Business Intelligence System for Management of Academic Organization's Carbon Dioxide Emission

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Abstract. This paper investigated the assessment of carbon dioxide emissions in academic organizations affiliated with the Faculty of Science, Energy, and Environment at King Mongkut's University of Technology North Bangkok in Rayong campus, and presented business intelligence strategies to reduce carbon dioxide (CO_2) emissions. We calculate the tons of carbon dioxide equivalent (CO_2 eq) for 2 years (2023-2024) of data from surveys, sources, and various activities responsible for CO_2 emissions, presenting the results through charts on the dashboard in a visually compelling and understandable way. According to the study, total CO_2 emissions are 484.96 tons CO_2 eq, with the top four sources of CO_2 emissions being electricity, R410a, Diesel fuel, and garbage, respectively. Based on business intelligence methodologies, several strategies for reducing CO_2 emissions have been evaluated and identified, including immediate reduction measures, assigning responsibility and implementing monitoring, collaboration with specialists, raising awareness and promoting communication, and fostering innovation and incentives.

1 Introduction

Greenhouse gases (GHGs), such as sulfur dioxide (SO_2), nitrous oxide (N_2O), methane (CH_4), and carbon dioxide (CO_2), play a crucial role in our ecosystem, and it is vital to understand their impact on the environment [1]. Without these GHGs, the Earth's temperature would become unstable, leading to catastrophic consequences for our planet's atmosphere and environment. Despite their importance, human activities such as burning fossil fuels, deforestation, power generation, cement production, and industrial processes have led to a continuing increase in GHGs, especially CO_2. These activities are a primary factor in the rapid changes in Earth's climate and weather systems, resulting in the increasing average atmospheric temperature, commonly referred to as global warming. The primary factor contributing to global warming is CO_2, which has adverse effects on humans and other organisms [2]. Therefore, it is crucial to restrict CO_2 emissions to reduce the effects of climate change and its associated impacts.

The carbon footprint (CF) is the total amount of GHGs that an individual, organization, event, or product emits into the atmosphere, directly or indirectly. These emissions are expressed in equivalent tons of CO_2, taking into account the global warming potential (GWP) of each gas [3]. CF is a valuable metric for quantifying the impact of people, businesses, goods, and services on climate change. By measuring a company's CF, it can better understand its primary sources of emissions and find ways to minimize them. This can lead to more informed decisions, increased stakeholder participation, and a more substantial contribution to combating climate change [4].

The Sustainable Development Goals (SDGs) are comprehensive global development objectives consisting of 17 goals and 169 targets. On September 25, 2015, all 193 United Nations member countries unanimously adopted these goals [5-7]. These goals address global challenges, including poverty, inequality, climate change, environmental degradation, and the pursuit of peace and justice. This roadmap provides a framework for governments and organizations to work together towards a more sustainable and equitable future for everyone and the planet. In the context of academic organizations, the term "green campus" refers to the concept of sustainability on campus [8-11].

Over the past three decades, Business Intelligence (BI) has gained significant traction as organizations have realized the value of analyzing data for informed decision-making [12-14]. By leveraging BI tools, businesses can extract, interpret, and transform large volumes of data into meaningful insights, providing a competitive edge in today's fast-paced and data-driven business environment. This enables them to adopt energy-efficient practices, utilize sustainable materials, and promote low-carbon technologies [15]. As such, BI has become an essential component of any modern business strategy, enabling organizations to identify trends, patterns, and opportunities that would otherwise go unnoticed.

With the motivation above, we analyzed CO_2 emissions from the operations and activities of an academic organization for the period of 2023-2024. We primarily focused on the CO_2 emissions associated

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with the Faculty of Science, Energy, and Environment's operations at King Mongkut's University of Technology North Bangkok in Rayong Campus. We used BI techniques and developed a data dashboard to assess the factors responsible for CO_2 emissions. Based on our analysis, we have identified several strategies that could help reduce CO_2 emissions. Furthermore, our work aligns with SDG Goal 13, focusing on environmental sustainability, and we are actively implementing timely measures to mitigate the impacts of climate change and address its repercussions. In addition, the significant contributions and highlights of this paper are summarized in the following key points:

- We assess CO_2 emissions at academic organizations such as diesel fuel, R410a, electricity, A4 paper, and garbage.
- We apply a BI strategy to analyze problems and recommend solutions for reducing CO_2 emissions.
- We present our results using dashboards and diagrams.

