per useful area	$\mathrm{KPI_{E6}} = \frac{\text{annual energy costs}}{\text{useful area}}$
	Energy costs per student	$\mathrm{KPI_{E7}} = \frac{\text{energy annual costs}}{\text{nr of studentss}}$
	CO_2 annual emissions	$\mathrm{KPI_{E8}} = \frac{\text{annual electricity consumption} \times EF_e + \sum_i (\text{annual consumption of fuel}_i \times \text{density}_i \times CF_i \times EF_i)}{\text{nr of students}}$ Where: *i* = type of fuel (diesel; LPG; natural gas); CF_i = conversion factor to kWh of fuel *i* [FE_e = emission factor associated to electrical energy consumption EF_i = emission factor associated to fuel *I*

Four intermediate scores were generated. The scores highlighted in grey (table 14) were added together to form two intermediate scores: one for energy consumption and another for energy costs. Excluding renewable energy score, just as in the water sector, high results for KPIs translate in low scores due to the adverse effects of high energy consumption.

Table 14 – Calculations, scenarios and weightings of scores for energy sector.

Sector	Score designation	Score calculation	Less favourable scenario	More favourable scenario	Weighting for final score
Energy	Energy consumption per useful area	$\mathrm{S_{E1}} = \frac{(\max(\mathrm{KPI_{E1}}) - \mathrm{KPI_{E1}}) \times 5}{\max(\mathrm{KPI_{E1}}) - \min(\mathrm{KPI_{E1}}) \times 0.95}$	Highest $\mathrm{KPI_{E1}}$ found	Lowest $\mathrm{KPI_{E1}}$ found less 5%	$\frac{1}{2}$
	Energy consumption per student	$\mathrm{S_{E2}} = \frac{(\max(\mathrm{KPI_{E1}}) - \mathrm{KPI_{E1}}) \times 5}{\max(\mathrm{KPI_{E1}}) - \min(\mathrm{KPI_{E1}}) \times 0.95}$	Highest $\mathrm{KPI_{E2}}$ found	Lowest $\mathrm{KPI_{E2}}$ found less 5%	$\frac{1}{2}$

	Percentage of onsite produced renewable energy consumption	$S_{E3} = KPI_{E3} \times 5$	Lowest KPI_{E3} found	100% renewable energy	$\frac{1}{2}$
	Energy costs per useful area	$S_{E4} = \frac{(\max(KPI_{E4}) - KPI_{E4}) \times 5}{\max(KPI_{E4}) - \min(KPI_{E4}) \times 0.95}$	Highest KPI_{E4} found	Lowest KPI_{E4} found less 5%	$\frac{1}{2}$
	Energy costs per student	$S_{E5} = \frac{(\max(KPI_{E5}) - KPI_{E5}) \times 5}{\max(KPI_{E5}) - \min(KPI_{E5}) \times 0.95}$	Highest KPI_{E5} found	Lowest KPI_{E5} found less 5%	$\frac{1}{2}$
	CO_2 annual emissions	$S_{E6} = \frac{(\max(KPI_{E6}) - KPI_{E6}) \times 5}{\max(KPI_{E6}) - \min(KPI_{E6}) \times 0.95}$	Highest KPI_{E6} found	Lowest KPI_{E6} found less 5%	1

A final score for energy was determined by calculating the average between energy consumption, energy cost and CO_2 emissions.

4. FINDINGS

4.1 Mobility

The mobility sector was assessed through surveys to analyse 3 main factors: parking characteristics, public transport network, and users' behaviour regarding home-school path. Parking characteristics include different parking spaces for low-carbon transport modes such as electric vehicles or bicycles (KPI_{M1}, KPI_{M2}); the public transport network includes information about the schools' surroundings such as the number of stops for each transport mode in distance radius, number of vehicles passing daily at different times and the distance between the nearest stop and the school (KPI_{M3}); users' behaviour was assessed through a behaviour questionnaire about the school community's behaviour practices regarding the mode of transportation used in home-school path and the associated CO_2 emissions (KPI_{M4}) (ClimACT, 2017a).

The users' behaviour towards modes of transport to school revealed that an average of 41% of students go to school by foot, 31% by car and around 18% by bus (figure 4 (left)). It appears there may be a relation between distances and the means of transport used, for example, S6 presents more diverse modes of transportation as it has a larger home-school distance with an avergage of 20.5 km. S1 and S5, having the shortest average distance of 2.7km and 2.9km respectively, show highest percentage of walking as mode of transportation with 55% and 44% respectively. Therefore it can be concluded th3those who live closer to the schools opt for soft or green mobility.

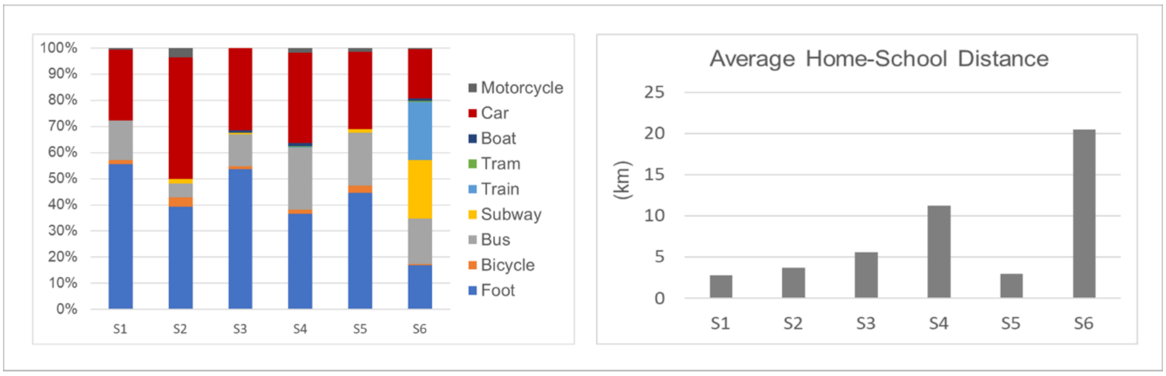

Figure 4 - Percentage of students' responses to home-school mode of transportation (left); average distance from home to school in kilometres (right).

First audit results for KPIs shown in table 15 indicate that, except for S6, neither schools presented parking spaces for electric cars and bicycles, thus creating space for low-carbon options. The number of public transport passing daily per hour is highest at S6 indicating that the school's location gives access to a more diverse transport network and passage frequency. As for CO_2 emissions, S6 shows the highest results of about 469 kg CO_2 per student, followed by S4 of about 295 kg CO_2 per student. This high emission result for S6 could be due to the fact that it is the only school where users go back home and return to school more than once a day, consequentely increasing the carbon footprint.

Table 15 - KPI results for mobility – first and second audits.

KPI - Mobility	S1		S2		S3		S4		S5		S6	
	1st audit	2nd audit	1st audit	2nd audit	1st audit	2nd audit	1st audit	2nd audit	1st audit	2nd audit	1st audit	2nd audit
KPI_{M1} - Parking spaces for electric cars/student	0	0	0	0	0	0	0	0	0	0	0.001	0.001
KPI_{M2} - Parking spaces for bicycles/student	0	0.009	0	0	0	0	0	0.020	0	0.010	0.006	0.005
KPI_{M3} - Public transports passing daily/hour	9.15	9.15	29.00	29.00	23.77	23.77	25.31	25.31	7.69	7.69	120.31	120.31
KPI_{M4} - Annual CO_2 Emissions ($kgCO_2.student^{-1}$)	51.87	67.89	97.22	46.22	108.82	131.60	294.84	341.49	54.49	67.24	468.75	472.64

After the initial assessment, it was evident that bicycle parking spaces and charging places for electric cars needed to be prioritized. The schools also needed to raise awareness about behaviour change by opting for more sustainable ways of commuting to school. LCE action plans and retrofit solutions and activities were implemented based on the initial baseline results of each school. For example, S2 did an «eco-bike» cycling tour through the nearest neighborhoods, allowing students to create their own path to school without traffic and pollution in order to reduce their carbon footprint, while S6 offered training courses and driving lessons for electric bicycles to raise motivation in the school community to swap their cars for (electric) bicycles (Lizana et al., 2019).

According to the second audit, parking spaces for bicycles were added in S1, 15 bicycle spaces in S4, 5 spaces in S5, while S6 acquired 3 bicycles. Second audit results (table 15) revealed that KPIs remained the same for parking spaces for electric cars, mainly due to the absence of necessity for use of electric vehicles and/or lack of financial investment. Regarding parking spaces for bicycles, the performance increased for S1, S4 and S5 where parking spaces were made available. With respect to annual CO_2 emissions, S2 was the only school to reduce its emissions from 97 kg CO_2 per student/year to 46 kg CO_2 per student/year, a reduction of 52%, while S4 had the highest increase of almost 47 kg CO_2 per student. The reason for CO_2 emissions reduction in S2 is that in the second audit it had the most significant decrease in the percentage of students who opted for cars in their commute to school and showed an increase in commute by foot; S4 on the other hand showed the highest increase of cars as option for commute, as shown in figure 5.

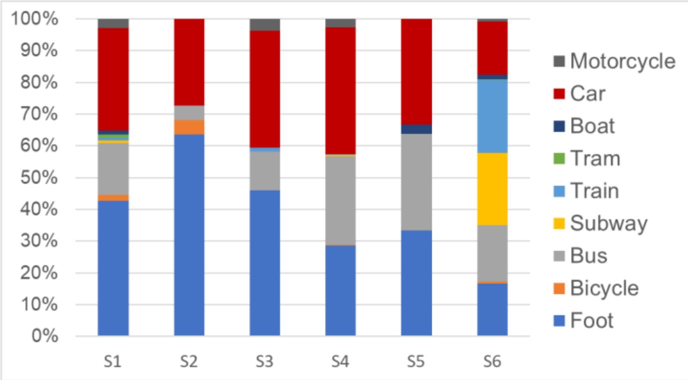

Figure 5 - Percentage of students' responses to home-school mode of transportation – second audit.

To assess the evolution of the schools after two years, scores were attributed and are presented below in figure 6. The parking score reveals an improvement in S1, S4 and S5. For public transport, meaning the availability of public transport networks in the schools' surroundings, the frequency with which public transportation passes daily and the existing number of stops, S6 showed the highest scores of 4.8 for the first and second audit. Scores remained the same for the remaining schools, but with very low values of under 2, particularly in S1 and S5, showing that there is a lot that can be improved. Regarding CO_2 emissions, only S2 showed a reduction by increasing its score from 2.9 to 4; the remaing schools' scores are consistant with the lack of good performance shown in their KPI analysis.

Figure 6 - Scores for parking spaces (top left), public transport (top right), and CO_2 emissions (bottom center).

