Lisbon School of Economics & Management
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MASTER

MASTERS IN MANAGEMENT

MASTER´S FINAL WORK

PROJECT

PATH TO A GREEN CAMPUS – ANALYSIS AND PROPOSALS FOR ENERGY SUSTAINABILITY AT ISEG

SIMÃO CHARNEIRA BARRADAS

MARCH – 2024

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ABSTRACT

This project aims to propose a set of measures that could reduce ISEG's energy consumption and promote the creation of energy-efficient buildings. This work comes at a time when it is imperative to mitigate climate change and contribute to the development of sustainable systems, in order to preserve and guarantee a future of quality for generations to come. The work elaborated will allow ISEG to strengthen its commitment to sustainable development goals and will help in the mission to create a green campus.

A literature review and a supporting benchmark were carried out in order to support and substantiate all the work developed in this project. Total energy consumption in recent years was also analysed in order to understand the school's reality.

We found that the measures implemented by the school are in line with what is being done by other institutions around the globe. In addition, it is also possible to see a decrease in energy consumption in the year 2023, which means that the measures implemented in recent years are having a positive effect. The success of the measures is highly dependent on the commitment of the school management and the involvement of the entire academic community. For this to happen, awareness-raising campaigns need to be created in order to give visibility to the objectives and what is being done.

The goal of reducing energy consumption is to reduce greenhouse gas emissions, making it possible to meet the targets of the Portuguese government and, above all, to set an example for other higher education institutions in Portugal.

Keywords: Energy efficiency measures, sustainable practices, carbon neutrality, university, benchmarking, green campus, energy consumption monitoring, motion sensors, green roofs, academic community awareness.

RESUMO

Este projeto tem como objetivo propor um conjunto de medidas que poderão reduzir o consumo de energia do ISEG e promover a criação de edifícios energeticamente eficientes. Este trabalho desponta numa altura em que é imperativo mitigar as alterações climáticas e contribuir para o desenvolvimento de sistemas sustentáveis, de forma a salvaguardar e a garantir um futuro de qualidade para as gerações vindouras. Este projeto permitirá ao ISEG reforçar o seu compromisso com os objetivos de desenvolvimento sustentável e ajudará na missão da criação de um campus verde.

Foi realizada uma revisão de literatura e um benchmark de apoio de forma a sustentar e fundamentar todo o trabalho desenvolvido neste projeto. Foram também analisados os consumos de energia totais do últimos anos de modo a perceber a realidade da escola.

Chegamos à conclusão que as medidas implementadas pela universidade estão em linha com o que está a ser feito por outras instituições à volta do globo. Para além disso, também é possível verificar uma diminuição no consumo de energia, no ano de 2023, o que significa que as medidas concretizadas nos anos transatos estão a ter um efeito positivo. O sucesso das medidas estão altamente dependente do compromisso da direção da escola e do envolvimento de toda a comunidade académica. Para isto, é necessário a criação de campanhas de sensibilização, de forma a dar visibilidade aos objetivos e ao que está a ser feito.

O objetivo da diminuição dos consumos de energia é reduzir as emissões de gases de efeito, permitindo cumprir com os targets do estado português e, acima de tudo, ser um exemplo para outras instituições de ensino superior em Portugal.

Palavras chave: Medidas de eficiência energética, práticas sustentáveis, neutralidade carbónica, universidade, *benchmarking*, *green campus*, monitorização do consumo de energia, sensores de movimento, *green roofs*, sensibilização da comunidade académica.

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TABLE OF CONTENTS

INDEX OF ILLUSTRATIONS

INDEX OF TABLES

Index of Charts

Index of Images

ABBREVIATIONS

CO2 – Carbon Dioxide

DL – Decree-Law

ECO.AP 2030 - Programa de Eficiência de Recursos na Administração Pública 2030

ECS – Energy Certification System

EEA – European Environment Agency

EPBD - Energy Performance of Buildings Directive

EU – European Union

GHG - Greenhouse Gases

HVAC – Heating, Ventilation and Ar-Conditioning

IPMA – Instituto Português do Mar e Atmosfera

ISEG – Instituto Superior de Economia e Gestão

LULUCF - Land Use, Land Use Change and Forests - sectors

NZCB – Net-Zero Carbon Building

PNEC 2030 - Plano Nacional Energia e Clima 2021-2030

RCCTE – Codes for the Thermal Performance Buildings

RF - Radiofrequencies

RSECE – Energy Systems for Air Conditioning

SDGs – Sustainable Development Goals

WGBC – World Green Building Council

ZEB – Zero-Energy Building

1. INTRODUCTION

1.1 Theoretical Context

Energy consumption has been increasing at an uncontrolled rate. The pace at which the demand for energy is increasing is not aligned with the capability to renew conventional energy sources. In recent decades, the temperature has risen by 0.7ºC over the period 1961-1990 and if we take into account since 1850, shortly after the end of the industrial revolution, temperatures have increased 1.1℃ ("Average Temperature Anomaly", 2023).

Change in behaviours are emerging as people are becoming more aware of the planetary boundaries and the need to reduce carbon emissions. This behavioural changes have become imperative in the search for a sustainable environment. The United Nations Brundtland Commission defined sustainability as "meeting the needs of the present without compromising the ability of future generations to meet their own needs" ("United Nations", n.d., para.2).

Unmanaged energy consumption in buildings is presently an area of critical concern. As the climate crisis intensifies, actions are urgently needed in regard to how the assets of built and operated environments are managed (Masson-Delmotte et al., 2018). The way that these structures are used puts our health and the environment at risk. According to the 2022 Global Status Report for Buildings and Construction, buildings were responsible for more than a third of all energy-related carbon emissions in 2021 (Environment, 2022).

Moreover, university campuses are considered one of the largest energy consumers in the commercial building category due to their usage and community impact (Najihah, 2013, as cited in Shafie et al., 2021). One of the important steps to be taken to achieve the goals of the 2015 Paris Agreement is to create facilities with a zero-carbon footprint (Net Zero Carbon Buildings, 2019).

The Portuguese government is committed to promoting energy efficiency and as proof of this, it has created the (Programa de Eficiência de Recursos na Administração Pública) (ECO.AP 2030). Public organisms in Portugal must adopt energy efficiency measures. ECO.AP 2030 is an ambitious program with the aim of presenting concrete actions to reduce energy, water and material consumption, as well as greenhouse gas emissions.

In a nutshell, by 2030 Portugal is committed to reduce primary energy consumption by 40%, guarantee that 10% of energy consumption is provided by self-sufficiency measures, reduce water consumption by 20%, reduce materials by 20% and reach a 5% energy and water renewal rate for buildings under the scope of ECO.AP (Resolução Do Conselho de Ministros n.º 104/2020 | DR, 2020).

Alongside with the ECO.AP 2030, on July 14 of 2020, the Portuguese government has also approved the (Plano Nacional Energia e Clima 2021-2030) (PNEC 2030). This plan establishes targets and objectives with regard to greenhouse gas emissions, renewable energies, energy efficiency, energy security, the creation of an internal market and research, as well as innovation and competitiveness. Portugal is therefore committed to reduce greenhouse gas emissions by 2030 by 45% to 55%, achieving energy efficiency of 35%, incorporating 47% of renewable energies overall, 20% in the transport sector and 15% in electricity interconnections (Resolução Do Conselho de Ministros n.º 53/2020 | DR, 2020).

With the increasing focus on sustainable growth and the reduction of carbon emissions, there is a need to preserve the university campuses environment (Franco & Leccese, 2019). The need for a Green Campus definition highlights the importance of sustainability practices at universities in order to comply with the rules on energy efficiency in buildings and represents a value that all educational institutions should follow. The environmental and energy impact of schools may be reduced through the implementation of organizational, technological and energy efficiency measures (Kolokotsa et al., 2016).

Energy industries are increasingly integrating information and communication technologies with intelligent and environmentally friendly networks (Smart Grids). Lee & Kim (2020) define that Smart Grid as an electrical grid system capable of improving efficiency through the use and incorporation of information and communication technologies in the processes of production, distribution and consumption of electricity working alongside clients and suppliers. Furthermore, the authors state that associated to Smart Grids are Smart Meters, which are remote meter reading and management devices capable of notifying consumers and suppliers of the amount of energy being consumed.

1.2 Problem, Research Question and Objectives of the Project

Recently, Instituto Superior de Economia e Gestão (ISEG) has stood out from other national institutions for its commitment to promoting an eco-conscious and socially responsible environment. This requires continuous action on the campus by committing to monitor and control all consumption of water and energy, to have efficient waste management and to promote sustainable mobility.

ISEG's allegiances are expressed in the 2030 Sustainability Strategy:

Illustration 1: ISEG's Sustainable Development Goals

Source: *https://www.iseg.ulisboa.pt*

This project relates to SDGs 7 (Affordable and Clean Energy), 11 (Sustainable Cities and Communities), 12 (Responsible Consumption and Production) and 13 (Climate Change).

This project aims to analyse energy consumption and the strategies implemented at ISEG seeking to propose solutions of improvement that promote energy efficiency in order to achieve a carbon-neutral footprint, in line with the campus's sustainable initiatives. Therefore, the main objective of this project is to identify and provide ISEG with proposals to reduce energy consumption on campus, create energy-efficient buildings and reduce its carbon footprint.

In order to achieve the objectives put forward by this project, first a benchmark analysis was performed to understand what is being done at other universities. Then, an analysis of ISEG's energy consumption over the past five years was conducted. Based on that, it was possible to identify key factors that influence energy consumption, analyse the measures adopted by ISEG and recommend a set of initiatives for improvement.

This document is structured as the following: first it presents the literature review, which lays the existing groundwork for conducting the study, followed by the methods section. Then, the project is presented, and the document ends with the conclusions, limitations and suggestions for a future research.

2. LITERATURE REVIEW

2.1 Climate Change

The rapid growth of the global population has led to an exponential increase in the demand for energy (Olabi & Abdelkareem, 2022). The World Energy Consumption refers to the total energy used to support human activities all over the world (Yu et al., 2016).

Over the years, this has led to the planet's climate change. NASA defines climate change as "long-term change in the average weather patterns that have come to define Earth's local, regional and global climates" (Shaftel, n.d., para.1). In the coming decades, climate change will cause rare events such as extreme temperatures, floods, droughts and wildfires that will put the lives of communities at risk (Anderson et al., 2019, as cited in Tong & Ebi, 2019).

The barriers of planet earth have been stretched beyond the safe and stable limit as a direct cause of human activities (Rockström et al., 2009). Despite the fact that fossil fuels are not sustainable and are harmful to health (Yang et al., 2021; Curtin et al., 2019, as cited in Olabi & Abdelkareem, 2022) they remain the largest source of energy. During the production of these fuels, various greenhouse gases, such as carbon dioxide, methane and nitrous oxide, are emitted on a large scale. It is well known that energy production is the main emitter of greenhouse gases (Patiño-Cambeiro et al., 2019). If there is no change in the effects of greenhouse gases there will be severe consequences for the planet, including climate change, serious health problems, rising sea levels, ecosystem changes and many others (Olabi et al., 2022).

Due to an increase in demand for coal for energy production, all respected agencies estimate that energy consumption will rise in the coming years (Ahmad et al., 2020, as cited in Aktar et al., 2021).

2.1.1 Climate Changes in Portugal

Portuguese territory is divided into mainland Portugal, Madeira and the Azores Archipelagos. Occupying a total area of $92{,}212\,KM^2$. Portuguese weather is characterised by mild winters and warm summers ("Portal Diplomático", n.d.). The factors that most influence Portugal's climate are latitude, orography and proximity to the

Atlantic Ocean. With regard to rainfall and temperature, there are some variations in the north-south and east-west relationship, as well as in seasonality (Miranda et al., 2002).

Portugal is highly vulnerable to climate change. In December 2019, during the European Council meeting, Ursula von der Leyen stated that "Portugal is one of the countries most affected by Climate Change" ("President von Der Leyen in the EP on the European Council", 2019, para.13). Southern Europe has seen rising temperatures and decreasing precipitation. Mediterranean weather is typified by mild, wet winters and hot, dry summers. However, it is also subject to a wide range of atmospheric impacts and climate changes, such as droughts, floods and other phenomena (Michaelides et al., 2018).

Based on data from the National Inventory Report (2022), greenhouse gas emissions in 2020 were estimated at around 57.6 Mt CO2e (not counting emissions from the LULUCF - Land Use, Land Use Change and Forests - sectors). This represents a decrease of 1.5% in comparison to 1990 and 9.5% in relation to 2019.

If we take the LULUCF sector into account, the total value of emissions in 2020 is estimated at 52.9 Mt CO2e. These figures represent a decrease of 19.3% compared to 1990 and 10.6% in relation to 2019.