2 Management

This section presents the process of taking action to achieve organizational goals [16].

2.1 Planning:

Planning entails establishing the scope of the business, setting goals and objectives, and determining the steps to achieve those goals. Based on the scope, the work's goals and procedures are evident. Having previously stated, the executives continued. The next task is to put together an organization.

2.2 Organization:

Management of organizations encompasses staffing, departmentalization, resource allocation, and management, enabling the company to implement its strategy and achieve its predetermined goals.

2.3 Commanding:

Giving commands is the act of issuing instructions in various contexts, particularly between superiors and subordinates.

2.4 Coordinating:

Coordinating involves reaching out to us with questions or requesting assistance to ensure the organization's operations are completed efficiently. The objective was achieved in relation to the group's goals.

2.5 Controlling:

Control refers to the organization's ability to maintain activities. Different organizational processes are guided by the norms, expectations, or strategies that have been established.

3 Business Intelligence

Business intelligence (BI) refers to the technologies, strategies, techniques, and practices that organizations employ to analyze information. The purpose of BI is to assist organizations in making more informed, data-driven decisions. BI tools help organizations understand complicated data through reports, dashboards, and data visualizations, uncovering trends and insights to drive strategic decisions [17].

3.1 Framework for business intelligence

3.1.1 Data warehouse:

The data warehouse is a centralized repository that accumulates data from both internal and external sources, holding large amounts of data in a format suitable for professional use. It plays a vital role in BI and analytics, providing firms with the necessary data to make decisions and gain a competitive advantage.

3.1.2 Business analytics:

Business analytics is the use of data, statistical analysis, and quantitative methods to gain insights and inform business decisions. It involves examining, analyzing, and interpreting data to identify trends and patterns that can be used to optimize business processes and improve outcomes. The purpose of business analytics is to enable organizations to make data-driven decisions that promote growth, enhance efficiency, and improve overall business performance.

3.1.3 Business process management:

Business process management is critical for every organization's governance and operational performance analysis. However, most firms have separate work processes, resulting in numerous applications, which makes it challenging to combine the systems efficiently. To address this challenge, the concept of gathering and improving procedures emerged. The idea is to arrange corporate processes so that they can be integrated and function together efficiently. This will help increase the efficiency and reuse of numerous systems, allowing enterprises to employ the services they require simultaneously. Each corporation uses business process management to govern and analyze operating results, linking and completing business tasks. Several efficient systems can be utilized and reused. The objective is to organize the company's operations so that services can be shared, enabling each organization to use the services it needs simultaneously.

3.1.4 User interface:

The user interface is a critical component within a system, serving as the primary means of interaction between the user and the system. It is responsible for facilitating communication, interpreting user input, and presenting output in a clear and concise manner. An effective user interface is crucial for ensuring an optimal user experience and satisfaction, and can directly impact the overall success of a system. Designing and implementing user interfaces that meet users' needs and provide a seamless and intuitive experience is crucial.

3.2 Business intelligence processes

Rick Sherman is considered an authority in BI and plays a significant role in advancing knowledge and practices within the industry. He has presented a definition of the BI process. This process, central to data analysis and decision-making, is crucial for organizations seeking to derive meaningful insights from their data. By providing a clear and concise definition of the BI process, he has contributed to advancing knowledge in this critical field. His insights will prove valuable to researchers, practitioners, and business leaders [18].

3.2.1 Data source:

The initial step in the BI process is identifying and defining the data sources. These sources are subsequently categorized into two types: internal and external, before being integrated into the data warehouse or data mart. This process lays the foundation for the subsequent stages of BI and is crucial for the accurate analysis of data and the generation of valuable insights.

3.2.2 Dimensional data model:

Data warehousing utilizes a specialized type of data model known as the dimensional data model. The dimensional model utilizes two primary types of tables to optimize the organization and structure of data for reporting and querying purposes.

- Dimension tables are essential to data analysis as they furnish crucial descriptive attributes about the items under scrutiny. The primary key in each dimension table is a unique identifier, while other columns provide supplementary information about the object.
- Fact tables comprise numerical data and foreign keys that establish a linkage to the dimension tables. The composite key that serves as the primary key is generally composed of foreign keys that interconnect to the dimension tables.