Final scores shown in figure 7 reveal an average of 1.95 for the first audit and 2 for the second audit, considering the results of the six schools. All but S3, S5 and S6 made improvements, despite S6 having the highest final scores for both audits. The decrease in final score for S6 in the second audit was due to its decrease in parking score. Although there was not much difference in the audits' KPIs, parking spaces had a higher weighting and therefore resulted in a significant decrease in score for S6. This outcome reveals the need to prioritze infrastructure for bicycle and electric cars and to promote the use of public transport and soft mobility instead of individual car ride.

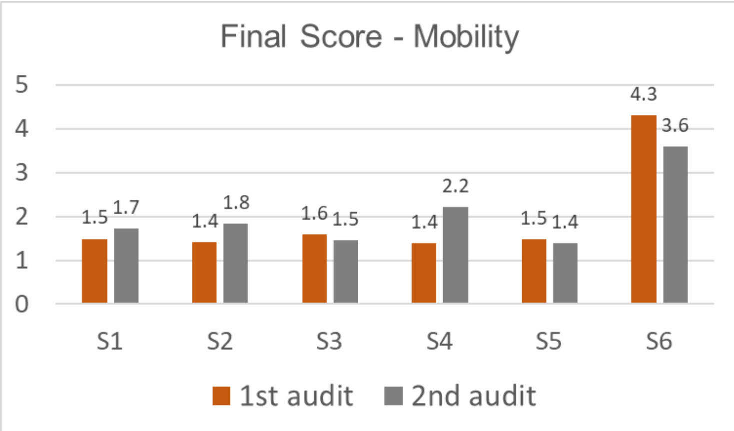

Figure 7 - Final scores for the transport sector – first and second audits.

4.2 Green Procurement

The Green Procurement sector evaluates the environmental impact associated with the purchase of products and services by the school. Its assessment was based on the evaluation of electric and electronic equipment with or without EU energy Label A+ or higher and determining its percentage (KPI_{GP1}); the amount of paper and recycled paper used (KPI_{GP2}, KPI_{GP3}); staff training in green procurement and certification of staff in eco-driving (KPI_{GP4}, KPI_{GP5}); acquisition of food produce from local producers and with biological certification (KPI_{GP6}) and the number of local suppliers of school services (KPI_{GP7}).

Initial audits in green procurement presented low KPI values, some of which are non-existent. Results in table 16 show that there was no training of staff in green procurement or eco-driving in any of the 6 schools. It should be noted that the schools in question are public schools so the sources of support for funding of actions and restructuring is more limited than if it were the case for private schools.

Paper consumption is the indicator with the highest result in S1 with 3.73 kg/student/year and the lowest in S3 with 0.04 kg/student/year. It is notable that none of the schools use recycled paper. In what concerns KPI for use of electronic equipment with better efficiency, S5 and S6 present equipment with higher efficiency, while S4 shows a low KPI of 0.09. All schools use school services from local suppliers except for S2 and S6 where it is unknown and only S4 acquires food goods containing biological certificate.

Initial results demonstrated that schools needed to promote awareness about the importance of green procurement, especially in the areas of acquisition of local and biological products and eco-driving training and education. Eco-driving is the concept of change in driving behaviour in a manner that reduces fuel consumption and GHG emissions (Martin et al., 2012; Ho et al., 2015). The act of eco-driving considers factors such as speed, acceleration and deceleration and route choice, which all have an impact on the amount of fuel consumed, emissions and costs (Huang et al., 2018). By purchasing locally, significant carbon footprint reductions can made from transport, packaging and storage of food products; and buying products with biological certificate ensures that they have been produced, stored, processed, handled and marketed in line with specific standards and certified as «organic», i.e., produced and processed ecologically (FAO, 2021).

Table 16 - KPI results for green procurement – first and second audit.

	S1		S2		S3		S4		S5		S6	
KPI - Green Procurement	1st audit	2nd audit	1st audit	2nd audit	1st audit	2nd audit	1st audit	2nd audit	1st audit	2nd audit	1st audit	2nd audit
KPI_{GP1} - Equipment efficiency	0.72	0.74	0.22	0.22	0.72	0.72	0.09	0.09	0.88	0.88	0.82	0.82
KPI_{GP2} - Paper used (kg/student)/yr	3.73	1.28	0.05	0.71	0.04	1.34	0.81	2.78	1.76	1.76	1.17	1.12
KPI_{GP3} - Recycled paper	0	0	0	0	0	0	0	0	0	0	0	0
KPI_{GP4} - Training in green procurement/staff	0	0	0	0	0	0	0	0	0	0	0	0
KPI_{GP5} - Eco-driving certification	0	0	0	0	0	0	0	0	0	0	0	0
KPI_{GP6} - Food with biological certificate	0	0	0	0	0	0	0.27	0.27	0	0	0	0
KPI_{GP7} - Local suppliers	0.75	0.6	0	0	0.33	0.33	0.29	1.00	0.2	0.14	0	0

To assist the school communities in green procurement, various activities were directed at improving schools' management of green choices. In S3, awareness was raised about paper-use and helping the school community to learn the importance of consumption reduction and alerting them about paper life cycle. S3 also promoted a sustainable diet without food waste and from local suppliers by performing awareness campaigns on how local foods contribute to low CO_2 emissions. In S4, students were given a workshop about healthy food options and were taught the importance of buying local produce with biological certification so that they gain a sustainable diet without food waste and be aware of the environmental implications related to the type of diet and food origin (Lizana et al., 2019).

Information obtained from audits showed that in S1 a refrigerator class A++ was purchased, along with 12 fixed computers and 12 screens of the same class. S4 disposed of a stove, as well as computer monitors and keypads. S5 substituted fluorescent lightbulbs for LED lights, and S6 purchased recycled paper.

KPI results for the second audit revealed an increase in performance for S1 regarding electronic equipment efficiency as a result of green purchases. Only S1 and S6 decreased their consumption in paper by 2.45 kg/student/year and 0.05 kg/student/year, respectively, while S3 and S4's consumption increased significantly. Regarding purchase from local suppliers, the only improvement made was in S4 with an increase in performance of 0.71.

With regard to scores (figure 8), electronic equipment efficiency showed good results for both audits, except for S2 and S4 that have margin for improvement. Overall, there were no improvements in between audits. Concerning paper consumption score, only S1 made an improvement due to its higher reduction in consumption with a score of 1.35, but still has great room for progress. S4 had a score of 0 for paper consumption in the second audit as it had the highest value of consumption per student at 2.78kg. As for purchases from local suppliers, S2 and S6 had scores of 0 and only S4 made a significant improvement. There were no scores for the quantity of paper recycled, staff training in green procurement, nor for staff with eco-driving certification, as a reflection of the associated KPIs.

Figure 8 - Scores for electric equipment efficiency (top left), paper consumption (top right), suppliers (bottom left) and biological food (bottom right).

Figure 9 shows a decrease in average final scores of 1.6 from the first audit to 1.4 for the second audit. This decrease was likely not intentional as schools can show willingness in acquiring green products, but efforts may not always translate into actual purchases and greener choices (Joshi & Rahman, 2015). Only S1 showed improvement with an increase of 0.7.

This sector requires more attention concerning behaviour change, meaning that schools need to implement more effective actions and raise awareness to increase its performance in green procurement, particularly in S4 where there was a significant decrease in the second audit likely due to its low score for paper consumption which had a higher weighting.

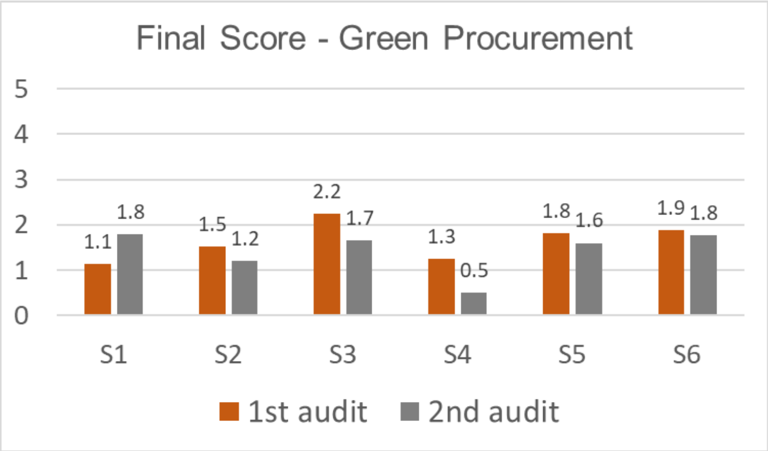

Figure 9 - Final scores for green procurement sector – first and second audits.

4.3 Green Spaces

Green spaces sector is divided into 4 sub-areas: green areas (KPI_{GS1} - KPI_{GS4}) that evaluates the number of trees and green area per non-covered area; CO_2 sequestration (KPI_{GS5}) which is calculated considering the number of trees and the estimated sequestration rate per tree, along with the grass area and the estimated sequestration rate per grass area; the use of chemicals such as fertilizers and pesticides (KPI_{GS6}); and CO_2 emissions from maintenance activities, i.e., type of equipment used and related energy and fuel (diesel, gasoline, oil) consumption; the type of irrigation and associated water consumption and gardening treatments (application of fertilizers and pesticides) (KPI_{GS7}).

Table 17 shows the covered area and non-covered area of each school. The covered area corresponds to the area covered by buildings plus area used for outdoor sport activities. Non-covered area consists of the total school area excluding the covered area, i.e., sum of all areas that have vegetation and lawn within the school, corresponding to the green area. The non-covered area relative to the total school area reveals there is more space to increase in greenery.

Table 17 - Area by type of occupation.

Occupation (m2)	S1	S2	S3	S4	S5	S6
Covered area	6943	1842	6330	7066	7829	7486
Non-covered area	7395	405	11126	20241	11274	3752
Total school area	22645	4309	21780	34258	27548	19640

Information obtained in audits indicated existing predominant tree species in each school: meek pine in S1, pine in S2 and S3, olive tree in S4 and S5 (including stone pine, cork oaks, and almond trees in S5) and sycamore tree in S6. The estimated sequestration rate of the predominant tree species is 5.03 kgCO_2/tree/year for meek pine species, 3.18 kgCO_2/tree/year for pine tree, 2.46 kgCO_2/tree/year for olive tree and 21.81 kgCO_2/tree/year for sycamore tree.