The sectors that contributed most to Carbon Dioxide (CO2) emissions in Portugal are Energy (67.1%), Industrial Procedures and Product Use (13.2%), Agriculture (12.2%) and Waste (7.6%). Within the energy sector, the highlights were Transportation (25%), Energy Production and Transformation (18.1%), Combustion in Energy (13.3%), Others (8%) and Fugitive Emissions (1.9%).

2.2 Carbon Footprint in Universities

The carbon footprint is defined as environmental emissions caused by institutions, companies, products, individuals or activities, transportation and several production procedures (M. A. Bashir et al., 2023; M. F. Bashir et al., 2023; Helmers et al., 2021). There are six types of greenhouse gases (GHG) that must be enumerated and tracked, including carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride ("Homepage | GHG Protocol", 2021).

The amount of greenhouse gases produced by university campuses can be decreased through different sustainability measures and by adopting green buildings (Pereira Ribeiro et al., 2021). S. Lee & Lee (2021) reinforce the idea that calculating the carbon footprint can increase initiatives by universities to achieve carbon neutrality and to increase sustainable waste management.

It is extremely important to understand the practices and measures adopted by universities, since the academic community is an agent of change in their communities (Adjei et al., 2021). In this respect, when schools develop plans to reduce their carbon footprint, they also have a responsibility to pass on this knowledge to other entities and other potential stakeholders with the aim of mitigating climate change (Booth et al., 2020).

2.3 Energy Use at Universities

The organizational structure of a university varies depending on the type of institution, culture, history and other relevant factors (Pusser & Loss, 2003). These differences result in different needs and energy demands (Wadud et al., 2019).

Universities use energy for different applications. These mostly include lighting, heating, cooling, transportation and the recurrent use of equipment and materials. In general, heating and cooling devices are responsible for the majority of energy consumption (Leal Filho et al., 2019).

Energy consumption varies throughout the year, and there are huge differences between winter and summer in terms of electricity and heating (Leal Filho et al., 2019). Seasonality has a greater effect on heating/cooling than on electricity (Guan et al., 2015; Kim et al., 2010; Rewthong et al., 2015).

Another factor to consider, which has been pointed out by several studies, is student's activity, which influences energy consumption. During vacation periods, when there are fewer students and staff on campus, the usage of energy tends to be considerably lower (M. Jafary et al., 2016; Kim et al., 2010; Tang, 2012).

A new and important factor is that energy consumption is also influenced by the type of building. Those related to research and investigation consume more electricity than a classroom, library or administration facility (Ma, 2013; Khoshbakht et al., 2018).

Energy demand also varies from subject to subject. Universities that use large-scale equipment and buildings, such as schools of engineering and natural sciences, end up consuming more energy and have different needs (Zhou et al., 2013; Yuan, et al., 2014).

Lighting, ventilation and cooling are among the highest electricity consumers in schools ("E Source Customer Direct", 2015; "Carbon Trust", 2012, as cited Leal Filho et al., 2019).

2.4 Energy Efficiency

Nowadays, the search for energy efficiency is becoming a vital necessity in order to face the global challenges associated with climate change and the depletion of natural resources. According to the European Environment Agency (EEA), energy efficiency means using less energy to perform the same task or achieve the same end result, while minimizing energy waste ("European Environment Agency", 2023).

Under the Energy Efficiency Directive 2012/27/EU, (2012) the European Union (EU) set a target of saving energy by 20% by 2020 compared to 1990. According to the EEA, the target has been met, and the EU has reduced the release of greenhouse gases by 31% compared to 1990 ("Is Europe Reducing Its Greenhouse Gas Emissions?", 2022). For many years, it was believed that we would not be able to meet the targets, but with the outbreak of the COVID-19 pandemic, primary and final energy consumption has fallen considerably.

The new European Climate Law, presented in July 2021, defined the objectives for 2030 and 2050. The goals for 2030 is to reduce emissions by 55% and by 2050 the ultimate challenge is to have net-zero carbon emissions (Regulation (EU) 2021/1119, 2021).

2.4.1 Energy Efficiency in Portugal

According to the report ("Energia Em Números", 2023) shared by (ADENE - Agência para a energia), Portugal is still an energy-dependent country. The nation's energy dependence in 2021 stood at 67.1%. It should be noted that the (Plano Nacional Energia e Clima) (PNEC 2030) set a target of 65% by 2030. In the EU, Portugal ranked the tenth most energy-dependent country, 11.4 percentage points above the European average. On the other hand, in 2021, renewable energies represented around 34% of gross final energy consumption, making Portugal the fifth country in the EU where renewable energies have the greatest weight. In the same year, the weight of renewable energy sources in electricity production represented 58.4%, making Portugal the fourth EU nation with the highest share of electricity from renewable energy sources.

According to “Energy Efficiency Watch Survey", (2021), Portugal was the country of the EU that climbed the most positions compared to 2015. Portugal rose from the twenty-first position to seventh. According to the study, which involved more than 1,270 European experts, Portugal's large qualitative leap was due to the increase in energy efficiency in the industrial, transport and buildings sectors.

Milheiro, (2021) states that Portugal is presented in this report as an example to follow when it comes to implementing energy efficiency policies. Portugal stands out in product labelling, building performance requirements and building certification. The majority of experts, around 90%, consider the measures implemented to be partially effective or very effective.

Portugal's success is also due to the support being given to achieve carbon neutrality by 2050. Specialists also consider that the country is succeeding in raising public awareness of the issues of energy efficiency and climate change.

2.5 Energy Efficiency in Buildings

The buildings energy sector is directly involved in 40% of the world's energy consumption and up to 45% of CO_2 gas emissions (Varlamis et al., 2022).

In order to achieve environmental goals and reduce fossil fuel production, it is necessary to minimize energy consumption and the carbon footprint of industrial, residential and commercial buildings (Bandeiras et al., 2020).

One way of mitigating the impact of buildings on society, the environment and the economy is through sustainable and green buildings (Zhang et al., 2019, as cited in Hafez et al., 2023). When it comes to this type of construction, energy efficiency is the key factor (Shi et al., 2016). The use of energy efficiency measures is the fastest way to limit and reduce the impact of buildings on society, the environment and the economy (X. Chen et al., 2015, as cited in Hafez et al., 2023).

As part of the so-called Objective 55 package, the European Commission adopted a legislative proposal on December 15, 2021, to update the Energy Performance of Buildings Directive (EPBD) (Proposal (recast), 2021).

According to the “Energy Saving News" (2022), in March 2023, the European Parliament backed plans for an impact-neutral building sector by 2050. The objectives are to improve the energy efficiency of buildings. For example, reducing energy poverty, electricity bills and improving the quality of indoor environments by making them healthier. All new infrastructures must be zero-emission from 2028.

This news item claims that the new rules imposed by the European Parliament state that buildings cannot have an energy rating lower than D, on a scale of A to G. These need to produce their own solar energy, measures must be implemented to reduce electricity bills, national funding efforts are required to reduce energy dependency and home appliances must be energy efficient.

2.5.1 Innitiatives in Portugal

Since the 1990s, concern about the consumption of buildings has been an issue in Portugal. At the time, the Codes for the Thermal Performance of Buildings (RCCTE) and Energy Systems for Air Conditioning (RSECE) were published (Neves et al., 2015, as cited in Vaquero, 2020, p.1).

The Energy Certification System (ECS) was introduced in 2007 and was implemented by the (Decreto-Lei n.º 78/2006 | DR, 2006). In addition, due to the obligation imposed by EPBD (Directive 2002/91/EC, 2002), published in 2002, (Decreto-Lei n.º 79/2006 | DR, 2006) and (Decreto-Lei n.º 80/2006 | DR, 2006) DL 80/2006 were also approved. These two documents defined the energy efficiency rules that all new and refurbished buildings must follow, the energy efficiency class and the methodologies used to obtain energy efficiency indicators.

In the same way, there are two other initiatives in Portugal developed by ADENE. The first is the "Classe+" brand for the energy labelling of products. For example, the energy performance of windows from A+ to F. The second concerns the "casA+ Portal" where property owners or tenants can check property information, register or consult property characteristics and access plans with energy efficiency solutions.

2.6 Green Campus

According to the United States Green Building Council, a green campus is a higher education community that aims to increase its energy efficiency, preserve scarce resources and maintain environmental quality by teaching sustainable practices, healthy living habits and decent learning environments for all ("The Roadmap to A Green Campus", 2016).

In order to develop quality green campuses, all data needs to be conveyed, analysed and verified. From a general perspective, the information that is usually analysed with regard to these such campuses includes planning and management, energy efficiency, waste management, water consumption, the use of sustainable transport, innovation, environmental quality, and green education (Ridhosari & Rahman, 2020).

2.7 Energy Efficiency and Renewable Energy at Universities

When we think of a sustainable development scenario, we must be aware of the weight that universities have in the way they use energy (Guan et al., 2016). Energy efficiency measures can range from simple actions such as reducing energy waste to more elaborate solutions such as energy-efficient buildings (Salvia & Schneider, 2019).

There are numerous advantages of implementing measures. For example, reduced pollution (Chang et al., 2018), a smaller carbon footprint (Chen et al., 2018) and greater energy security (de la Rue du Can et al., 2018).

Implementing energy efficiency measures on school grounds helps to contribute to the Sustainable Development Goals (SDGs), namely Goal 4 (Quality Education) and Goal 7 (Affordable and Clean Energy). Increasing energy efficiency is not only financially beneficial, but also ethically (Allen & Marquart-Pyatt, 2017). Because of their size and population, university campuses can be compared to small towns. In this way, efforts to increase their energy efficiency are similar to those of these such localities, but on a smaller scale (Kolokotsa et al., 2016; Leon et al., 2018).

The process is not an easy one, so there are a number of challenges that can be mentioned. One of the biggest problems is the lack of resources, initiatives and support from top management (Ávila et al., 2017). Lack of interest from students, teachers and other members of staff (Boulton et al., 2017). Low interest in or little knowledge about sustainability issues and technological innovations (Adams et al., 2018).

Therefore, in order for a school to successfully implement energy efficiency measures, there needs to be a strong integration of the senior executive chains, awareness-raising and commitment on the part of students and teachers (Leal Filho et al., 2019). Positive results are acquired through small changes in habits (Allen & Marquart-Pyatt, 2017; Boulton et al., 2017; Bull et al., 2018).

Alongside the efficiency measures that can be implemented, the use of renewable energies also plays an important role in reducing the negative impact of human actions on the planet. The most important sources of clean energy are solar, wind, hydroelectric, biomass, geothermal and photovoltaic (Mohammadi & Mehrpooya, 2018; Zerrahn et al., 2018).

2.8 Zero Energy Buildings

A zero-energy building (ZEB) is an energy-efficient building where the actual annual energy supplied is equal to or less than the renewable energy exported from the site (A Common Definition for Zero Energy Buildings, 2015). In other words, the main objective of a ZEB is to reduce the consumption of non-renewable energy in the construction sector by implementing energy efficiency measures. The renewable energy locally produced by the building must be greater than or equal to the energy required (Bandeiras et al., 2020).

ZEBs are connected to the public grid and use renewable energy to reduce the amount of imported energy. The power supplied includes all energy from electricity to heating and cooling. Exported energy refers to the excess renewable energy that is sent off-site. The energy produced on site comes from renewable energy sources such as solar and wind power. Any type of energy generated off-site is considered to be supplied energy. The perimeter of the site can be more than the construction area of the building, which means that instead of a single building, the site boundary can include several structures that share the same system (Torcellini et al., 2006, as cited in Bandeiras et al., 2020).

The most recent literature reviews presents new definitions of ZEBS and helps in the interpretation of this concept.

The report A Common Definition for Zero Energy Buildings (2015), extends the concept of ZEBs to zero energy campus, portfolios and community. Piderit et al. (as cited in Bandeiras et al., 2020), proposed a framework for the new standard for achieving ZEBs and this study acknowledged the necessity of public policies in order to accomplish the implementation of zero energy buildings and to establish a uniform framework for the implementation of ZEBs. Fabrizio (as cited in Bandeiras et al., 2020), identified two key concepts to describe ZEBs, namely optimization and the holistic plan. Vidal et al. (as cited in Bandeiras et al., 2020), raised the issue of possible adverse health effects in overheated ZEBs with overly powerful heating systems in northern Spain. Khakian et al. (as cited in Bandeiras et al., 2020), carried out a study on energy quality to assess the energy efficiency of two-storey buildings located in mountainous areas and to determine the influence of parameters such as building orientation, quality of materials used, type of windows and insulation systems.

2.9 Net-Zero Carbon Buildings

Net-zero carbon buildings (NZCB) have been seen as an opportunity to reduce carbon emissions in the construction and building sector. There has been a worldwide trend to build NZCBs as a way of energy transition (Tronchin et al., 2018; Wang et al., 2018), promoting green buildings (From Thousands to Billions, n.d.) and addressing climate change (Ohene, Chan, et al., 2022b).