3.2.3 Data warehouse/Data marts:

To successfully import data into data warehouses or data markets, which are subsets of data warehouses, you must properly format the data according to the requirements of the data transformation process. The data formatting will ensure that the data is processed efficiently and that the insights generated are accurate and reliable.

- Extract is the process of choosing needed data from multiple sources and transforming it.
- Transform is selecting and filtering information. Raw data cannot be utilized to make well-informed decisions. Therefore, it must be modified to ensure it meets the required quality and standards before being used in subsequent data-filling and decision-making processes.
- Load is the process of storing transformed data in a data warehouse. This process is critical in ensuring efficient data management and seamless utilization when making informed business decisions.

3.2.4 Data creation in a cube pattern:

The data structure is multilayered, and dimensions facilitate data analysis. The various retrieval techniques are accessible, and the slice-and-dice approach yields significant savings in query time.

3.2.5 Report:

Dashboards and reports are essential to BI, providing executives with an overall picture of an organization. However, if they require more detailed information, they need supporting reports that can take the form of previously prepared reports. In situations where executives need immediate responses, ad-hoc reports come in handy. These reports provide management with the necessary information to make informed decisions.

4 Carbon Footprint

Compiling a comprehensive list of greenhouse gas emissions is necessary to determine an organization's CF. This process requires executing five crucial steps [19].

4.1 Organization boundary:

Establishing clear organizational boundaries is imperative to ensure effective management. Furthermore, keeping a record of greenhouse gas emissions and absorption within a designated timeframe is recommended. This practice not only helps monitor environmental impact but also enables informed decision-making.

4.2 Operational boundaries:

An organization's operational scope is quantified based on the volume of greenhouse gas emissions generated by every activity conducted within its premises, with activities categorized into three distinct classifications.

- Scope 1 is an organization's direct greenhouse gas emissions and absorption. These include emissions from internal operations, such as stationary and mobile combustion, as well as leaks.

- Scope 2 is indirect emissions and absorption of GHGs from energy consumption, such as the amount of GHGs produced during the generation of heat, steam, or electricity from sources outside the organization and then used internally.
- Scope 3 is indirect emissions from sources not owned or directly controlled by the entity, arising from activities other than those mentioned in categories 1 and 2, such as employee commuting, garbage amount, and A4 paper use.

4.3 Identifying sources of greenhouse gas emissions and evaluating the organization's CF:

In calculating an organization's CF, it is crucial to consider the resources available for gathering greenhouse gas emissions data and selecting the appropriate computational approach to determine the greenhouse gas emission factor, as in (1). It is essential to ensure that the following GHGs are included in the CF calculation: CO_2, hydrofluorocarbons gas group (HFCs), CH_4, SO_2, N_2O, and perfluorocarbon gas group (PFCs), as they have the potential to cause global warming. To determine the global warming potential of these GHGs over 100 years, refer to Table 1. [20].

$$GHG = \text{Activity data} \times EF, \qquad (1)$$

where *GHG* is the amount of greenhouse gases, activity data is information about activities that cause GHGs, and EF is the greenhouse gas emissions factor.

Table 1. The potential value of causing global warming.

greenhouse gases	Potential to cause global warming (times of carbon dioxide)
Carbon Dioxide (CO_2)	1
Methane (CH_4)	25
Nitrous Oxide (N_2O)	298
Hydrofluorocarbons (HFCs)	7462
Perfluorocarbons (PFCs)	9795
Sulfur Hexafluoride (SF_6)	22,800

4.4 Computation:

The process of preparing a greenhouse gas inventory involves collecting data from all three activity types to compute the quantity of GHGs produced accurately. Once the data has been gathered, the resulting figures are then summarized for further analysis and evaluation.

4.5 Identifying and tackling uncertainty:

This step is significant in ensuring the accuracy of the data collected on greenhouse gas emissions and absorption. It addresses the uncertainties that may arise from utilizing different greenhouse gas emission factors from various reference sources in the calculations. Thus, the organization responsible for the assessment must incorporate the findings of the uncertainty assessment into its review process. Tables 2 and 3 serve as an excellent illustration of this.