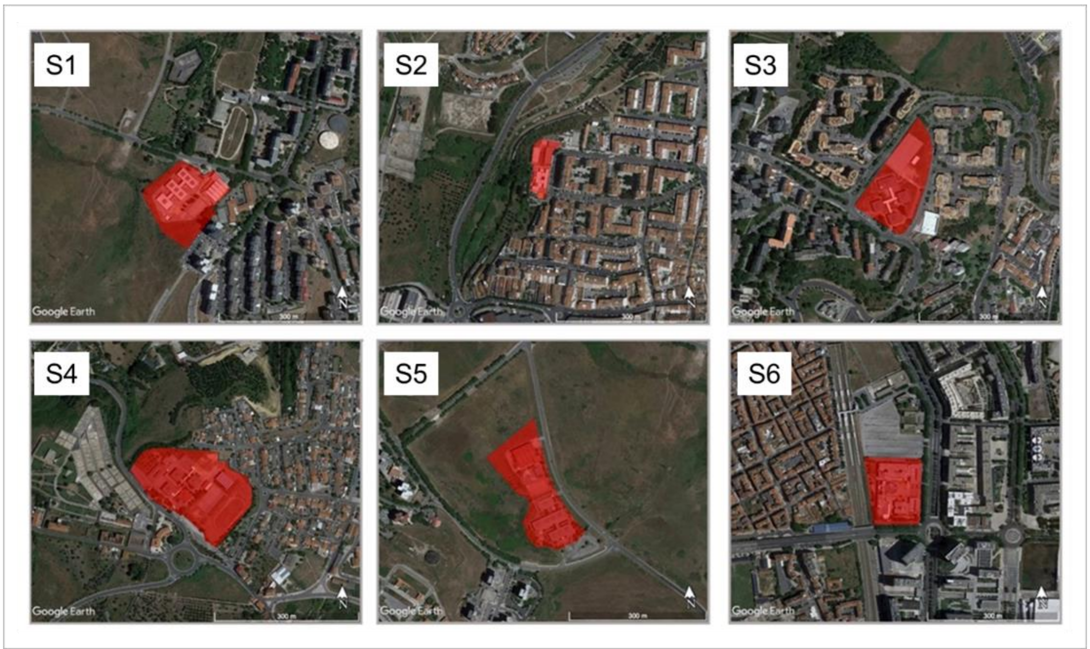

Figure 10 - Total school areas. Adapted from: d'Espiney (2017).

First audit KPIs are presented in table 18 and show that S2 has the best results for number of trees per student and per non-covered area at 0.36 and 0.04. S4 showed best results for green area per non-covered area and green area per student at 74% and 27m^2, followed by S5 with 57% and 23m^2 /student, respectively. As for annual CO_2 sink, S4 showed the best result, despite having olive trees as the predominant species, which is the species with the lowest sequestration rate of 2.46 $kgCO_2$/year. Values for chemicals used for gardening are practically non-existent, only showing results for S4 and S6 which are the two schools that use pesticides and fertilizers. Regarding CO_2 emitted during maintenance of green areas (use of equipment, irrigation), results for the first audit are null for most of the schools, with the exception of S2 and S6 with 0.02 $kgCO_2/year/m^2$ and 0.04 $kgCO_2/year/m^2$, respectively.

Table 18 - KPI results for green spaces – first and second audits.

KPI - Green spaces	S1		S2		S3		S4		S5		S6	
	1st audit	2nd audit	1st audit	2nd audit	1st audit	2nd audit	1st audit	2nd audit	1st audit	2nd audit	1st audit	2nd audit
KPI_{GS1} - No. of trees per non-covered area	0.004	0.004	0.04	0.040	0.003	0.003	0.004	0.004	0.009	0.009	0.006	0.006
KPI_{GS2} - No. of trees per student	0.10	0.108	0.36	0.34	0.062	0.064	0.133	0.133	0.36	0.35	0.040	0.039
KPI_{GS3} - Green area/non-covered area (%)	47.09	47.09	16.42	16.42	72.01	72.01	74.44	74.44	57.17	57.17	30.87	30.87
KPI_{GS4} - Green area per student (m2/student)	12.53	12.64	1.47	1.37	15.41	15.94	27.28	26.99	23.34	23.34	2.12	2.01
KPI_{GS5} - Annual CO_2 sinked/non-covered area	0.39	0.39	0.26	0.26	0.57	0.57	0.59	0.59	0.46	0.46	0.37	0.37
KPI_{GS6} - Chemicals/green area maintenace (kgCO2/m2)	0	0	0	0	0	0	0.001	0.001	0	0	0.001	0.001
KPI_{GS7} - CO_2 emitted/non-covered area (kgCO2/year.m2)	0	0	0.02	0	0	0	0	0	0	0	0.04	0.04

To improve the performances in this sector, various activities were done to enhance green spaces, such as construction of a biological and pedagogical garden in S3. S1, in collaboration with the City Council of Loures, planted two quince trees - *Cydonia oblonga*; in collaboration with the Rediscover Earth Project, a tamarisk tree was planted (African tamarisk), as well as a Tamujo tree (Flueggea tinctoria - shrub). S4 planted a lemon tree, an oak tree and recovered a vegetable garden; S6 planted a quercus tree and S5 created a mandala garden in which they planted different vegetable species with sufficient productivity for sale. Support for soil and planting acquisitions were provided by the Municipality and maintenance was done by students, giving them responsibility and an active role, which contributes to their learning (Lizana et al., 2019).

After these solutions were implemented, results for the second audit in table 18 show that S1 and S3 increased the number of trees per student and green area per student. S5 shows a decrease in the number of trees per student likely due to trees that were cut because they were damaged. In regard to CO_2 emissions from maintenance, S6 did not register any improvements, while S2 reduced its emissions likely due to the discontinuation of the use of gasoline as fuel.

Scores for green spaces in figure 11 reveal practically no differences between the first and second audit. With respect to CO_2 emissions, S2 and S4 both showed a score's increase of 2.8 and 0.58, respectively. S6 had a score of 0 for emissions in both audits due to its high consumption of fuel and water for gardening activities, whereas the rest of the schools showed maximum scores of 5. For green areas score, which comprise KPI_{GS1}, KPI_{GS2}, KPI_{GS3} and KPI_{GS4}, S2 had the highest values of 2.9 for both audits seeing as it presented the best performances for those indicators. CO_2 sequestration scores show best results for S4 followed by S3 with 4.7 and 4.6, respectively. As for use of chemicals, all schools had maximum scores except for S4 and S6 due to them being the only schools that use fertilizers and pesticides.

Figure 11 - First and second audit scores for green areas (top left); CO_2 sequestration (top right); use of chemicals (bottom left); and CO_2 emissions (bottom right).

Looking to the final score, it shows that S2 was the only school that improved its performance. Scores for the remaining schools remained constant.

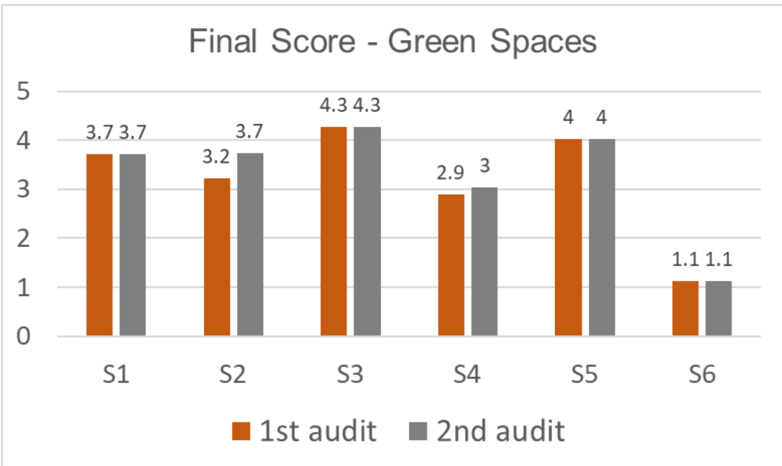

Figure 12 - Final score for green spaces sector – first and second audits.

4.4 Energy

The energy sector evaluated energy consumption in a first phase through the years 2014-2016 and a second phase 2017-2018, and its associated CO_2 emissions. The sector is divided into 4 sub-areas: energy consumption, where a final energy consumption was assessed per area and per student, using all energy source - electricity, diesel, liquified petroleum gas (LPG) (KPI_{E1} + KPI_{E2}); use of renewable energy, where on-site renewable energy production was evaluated in schools (KPI_{E3}); annual energy cost per area and per student (KPI_{E4} + KPI_{E5}); and assessment of CO_2 emissions related to annual energy consumption of the school, used as carbon footprint per student (KPI_{E6}).

Concerning energy sources, S1, S4 and S6 are provided energy from grid electricity and natural gas; S2 from grid electricity, natural gas, and thermal renewable; S3 from electricity grid, LPG, and natural gas and S5 from electricity grid and LPG.

Figure 13 below shows the final energy consumption from all energy sources and the associated annual cost, revealing S6 as having the highest results, and S2 the lowest in both cases. Typically, different levels of education require differences in energy consumption and in this case S6, a university, will have different energy use, occupancy density, and different hours of use than primary and secondary schools (Dias Pereira et al., 2014).

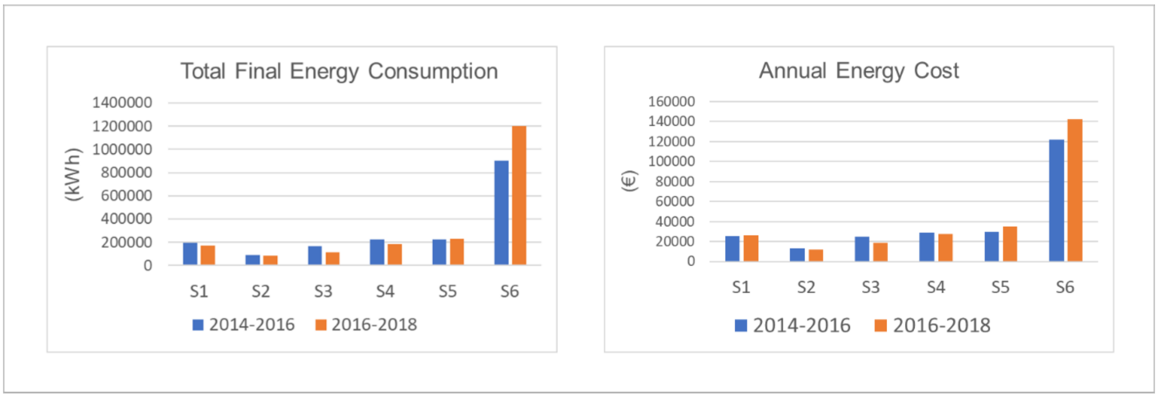

Figure 13 - Total final energy consumption (grid electricity + LPG + natural gas + on-site renewables) (left); annual energy cost (right) – 2014-2016-first audit; 2016-2018-second audit.