A NZCB can easily be described as a building that uses various energy efficiency strategies to reduce its energy demand, as well as using clean energy from renewable sources to offset the remaining energy demand (Sartori et al., 2012, as cited in Ohene et al., 2022).

Based on the article Net Zero Carbon Buildings (2019), there are two approaches to zero emissions buildings. The first relates to the construction sector and the other to operational energy.

From a construction standpoint, a building reaches net-zero carbon status when the carbon emissions correlated to its construction reach zero or become negative, achieved through offsets or the export of renewable energy from the site.

Considering operational energy, a building is regarded net-zero carbon when the total amount of carbon emissions associated with the building's operational activities is zero or negative, which means that the building is highly efficient all year round and powered by renewable energy sources from on-site or off-site. Any remaining carbon balance is offset.

Through the NZCB concept it is also possible to associate energy efficiency with renewable technologies in order to create sustainable and healthy buildings for those who live in them and beyond, and thereby contribute to energy security (Ohene, Chan, et al., 2022b). In addition to what has already been said, NZCBs make it possible to reduce electricity costs throughout the building's life cycle and minimize environmental pollution (Ohene, Hsu, et al., 2022).

According to data from the World Green Building Council (WGBC), in order to achieve 100% NZCB by 2050, new buildings must start operating with zero carbon emissions from 2030, so as to prevent carbon-emitting systems from being impeded in the coming years (From Thousands to Billions, n.d.).

3. METHODS

This section describes the methods applied to carry out the study in relation to the objectives of the present project.

In order to understand which initiatives are being adopted by other universities, this project conducted a benchmark analysis, with the aim of identifying the best practices and measures that other universities are adopting. The schools chosen for analysis are, like ISEG, institutions that are concerned with sustainability, green campuses, energy consumption and their carbon footprint. In addition, another relevant factor for the choice of these universities was the fact that they had well-developed sustainability reports with rich and insightful information. The following schools were therefore considered in this analysis: Instituto Universitário de Lisboa (ISCTE), Harvard University, University of Copenhagen - Københavns Universitet, Columbia University, Bocconi University and Escola Superior d'Administració i Direcció d'Empreses (ESADE). The research involves colleges from all over the world, including Portugal, the United States of America, Denmark, Italy and Spain.

The benchmark focused essentially on analysing the sustainability reports of those institutions. In order to understand which practices each school was adopting, several summary tables were compiled, which can be accessed in the appendices. Those tables aim to systematize all the information in the reports and divide the measures applied into their respective categories. The following categories were considered: Research and Development, Awareness, Carbon Footprint, Energy Production, Energy Consumption and Waste Management. Through these tables it is possible to quickly and succinctly identify the measures applied to each of the themes. Among all topics mentioned above, the one that is most relevant to this project is energy consumption.

After conducting the benchmark analysis, internal data analysis was carried out. For that, a file with the energy consumption in 2019, 2021, 2022 and 2023 (2020 was not provided) of all buildings represented in Kw/h supported the data analysis. After processing the data in the Excel file, it was possible to perform several analyses exploring aspects related to consumption patterns and financial implications in order to identify possible factors that are related to energy consumption.

The analysis begins with a macro-level perspective and allows to drill-down to a micro-level examination. The first step was to analyse annual energy consumption and the financial impact per year. The energy consumption per month for the years 2019, 2021, 2022 and 2023 was then analysed, with the aim of finding a pattern that represented the months with the highest and lowest demand. After this, it was important to see if ISEG's energy consumption was in line with that of other universities. To achieve this, a comparative analysis was conducted specifically analysing energy consumption per student and per square metre, comparing those results with ISCTE and ESADE. The aforementioned analysis concentrated solely on educational institutions that are similar to ISEG and that are located on the Iberian Peninsula, securing uniformity in all relevant characteristics.

After that, the factors that mainly contribute to the school's energy consumption were identified. In order to facilitate this process, an analysis of the energy consumed per day was conducted, which can be consulted in the appendices. In addition, other factors were taken into account, such as weather conditions (temperature, rainfall, air velocity and temperature variation), the calendar year (working days and holidays) and the school calendar for the academic activities. Analyses which were imperative for identifying any correlation between energy consumption and other factors. After completing this task, the university's sustainability reports were analysed as to identify the main policies that have been adopted in recent years. In addition, a comparison was made between the main changes implemented by ISEG and the other schools in the benchmark.

The final phase of the project involves presenting measures to reduce energy consumption and greenhouse gases. In order to facilitate this process, several interviews were held with the Engineer in charge of the Logistics Department and Technical Support Division, where the main objective was to identify ISEG's needs and possible areas for improvement. In this part, the benchmark was used to check whether there were any practices that could be applied at ISEG.

4. PROJECT DESCRIPTION

4.1 Introduction

ISEG was Portugal's first Management and Economics School. The institution began its activities in 1911 and is currently part of the "Universidade de Lisboa". ISEG is synonymous with high standard education and is recognized worldwide (Financial Times, AACSB or AMBA). ISEG is also a symbol of continuous innovation among students, teachers, and top management.

ISEG's mission and values are "the creation, transmission and social and economic valorization of knowledge and culture in the areas of Economics, Finance and Business Sciences, in a context of plurality and guarantee of intellectual and scientific freedom and respect for ethics and social responsibility" ("Missão e Visão", n.d., para. 1).

The university consists of six buildings that make up the campus. It is located in the city centre of Lisbon, between Lapa and Assembleia da República.

Image 1: ISEG Campus

Source: Google Images

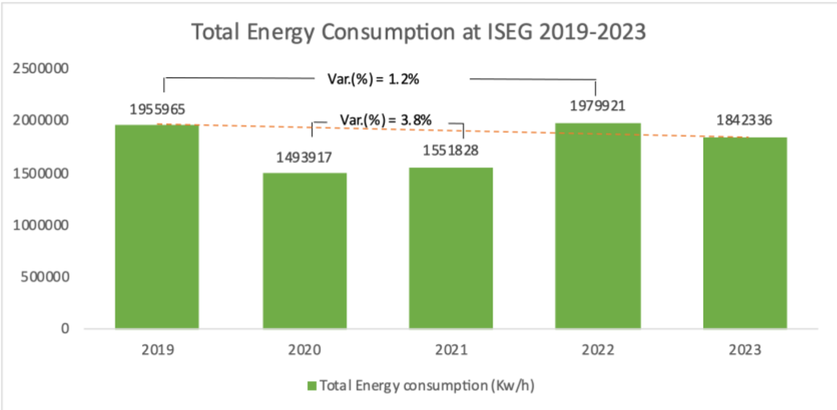
ISEG is highly committed to sustainability and recognizes that the quality of life of future generations depends on how we deal with current challenges. ISEG fosters a culture of solidarity and collaboration that helps promote sustainable development. Sustainability is present at the school in the following areas: research, education, campus and community.

ISEG is committed to achieve a carbon-neutral campus by 2030. Throughout the school grounds, there is a concern for the efficient use of electricity in order to increase energy efficiency. The university is implementing new technological solutions for monitoring all energy, water and solid waste consumption, installation of more efficient appliances, a more low-energy lighting system while changing the behaviour of the academic community. Since 2019, ISEG has been calculating its greenhouse gas emissions and there is a plan to achieve carbon neutrality by 2030. This programme includes a set of measures to reduce Scope 1, 2 and 3 emissions and an aim to offset the remaining emissions. ISEG is also focused on creating partnerships with organic and locally grown food suppliers, with the goal of providing the entire educational realm with a range of fresh, healthy and local products on a regular and weekly basis. Last but not least, is the school's commitment to creating initiatives that promote physical and mental well-being.

4.2 Overview of ISEG Numbers

Firstly, it is necessary to analyse ISEG's energy consumption on a large scale.

Chart 1: Total Energy Consumption from 2019 to 2023



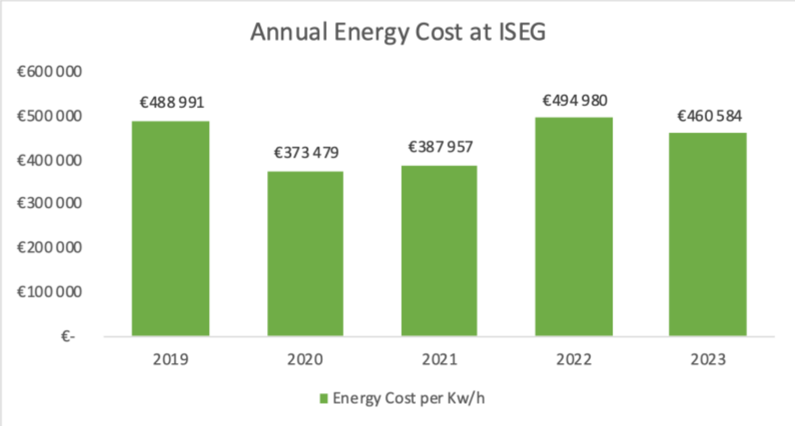
Source: ISEG Data

As we can see from Chart 1, there are two years, 2020 and 2021, in which energy consumption declines considerably. However, this decrease in the use of energy was almost entirely due to the worldwide COVID-19 pandemic which caused a large reduction of the activities held at ISEG to decrease drastically. In 2020, both professors and students were working and studying from home because of the two major lockdowns that affected the country. In 2021, with the easing up of the restrictive measures, ISEG adopted a hybrid system where half the class could attend lectures in person while the other half engaged remotely, rotating on a weekly basis. The variation in the two years considered for COVID-19 was 3.8%

Looking at 2019, the pre-pandemic year, and 2022, the post-pandemic year, it is possible to see that energy consumption was very similar, with a variation of only 1.2%. This means that the amount of energy ISEG was consuming before the COVID-19 virus broke out was practically the same as what it was consuming after the pandemic had been controlled, meaning there was no effect from energy efficiency measures in 2022.

In 2023, the energy consumption numbers were lower than in 2019 and 2022. This may suggest a positive effect of some energy efficiency measures.

Chart 2: Annual Energy Cost



Source: ISEG Data

The annual energy costs of ISEG are shown in Chart 2. To calculate the amount, an estimate of 0.25 cents per Kw/h was taken, this value was multiplied by the annual energy consumption figure identified in Chart 1. The forecast of the tariff per Kw/h was suggested by the ISEG Engineer, who is responsible for monitoring the university's energy consumption. This rough calculation is the sum of the four types of power contracted by ISEG. It can be concluded that, as explained above, energy expenditure decreases in the years of the pandemic and increases in the remaining years. Energy consumption and cost have a proportional relationship, in other words, the higher the consumption, the higher the electricity invoice. In the last five years, ISEG has spent approximately 2.2 million euros in electricity bills, which results in an annual average of around 440 thousand euros.

Having looked at ISEG's numbers in a general way, it is important to analyse which months have the highest consumption.

Table 1: Total and Average Energy Consumption per Year and Month

Month	2019	2021	2022	2023
January	186733,00	162127,00	164539,00	171731,00
February	169401,00	116231,00	154789,25	169731,75
March	168094,75	106202,25	183280,00	163751,25
April	154776,50	106412,50	163941,50	125461,50
May	172105,75	116389,25	179009,00	159907,75
June	144627,75	124639,75	167250,25	176916,25
July	160248,50	129279,75	192374,50	167290,00
August	119007,50	105690,25	129657,25	101522,00
September	181548,75	154391,00	176432,75	174532,00
October	181895,00	142539,75	169350,25	149532,00
November	160038,50	144835,75	152789,50	148585,00
December	157487,75	143090,00	146507,75	133375,00
Total	**1955965**	**1551828**	**1979921**	**1842336**
Average	**162997**	**129319**	**164993**	**153528**

Source: ISEG Data

Table 1 shows the energy used for each month for the years 2019, 2021, 2022 and 2023. By contrast with Chart 1 and 2, where it was possible to consider a 5-year time period, for this analysis only the figures for the years 2019, 2021, 2022 and 2023 were available. Consequently, the year 2020 is left out on purpose due to a lack of data.

As we can see in Table 1, there is a considerable inconsistency in terms of the months with the highest and lowest consumption. The only month that appears constant in all the years is August, with the lowest usage. Due to this great variability, it is necessary to carry out a more detailed analysis in order to identify potential factors and explanations that affect energy consumption at the university.

Charts 3, 4 and 5 found in appendices shows the segregation of energy consumption for all ISEG buildings and were extracted from the 2019 energy certificates. The graphs show that, on average, 54% of the energy consumed is related to the HVAC system and 27% to lighting. This means that HVAC and lighting account for 81% of total energy.