5 Business Intelligence for Management of Organization's CO_2 Emission

The Plan-Do-Check-Act (PDCA) management methodology is widely used in businesses to monitor and enhance their processes and products [21]. We have taken this approach one step further by incorporating BI into PDCA methodology, which we refer to as BI-PDCA, as illustrated in Figure 1.

5.1 Business intelligence planning:

A SWOT analysis is an essential strategic planning tool for identifying and evaluating an organization's Strengths, Weaknesses, Opportunities, and Threats. This tool can help organizations manage their CF more effectively by leveraging BI to create a comprehensive plan. Key performance indicators (KPIs) are established to measure success, and database models are developed for BI systems. These approaches can help organizations optimize their CF management efforts and achieve their goals more efficiently.

5.2 Business intelligence doing:

Proceed with the BI objectives as per the established plan.

Table 2. Reference score of data quality used in studies.

Value Type	Data Quality Level			
Activity Data	X = 6 points	Y = 3 points		Z = 1 points
	Automatic Continuous	Regular Measurement		Estimation
Emission Factor	C = 4 points	D = 3 points	E = 2 points	F = 1 point
	Quality Measurement	Manufacturer /National	Regional	International

Table 3. Level of uncertrainty and data quality.

Rating	Scoring	Description
1	1-6	High uncertainty & Poor quality
2	7-12	Little uncertainty & Moderate quality
3	13-18	Slightly uncertainty & Good quality
4	19-24	Low uncertainty & Excellent quality

Table 4. Level of uncertrainty and data quality.

Scope	Emission Sources	Data		Greenhouse gas emissions		
		Source	Amount	Factor	Tons CO_2eq	Factor Sources
1	Diessel fuel	Receipts	6672.809 L	2.7078	18.93	IPCC Vol.2 Table 3.3.1, DEDE
1	R140a	Receipts	27.27 kg	1923.5	52.45	IPCC: GWP (AR5)
2	Electricity	Receipts	795,386.6 KWh	0.4999	397.61	Thai National LCI Database, TIISMTEC-NSTDA, AR5 (with TGO electricity 2016-2018)
3	A4 Paper	Record	2696.1 Kg	0.6677	1.80	Thai National LCI Database, TIIS-MTEC-NSTDA
3	Garbage	Record	12,799.8 Kg	0.7933	10.15	Thai National LCI Database, TIISMTEC-NSTDA, AR5 (with TGO electricity 2016-2018)
3	Scrap paper	Record	1196.7 Kg	2.93	3.51	2006 IPCC Volume 5: Waste
3	Clear glass bottle	Record	209.7 Kg	0.8075	0.17	Thai National LCI Database, TIIS-MTEC-NSTDA
3	Aluminum can	Record	30.4 Kg	1.4682	0.05	Ecoinvent 2.2, IPCC 2007 GWP 100a
3	Plastic water bottle	Record	506.1 Kg	0.5751	0.29	Ecoinvent 2.2, IPCC 2007 GWP 100a

5.3 Business intelligence checking:

KPIs are employed to evaluate the success of a plan and assess whether it has met expectations. As the assessment process unfolds, it is essential to acknowledge that both successful and unsuccessful outcomes are possible. As an assessor, it is crucial to acknowledge this possibility. In the event of a successful plan, we must determine the contributing factors that led to its triumph rather than attributing it solely to chance. Conversely, if the plan did not unfold as intended, it is essential to ascertain the underlying reasons for its failure.

5.4 Business intelligence acting:

Upon completion of the examination, the team has identified areas for improvement that require incorporation into the relevant procedures. The team will conduct an in-depth analysis to identify the factors that impede the success of the original plan and devise appropriate mitigation strategies. Following the completion of the revised operational plan, the team will resume the cycle of continuously performing BI-PDCA to ensure sustained improvements.

Table 5. Assessing data uncertainty.

Emission Sources	Score		Evaluation Results	Quality Level
	Collect	EF		
Diesel fuel	3	2	9	2
R140a	3	2	9	2
Electricity	3	3	9	2
A4 Paper	3	3	9	2
Garbage	3	3	9	2
Scrap paper	3	3	9	2
Clear glass bottle	3	3	9	2
Aluminum can	3	3	9	2
Plastic water bottle	3	3	9	2

6 Case Study of Faculty of Science, Energy and Environment in King Mongkut's University of Technology North Bangkok in Rayong Campus

This research was conducted at the Faculty of Science, Energy, and Environment of King Mongkut's University of Technology North Bangkok in Rayong Campus. The CF will be calculated by considering all the activities of our academic organization that generate CO_2 emissions. We have all the necessary information, which was methodically collected from the academic organization's records and receipts.