KPI results for the first audit in table 19 indicate that final energy consumption per area and associated costs per area was highest in S6, followed by S2. Despite S2 presenting the lowest number of students and the smallest school area of 2200 m^2, it had the second highest final energy consumption per area of nearly 42 kWh/year. As for final energy consumption and associated costs per student, S6 continues with the highest results at around 510 kWh/year and 69€/year, followed by S5 at 468 kWh/year and 61€/year, respectively. Regarding onsite renewable energy, S2 was the only one to have on-site thermal renewable at 3% production. As for annual carbon footprint per student ($kgCO_2$/student/year), S5 and S6 have the highest results, as expected, of 180 $kgCO_2$/student and 213 $kgCO_2$/student, respectively, while S3 shows the lowest carbon footprint at 79$kgCO_2$ per student.

Table 19 - KPI results for the energy sector – first and second audits.

	S1		S2		S3		S4		S5		S6	
KPI - Energy	1st audit	2nd audit	1st audit	2nd audit	1st audit	2nd audit	1st audit	2nd audit	1st audit	2nd audit	1st audit	2nd audit
KPI_{E1} - Final energy consumption/m2 (anual) [kWh/m2]	25.77	23.08	41.93	37.89	25.16	17.52	31.13	25.82	29.16	30.00	56.02	74.50
KPI_{E2} - Final energy consumption/student [kWh/student]	328.7	297.0	335.6	282.7	231.5	166.7	303.1	248.7	468.2	481.75	509.9	644.7
KPI_{E3} - (%) renewables energy production	0	0	2.6	2.6	0	0	0	0	0	0	0	0
KPI_{E4} - Energy cost per m2 (annual) [€/m2]	3.41	3.51	6.14	5.53	3.72	2.85	4.00	3.83	3.81	4.49	7.55	8.84
KPI_{E5} - Energy cost per student [€/student]	43.49	45.15	49.11	41.27	34.22	27.09	38.95	36.93	61.23	72.15	68.68	76.53
KPI_{E6} - Carbon footprint/student (annual) [kgCO2/student]	124.0	117.1	131.5	112.6	79.25	63.61	111.1	96.48	180.3	187.6	213.9	270.5

Actions that enable training and awareness about energy consumption and the importance of reducing consumption were emphasized in all 6 schools: construction of solar ovens with reused or recycled materials to raise awareness about solar energy and to teach the community about the importance of clean energies and their applications; energy savings awareness by implementing actions to reinforce the creation of eco-friendlier habits regarding energy consumption practices; mobilization of students to save energy in their daily routine, showing them that small actions can have a big impact on the environment (Lizana et al., 2019).

Second audit KPI results in table 19 reveal reductions in energy consumption per area and per student in all schools except for S5 and S6. In relation to energy cost per area and per student, all but S1, S5, and S6 reduced their costs. Renewable energy performance maintained the same performance for S2, while carbon footprints decreased in all schools except for S5 and S6. The increase in consumption and cost in both S5 and S6 could be due to occurences of inefficiencies such as equipment not being turned off during the weekend or holidays, or having extra number of appliances (microwaves, refrigerators) (Rauland et al., 2019). It is also important to note that S6 had an increase of 5% in the number of students.

Regarding the obtained scores' results, figure 14 reveals that S6 had all scores of 0 as a reflection of KPIs. Scores for energy consumption and energy cost shows S3 had the best results of scores of nearly 5 in both audits, followed by S1 and S4. The school with the most progress from the first audit was S2 with a score increase of +0.8 for consumption and +0.9 for costs. With respect to carbon footprint, all schools except for S6 showed improvements.

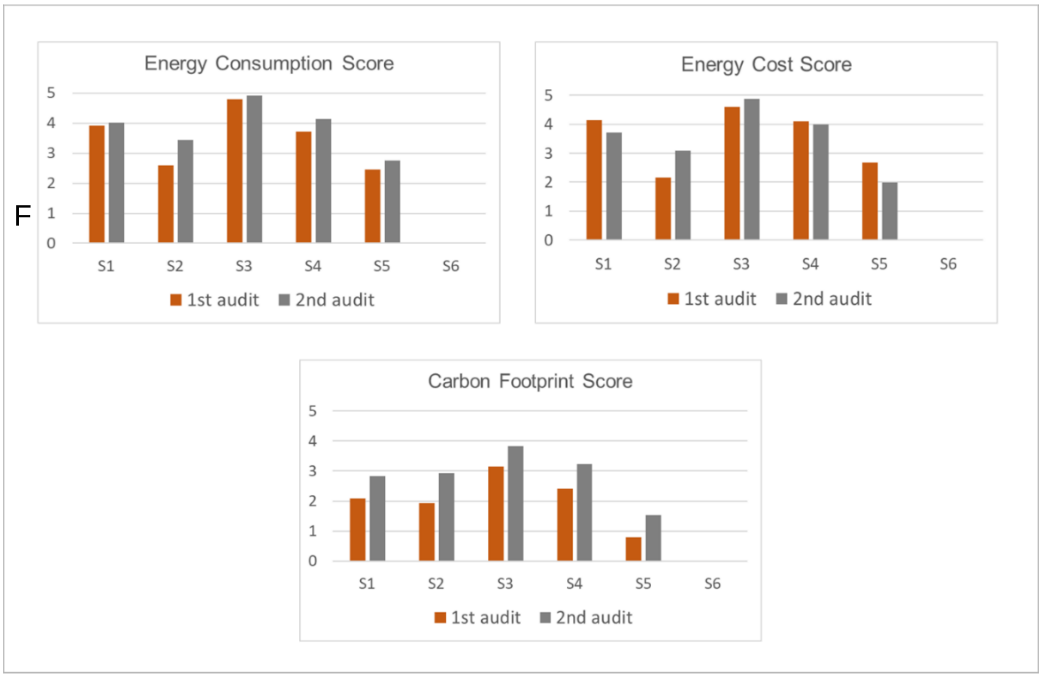

Figure 14 - First and second audit scores for energy consumption (top left), energy cost (top right), and carbon emissions (bottom center).

First and second audits' final scores (figure 15) revealed improvements in all schools, most notably in S2 by +0.7. Since S6 had the highest consumption, cost and carbon footprint in both audits, it resulted in scores of zero. Being that S6 is a university with a larger scale, with classes at all hours, libraries functioning the entire day and presence of laboraties, there is more power consumption and more diffculty in managing energy systems (Qu et al., 2015). Results for S6 show potential for improvements in energy savings.

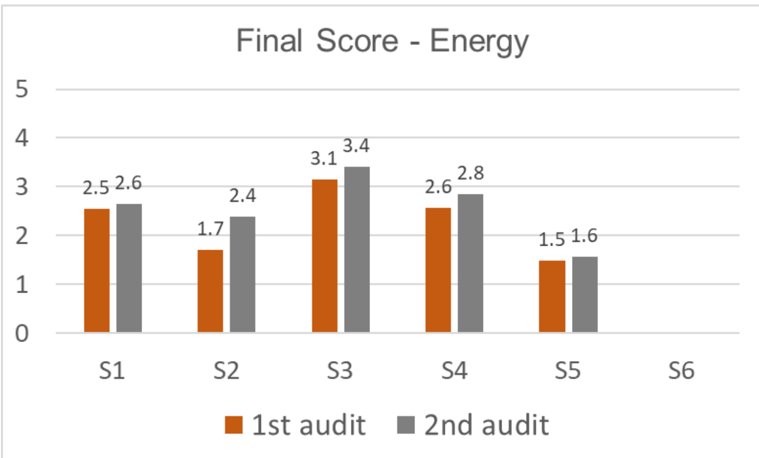

Figure 15 – Final scores for the energy sector – first and second audits.

4.5 Water

The water sector evaluates the schools' water consumption during the first three years of the first phase (2014, 2015, 2016) and during two years of the second phase (2017, 2018), and its associated cost. The sector is divided into two sub-areas: water consumption, consisting of annual consumption per area and per student (KPI_{WR1} & KPI_{WR2}), and water cost consisting of annual costs per area and per student (KPI_{WR3} & KPI_{WR4}). Figure 16 shows the average water consumption for both audits.

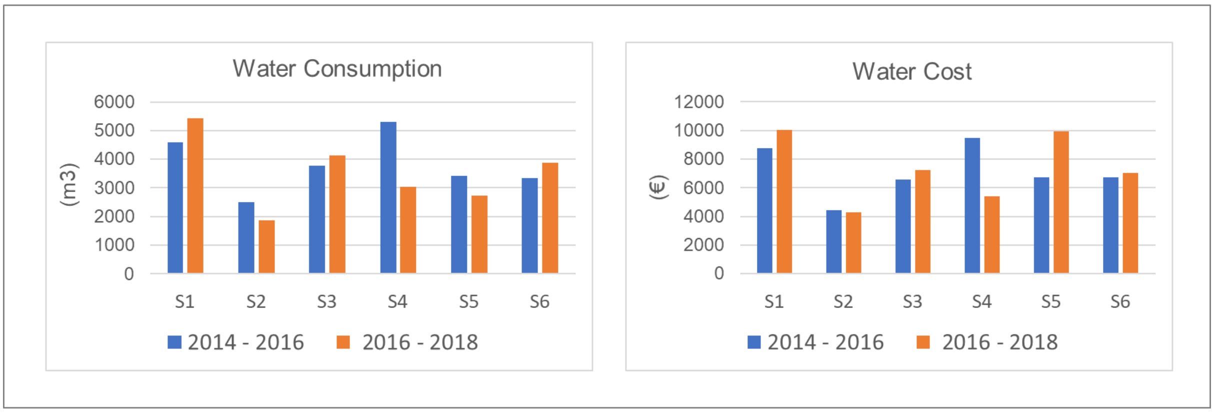

Figure 16 - Average of water consumption (left) – first audit (2014-2016) and second audit (2016-2018); average water cost (right) – first audit (2014-2016) and second audit (2016-2018).

KPI results for the first audit, presented in table 20, show that S2 has the highest water consumption per area and per student, while S6 has the lowest. This could be due to S6 having water-saving devices such as timed taps with low flow rates, and toilet flushes to reduce water volume per flush and having drop-by-drop irrigation system (d'Espiney, 2017). S2 has students of younger ages and requires a more diverse use of water in everyday school activities (Farina et al., 2011). Regarding water costs, we can see the same pattern with S2 having the highest cost and S6 the lowest.

Table 20 - KPI results for the water sector – first and second audits.