4.3 Factors that have an impact on ISEG's Energy Consumption

One factor that can directly influence energy consumption is the number of students who are enrolled and attend the campus. With this in mind, the following investigation was carried out, where a Portuguese and a Spanish university were considered, focusing the study on the Iberian Peninsula, where similar characteristics apply.

ISEG currently has around 5200 students and an average energy consumption, based on years 2019-23, of 1764793 Kw/h. Looking at the 2019 figures and making a direct comparison with ISCTE, energy consumption in all ISEG buildings was 1955965 Kw/h, while at ISCTE it was 3344000 Kw/h. Bearing in mind that ISCTE had more or less 9900 students in 2019 and ISEG 5200, this gives an average per student of 337.54 Kw/h at ISCTE and 369.89 Kw/h at ISEG. It can be concluded that, despite the difference in student population, both Portuguese schools had a similar energy consumption per pupil. Regarding a Business School in Spain, ESADE, in 2022 it had an energy usage of 6022328 Kw/h, while ISEG, in the same year, had a total consumption of 1979921 Kw/h. The Spanish university had approximately, 15400 students enrolled, doing the calculations, it can be deduced that ISEG had an energy consumption per student of 374.42 Kw/h and ESADE 389.37 Kw/h. Once again, it is concluded that despite the variation in the number of students, both schools consume a similar amount of energy.

Table 2: Energy Consumption per Student (all values of 2022, except ISCTE from 2019)

	ISEG	ISCTE	HARVARD	COPENHAGEN	COLUMBIA	BOCCONI	ESADE
Energy Consumption (Kw/h)	1979921	3344000	928156	165307000	NA	27965556	6022328
Number of students enrolled	5400	9907	25266	30311	34782	15126	15467
Energy consumption by student (Kw/h)	366,65	337,54	36,74	5453,70	NA	1848,84	389,37

Source: Sustainability Reports (ISEG, ISCTE; Harvard, Copenhagen, Columbia, Bocconi and ESADE)

Besides the number of students enrolled, the total area of the campus can also influence energy consumption. The study was again focused on the Iberian Peninsula.

ISEG, has a total area of 27,127 square meters whereas ISCTE's area is 45,000 square meters. Looking at the figures for 2019, we come to the conclusion that ISEG has an energy consumption per square meter of 72.10 Kw/h and ISCTE of 74.31 Kw/h, there is barely a difference. In the case of ESADE, a Spanish university, with a total area of 78,000 square meters, and considering the energy consumption figures for 2022, we concluded that ISEG's consumption is 72.99 Kw/h per square meter and ESADE's is 77.21 Kw/h per square meter. Once again, the calculated values show no significant difference. It can therefore be concluded that although the three schools have campuses of different sizes, the energy consumption per square meter is similar in all of them. Furthermore, it can also be concluded that the energy consumption values per student and per square meter at ISEG are in line with other similar universities. However, there is still potential for improvement.

For the analysis that is being carried out, it is important to note that energy consumption is different for weekdays compared to weekends and holidays.

Table 3 shows the months of October and November 2022, where this difference can be seen quite clearly. On all days of the week, the value of energy consumption was higher than the average for the month and the opposite is happening on weekends and national holidays, such as October 5th and November 1st. Although there is a decrease in energy consumption on days when there is very little activity on campus, we can see that the amount of Kw/h consumed is still relatively high. This, among other unknown reasons, is due to the fact that there are buildings at ISEG that are open 24 hours a day and 7 days a week, such as the library. The variation is around 32.83% for the month of October and 39.42% for November.

Table 3: Difference in Energy Consumption from Weekdays to Weekends and Holidays

Day	Day of the Week	Oct-22	Day of the Week	Nov-22
1	Saturday	4458	Tuesday	3989,25
2	Sunday	3953,5	Wednesday	5543
3	Monday	6389,75	Thursday	5809,75
4	Tuesday	6351,5	Friday	5281,25
5	Wednesday	4072,5	Saturday	3986
6	Thursday	6269	Sunday	3438,25
7	Friday	6199	Monday	5587,25
8	Saturday	4521,25	Tuesday	5741,75
9	Sunday	3814,5	Wednesday	5456,5
10	Monday	5995	Thursday	5601
11	Tuesday	6509,75	Friday	5344,25
12	Wednesday	6638,5	Saturday	4039,75
13	Thursday	6383	Sunday	3561,5
14	Friday	6099,75	Monday	5424
15	Saturday	4447	Tuesday	5812,5
16	Sunday	3867,75	Wednesday	5924,5
17	Monday	6226,5	Thursday	5695,75
18	Tuesday	6677,75	Friday	5274
19	Wednesday	6151,5	Saturday	4049,25
20	Thursday	6103,25	Sunday	3408,75
21	Friday	5696,75	Monday	5603,25
22	Saturday	4449,25	Tuesday	5974,5
23	Sunday	3684	Wednesday	5819,25
24	Monday	5782,25	Thursday	5697,5
25	Tuesday	6027,75	Friday	5302
26	Wednesday	6394,25	Saturday	4181
27	Thursday	6109,75	Sunday	3555,75
28	Friday	5912,5	Monday	5689
29	Saturday	4574,25	Tuesday	5904,5
30	Sunday	3841,75	Wednesday	6094,5
31	Monday	5749	Thursday	

Source: ISEG Data

Table 4: Variation in Energy Consumption from Weekdays to Weekends and Holidays

	October	November
Total	169350,25	152789,5
Average	5462,91	5092,98
Average week days	6183,33	5646,67
Average weekends and holidays	4153,07	3420,95
Variation	**32,83%**	**39,42%**

Source: ISEG Data

In order to distinguish weekdays from weekends and holidays, it is also important to mention that energy consumption at ISEG is directly influenced by the school calendar. Using the 2022/2023 academic calendar and Table 5 as an example, we can see that there is a decrease in consumption during the Easter and Summer holidays. Easter break, according to the official university calendar, took place between April 3 and 9, 2023. In the area shown in Table 5, we can see that consumption decreased during this period, except for the first two days. In August, according to official data, all ISEG buildings and services were closed between August 7 and 18, 2023. In the same vein, we can observe that energy consumption fell considerably during this period, again with the exception of the first two days. The fact that there were two days when consumption was above average, during vacation periods, may suggest that there is a delay in calculating energy consumption.

Table 5: Difference in Energy Consumption taking into account the School Calendar

Day	Day of the Week	Apr-23	Day of the Week	Aug-23
1	Saturday	3551,5	Tuesday	4686
2	Sunday	2844,25	Wednesday	5233
3	Monday	4213,75	Thursday	4383,25
4	Tuesday	4221	Friday	4326,5
5	Wednesday	4050,5	Saturday	4238,25
6	Thursday	3955,25	Sunday	3487
7	Friday	3203	Monday	4383,5
8	Saturday	3322,75	Tuesday	3809
9	Sunday	2715,75	Wednesday	2903,25
10	Monday	4411,75	Thursday	2682,25
11	Tuesday	4692,5	Friday	2596
12	Wednesday	4669	Saturday	2370
13	Thursday	4769	Sunday	1734,25
14	Friday	4585,5	Monday	2304,5
15	Saturday	3550	Tuesday	2017,75
16	Sunday	2802,75	Wednesday	2303,25
17	Monday	4888,75	Thursday	2449,5
18	Tuesday	5136	Friday	2455
19	Wednesday	5483,75	Saturday	2384,75
20	Thursday	4970,75	Sunday	1809,25
21	Friday	4718,25	Monday	3084,25
22	Saturday	3571,5	Tuesday	3650,5
23	Sunday	2781,25	Wednesday	3911
24	Monday	4464,75	Thursday	3970,5
25	Tuesday	3246,5	Friday	3696,5
26	Wednesday	5175,25	Saturday	3237
27	Thursday	5928,25	Sunday	2491,25
28	Friday	5700,25	Monday	3658,5
29	Saturday	4441	Tuesday	3659,75
30	Sunday	3397	Wednesday	3687
31	Monday		Thursday	3919,5

Source: ISEG Data

Another relevant factor that influences energy consumption is the weather. Buildings are highly vulnerable to heat and cold waves and climate change, since the amount of energy needed to maintain comfort in an interior space is highly dependent on external weather conditions (Jandaghian & Berardi, 2020). The major environmental factors that influence thermal comfort are temperature, air velocity, relative humidity and mean radiant temperature (Arens et al., 2010). Table 6 and 7 shows the temperature and rainfall values, as well as the average temperature and air velocity for each month. The data was taken from the monthly reports of the (Instituto Português do Mar e Atmosfera) (IPMA). The relative humidity value does not appear in the table, as it is not included in the reports submitted by the IPMA. As we can see, May 2022 was an extremely hot and dry month, and this is reflected in the energy consumption. The temperature variation was around 3.47 degrees. According to IPMA data, May 2022 was the hottest May in 92 years. July 2022 was an extremely hot and very dry month, with a temperature variation of 2.97

degrees and according to IPMA data it was the hottest July since 1931. In the same breath, June 2023 was very hot and rainy, with a variation of 2.49 degrees and was considered by the IPMA to be the fifth-hottest June since 1931. The three months shown are considered high energy consumption months for the respective years.

Table 6: Meteorological Data by Month in 2022

Month	Temperature	Rain	Average Temperature (°C)	Var. °C (1971-2022)	Air Velocity (Km/h)	Energy Consumption (Kw/h)
January	Hot	Very Dry	9,65	0,84	11,8	164539
February	Very Hot	Extremely Dry	11,31	1,33	11,7	154789
March	Normal	Rainy	11,88	-0,04	16,1	183280
April	Normal	Dry	13,38	0,23	17,6	163942
May	Extremely Hot	Extremely Dry	19,19	3,47	15,8	179009
June	Hot	Dry	20,4	0,98	17,2	167250
July	Extremely Hot	Very Dry	25,14	2,97	16	192375
August	Very Hot	Very Dry	23,3	1,15	15,4	129657
September	Hot	Rainy	20,64	0,42	15,4	176433
October	Very Hot	Rainy	18,73	2,53	13,5	169350
November	Hot	Rainy	13,3	0,93	11,1	152790
December	Very Hot	Very Rainy	12,72	2,76	NA	146508

Source: Instituto Portugês do Mar e da Atmosfera

Table 7: Meteorological Data by Month in 2023

Month	Temperature	Rain	Average Temperature (°C)	Var. °C (1971-2023)	Air Velocity (Km/h)	Energy Consumption (Kw/h)
January	Hot	Normal	9,14	0,33	NA	171731
February	Normal	Extremely Dry	9,94	-0,04	12,6	169732
March	Hot	Dry	13,12	1,21	NA	163751
April	Very Hot	Extremely Dry	16,59	3,43	13,9	125462
May	Very Hot	Very Dry	18,19	2,47	17,7	159908
June	Very Hot	Rainy	21,92	2,49	17,5	176916
July	Normal	Very Dry	22,51	0,34	19,4	167290
August	Extremely Hot	Dry	24,27	2,12	19,8	101522
September	Hot	Rainy	20,65	0,43	13,6	174532
October	Extremely Hot	Very Rainy	18,96	2,42	13,4	149532
November	Very Hot	Normal	13,78	1,33	12,2	148585
December	Normal	Very Dry	9,99	0,51	11,2	133375

Source: Instituto Português do Mar e da Atmosfera

4.4 Measures Implemented by ISEG

After understanding which factors influence energy consumption at ISEG, we need to analyse whether the university is able to reduce consumption and what measures are being implemented.

Table 8: Variation in Energy Consumption from 2021 to 2022

Month	2021	2022	Var.(%)
January	162127,00	164539,00	1,49%
February	116231,00	154789,25	33,17%
March	106202,25	183280,00	72,58%
April	106412,50	163941,50	54,06%
May	116389,25	179009,00	53,80%
June	124639,75	167250,25	34,19%
July	129279,75	192374,50	48,80%
August	105690,25	129657,25	22,68%
September	154391,00	176432,75	14,28%
October	142539,75	169350,25	18,81%
November	144835,75	152789,50	5,49%
December	143090,00	146507,75	2,39%
Total	**1551828**	**1979921**	**27,59%**

Table 9: Variation in Energy Consumption from 2022 to 2023

Month	2022	2023	Var.(%)
January	164539,00	171731,00	4,37%
February	154789,25	169731,75	9,65%
March	183280,00	163751,25	-10,66%
April	163941,50	125461,50	-23,47%
May	179009,00	159907,75	-10,67%
June	167250,25	176916,25	5,78%
July	192374,50	167290,00	-13,04%
August	129657,25	101522,00	-21,70%
September	176432,75	174532,00	-1,08%
October	169350,25	149532,00	-11,70%
November	152789,50	148585,00	-2,75%
December	146507,75	133375,00	-8,96%
Total	**1979921**	**1842336**	**-6,95%**

Source: ISEG Data

As we can see in Table 8, the total value of energy consumption on campus increased by around 27.59% from 2021 to 2022. This is due to the fact that the year 2022 was marked by the complete return of face-to-face classes. The university returned to the activity it had in pre-pandemic years. In 2021, the school operated under a hybrid system, meaning that classes were divided into groups and part of the students had online classes and the other had the possibility of attending classes in person.