6.1 Quantity of the organization's CF

The data emission source is obtained from receipts and documented in the office. The emission factor is obtained from regional and national sources, as shown in Tables 4 and 5.

The bar plot illustrates the CF from source emissions over 2 years (2023-2024), as shown in Figure 2. Electricity, R410a, diesel fuel, and garbage are the top 4 source emissions, as shown in Figure 3. Electricity has the highest emissions, at 397.61 tons CO_2 eq, accounting for 81.99% of the total. September shows the highest emissions, peaking at 40.02 tons CO_2 eq. Emissions appear relatively stable and consistent from April through December, ranging from 27.74 to 31.81 tons CO_2 eq, with minor fluctuations. R410a was only recorded in November, at 52.45 tons CO_2 eq, which is 10.82% of the total. Diesel fuel emissions are at 18.93 tons CO_2 eq, which is 3.90% of the total. May shows the highest emissions, peaking at 2.52 tons CO_2 eq. This peak is significantly higher than in other months. Garbage emissions are at 10.154 tons CO_2 eq, 2.09%. February shows the highest emissions, peaking at 1.04 tons CO_2 eq. The lowest value is observed in March, at a notably lower emission level of 0.43 tons CO_2 eq, which is an extreme outlier compared to the rest of the data. Garbage, scrap paper, clear glass bottles, aluminum cans, and plastic water bottles have a positive correlation, as shown in Figure 4.

6.2 Discussion

In 2023-2024, an assessment was conducted to determine the CF of the Faculty of Science, Energy, and Environment at King Mongkut's University of Technology North Bangkok in Rayong Campus. According to the assessment, the total amount of greenhouse gas emissions generated by the academic organization's operations was 484.96 tons CO_2 eq, equivalent to 1.28 tons CO_2 eq per person.

The assessment found that the academic organization's energy use was the second scope of its operating activity, contributing to greenhouse gas emissions. Specifically, the academic organization's electricity use for teaching and learning activities, including air conditioning, lighting, and lift usage, contributed significantly to these emissions. Additionally, almost all students and teachers require high electrical power to use experimental equipment.

Further, the assessment revealed that the academic organizations used diesel fuel for various activities, including meetings, training, cooperation, educational guidance, student affairs, and more. The educational guidance activities were frequent in May, while garbage production was low in March due to fewer people in the office and fewer purchases. The causes of greenhouse gas emissions are summarized in Figure 5.