	S1		S2		S3		S4		S5		S6	
KPI - Water	1st audit	2nd audit	1st audit	2nd audit	1st audit	2nd audit	1st audit	2nd audit	1st audit	2nd audit	1st audit	2nd audit
KPI_{WR1} - Water consumption (m3/m2)	0.61	0.72	1.14	0.85	0.57	0.62	0.73	0.42	0.44	0.35	0.21	0.24
KPI_{WR2} - Water consumption (m3/student)	7.79	9.22	9.09	6.82	5.23	5.72	7.14	4.08	7.09	5.63	1.89	2.19
KPI_{WR3} - Water cost (€/m2)	1.16	1.33	2.00	1.94	0.99	1.09	1.31	0.75	0.86	1.28	0.42	0.44
KPI_{WR4} - Water cost (€/student)	14.82	16.98	16.04	15.52	9.12	10.03	12.78	7.28	13.88	20.57	3.79	3.96

To reduce water consumption S1, S2 and S3 participated in awareness campaigns about water savings with the purpose of creating new eco-habits so that students understand that less water consumption leads to less CO_2 emissions (Lizana et al., 2019).

The second audit (table 20) reveals reductions in water consumption per area and per student for S2, S4 and S5, while S2 and S4 also reduced their costs. S2 remained the school with the highest consumption values for the reasons previously mentioned, despite having reduced in consumption and costs. S5 is notably the only school to decrease water consumption per area and per student but increased in water costs per area and per student by 1.4 €/m^2 and 7.5 €/student, respectively. This discrepancy between consumption and cost could be owed to change in water tariffs or that the school might have been overcharged on their water bills.

Figure 17 below shows S6 as having nearly the highest values in both audits, for each intermediate scores. S2, as a reflection of KPIs, presented scores of 0 both for water consumptions per area and per student, as well as water costs per area and per student, but did show improvement for water consumption and water cost per student in the second audit. This shows that efforts to make reductions led to a positive result. In S5, due to a significant increase in water cost per student in the second audit, water cost per student resulted in a score of 0. Overall, intermediate scores appear to show inconsistencies between consumption and costs, whether it be per area or per student.

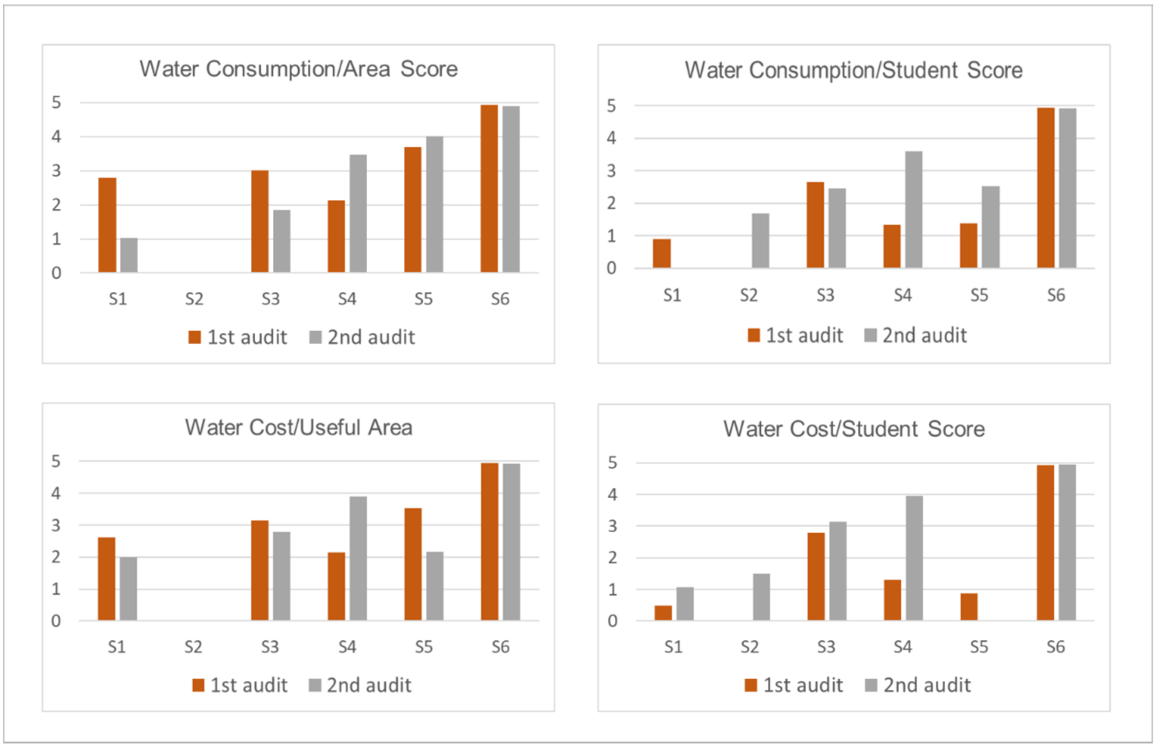

Figure 17 - First and second audit scores for water consumption per area (top left), water consumption per student (top right), water cost per area (bottom left), and water cost per student (bottom right).

Final scores for the water sector in figure 18 show S2 as having the lowest results due to its values for KPIs but did make an improvement of +0.8 from the first audit, indicating that awareness campaigns along with improvement actions made a difference. S4 made the most significant final score improvement of +2 as it reduced water consumption and costs significantly. Scores for S1 and S3 are consistent with intermediate scores.

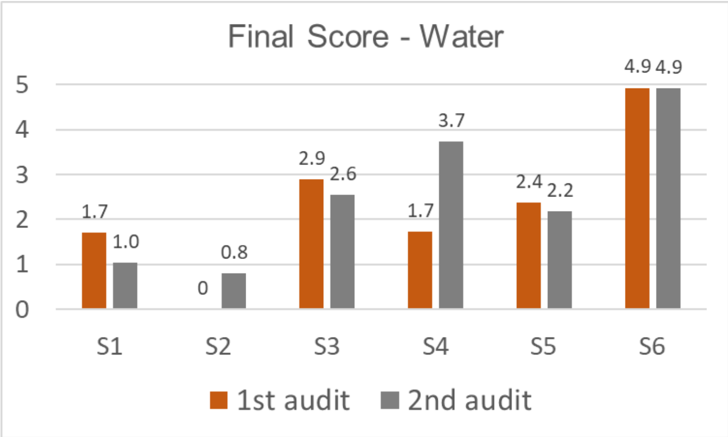

Figure 18 - Final scores for water sector – first and second audits.

4.6 Waste

The waste sector is quantified according to the volume of waste produced, recycled, and reused in schools. The assessment is divided into 3 sub-areas: determining waste produced (non-recyclables and reusables) in schools, with the aim of implementing strategies for waste reduction (KPI_{W1}); determining the type and volume of waste recycled in schools, compared to the amount of waste produced (KPI_{W2}); determining the amount of waste reused for further life cycle in schools (KPI_{W3}).

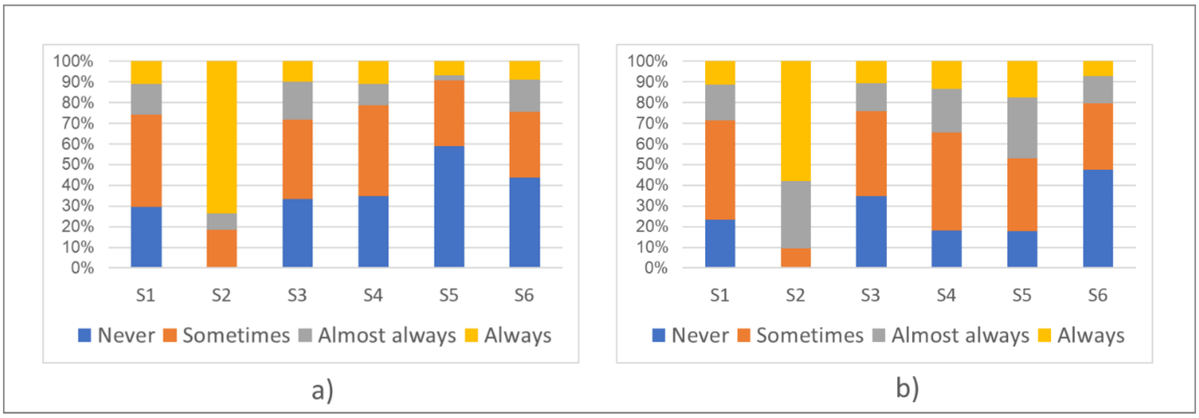

Figure 19 - Percentage of students' answers to separating waste in school : a) 1st audit ; b) 2nd audit

An online behaviour questionnaire was conducted to see if individuals practiced recycling in schools. The questionnaire from the first audit presented in figure 19a revealed that, out of all the students that answered, 37% said they never separate waste for recycling and nearly 12% always separate waste. Individually, S2 showed that students are more conscious about recycling.

The average volume of total waste produced in five of the six schools (S5 excluded due to lack of information) in the first audit was 9.6 l/student/week. S1 showed the highest volume at 12 l/student/week and S6 showed the lowest at 7 l/student/week, despite S6 having more students. S5 had no available information for the volume of non-recyclables and reused waste, recycled waste or waste reused for the first audit.

With reference to KPIs, also expressed in litres per student per week, results presented in table 21 show that the average amount of non-recyclables and reused waste produced in four of the schools in the first audit was 7 l/student/week (information was unavailable for S2). S3 and S6 presented the highest volume of non-recyclables and reused waste produced, rounding 9 and 7 litres/student/week, respectively. As for waste recycled, the average volume for all six schools rounded 5 litres/student/week, with S2 presenting the highest result at around 8 l/student, indicating that students have the habit of recycling in school, which is reflected in figure 19a. There were no data available for waste reused for the first audit.

Table 21 - KPI results for the waste sector - first and second audits.

	S1		S2		S3		S4		S5		S6	
KPI - Waste	1st audit	2nd audit	1st audit	2nd audit	1st audit	2nd audit	1st audit	2nd audit	1st audit	2nd audit	1st audit	2nd audit
KPI_{W1} - Waste produced (l/student) (non-rec & reused)	6.37	8.44	-	4.00	8.94	1.05	5.69	6.67	-	6.79	7.33	7.33
KPI_{W2} - Waste recycled (l/student)	5.68	4.54	8.12	8.12	1.51	3.00	4.53	4.04	-	2.48	-	-
KPI_{W3} - Waste reused (l/student)	-	-	-	0.05	-	-	-	-	-	-	-	-

Measures and activities were implemented in efforts to reduce the volume of waste produced and to increase the amount of recycled and reused materials in schools. All six schools participated in environmental education programs with the goal of reducing waste by collecting paper, plastic metal, batteries, and electrical and electronic waste used in their school, with the purpose of promoting recycling and good environmental practices. In S1 there were cleaning activities of the school area to raise awareness of the importance of having good habits concerning the environment, while S3 promoted collection and reuse of waste by reusing recycled materials to assemble toys and school supplies. As solutions to increase waste reused, all schools used reused materials to make Christmas decorations and in S2 there was an activity designing costumes with reused materials (Lizana et al., 2019).