Looking at Table 9 showing energy consumption for the year 2023, we can see that the numbers have decreased in 9 out of 12 months. It is important to emphasize that the average temperature for the month of 2022 was 16.64 degrees, and in 2023 it was around 16.59 degrees. As we can see in Table 9, there is a decrease of around 7%, 137585 Kw/h, in the total energy consumed compared to 2022. Since both years had practically a similar average temperature, it is believed that weather conditions did not have a major influence on this decrease. Therefore, we can consider that there is a great effort on the part of the university to reduce energy consumption.

At this stage, it is important to understand what measures were adopted in 2022 that allowed energy consumption numbers to fall. Table number 10, shows all the initiatives that were adopted by ISEG and that are included in the 2022 Sustainability Report.

Table 8: Initiatives for a Sustainable Campus Implemented by ISEG in 2022

Application area	Measure implemented
Improving infrastructures	Installation of 10 water filtration machines.
Lighting on Campus	Replacement of 466 light bulbs, around 99% of the campus' bulbs, with LED equipment.
Efficiency of air conditioning systems	Replacement of 6 air-conditioning units in the Quelhas 2 Building and Francesinhas 2 Building with newer, more efficient equipment
Reduction in paper consumption	Reducing paper consumption by promoting a transition to digital and online processes.
Plastic	Initiatives such as the distribution of reusable bottles to promote a reduction in plastic consumption.
Waste of Electrical and Electronic Equipment (WEEE)	In 2022, all WEEE was carefully stored and duly sent for recycling.

Source: ISEG Sustainability Report (2022)

As we can see from Table 10, there are 2 measures that directly influence energy consumption, such as changing light bulbs to LEDs and replacing air conditioning units with more modern and efficient equipment.

The transition to LED bulbs has numerous advantages over traditional lights. According to the article “Euroconsumers" (2022), by Elsa Agente, an expert at (DECO PROTeste Sustentabilidade), LED bulbs are more efficient, long-lasting and after many years of use they continue to provide the same intensity of light, regardless of how many times they are switched on. Nevertheless, the price is higher than rival bulbs, but it has been gradually decreasing over time. If we take the following example and consider a 60W incandescent bulb that is switched on for 2 hours a day, 5 days a week and 11 months a year, it uses around 30 Kw/h, that is more than €7 a year in electricity. On the other hand, considering the same scenario, an LED bulb uses just over 3.30 kw/h, which represents around 80 cents of electricity per year. It should be noted that, according to the published article, lighting accounts for only 10% of an electricity bill. However, depending on the circumstances, savings can still be significant. This is why the transition to LED equipment is advisable. In terms of price, the halogen bulb can be purchased from €1.5, a compact fluorescent for around €3 and an LED can vary between €1.5 and €5.

The article states that in general, the advantages of the bulb are its greater efficiency, durability and resistance, the bulb itself does not heat up while its on, when they are switched on they can reach their maximum performance in less than 1 second, they do not need time to heat up, can be controlled by a remote control and are highly recyclable.

ISEG has changed 99% of its light bulbs on campus to LEDs, around 466 lights, and this will enable the university to reduce energy consumption, as was seen in the year of 2023.

The other major change made by the university was the replacement of air-conditioning units that were no longer fit for purpose and were not efficient enough. Unlike lighting, heating, ventilation and air-conditioning (HVAC) systems account for 40-60% of a building's total energy consumption (Pérez-Lombard et al., 2008). This makes it imperative to update the units and to ensure a regulated and rational use of these appliances. Replacing air conditioners not only makes it possible to use more energy-efficient machinery, it also makes it possible to use refrigerant gases, such as R32, which is a hydrofluorocarbon with zero ozone depletion and low atmospheric warming. It is an important step towards carbon neutrality.

In order to optimize and guarantee a reduction in the energy consumed by HVAC systems, it is necessary to consider improvements to the structure of the building, in-depth study of planning parameters such as occupancy, comfort, building type, cost and health, possible incorporation of renewable technologies, use of advanced control and regulation systems, use of water and energy control and recovery systems and adaptation/renovation of existing systems (Asim et al., 2022).

ISEG, between the Quelhas 2 and Francesinhas 2 buildings, replaced 6 air conditioning units. The models chosen were Mitshubishi multisplits and the university spent around €13462 on this upgrade operation.

Although it is very difficult to say precisely what impact these changes are having on energy consumption, we can see from Table 9 that the values have fallen compared to the homologous period. In order to conclude with certainty that this reduction was due to the changes made by ISEG, it was necessary to monitor energy consumption even more precisely. For example, by using a meter next to the air conditioning units to measure the exact amount of electricity used.

In addition, in one of the meetings with ISEG's Engineer, it was stated that much of the decrease in 2023 was due to constant vigilance and control. He added that it is also necessary to raise awareness among the entire academic community and that often the biggest obstacle to reducing energy consumption is the fact that people are not willing to give up their comfort and quality of life. For example, not running the air conditioning at excessive temperatures during very cold or hot periods.

With regard to the benchmark carried out, it is important to mention that the measures that are being implemented at ISEG are in line with the work being developed by other universities. Replacing lighting with LED bulbs and upgrading air-conditioning equipment with newer, more efficient devices is common practice and leads to major energy savings and a reduction in carbon emissions. Some of the schools included in the benchmark are making changes to their laboratories, as they are spaces which, due to their activity and the type of equipment used, can consume a lot of energy. It is therefore imperative to make these spaces more efficient. As ISEG does not have laboratories, this type of measure does not apply.

In order to continue to achieve its objectives and reach a carbon-neutral campus by 2030, ISEG must keep implementing and studying new energy efficiency measures.

4.5 Proposals for Energy Efficiency Measures

This part of the project involves presenting measures that could make ISEG's buildings more energy efficient and consequently reduce the campus's carbon footprint.

4.5.1 Consumption Monitoring Systems

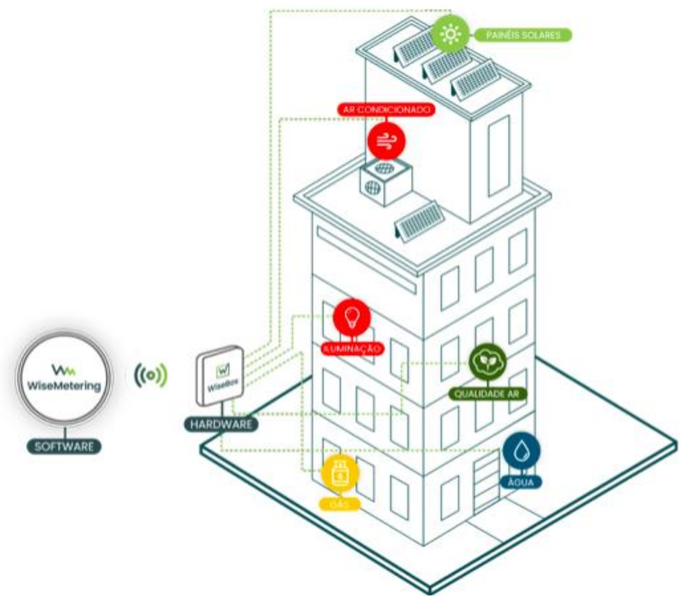
Currently, ISEG is already monitoring energy consumption in all its buildings. However, there is no system capable of measuring the consumption of specific appliances. Consider the following case: there is a great effort on the part of the university to modernize the air conditioning systems, but there is still no tool to see how much energy is being consumed by each unit. Therefore, the first suggestion for improvement is to install monitoring equipment for energy consumption and use a program to keep track of it. If the university's aim is to reduce its electricity costs, make the campus more efficient and reduce its carbon footprint, then all consumption needs to be properly identified and monitored. Only in this way will it be possible to identify possible areas for action and draw up improvement plans. Through the benchmark carried out, it was possible to see that schools such as Harvard and Columbia are investing in and developing high-performance monitoring systems and also performing regular energy audits of their buildings. Columbia University plans to conduct 29 audits in the near future.

In this regard, ISEG should consider hiring the services of the company WiseMetering.

WiseMetering is an energy management platform whose main objectives are to optimize consumption and reduce electricity costs. It operates in the retail and buildings sectors. In the buildings sector, which is where ISEG belongs, the main focus is on correctly monitoring consumption, sending alerts about decision-making and anomalies and identifying opportunities for optimization and savings.

The platform's activity is supported by a hardware network (multi-site), which locally consists of a WiseBox and a pair of peripherals (energy meters, temperature sensors, gas meters, among others). The aforementioned network makes it possible to control and monitor the operation of equipment relevant to energy consumption at each site. The WiseBox and the peripherals are programmed using WiseMetering software. In addition, the company offers consultancy services to support the software, making it possible to make the necessary adjustments to achieve savings.

Illustration 2: WiseMetering in a Building



Source: https://www.wisemetering.com/a-plataforma/

The benefits associated with investing in WiseMetering's services are the following: overall savings of around 20%, savings in energy costs, central and remote supervision, benchmarking, detailed reports, invoice validation, investment support, maintenance and operation activities, increased performance and correct allocation of resources.

Some of WiseMetering's main clients are Sonae, Tagus Park, Delta, CUF, Vodafone, PNB Paribas, El Cortes Inglês, Nespresso, CTT, and Altice.

Table 11: Services Offered by WiseMetering

Standard	Advanced	Premium
WiseBox ✓	Includes the Standard package, plus:	Includes the Advanced package, plus:
Communications package ✓	API access - Advanced version ✓	API access - Premium version ✓
Unlimited users ✓	5-year data retention ✓	Unlimited data retention
Minimum 2-year contract ✓	Tenant management module ✓	Technical support ✓
2-year data retention ✓	Advanced reports ✓	2 customized reports included ✓
Training ✓	ISO 50001* processes ✓	Integration with other platforms ✓
Data monitoring and analysis ✓	Access to opportunity library** ✓	
Alarming ✓	* Roadmap 2024	
Objectives ✓		
Invoices ✓		
Opportunities ✓		
Standard reports ✓		

Source: https://www.wisemetering.com/precario/

Table 12: Prices per Service and Level

	Standard	Advanced	Premium
X-Small Until 5 sensors and 1 Wise-Box included	45€ Per month and building	63€ Per month and building	83€ Per month and building
Small Until 50 sensors and 1 WiseBox included	145€ Per month and building	203€ Per month and building	243€ Per month and building
Medium Until 100 sensors and 2 WiseBox's included	195€ Per month and building	273€ Per month and building	333€ Per month and building
Large Until 200 sensors and 4 WiseBox's included	270€ Per month and building	378€ Per month and building	458€ Per month and building
X-Large Until 400 sensors and 6 WiseBox's included	370€ Per month and building	518€ Per month and building	678€ Per month and building

This project proposes to contract the services of WiseMetering and subscribe to the Small plan (50 sensors and 1 WiseBox) in the Standard version. The equipment would be installed in Francesinhas 1, as it is one of the main buildings with a high volume of activity, this method would be tested over a period of 2 years. In an initial test phase, 2 sensors would be applied per floor, separating lighting and the HVAC. In total, 10 sensors would be installed between floors -1, 0, 1, 2 and the rooftop. In January, a meeting was held with WiseMetering's commercial team, in which they agreed to present a proposal for installing the service. ISEG's engineer was present at the session and will evaluate the proposed together with the university's administration. Other companies in the sector will possibly be contacted as a means of finding the most attractive deal for ISEG.

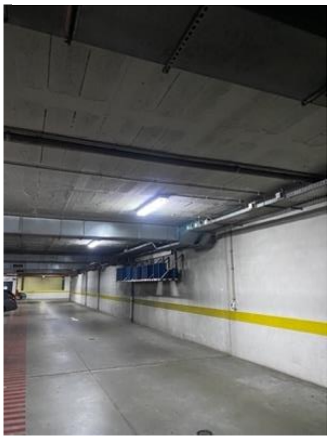
4.5.2 Motion Sensors

During one of the visits to the university's buildings, it was possible to notice that there are areas where the lights are constantly on, regardless of whether anyone is in the room, and that the use of motion and presence sensors is almost non-existent. Therefore, the second proposal for improvement involves installing sensors in the underground parking lot, classrooms and library.

A study carried out at South Korea's H University in Seoul has shown that by installing radio frequencies (RF) sensors in the school's underground parking lot, it was possible to reduce energy consumption in the car park by 77.6% (Lee & Kim, 2020).