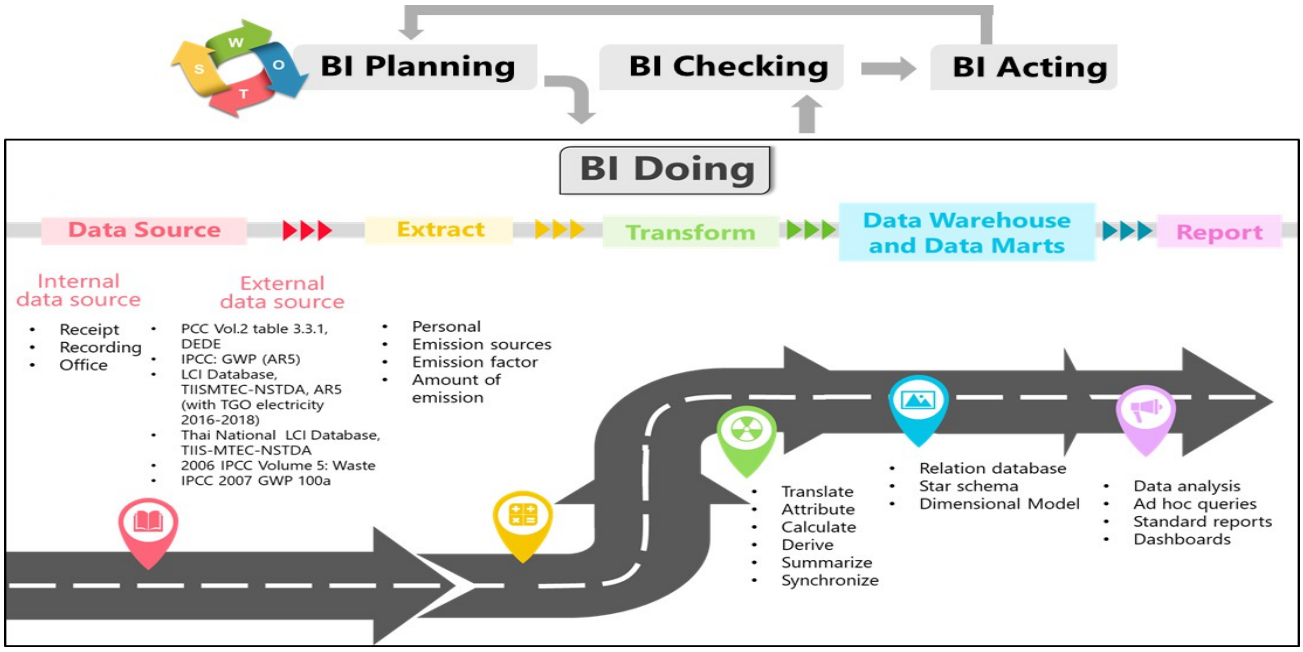

Fig. 1. Business intelligence system diagram.

6.3 Guidelines for reducing greenhouse gas emissions

The SWOT analysis provides the following recommendations for reducing greenhouse gas emissions:

6.3.1 Promptly implement measures to curtail greenhouse gas emissions in all aspects of operations, including cutting back on electricity consumption. It is of utmost importance to expeditiously implement measures aimed at curtailing greenhouse gas emissions
in all facets of operations, including reducing electricity consumption. These can be achieved by promoting energy conservation, substituting electric bulbs with LED bulbs, minimizing solar exposure in office buildings, and other similar measures.

6.3.2 Designating a person to evaluate the organization's CF is advisable as part of a complete management strategy to decrease greenhouse gas emissions. Establishing clear and precise metrics for reducing greenhouse gas emissions is essential, enabling continual monitoring and evaluation of operations.

6.3.3 Employees are recommended to establish a collaborative partnership with organizations that specialize in CF assessment. This will equip your employees with the necessary knowledge and skills to evaluate the company's CF.

6.3.4 Inform staff members and service recipients regularly about policies aimed at cutting greenhouse gas emissions. To encourage participation in and awareness of the need to reduce greenhouse gas emissions.

6.3.5 Employees should cultivate a culture of innovation and excellence by encouraging employees to develop energy-saving and management technologies.

One practical approach is to organize an inventiocompetitionon, which provides a platform for employees tshowcasese their talent and creativity. Rewarding outstanding performers can further incentivize them to strive for excellence and contribute to the organization'energy-saving endeavors.