In the second audit, only S3 made a notable improvement by reducing its total waste production by 6.4 l/student/week and non-recyclable and reusable waste by 7.9 l/student/week, hence the score of 5 (figure 20) for waste produced in the second audit. The remaining schools maintained relatively the same volumes of waste while S2 showed results for waste reused at 0.05 l/student/week. Concerning the quantity of waste recycled, S3 also improved from the first audit, increasing the amount of waste recycled by 1.5 l/student/year.

The second audit questionnaire in figure 19b shows there was a reduction in students' response to 'never practicing recycling in school' by 31%. Although the questionnaire did not entail the same group of students and was not a reflection of KPI for waste recycled, it could be indicative of an increase in students' awareness of the importance of recycling.

In relation to intermediate scores for waste produced (figure 20), results vary between schools and between audits. For example, S1 and S4 had significant increases in waste production in the second audit, contrary to S3 that made a massive reduction. There are some difficulties for schools to determine the exact amount of waste produced, therefore there might have been under or over calculations in between audits.

Figure 20 - First and second audit scores for waste produced (top left), waste reused (top right) and waste recycled (bottom center).

igure 21 below shows final scores for the waste sector. The only schools that made improvements from the first audit were S2 and S3 with an increase in scores of 2.7 each. The waste sector certainly shows great potential for improvements.

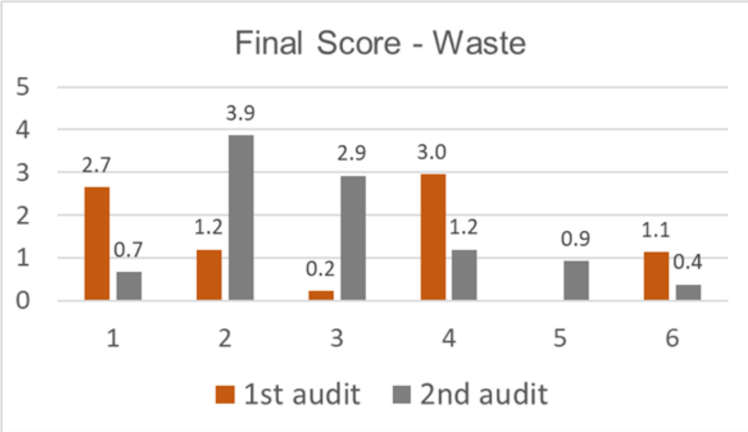

Figure 21 - Final scores for the waste sector – first and second audits.

4.7 CO_2 Emissions & Average of Final Scores

Annual CO_2 emissions per student were accounted for in mobility and energy sector. Figure 22 shows that, for mobility, S2 reduced emissions by 49%. The remaining schools had an average annual increase in emissions of 10%, resulting in an increase of 20 $kgCO_2$ per student per year.

For the energy sector, all schools except for S5 and S6 had reductions in annual emissions per student. S2 showed the highest reduction of 19 $kgCO_2$/student/year, followed by S3 and S4, indicating that the primary schools were more effective in applying actions and improvement measures to reduce the schools' energy consumptions.

Figure 22 - Annual carbon emissions per student from the transport sector (left) and the energy sector (right).

Figure 23 below shows the average environmental and energy final scores obtained for all six schools - first and second audits. S1 had shown the lowest scores and/or no improvements for water and waste, while S6 showed the lowest scores and/or no improvements for all sectors, including a score of zero for energy in both audits, resulting in scores presented below where improvements were made in all schools except for S1 and S6, with S2 presenting the most progress.

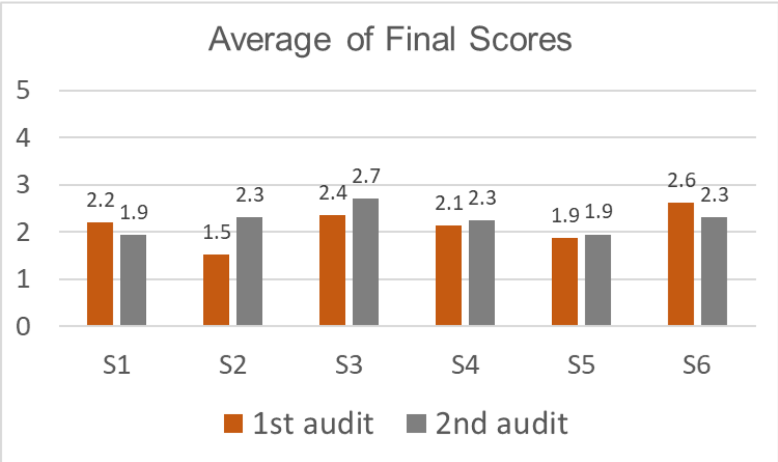

Figure 23 – Average of final scores for all sectors - first and second audit.

5. CONCLUSIONS

The scope of this thesis was to evaluate the environmental and energy performance of six ClimACT schools located in Portugal, in the areas of mobility, green procurement, green spaces, water, waste and energy. An evaluation of the schools' performance evolution spanning two years was made after action plans were implemented to reduce the schools' carbon footprints, in which the aim was to assess the ClimACT methodology applied and determine the real impact of the project. The methodology consisted of measuring the sustainability of each school through performance indicators and providing tools through activities and measures directed at promoting and supporting school communities in their transition to becoming low carbon schools.

The average environmental and energy final score of the six schools improved from 2.1/5 to 2.2/5 after the methodology implementation, reaching an improvement of nearly 5%. Regarding the impact that the project had in each school, S3 showed the highest average final scores in both audits at 2.4 for the first and 2.7 for the second. The school that made the most improvement was S2 with an increase in average final score of +0.8 (figure 23). S1, S5 and S6 all decreased in average final scores. The different results in schools allow for the interpretation that students of younger ages – in primary schools, most notably S2 – are more prone to positive behaviour changes than older students and adults. It also indicates that secondary schools and universities (in the case of S5 and S6) may contain factors that hinder the implementation of a methodology such as ClimACT.

Concerning environmental sectors, waste showed the highest improvement of +0.4, mostly due to the significant efforts made in S2 and S3, showing that action plans and promoting awareness had an impact in those schools. Water and energy sectors both had the second highest improvements of approximately +0.2 each. Mobility and green spaces scores stayed constant while green procurement had a reduction in average scores. In the case of mobility and green spaces, they are sectors that are difficult to make improvements in a short period of time. For example, mobility requires behaviour change from the school community and infrastructure changes, not only inside the schools but in general transport network - more bicycle lanes, increase in parking spaces for electric cars if necessary, and access to different types of public transport, etc. In relation to green procurement, schools are required to alter their criteria concerning purchases of goods and services when the community is not sensitized to the importance of more sustainable choices such as use of recycled paper, staff training in green procurement and eco-driving, and when the reality is that public schools do not have control over purchases of school office supplies, cleaning products and services, meal services, etc. Nevertheless, these are things that, overtime, can be accomplished with the right tools and support.

Overall, the findings of the project indicate that conducting these types of audits with a follow-up is an effective way of ensuring that audit work has a lasting impact if and when it determines progress in resolving deficiencies after implementing improvement measures. In this case, the ClimACT methodology made a difference in environmental performances as the majority of schools managed to reduce their carbon footprint. However, there is still a large margin of improvement for the schools.

6. FUTURE PERSPECTIVES

In looking towards more sustainable schools and ensuring that guidelines and recommendations are implemented efficiently, the main priority should be to prepare the school community beforehand by incorporating the concept of sustainability into the curriculum so that students start acquiring sustainable behavioral patterns throughout their academic lives. It would also help if the construction and design of schools were further directed towards sustainability, where the overall objective is to minimize the energy consumption and help create high performance environments.

For future work concerning projects such as ClimACT, the prospect is that schools manage to define action plans and retrofit solutions that fit the specific needs of each school, as well as improvement in infrastructure where is needed so that schools can fully benefit from implemented measures. Schools should also engage students in the audit itself so that they understand the purpose of activities and action plans, thus contributing to their training and environmental awareness while creating a healthy school environment. Teachers and staff should be adequately prepared beforehand so that accurate information is given during the audit process. A solution to that would be to create a more efficient process to facilitate data collection in schools. In the case of ClimACT, schools had access to the information requested, but certain details were not available.

Concerning environmental sectors, given the increase in CO_2 emissions for mobility, schools should engage in car sharing and active travel whenever possible. For that, local authorities should provide safe access to bicycle paths and pedestrian lanes. A bike rental system can be created through school partnerships benefitting, for instance, university students. Public transport systems should be made safe, convenient, and affordable to incentivize use of public transportation (WHO, 2008).

With respect to waste, schools should provide for recycling options and attempt to reduce, reuse and recycle as much as possible. Concerning food waste, efforts can be made to buy only the amount of food products that is needed; the practice of composting should be implemented, which can save on costs for fertilisers and other chemicals. To cut down on plastic waste, students can be provided reusable water bottles and water refill stations can be installed within the schools.

In regard to green procurement, school communities can be more aware of the origins of products and services, and how their purchase power can have an impact on carbon emissions. To successfully achieve this, there must be staff training and guidance which can be done through workshops and environmental training initiatives. Regarding paper consumption, schools can provide recycled paper for material use, especially in primary schools where there are various activities, homework and school projects that require paper consumption. As for universities, the possibility of becoming paper-free is more attainable since the majority of students and teachers own computers and other electronic equipment, allowing for electronic storing of documents and reduction in the necessity to print student work and study material.

Energy and water are two sectors that require education and behaviour change. Small gestures such as turning off the water when not in use and monitoring energy use can make a notable difference in consumption and utility bills. It is an opportunity to start educating students on this matter from a young age, such that they carry a positive conduct throughout the academic years.

In relation to the ClimACT methodology, when conducting behaviour questionnaires, schools should make sure to include the same group of students, teachers and staff in both audits to better understand the evolution in individual behaviour and accurately determine the effectiveness of implemented measures.

Projects like this present great benefits when school and campus grounds are used as teaching tools for research, innovation, and sustainability (European Commission, 2021; SERC, 2019). Hence, the importance of adopting a Living Lab approach where school communities, along with local counties, can engage in research questions and challenges to be addressed within the school environment (EU, 2019). This means that students can work together with adult professionals to co-create and design ideas and technologies (SALL, 2021) to solve real-life problems, i.e., there is a direct applicability of the research/science in the school community, with great potential to re-shape the education process with a holistic approach (European Commission, 2021).