Underground parking lots are often considered a viable option because they make use of space, permitting many vehicles to park. However, in most cases they have very little natural light, making them highly dependent on artificial light and thus contributing to higher electricity bills. Similarly, in ISEG's garage is that the lights are always on and therefore always consuming energy. In order to overcome this, this project suggests installing a sensor-switched LED indoor light. Meaning that when the light is not in use, it is switched off and whenever movement is detected, the light switches on automatically. We would also

Image 2: ISEG Underground Parking Lot



Source: Author

be upgrading the LED luminaires that have been installed at the site.

Illustration 3: Underground Parking Lot - Level -1 ($\sim 1423m^2$)

The equipment to be installed is from Steinel with the European Reference Number of 4007841078881. The product costs 247.90€ per unit on the lampamania.pt website. It is proposed to install 32 units, as shown in Figure 3 (red dots). The total cost of this investment is 7932.8€. A photo of the product can be seen in the appendices. Same upgrade should be studied for floor -2.

The same study states that, by using sensors, it is possible to reduce lighting consumption in classrooms by around 32.4% and that it is also possible to decrease the amount of energy spent on heating and cooling inside classrooms by around 27.9% (Lee & Kim, 2020).

Image 3: Classroom with the light on and not in use

Source: Author

These spaces, when we think of a university campus, are the most prominent and certainly those with the most use, whether by students or teachers. Therefore, this project recommends installing a RF sensor for the lighting and air-conditioning units. With this improvement, we ensure that the lights or air conditioning are not unduly switched on when the room is not in use. This improvement will enable ISEG to reduce energy consumption and is a follow-up to what has already been done with the replacement of light bulbs with LED devices.

The ISEG library, along with the classrooms, is a space that students use regularly and is open for long periods of time. More specifically, it is open from 9.30 a.m. to 8 p.m. on weekdays, from 9.30 a.m. to 5 p.m. on Saturdays and closed on Sundays and public holidays. In addition, the study room on the ground floor is open 24 hours a day.

In one of my visits to the campus, I noticed that the space reserved exclusively for Master's students was empty, but the lights remained on. The same was true of the other floors of the library, where it was possible to see that although there were students in the space, there were areas where there was no one, but the lights were on at their normal intensity. That being said, it is recommended that infrared sensors be installed in these spaces. In addition to these, the installation of a light control sensor is also recommended. This will allow the measurement of the amount of ambient light and will regulate the artificial light as necessary. Making it possible to optimize the use of the lights, the sensor detects when people are present and the lights are turned on, when there is no presence the sensor turns off the light leaving the space with only the ambient lights. The use of an infrared sensor is important because it means that the light does not go out even if someone is standing still in the space. This type of sensor works by reading temperature.

Image 4: Master's room with the light on and not in use

Source: Author

Taking into account the floor plan of level 1 of the library, it is recommended to install 6 infrared sensors with a six-meter range. The distribution of the sensors (red dots) can be seen in Figure 4. The equipment can be purchased on the lampamania.pt website, the product code is HD0018 and the unit price is €18.90. The total investment would be €113.4. A picture of the device can be seen in the attachments. The same work should be done for the other floors of the library.

Illustration 4: Library - Level 1 ($638m^2$)

4.5.3 Green Roofs

The following proposal for improvement concerns the creation of green roofs, which are considered a new approach to architecture and urban development. With these it is possible to increase the amount of green spaces, improve the quality of the environment and build sustainable urban spaces (Algarni et al., 2022; Manso et al., 2021). The phrase "green roof" refers to a roof that is completely or partially covered by vegetation, and which has several layers, such as waterproofing, drainage, insulation, plant growth and active layers (Smalls-Mantey & Montalto, 2021).

A study was carried out that considered 2 types of roofs, insulated and non-insulated, in 3 different geographical areas. The research was carried out in Medan, Indonesia, which has a hot and humid climate, in Najaf, Iraq, which has hot and dry weather, and in Moscow, Russia, where the climatic conditions are essentially cold and dry. The study concluded that green roofs have a greater impact on increasing energy efficiency in hot and humid climates (Ketut Acwin Dwijendra et al., 2023).

However, as you can see in Table 13, there are considerable reductions in all locations. It is possible to reduce the amount of energy spent on cooling the building and also on heating due to the increase in thermal resistance.

Table 9: Results of the Study

	Non-Insulated	Insulated
	Change in total energy (%)	
Medan, Indonesia	71%	69%
Najaq, Iraq	27%	30%
Moscow, Russia	19%	16%

Source: Ketut Acwin Dwijendra et al., (2023)

Given the large number of buildings at ISEG, this is undoubtedly a solution to be taken into consideration in more detail in the near future.

4.5.4 Additional Measures

ISEG should continue the process of replacing old and damaged air conditioning units with new, efficient equipment. The priority units for change need to be correctly identified. Some of the machines in use on campus no longer meet the current guidelines and should therefore be replaced as soon as possible. The type of gas used by appliances also has an influence on carbon emissions, which is why the best gas to use is R32. This gas is a hydrofluorocarbon, with zero ozone depletion and low global warming potential. In addition to air conditioners, ISEG needs to keep an eye on the consumption and condition of other equipment used, seeking to replace less efficient ones.

In the same way, ISEG should work with the University of Lisbon to review current rates of an estimated 0.25 cents per Kw/h as they are higher than average market prices.

Other building optimization and efficiency solutions should be studied, such as the installation of automatic doors at the main entrances.

4.6 Marketing Campaigns and Rising Awarenees

Through literature review and various meetings with the school's engineer, it became quite clear that in order to reduce energy consumption, the entire academic community needs to be involved. The creation of energy-efficient buildings is only possible through a high level of involvement from all stakeholders. ISEG administration needs to be committed and willing to invest in innovative solutions, and all teachers and students need to adopt correct responsible behaviours. In order to oversee all the effort and investment that ISEG has been making to make its school as sustainable as possible, it is necessary to create a high level of awareness. Thus, there is a need for various marketing campaigns that promote sustainable practices and increase the levels of involvement of the student community.

ISEG has announced in its 2022 Sustainability Report that it has replaced 99% of light bulbs on campus with LEDs. Following the same line of approach, this project proposes the promotion of an online fair with the aim of encouraging anyone interested in buying one or more LED bulbs. This has already been implemented at Harvard University, where more than 1,800 LED light bulbs were sold through the event. The initiative would be promoted through ISEG's media, namely the website, email and social networks, and through the involvement of the university's student association. Everyone would be welcome to take part and could buy as many bulbs as they feel necessary, the minimum quantity would be one bulb per person. The LEDs would be purchased at a competitive price, at which the school would not have any financial gain. In order to facilitate the ordering process, a form would be created in Microsoft Forms where interested parties would enter their personal details and the quantity of LEDs they would be interested in buying. The appliances would be paid for and picked up at the school. This would allow for greater visibility to what is being done to reduce energy consumption and for the achievement of a carbon-neutral campus by 2030. Most importantly, it would raise awareness in the community.

5. CONCLUSIONS

This project was conceived to help reduce energy consumption and create energy-efficient buildings at ISEG. The energy consumption of all the campus blocks in recent years was analysed, the factors that contribute to electricity consumption were identified, a benchmark was carried out to support the project and optimization proposals were presented, with the aim of reducing energy consumption and consequently the university's carbon footprint.

5.1 Research Implications

Through the analysis carried out, it was possible to compare some points that were mentioned in the Literature Review.

The results show that energy consumption is directly affected by the type and quantity of activities performed on campus; the greater the number of activities, the greater the energy consumption; this result is similar to that of Leal Filho et al. (2019), who states that the type of activities affects energy consumption. Weather conditions also play an important role in the amount of energy used in a given month, as mentioned by Leal Filho et al. (2019), who mentions a variation between summer and winter months. Energy consumption during vacation periods or when there are no ongoing classes is also lower and is in line with what M. Jafaray et al. (2016), Kim et al. (2010) and Tang (2012), say when they state that energy consumption is lower during vacation periods when there are no students or teachers at school. HVAC systems at ISEG account for around 58% of total energy consumption, and this is in line with what Pérez-Lombard et al. (2008) says when he mentions that HVAC accounts for 40 to 60% of a building's total consumption. The conversations had with the ISEG engineer revealed that the success of the initiatives and the possibility of reducing energy consumption is highly dependent on the commitment of the university’s top management and the behaviour and awareness of the academic community. Leal Filho et al. (2019), says that a school can only implement energy efficiency measures if there is strong involvement from top management, students and teachers.

5.2 Main Conclusions

After analysing and comparing with the benchmark, it can be concluded that ISEG is in line with what is being done at other institutions. The benchmark was important to understand what was being done at other schools and whether the strategies ISEG has been adopting are appropriate. ISEG has a very ambitious carbon neutrality project and for this to become a reality it has to have solid underpinnings. It is currently believed that the university is well on the way to achieving its objectives and an example of this was, in the last audit, obtaining the ISO 14001 certificate, which demonstrates a commitment to continuous improvement and environmental management.

The proposed improvement measures include implementing a system capable of measuring energy consumption by building in detail. Currently, only total energy consumption can be calculated. It is not possible to adopt energy efficiency measures if we do not know specifically where the highest energy usage is. Without a specific measurement of energy consumption, it becomes more difficult to identify which equipment needs to be replaced and which areas need intervention. In addition to this, some more elementary measures were also proposed to help ISEG lay the foundations for achieving its objectives. The installation of sensors in the parking lot, classrooms and library, has also been proposed, which is believed will lead to significant energy savings. In the meantime, it has also been suggested that the adoption of green roofs be studied in order to optimize energy conservation in buildings.

5.3 Limitations

There are some limitations, including the fact that there is no detailed view of energy consumption, making it difficult to analyse and present proposals. The unpredictability of weather conditions also makes it difficult to create a pattern with regard to the months with the highest and lowest consumption. This project failed to identify the equipment that consumes the most energy. In future studies, when there is already concrete monitoring of energy consumption, it is expected that it will be easier to present measures.

5.4 Recommendations

The work carried out in this project not only has an impact on ISEG, but on all other higher education institutions seeking to adopt sustainable practices. This work contributes to SGDs 7 (Affordable and Clean Energy), 11 (Sustainable Cities and Communities), 12 (Responsible Consumption and Production) and 13 (Climate Change). The importance of promoting a green campus goes far beyond reducing financial expenditure on electricity. The greatest impact is on the community and the environment.

It is strongly recommended that the measures presented be adopted, allowing operating costs to be reduced and, above all, reinforcing ISEG's commitment to sustainability. The success of these actions is highly dependent on the commitment of ISEG's top management and the involvement of the entire academic community.

5.5 Future Studies and Research Directions

Future research directions could include calculating ISEG's carbon footprint, accounting for direct and indirect emissions. ISEG could work alongside with energy suppliers to optimize energy sources and management costs. The implementation of renewable energy sources is something that is planned by the school and further studies should be carried out to ensure the correct feasibility of implementation. In the meantime, additional studies could be carried out to assess the impact of the energy efficiency measures that will be implemented and behavioral studies to measure the impact of awareness campaigns among the academic community, as well as to identify new strategies for reducing energy consumption.