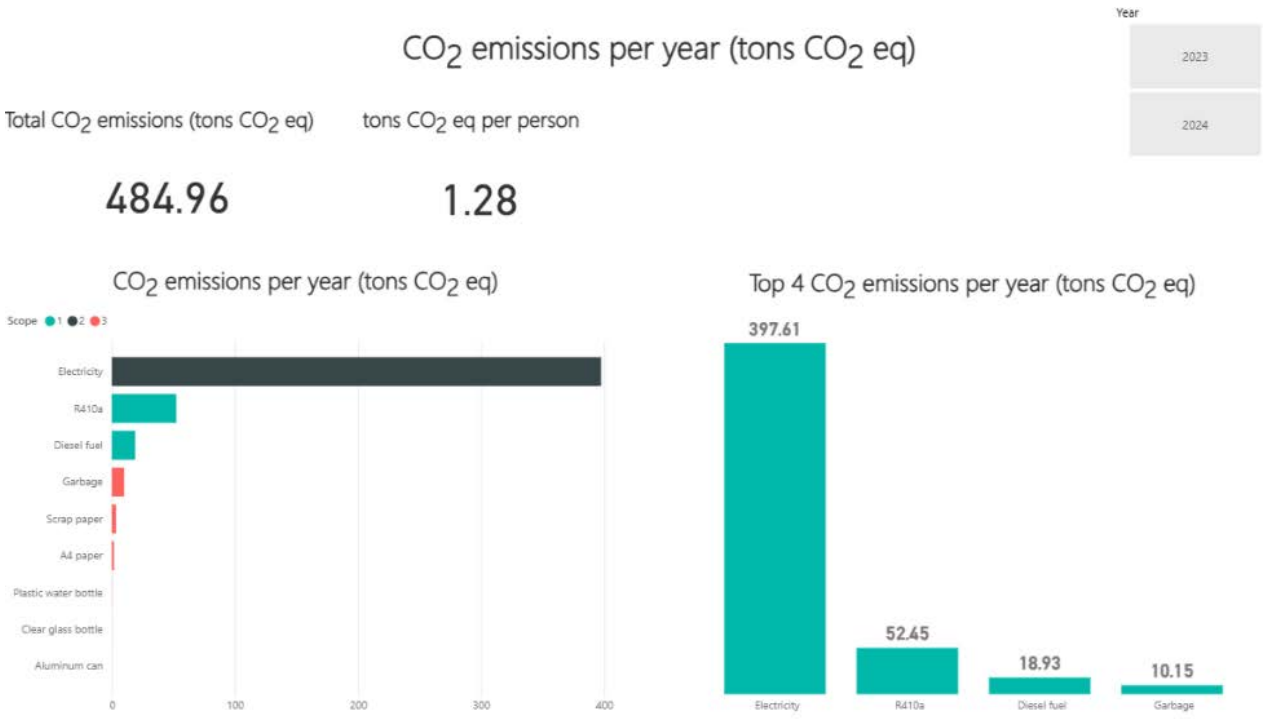

Fig. 2. CO_2 emissions per year (tons CO_2 eq).

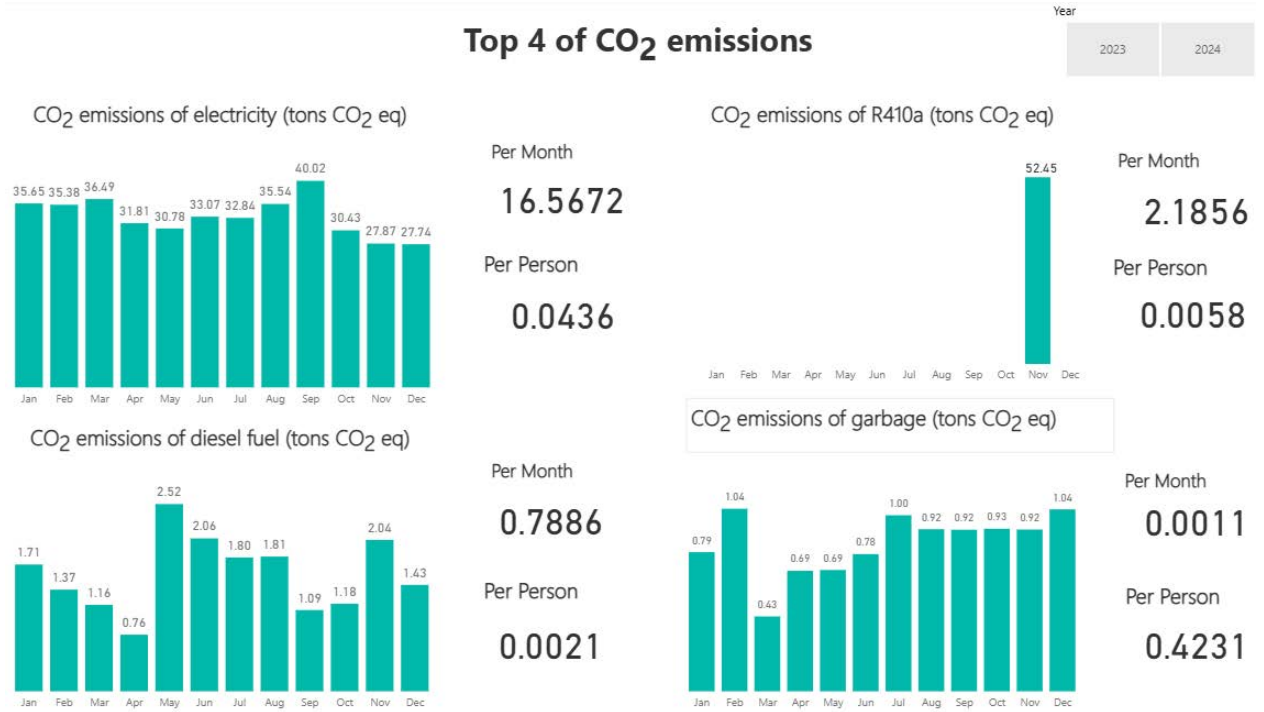

Fig. 3. Top 4 of CO_2 emissions.