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ANNEX

Annex I – Behaviour Questionnaires

School Identification	Teacher Identification	Class	Low Carbon Brigade Member
			Yes [ ] No [ ]
Student [ ]		Age	Gender
Teacher [ ]	Staff [ ]		F [ ] M [ ]

Questionnaire ClimACT | 1	Answers
1. Waste	
1.1. Do you separate recyclable waste at school and put it in the recycling bin?	Never [ ] Sometimes [ ] Almost Always [ ] Always [ ]
1.2 Do you separate the paper/cardboard at home?	Never [ ] Sometimes [ ] Almost Always [ ] Always [ ]
1.3. Do you separate the plastic/metal packaging at home?	Never [ ] Sometimes [ ] Almost Always [ ] Always [ ]
1.4. Do you separate the glass packaging at home?	Never [ ] Sometimes [ ] Almost Always [ ] Always [ ]
1.5. Do you separate the organic waste to use it as fertilizer at home?	Never [ ] Sometimes [ ] Almost Always [ ] Always [ ]
1.6. Do your family use reusable bags for shopping?	Never [ ] Sometimes [ ] Almost Always [ ] Always [ ]
1.7. Do you deliver electrical and electronical equipments for recycling?	Never [ ] Sometimes [ ] Almost Always [ ] Always [ ]
1.8. Do you try to repair electrical and electronic equipment when they break down?	Never [ ] Sometimes [ ] Almost Always [ ] Always [ ] Not applicable to under 10 years [ ]
1.9. Do you use any second hand scholar book?	Never [ ] Sometimes [ ] Almost Always [ ] Always [ ] Not applicable to under 10 years [ ]
2. Energy	
2.1. Do you switch off the lights when they are not needed?	Never [ ] Sometimes [ ] Almost Always [ ] Always [ ]
2.2. Do you leave the TV on standby at home?	Never [ ] Sometimes [ ] Almost Always [ ] Always [ ]
2.3. Do you turn the computer into hibernation mode instead of shutting it down in the evenings?	Never [ ] Sometimes [ ] Almost Always [ ] Always [ ]
2.4. Do you leave chargers plugged in when they are not charging any device?	Never [ ] Sometimes [ ] Almost Always [ ] Always [ ]
2.5. Do you have solar panels installed at home?	No [ ] Yes [ ] No, but I plan to [ ] Not applicable to under 10 years [ ]
2.6. Could you reduce energy consumption at home?	No [ ] Yes [ ] If yes, how? Not applicable to under 10 years [ ]
2.7. Does your home have an energy efficiency accreditation?	No [ ] Yes [ ] If yes, what is? ____ Not applicable to under 10 years [ ]
2.8. Do you take into account energy efficiency labelling when you buy a new electrical or electronic equipment?	Never [ ] Sometimes [ ] Almost Always [ ] Always [ ] Not applicable to under 10 years [ ]
2.9. Do you take into account the lifespan of a product when you buy a new one?	Never [ ] Sometimes [ ] Almost Always [ ] Always [ ] Not applicable to under 10 years [ ]

4. Transports	
4.1. Do you travel to the school by foot?	Never [ ] Sometimes [ ] Almost Always [ ] Always [ ] If yes indicate the time you spend going from your home to school: ___ minutes
4.2. Do you travel to the school by bicycle?	Never [ ] Sometimes [ ] Almost Always [ ] Always [ ] If yes indicate the time you spend going from your home to school: ___ minutes
4.3. Do you travel to the school by bus?	Never [ ] Sometimes [ ] Almost Always [ ] Always [ ] If yes indicate the time you spend going from your home to school: ___ minutes
4.4. Do you travel to the school by subway?	Never [ ] Sometimes [ ] Almost Always [ ] Always [ ] If yes indicate the time you spend going from your home to school: ___ minutes
4.5. Do you travel to the school by train?	Never [ ] Sometimes [ ] Almost Always [ ] Always [ ] If yes indicate the time you
4.6. Do you travel to the school by tram?	Always [ ] Always [ ] If yes indicate the time you spend going from your home to school: ___ minutes
4.7. Do you travel to the school by boat?	Never [ ] Sometimes [ ] Almost Always [ ] Always [ ] If yes indicate the time you spend going from your home to school: ___ minutes
4.8. Do you travel to the school by car?	Never [ ] Sometimes [ ] Almost Always [ ] Always [ ] If yes indicate the time you spend going from your home to school: ___ minutes
4.9. Do you travel to the school by motorcycle?	Never [ ] Sometimes [ ] Almost Always [ ] Always [ ] If yes indicate the time you spend going from your home to school: ___ minutes
4.10. Do you practice car sharing when you travel to the school? If yes, how many passengers go to your school with you?	No [ ] Yes [ ] _____
4.11 Do you go back to your home and return to school more than once per day?	No [ ] Yes [ ]
4.12. What is the distance between your home and school?	_______ km
4.13 How much do you spend on your trips home – school, using car or motorcycle each month?	______€
4.14 How much do you spend on your trips home - school using public transports each month?	______€
4.15. If there was a bike path between your home and the school, would you rather the bike?	Never [ ] Sometimes [ ] Almost Always [ ] Always [ ] Not applicable to under 10 years [ ]
4.16. Do you use the public transport when you go out with your family on the weekends?	Never [ ] Sometimes [ ] Almost Always [ ] Always [ ]

5. Citizenship	
5.1. How often do you eat meat at home?	Never [ ] Once a week [ ] Sometimes [ ] Everyday [ ]
5.2. How often do you eat fish at home?	Never [ ] Once a week [ ] Sometimes [ ] Everyday [ ]
5.3. Have you ever subscribed any environmental petition?	No [ ] Yes [ ] No, but I plan to [ ] Not applicable to under 10 years [ ]
5.4. Have you ever reported an environmental offence in your town?	No [ ] Yes [ ] No, but I plan to [ ] Not applicable to under 10 years [ ]
5.5. Do you belong to any association/Non-Governmental Organization (NGO)?	No [ ] Yes [ ] No, but I plan to [ ] If yes, what is? ____ Not applicable to under 10 years [ ]
5.6. Have you ever participated in a beach, forest or other cleanup?	No [ ] Yes [ ] No, but I plan to [ ]
5.7. Have you ever participated in tree-planting campaigns?	No [ ] Yes [ ] No, but I plan to [ ]
5.8. Would you like to participate in keeping a vegetable garden?	No [ ] Yes [ ] Maybe [ ]
5. 9. What do you think you could do, or help to do, in order to transform your school in an environmentally and climate friendly school?	(open question)

Source: ClimACT, 2016

Annex II - Checklists

A) Administrative data	
A1. Name of the school	
A2. Type of school	
A3. Age-range of students	
A4. Country	
A5. City	
A6. Address	
A7. Low Carbon Coordinator	
A8. Name/role of the persons that provide information for this questionnaire	
General Foto of the School	

B) Physical characteristics	
B1. Year of construction	
B2. Area of the school (m2)	
B3. Gross floor area (m2)	
B4. Usable floor area (m2)	
B5. Indoor conditioned area (m2)	
B6. Number of floors	
B7. Number of classrooms	
B8. Area of the classrooms (m2)	
B9. Canteen (Y/N)	
B10. Gymnasium (Y/N)	
B11. Description and year of any refurbishment process or upgrading of heating, ventilation and air conditioned & refrigeration (HVAC&R) systems	
B12. Definition of national/regional technical codes of school design (e.g.: Andalusian school design code: http://www.juntadeandalucia.es/boja/2003/43/3)	

C) Use of the building	
C1. Number of occupants	
C1.1. Students	
C1.2. Teachers	
C1.3. Administrative Staff	
C1.4. Auxiliar Staff	
C2. Number of occupants per classroom	

D) Energy consumption	
D1. Is eletricity consumed? (Y/N)	
D1.1. Annual average bill (kWh, €)	
D1.2. What are the main uses of electricity (eg: air conditioning, ventilation, lighting,...)?	
D2. Is natural gas consumed? (Y/N)	
D2.1. Annual average bill (kWh, m3, €)	
D2.2. What are the main uses of natural gas (eg: hot water, heating,...)?	
D3. Is propane/LPG consumed? (Y/N)	
D3.1. Annual average billl (kg, €)	
D3.2. What are the main uses of propane/LPG (eg: hot water, heating,...)?	
D4. Is oil/diesel consumed? (Y/N)	
D4.1. Annual average billl (kg, €)	
D4.2. What are the main uses of oil/diesel (eg: hot water, heating,...)?	
D5. Are other fuels or other energies consumed? (Y/N) Which? (eg: biomass,...)	
D5.1. Annual average bill (energy units, €)	
D5.2. What are the main uses of other fuels or other energies (eg: hot water, heating, ...)?	
Observations/comments on energy consumption	

E) Energy production	
E1. Is there energy production (eg: photovoltaic panels)?	
E1.1. What portion of this energy is consumed in the building?	
Observations/comments on energy production	

F) Lighting	
Fi) Interior Lighting	
Fi1. What type of lighting is predominantly used in the building (eg: fluorescent, incandescent, halogen, LED,...)?	
Fi1.1. Definition of available technical data. Characterization (eg.: power (W), luminous flux (lumen),...)	
Fi1.2. Approximate year of the system installation	
Fi1.3. Brand and model of the system (most common system)	
Fi2. What is the lighting schedule?	
Fi3. Are there systems for automatic control (eg: motion sensor, time clock, photocell,...)? Which and where?	

Fe) Exterior Lighting	
Fe1. What type of lighting is predominantly used in the exterior (eg: fluorescent, incandescent, halogen, LED, metal halide...)?	
Fe1.1. Definition of available technical data. Characterization (eg.: power (W), luminous flux (lumen),..)	
Fe1.2. Approximate year of the system installation	
Fe1.3. Brand and model of the system (most common system)	
Fe2. What is the lighting schedule?	
Fe3. Are there systems for automatic control (eg: motion sensor, time clock, photocell,...)? Which and where?	
Observations/comments on lighting	

G) Heating	
G1. Are there heating systems in the building?	
G2. Equipment used for heating in the building:	
G2.1. Type of system (centralized system, single units,...)?	
G2.2. Which is the temperature setpoint for heating?	
G2.3. Type of equipment (eg: heat pump, boiler, radiators...)	
G2.4. Type of energy/fuel consumed (eg: eletricity, natural gas, propane,...)	
G2.5. Definition of available technical data. Characterization (eg: power, yield, EER, COP,..)	
G2.6. Approximate year of the system installation	
G2.7. Brand and model of the system (most common system)	
G3. Utilisation schedules	
G3.1. The heating is used in which months of the year?	
G3.2. How many hours a day is the heating on during those months?	
G4. Is there regular maintenance work?	
G4.1. Definition of maintenance frequency	
G4.2. Definition of annual maintenance cost	
Observations/comments on heating	

H) Cooling	
H1. Are there cooling systems in the building?	
H2. Equipament used for cooling in the building:	
H2.1. Type of system (centralized system, single units,...)?	
H2.2. Which is the temperature setpoint for cooling?	
H2.3. Type of equipment (eg: chiller, monosplits,...)?	
H2.4. Type of energy/fuel consumed (eg: eletricity, natural gas,	
H2.5. Definition of available technical data. Characterization (eg: power, yield, EER, COP,..)	
H2.6. Approximate year of the system installation	
H2.7. Brand and model of the system (most common system)	
H3. Utilisation schedules	
H3.1. In which months of the year is the cooling used ?	
H3.2. How many hours a day is the cooling on during those months?	
H4. Is there regular maintenance work?	
H4.1. Definition of maintenance frequency	
H4.2. Definition of annual maintenance cost	
Observations/comments on cooling	

I) Ventilation	
I1. Is there mechanical ventilation in classrooms?	
I1.1. Type of system/equipment of ventilation	
I1.2. Approximate year of the system installation	
I1.3. Definition of available technical data. Characterization (eg.: ventilation rate, electric power,...)	
I1.4. How many hours per day is the mechanical ventilation in classroom on?	
I2. Is there natural ventilation in classrooms?	
I2.1. Type of system/equipment of natural ventilation (eg: windows, free-cooling system,...)	
I2.2. Is ventilation operating at night?	
I2.3. Does the teachers open the windows during the classes?	
I2.4 Does the teachers open the windows during the intervals?	