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APPENDICES

ISCTE

Measure Implemented	Application Area
Placement of wooden panels on campus and creation of videos to raise awareness among the academic community.	Awareness
Switching electricity suppliers to use energy sources with lower CO2 emissions.	Carbon Footprint
Promote the use of bicycles and carpooling.	Carbon Footprint
Photovoltaic panels will be installed.	Energy Production
Mapping energy consumption, replacing old equipment with new ones and installing LED lamps	Energy Consumption

COPENHAGEN

Measure Implemented	Type
Switching electricity suppliers to use energy sources with lower CO2 emissions.	Carbon Footprint
The school has also made efforts to lower energy consumption in the autumn and winter periods.	Energy Consumption

BOCCONI

Measure Implemented	Type
The university plans to better monitor energy consumption and greenhouse gas emissions.	Research and Development
100% of the electricity purchased by the university comes from renewable energy sources. Bocconi has been doing this since 2017.	Carbon Footprint
Investment in photovoltaic and geothermal panels. The Bocconi university has the second largest photovoltaic park in the city of Milan. It currently produces around 1.2MW.	Energy Production
The college is changing its lighting to the latest LED systems, replacing old equipment with more efficient ones and ISO 50001 energy management certification.	Energy Consumption
The new buildings at the campus are LEED Platinum certified.	Energy Consumption
Changes to heating systems and heat pumps.	Energy Consumption
The institution also intends to apply for public funds to renovate some of the buildings and residences. Bocconi recently renovated the Via Salasco building with funding from the "110% super bonus" program.	Energy Consumption
Programs against food waste that will help the college reduce its carbon footprint. Bocconi also intends to optimize the waste cycle at the school.	Waste

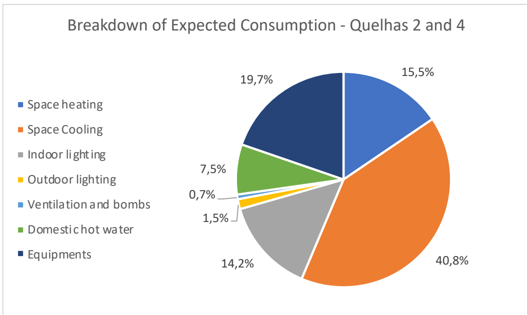
ESADE

Measure Implemented	Type
Integration of ESG criteria in the selection of service providers.	Awareness
ESADE asked its partners to adopt the United Nations Global Compact and the Esade Code of Ethics, 89% did.	Awareness
Redesign of promotional catalogs, taking sustainability criteria into account.	Carbon Footprint
Investment in solar panels, which have been installed in buildings 2 and 3 in Barcelona and in the Teaching Building in Sant Cugat.	Energy Production
Changing existing light bulbs to LEDs and replacing heating and cooling equipment with newer ones.	Energy Consumption

HARVARD

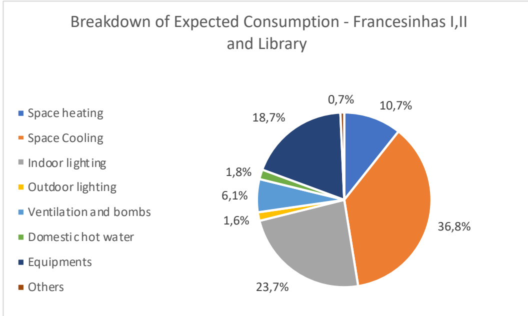
Measure Implemented	Type
The Harvard T.H. Chan School of Public Health has created a tool that helps the college measure and estimate the impacts of fossil fuels on society.	Research and Development
Harvard is committed to scientific research.	Research and Development
Harvard Management Company (HMC) announced that it wants to make its operations and facilities net zero by 2021.	Awareness
Harvard joined the Cool Food Pledge in 2019. The organizations that are part of this institution aim to reduce the carbon footprint of food by 25% by 2030.	Carbon Footprint
Harvard has invested in the installation of photovoltaic panels along with solar thermal and geothermal installations. The school has a solar capacity of 2,992MW on its campus. In addition, they sell the rest of the environmental benefit to local service providers in order to increase the source of renewable energy in the regional electricity grid.	Energy Production
Renovation of buildings belonging to Harvard University Housing Soldiers Field Park and installation of 225KW of photovoltaic panels.	Energy Production
Harvard University's 238-acre Arnold Arboretum in Boston is partially powered by solar energy.	Energy Production
The Faculty of Arts and Sciences (FAS) Center for Astrophysics has developed an energy efficiency project related to LED lighting. The reduced emissions resulting from this initiative are equivalent to 30 net zero emission homes.	Energy Consumption
The Office for Sustainability (OFS) held an online lighting fair encouraging people to buy LED bulbs at a discount. More than 1,800 lamps were sold, which translates into savings of around 23,000 dollars.	Energy Consumption
Harvard has developed a ventilation plan for the laboratories which saves energy while maintaining all safety conditions. Scientists were encouraged to use hoods only when necessary.	Energy Consumption
The FAS Sherman Fairchild Laboratory is a LEED Platinum-rated building and allows the college to reduce costs by $60,000 a year.	Energy Consumption
FAS encourages laboratories to change the temperature of their freezers from -800°C to -700°C.	Energy Consumption
The HouseZero team renovated a 1940s-era house and by using efficient construction techniques they were able to make the house produce more energy than it consumes.	Energy Consumption

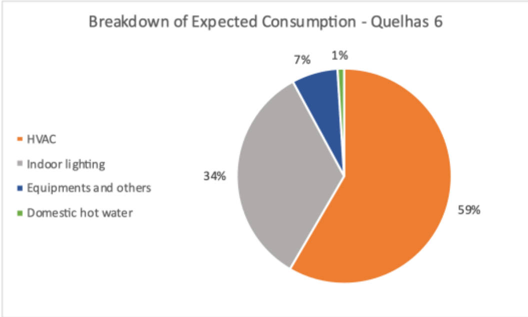
Breakdown of Expected Consumption – Charts 3,4 and 5



COLUMBIA

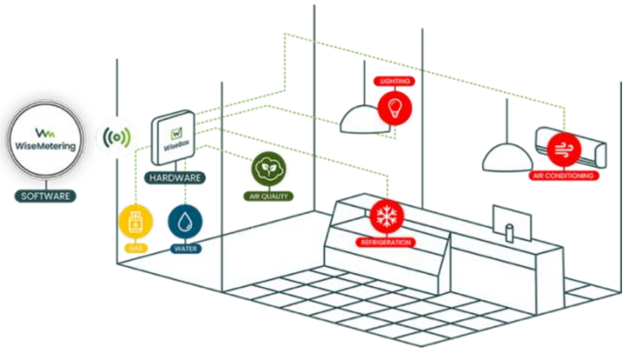
Measure Implemented	Type
Identification of all scope 1 and 2 emissions, and by 2030 the goal is to have all scope 3 emissions inventoried.	Research and Developent
The college is aware that the changes made to the Morningside Campus are not enough and that renewable energies are not a viable source either. Therefore, a study is underway in which three alternatives are being analyzed. Switching to electric steam boilers, steam heat pumps or hot water heat pumps.	Research and Developent
Columbia University is designing its first building not powered by fossil fuels. This is the renovation of a 6-storey building. The project will use a VRF system and cold-source heat pumps. An underground source test was also carried out to determine the thermal capacity of the campus.	Research and Developent
The school has managed to reduce greenhouse gas emissions at the Morningside Campus by around 45% since 2006. CUIMC has also reduced its emissions by around 44% since 2012. The college's Scope 1 emissions have risen slightly because two new buildings have opened and, according to the university, all pre-Covid activity has returned. In the short term, Columbia University has been buying carbon offsets in order to keep in line with its sustainability strategy.	Carbon Footprint
The college has a 10-year plan to expand the network of electric car chargers. In 2022, 2 new units were added.	Carbon Footprint
The school has a network of electric buses available for students to travel between campuses.	Carbon Footprint
In January 2023, the university updated its parking fees to encourage people to travel more sustainably. Creation of the "parking buddy" program that allows people to share costs and spaces.	Carbon Footprint
Partnership with the train network, reduced travel fees.	Carbon Footprint
The LDEO Campus plans to upgrade its fleet of vehicles to electric ones as the current ones reach the end of their useful life.	Carbon Footprint
At the Morningside Campus, 24 new bicycle parking spaces have been added.	Carbon Footprint
The college approached its furniture supplier to find out if the products complied with environmental and health standards.	Carbon Footprint
Columbia University also contacted its carpet supplier to find out if it was possible to recycle old carpets into new ones.	Carbon Footprint
Whenever there is flooring that needs replacing, the university replaces it with carbon-neutral flooring from Interface.	Carbon Footprint
Windows in historic buildings were assessed and standards updated.	Energy Consumption
Replacing old light bulbs with LEDs until 2030.	Energy Consumption
Columbia university is carrying out energy audits in more than 29 buildings.	Energy Consumption
The university is re-calibrating energy meters and is also upgrading the steam piping network.	Energy Consumption
Columbia University plans to modernize the energy consumed by the water system by switching to a more efficient one. The campus pumps will be replaced with new variable frequency drives (VFDs) pumps by 2024.	Energy Consumption
The university has built a new biomedical laboratory that is 100% electric. It is considered one of the first net-zero buildings in New York. The new building has heat pumps for heating, ventilation with heat recovery, glazed areas directed towards sunlight, electric vehicle charging, water management systems, green roofs, reinforced windows and LEED Gold certification.	Energy Consumption
The university's new tennis center, which will be ready by the end of 2023, is being built to achieve LEED Gold certification.	Energy Consumptio
The university created an initiative in which 150,000 pounds of furniture were prevented from ending up in landfill. Enough material to furnish living rooms, offices and bedrooms was donated to seven charities. The university's goal is to send zero waste to landfill.	Waste
Reuse of materials internally. Whenever this is not possible, the products are sent to non-profit institutions. In the past, the university has donated stoves, washers and dryers, musical instruments and furniture to more than 70 organizations.	Waste
The college is preparing a program to collect organic waste from residential buildings following a recommendation from the New York City Department of Sanitation.	Waste





Source: ISEG data

Wisebox demonstration



Steinel light + sensor for the underground parking lot

Infrared Sensor

Energy consumption per day in 2019

Day	January	February	March	April	May	June	July	August	September	October	Novmeber	December
1	3284,75	7445,75	6347,5	6230,25	3495,5	4284,00	5919	4398,5	3411,25	7138,25	3997,25	3094,25
2	5937,50	4920,5	4302,25	6374,25	5786,75	3342,25	5911,5	4473,25	6048,25	7107,75	4091,5	6529,75
3	6852,75	3503,25	3569,75	6325,75	5730,75	6457,00	5841,25	3427,5	6247	7124,25	3179	6647
4	6777,00	7947	5935,5	6283,75	3880,25	6217,75	5765,75	2751,25	6514,25	6618	6008,75	6969,25
5	4269,50	7609,5	4558,5	6048,75	3035,5	6040,50	5785	4425	6679	3810,5	6021,25	6617
6	3030,75	7456	6983,75	4225,5	5921,25	5999,50	3980,5	4377	6499,5	3568,25	5989	6127,25
7	7002,50	7150,5	6974,5	3512,25	6048,75	5908,50	3066,75	4300	4628,25	6887,25	5973,5	4402,75
8	7326,75	6643	6547,5	6224,75	6071,5	3971,75	5590,5	4268	3635,5	7481	5692	3486
9	7053,50	4234,5	4164,75	6231,5	6170,5	3219,25	5636,75	4091	6991	6827,5	4044	6308,25
10	7128,50	3131,5	3273,75	6078	6063,5	4139,00	6001	3271,25	6353	6853,5	2887,5	6502,5
11	7169,50	6740	6466,75	5765	4527,75	5808,50	6763,75	2628	6698,5	6597	5648,75	6835,5
12	4285,25	6684	6621,25	5768	3597,25	5742,75	6233	3570,75	7739,25	4751,75	6052,25	6621,5
13	2976,25	6523,25	6601,5	3980,25	7150,5	3799,25	4203,5	3490,5	8533,5	3436	5907,5	6314,5
14	7362,75	6666,75	6640	3221,75	7175,5	5750,00	3256,5	3607,75	5961	6463	5895,75	4183,75
15	7673,50	6596,75	6063,5	5568,75	7145,25	3922,00	5948,25	3566,75	4513	6568,75	5648,75	3639,5
16	7664,50	4136	3948	5383,75	6527,75	3083,50	5655,75	3653,5	7395,75	6590,75	4193,5	6254,25
17	7310,00	3035,25	3225,5	5690,25	5973,25	5662,25	5539	3125,75	7466,25	6781,5	3018,25	6036,25
18	7128,75	7559,5	6595,75	5236,25	4084	5725,25	5796,25	2670,5	6774,75	6320,75	6107,5	5907,5
19	4196,75	7088,25	6383,25	3805,5	3163,5	5714,75	6017,75	3638,25	7030,5	4856,75	6594,5	5762
20	3103,25	6950,5	6267,25	3810	6024,5	3577,25	3964,25	3696,25	6991	3257	6565,75	5365,5
21	7185,50	6771,5	6372,5	3161	6241,75	5657,50	3085	3761,5	4456,25	6136	6198	3758,75
22	7195,50	6419,75	6029,5	5221,25	6385,25	3918,25	5757,5	3803,75	3403,5	6364,5	6118,5	3055,75
23	6985,25	4123,25	3942	6246	6371,5	3008,50	5799,25	3805,75	6020,5	6456,5	4270	3913,25
24	6932,25	3413	3115	6141,5	6032,5	5115,50	5661	3190	6658,75	6245,5	3144,25	3628,5
25	6340,25	6450,5	5973,75	3915	4207,25	4737,50	5694	2714,5	6570,25	5878,25	6288,5	3598,5
26	4144,75	6624,5	5976,75	5533	3244,75	5403,00	5364	4168	6693,25	4375	6503,25	4951
27	3024,50	6647	5991,75	4002	6064,5	5566,00	3763,75	4809,25	6685	3393	6558,5	5022
28	6595,50	6929,75	5909,25	3084	6277,5	5637,75	2965,75	4950,75	4518,5	5981,5	6333,5	3920,75
29	6614,50		5880	5842,25	6649	4002,50	5255	5036,75	3601,25	6043	6170	3144
30	6836,00		4191,75	5866,25	6450,25	3216,25	5013,25	5184,25	6831	6035	4937,75	5110,75
31	7345,00		3242		6608		5014	4152,25		5947,25		3780,25
Total	186733,00	169401,00	168094,75	154776,50	172105,75	144627,75	160248,50	119007,50	181548,75	181895,00	160038,50	157487,75
Average	6023,65	6050,04	5422,41	5159,22	5551,80	4820,93	5169,31	3838,95	6051,63	5867,58	5334,62	5080,25