7 Conclusion

Greenhouse gases, mainly carbon dioxide, are the principal causes of climate change. Climate change presents serious environmental risks. This study assessed the CF from an academic institution and offered methods for monitoring and decreasing CO_2 emissions by combining BI and management techniques. The Faculty of Science, Energy, and the Environment at King Mongkut's University of Technology North Bangkok (Rayong Campus) calculated a total carbon emissions value of 484.96 tons of CO_2 eq, or 1.28 tons CO_2 eq per person, for the 2023-2024 year. Carbon emissions were accounted in four major accounting categories, being electricity (81.99%), R410a refrigerant (10.82%), diesel (3.90%), and garbage (2.09%). Scope 2 emissions made up 397.62 tons of CO_2 eq. In this study, the main source is electricity. It was used for teaching in classrooms, air conditioning, lighting, and powering equipment in the laboratories. The greatest emissions occurred in months with high academic and laboratory activity. There is a primary necessity in the academic institution sector to control their CF in order to maintain compliance with regulations, meet stakeholder requirements, and remain socially responsible in the cataclysm of climate change. This study brought BI together with the PDCA cycle as a basis to monitor mitigation options to enhance informed decision-making and enable continuous improvement. The POCCC management framework was also utilized to demonstrate that BI-driven strategies can align with assessing management function to improve systems within the study organization. The use of this framework provides a concrete way to take action, communicate consistently, coordinate workflows and resources effectively, and provide oversight of the work plan, which will improve the reduction of emissions. By using BI tools and considering the PDCA and POCCC management function, academic institutions will be able to monitor emissions, target carbon hot spots, implement sustainable practices, and gain competitive and environmental benefits in the long run.

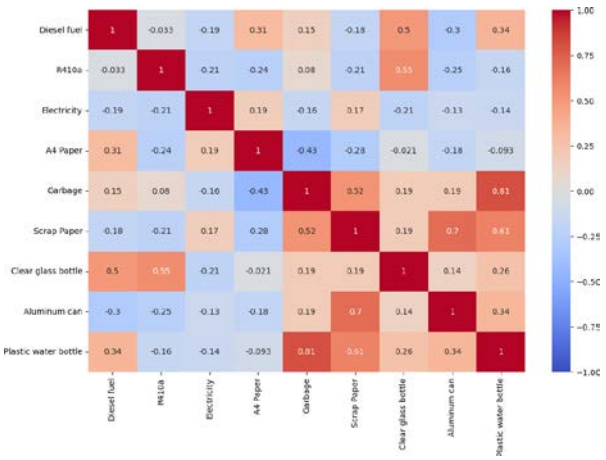

Fig. 4. Correlation matrix of emission sources.

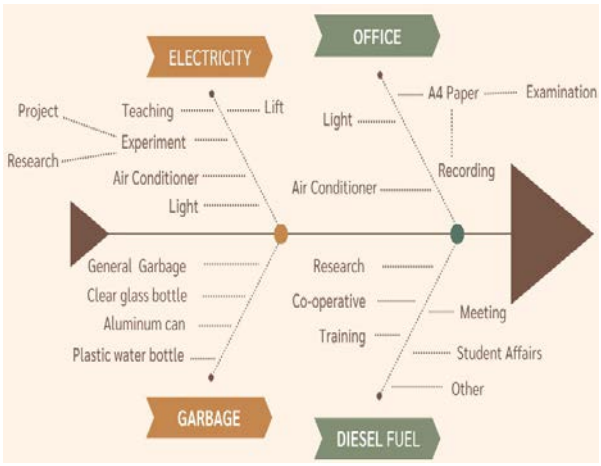

Fig. 5. The Causes of greenhouse gas emissions by fish bone diagram.

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