I3. Is there mechanical ventilation in other zones? Where? (eg: kitchen, toilets, parking, ,...)	
I3.1. Type of system/equipment of ventilation	
I3.2. Approximate year of the system installation	
I3.3 Definition of available technical data. Characterization (eg.: ventilation rate, electric power,...)	
I3.4. How many hours a day is the ventilation on?	
I4. Is there natural ventilation in other zones (eg: kitchen, toilets,...)? Where?	
I5. Is there regular maintenance work of mechanical ventilation systems?	
I5.1. Definition of maintenance frequency per system	
I5.2. Definition of annual maintenance cost per system	
Observations/comments on ventilation	

J) Other equipments	
J1. Are there digital blackboards in classrooms?	
J1.1. Are shading devices and lighting used when the digital blackboard is on?	
J2. Are there digital projectors in classrooms?	
J2.1. Are shading devices and lighting used when the digital projector is on?	

K) Energy metering	
K1. Electricity metering (Y/N and where)	
K1.1. General distribution board?	
K1.2. Partial distribution boards?	
K2. Natural gas metering (Y/N and where)	
K2.1. General meter?	
K2.2. Partial meters?	
K3. Propane/LPG metering (Y/N and where)	
K3.1. General meter?	
K3.2. Partial meters?	
Observations/comments on energy metering	

L) Energy management	
L1. Identification of the entity/person responsible for the Energy Management	
L1.1. Function, tasks and main responsabilities?	
L1.2. Heating, cooling and ventilation systems are manually or	
L2. Is there an energy management system?	
Observations/comments on energy management	

M) Energy audits	
M1. Was it previously held any energy audit in the building?	
M1.1. Date of the audit	
Observations/comments on energy audits	

N) Building envelope	
N1. How do you rate the quality of the facade and roof of the building (good/acceptable/bad)? *Good: high insulation* *Acceptable: moderate insulation* *Bad: without insulation*	
N1.1. Definition of facade and roof layers (if data is available)	
N2. How do you rate the quality of the building's windows	
N2.1 Definition of windows (e.g: sliding or hinged)	
N2.2. Are there infiltrations through the windows? Where?	
N2.3. Characterization of the glazing and window frames	
N3. Shading devices	
N3.1. Are there outdoor shading elements (eg: blinds, shutters,...)?	
N3.2. Are there indoor shading elements (eg: blinds, curtains,...)?	
N3.3. Are there natural shading elements or from the building	
Observations/comments on the building envelope	

Q) Waste management	
Q1. Is there any accounting for the amount of waste produced?	
Q2. Is there separation of waste for recycling?	
Q2.1. What types of waste are recycled?	
Q2.2. Is there any accounting for the amount of waste sent for recycling?	
Q2.2.1 How this accounting is done (global value, type,...)?	
Q3. Is there re-use of paper?	
Observations/comments on waste management	

R) Water	
R1. Monthly average bill (R3, €)	
R2. Water metering (Y/N and where)	
R2.1. General meter?	
R2.2. Partial meters?	
R3. Are there any devices for water saving (eg: flow controller taps, dual system of sanitary discharge,...)? Which?	
R4. Is there consumption of hot water in the building? (Y/N)	
R4.1. What kind of equipment is used for hot water production (e.g. heat pump, boiler, water heater,...)?	
R4.2. Which is the temperature setpoint for hot water (eg: in the storage tank)?	
R4.3. Type of energy/fuel consumed (eletricity, natural gas, propane,...)?	
R4.4 Definition of available technical data. Characterization (eg: power, yield, EER, COP,..)	
R4.5. Approximate year of the system installation	
R4.6. Brand and model of the system (most common system)	
R4.7. Are there solar thermal collectors installed and in operation? How many collectors?	
R4.8. Definition of available technical data. Characterization of solar collectors	
R5. Utilisation schedules of hot water	
R5.1. Hot water is used in which months of the year?	
R5.2. Where is hot water used (kitchen, toilets, baths,...)?	
R6. Sources of water available	
Observations/comments on the use of water	

S) Transports	
S1. Parking area	
S1.1. No. of parking spaces at school or periphery (up to a 100m radius)	
S1.2. No. of parking spaces for disabled at school or periphery (up to a 100m radius)	
S1.3. No. of parking spaces for electric cars at school or periphery (up to a 100m radius)	
S1.4. No. of parking spaces for bicycles at school or periphery (up to a 100m radius)	
S1.5 Foto of the Parking Area	
S2. Characterization of the transport network	
S2.1 Bus	
S2.1.1 No. of stops in a 100m radius	
S2.1.2 No. of stops in a 250m radius	
S2.1.3 No. of stops in a 500m radius	
S2.1.4 Daily average frequency passing per hour	
S2.1.5 Daily average frequency passing per rush hour	
S2.1.6 Distance between the nearest stop and school	
S2.2 Subway	
S2.2.1 No. of stops in a 100m radius	
S2.2.2 No. of stops in a 250m radius	
S2.2.3 No. of stops in a 500m radius	
S2.2.4 Daily average frequency passing per hour	
S2.2.5 Daily average frequency passing per rush hour	
S2.2.6 Distance between the nearest stop and school	
S2.3 Train	
S2.3.1 No. of stops in a 100m radius	
S2.3.2 No. of stops in a 250m radius	
S2.3.3 No. of stops in a 500m radius	
S2.3.4 Daily average frequency passing per hour	
S2.3.5 Daily average frequency passing per rush hour	
S2.3.6 Distance between the nearest stop and school	
S2.4 Boat	
S2.4.1 No. of stops in a 100m radius	
S2.4.2 No. of stops in a 250m radius	
S2.4.3 No. of stops in a 500m radius	
S2.4.4 Daily average frequency passing per hour	
S2.4.5 Daily average frequency passing per rush hour	
S2.4.6 Distance between the nearest stop and school	
Observations/comments on transports	

T) Green Spaces	
T1. General Information	
T1.1 Type of green spaces (garden/kitchen garden/trees)	
T1.2 Area of green space (m2)	
T1.3 Year of construction	
T1.4 Existence of amusement equipment (Y/N)	
T1.5 No. of seats	
T1.6 Photo of the green spaces	
T2. Energy	
T2.1 Amount of energy consumed by the green space	
T3. Water	
T3.1 Total water consumption of the green space per month	
T3.2 Sources of water consumed by the green space	
T3.3 Existence of lakes, streams, fountains	
T4. Maintenance	
T4.1 Entity in charge of the maintenance	
T4.2 Maintenance cost of the green space	
T4.3 Maintenance frequency of the green space	
T5. Biome information	
T5.1 Fauna species	
T5.2 Flora species	
T5.3 Native fauna species	
T5.4 Native flora species	
T5.5 Number of trees	
Comments on green spaces	

U) Green Procurement	
U1. Certifications Information	
U1.1 Existence of certificate ISO 14001: 2004 - Environmental Management Systems, taking into consideration environmental protection, pollution prevention, legal compliance and socio-economic needs (Y/N)	
U1.2 Existence of certificate ISO 9001 -International Standard for Quality Management Systems (Y/N)	
U1.3 No. of individuals in school with training in green procurement	
U1.4 No. of individuals with eco-driving certificate	

U2. Electronic equipment information	
U2.1 Energy star level of efficiency	
U2.1.1 No. of equipments with A+++	
U2.1.2 No. of equipments with A++	
U2.1.3 No. of equipments with A+	
U2.1.4 No. of equipments with A	
U2.1.5 No. of equipments with B	
U2.1.6 No. of equipments with C	
U2.1.7 No. of equipments with D	
U2.1.8 No. of equipments without star level of efficiency	
U2.2 Printers	
U2.2.1 No. of printers	
U2.2.2 No. of printers with optimum consumption	
U2.2.3 Amount of used paper (Kg/Month)	
U2.2.4 Amount of paper purchased directly to National producers (Kg/Month)	
U2.2.5 Amount of recycled paper used (Kg/Month)	
U2.2.6 Use of chlorine-free paper (Y/N)	
U3. Food products Information	
U3.1 Total amount of purchased food per month (Kg/Month)	
U3.2 Total amount of purchased food with biological certificate per month (Kg/Month)	
U3.3 Amount of produced edible oil per month (L/month)	
U3.4 Amount of produced edible oil delivered to the competent authority per month (L/month)	
U3.5 Quantity of separate food waste according to good food waste management practices per month (Kg/Month)	
U3.6 Quantity of food waste which are reused as fertilizer per month (Kg/Month)	
U3.7 Purchase site of products	
U3.7.1 No. of county providers	
U3.7.2 No. of district providers	
U3.7.3 No. of country providers	
U3.7.4 No. of international providers	
Comments on green procurement	

Source: ClimACT, 2017b

Annex III – Emission Factors (EF), Density, Conversion Factor

EF - mobility

Mode of Transport	Emission Factor ($kgCO_2$ /person/km)
Foot	0
Bicycle	0
Bus	0.015
Subway	0.034
Train	0.032
Tram	0.061
Boat	0.115
Car	0.146
Motorcycle	0.093

Energy density, Conversion Factor and EF - energy sector

Energy Type	Energy Density (Cf kWh/unit Cf)	Conversion Factor	Emission Factor (kgCO2/kWhCf)
Electricity	1	-	0.47
Diesel oil	12.02777778	835	0.266
GLP	13.13888889	1.5	0.227
Natural gas	12.52777778	0.8404	0.231
Biomass	4.333333333	-	0.000
Biomass (pellets)	4.666666667	-	0.000

Sources: Decree nº 228/90; Decree nº 15793-D/2013