Source: ISEG data

Energy consumption per day in 2021

Day	January	February	March	April	May	June	July	August	September	October	Novmeber	December
1	3866,75	4517,5	3671,75	3551,75	3028	4343,25	4641	3133	5060,75	4879,25	3380,25	3709
2	3607,25	4427,5	3643,5	2922,5	2974,25	4413	4687,75	3888,5	4948	3962,25	4823	6098,75
3	3349	4435,25	3568,25	2849,25	3937,75	3410	3722,75	3897,75	5024,25	3323	4944,5	5863,25
4	6063,5	4447,75	3620,25	2815,25	3960	4334	3239	4007,25	3938	4299,75	4942,5	4079,75
5	6422,25	4473,25	3625,75	3613,25	3944	3599	4352,5	4078,5	4058	3345,25	4906,5	3621,75
6	6754,5	3946,25	3092,75	3655,5	3846,25	3184,25	4169	3706,75	5351,25	5387,25	3539,5	5843
7	6752	3389	2586,25	3574,75	3937,5	4439	4100,75	3318,75	5861,25	5205,25	3206,75	5514
8	6901,5	4753	3759,5	3608	3393	4577,5	4095,75	3110,5	6233,25	4860,5	4898,75	3513,75
9	4744,5	4564,25	3609,5	3564	3024,25	4764	4514	3216,25	5922,75	3497,75	5061	5931,75
10	3884,75	4667,25	3653,25	3272,5	3978	3439,75	3786,75	3275,75	5910,25	3252,75	5194,5	5726
11	7257,5	4518	3644,25	2876,75	3956,25	4380	3216,5	3299	4720	5195,75	5228,75	3985,5
12	7400,75	4443	3576,5	3801,5	3877,75	3595,5	4140,75	3251,25	4178,25	5521	5041,25	3197,5
13	6835,25	3933,25	3051	3775	3974	3210,25	4202,75	3342,5	6226,25	5692	3813,5	5477,75
14	6489,25	3340,75	2539	3689,25	3878,5	4791	4475,25	3227,25	5928,25	5425,5	3422,25	5646,75
15	5938,75	4346,75	3465,75	3735	3218	5139,25	4437	3082,25	6003,25	5406	5060,5	5748,75
16	4265	4347	3447,75	3692,5	2911	4671,5	4448,75	3249,75	6089,25	3941,75	5323,5	5912,75
17	3764,25	4433,5	3466,25	3224,5	3779,25	4283,5	3819,5	3415	5609,75	3663	5502,75	5699,5
18	6431	4264,75	3479,75	2889,5	3753	4370,75	3164,25	3311,25	3958,25	5405,25	5525,5	3962,5
19	6357,75	4290	3690	3857,25	3730,25	3639,75	4437,75	3217,5	3720	5659	5268,5	3229,25
20	5872	3788,25	3114,25	3846	4044,5	3117,5	4616,5	3141,75	5276	5466	3999,5	5211
21	5759,5	3289,25	2796,5	3861,5	4288,75	4353,5	4566	2986,75	5423,5	5188,25	3583,25	5018
22	5432	4554,5	3610,25	3805,75	3442,25	4340,5	4446,5	2915,75	5704,5	4903	5441,75	5045,75
23	4106,25	4486,75	3704	3979	3063,5	4531	4521,25	3528	5519,5	3724,5	5433,75	4571,5
24	3500	4327,5	3696,75	3366,5	4118,25	4760,5	3646,25	3358,75	5257,75	3258,25	5763,25	3361,25
25	4964	4472,75	3684,5	3011	4009,5	4753,5	3074,75	3321	4024	4753	5976,5	3077,75
26	4638,25	4478,5	3680,5	3883,25	4523	3745,75	4645,25	3333,5	3713,75	4950,5	5853,75	3050,5
27	4579,5	2587	3159,25	3921,25	4345,5	3186,25	4918,25	3311,25	5256,25	5050,25	4364,75	4229,25
28	4629	2708,5	2728	3920,5	4516	4312,5	4605,75	3108,75	5189,5	4870	3836	4369,5
29	4612,75		3616,25	3901,5	3509,25	4436,5	4472,5	2848,5	5290	4943,75	5816,25	4513,5
30	3683		3641,25	3948,25	3097	4517	4545	3933,5	4995,25	3753	5683,25	4563,25
31	3265,25		3579,75		4330,75		3570	4874		3757		3317,5
Total	162127	116231	106202,25	106412,5	116389,25	124639,75	129279,75	105690,25	154391	142539,75	144835,75	143090
Average	5229,90	4151,11	3425,88	3547,08	3754,49	4154,66	4170,31	3409,36	5146,37	4598,06	4827,86	4615,81

Source: ISEG data

Energy consumption per day in 2022

Day	January	February	March	April	May	June	July	August	September	October	Novmeber	December
1	2963,5	6221,5	4681,25	6350,75	3650,5	6269,5	6436,75	5117,75	4309,5	4458	3989,25	4085,25
2	2967,25	6820	6328	4948,25	5301,5	6063,75	4959,25	4973,5	4750,25	3953,5	5543	5916,5
3	5023,25	6698,5	6305,25	4369,5	5412	5923	4164,75	4900,25	4315,5	6389,75	5809,75	4469,25
4	5038,5	6400,75	6533	6766	5535,25	4636,75	6353	4650,25	3819,75	6351,5	5281,25	3742,25
5	5104,5	4524,75	4952,5	7375,75	5690	3969	6525,75	4544,25	6094,25	4072,5	3986	6326,75
6	5034,25	4013,25	4499	6589,25	5472,75	6328,25	6478,5	3976,75	6304,25	6269	3438,25	6340,75
7	5091,75	6017,5	6708,25	6796,25	4260,25	6576,5	7412,5	3325,5	6372,5	6199	5587,25	6656,25
8	3773,25	5666,75	6551,5	6009,25	3874	6753,5	8211	3995,75	6570,75	4521,25	5741,75	4039
9	3407,75	5683,25	6527,5	4524,75	6094,5	6634,5	5936,5	4161	6579,5	3814,5	5456,5	5696,25
10	5652,75	5640,25	6490,25	4038,25	6334,5	5526,25	3778	4044,25	4770,75	5995	5601	4001,5
11	5541,75	5454	6509,75	5662	7367	5364,5	6852,75	3987,75	4267,25	6509,75	5344,25	3394
12	5439,75	4292	4775	5752	7484,75	4682	7573,25	4107,25	6403,25	6638,5	4039,75	5825,75
13	5542,75	4161	4464	5443,75	7254	5762	8230,25	3875	6849,75	6383	3561,5	5191,75
14	5857	6222	6774,25	4981	5760,5	6553,75	7529,5	3319	7122	6099,75	5424	5447,25
15	4079,75	6315,5	6152	4223,75	4175,25	6205,5	7605	4025	6935,75	4447	5812,5	5354,25
16	3378,75	6523,75	6507,5	3857,75	6096,5	4649,75	5241	4154	6747,5	3867,75	5924,5	5475
17	5953,25	6046,5	6423,5	3726,75	6534,75	6314,25	4321,5	4031,5	4797,75	6226,5	5695,75	3840
18	6328	6182,25	6067,5	5467,75	6575	4796	6735,5	4021	4141,75	6677,75	5274	3238,5
19	6909,75	4578,75	4641,75	6084	6577,75	3971	6622,75	4185,25	7625,75	6151,5	4049,25	5038,25
20	7028,25	4114,75	4537	6343,5	6982,75	5803,25	6719,75	3974	7687,5	6103,25	3408,75	5015,25
21	6961,5	5896,25	6417,75	6357,5	5278,5	5717,25	6598	3416	7325	5696,75	5603,25	4916,5
22	4875,25	5421,25	6501,25	6445,75	4109,75	5813,5	6794,5	4678	7111,5	4449,25	5974,5	4873
23	4283,5	5850,5	7100	4838,75	6909,25	5916	4819,5	4847,25	6546,75	3684	5819,25	4002
24	6696,5	6007,75	6853	4266,25	5760,75	5668,75	4218,75	4557,5	4622,5	5782,25	5697,5	3476,5
25	6685,5	5844,5	6398,75	4839,5	5910	4628,75	6860,25	4447,5	3822,75	6027,75	5302	3307
26	6895,75	4446,5	4774,5	6122,5	6544,75	3718	6918,25	4430,5	6213,5	6394,25	4181	4718,25
27	6321,25	4214	3940,25	6065	6793,25	5556,25	6391,75	4061,25	6265,5	6109,75	3555,75	4905,25
28	6335	5531,5	5830	5868	4877,5	5982	6515,5	3282,75	6067,25	5912,5	5689	4971
29	4544,5		6100,5	5708,75	3837,75	5678,25	6453,5	4366,75	5911,5	4574,25	5904,5	4710
30	4258		6416,25	4119,25	6094	5788,5	4909	4211,25	6081,25	3841,75	6094,5	4019
31	6566,5		6519		6460		4208,25	3989,5		5749		3515,5
Total	164539	154789,25	183280	163941,5	179009	167250,25	192374,5	129657,25	176432,75	169350,25	152789,5	146507,75
Average	5307,71	5528,19	5912,26	5464,72	5774,48	5575,01	6205,63	4182,49	5881,09	5462,91	5092,98	4726,06

Source: ISEG data

Energy consumption per day in 2023

Day	January	February	March	April	May	June	July	August	September*	October*	Novmeber*	December*
1	3203,75	7235	7226	3551,5	4062	5911,75	5387,5	4686				
2	5247,5	7234	7067	2844,25	5923	5888	4589,25	5233				
3	6018	6868,25	6619,25	4213,75	5849	4646,25	7418,5	4383,25				
4	6126,5	4818	4753,5	4221	5808,75	3749,5	7031	4326,5				
5	6182	3892,5	3753,5	4050,5	5558	6282,75	6795	4238,25				
6	6098,5	6688,25	6788,75	3955,25	4297,75	6188,25	6343,25	3487				
7	4291,75	6925	6320,5	3203	3380,75	6158	6157,75	4383,5				
8	3623	7098,25	6326,25	3322,75	5830,75	4740	4684,25	3809				
9	5665,25	7004,5	6131,25	2715,75	5710,5	5703,5	3723,5	2903,25				
10	5683,75	7073,75	5540,5	4411,75	5555,5	4067,5	6595	2682,25				
11	5394,75	4928,5	4121,25	4692,5	5592,5	3872,75	6823,25	2596				
12	5681,25	4240	3205,5	4669	5108,25	5933,5	6719,5	2370				
13	5591,75	7132,25	5558,5	4769	4217,75	4713,5	6427	1734,25				
14	4349	7093,75	5644,75	4585,5	3214	6155,25	6389	2304,5				
15	3642,75	6685,5	5637	3550	5415,25	6807,25	4556,75	2017,75				
16	5903	6755	5631,5	2802,75	6233	7082,75	3555,25	2303,25				
17	5983,5	6421,75	5294,5	4888,75	6086	5120	5970,5	2449,5				
18	6311,5	4490,75	4219	5136	6351	4057,75	6074,25	2455				
19	6351,75	3785,75	3467	5483,75	5700,25	6254,75	6133,75	2384,75				
20	5877,5	5614,75	5529,5	4970,75	4133,25	6101,25	5846,5	1809,25				
21	4117,75	5094,5	5529	4718,25	3404	5748,5	5828,5	3084,25				
22	3311,75	6302,5	5570,25	3571,5	5187	6199,75	4464,5	3650,5				
23	6213,25	6743,5	5607,75	2781,25	5519	7390	3612,25	3911				
24	6703,75	6718	5236	4464,75	5806,25	6110,25	5764	3970,5				
25	6875,5	4867,5	4163,75	3246,5	6098,5	4549,25	5290,75	3696,5				
26	6675	3902,25	3153,25	5175,25	5371,25	7703,25	4977,5	3237				
27	6720	6927,25	5292,5	5928,25	4269,75	7691,5	4539	2491,25				
28	4760,25	7190,75	5216,25	5700,25	3494	8154,5	4600,25	3658,5				
29	4017,5		5261,25	4441	5531,75	7253,25	3649	3659,75				
30	7537,5		5219	3397	5648,25	6681,75	2886,75	3687				
31	7572		4667,25		5550,75		4456,75	3919,5				
Total	171731	169731,75	163751,25	125461,5	159907,75	176916,25	167290	101522				
Average	5539,71	6061,85	5282,30	4182,05	5158,31	5897,21	5396,45	3274,90				

Source: ISEG data

* No data available