Open Access

Advances in Environmental and Engineering Research

Research Article

Carbon Footprint Assessment Initiative and Trees Role in Reducing Emissions

Omar Alelweet *

Civil Engineering Department, Technical and Vocational Training Corporation, Uniza Technical College, Kingdom of Saudia Arabia; E-Mail: ualalweet@tvtc.gov.sa

* **Correspondence:** Omar Alelweet; E-Mail: ualalweet@tvtc.gov.sa

Academic Editor: Islam Md Rizwanul Fattah

Special Issue: Advances in Environmental Research

Adv Environ Eng Res
2025, volume 6, issue 1
doi:10.21926/aeer.2501009

Received: October 08, 2024
Accepted: January 13, 2025
Published: January 23, 2025

Abstract

Given the present emphasis on climate change and CO_2 emissions, it is crucial to have specific guidelines to determine and mitigate carbon footprints. The following paper seeks to estimate the carbon emissions in kg of carbon dioxide equivalent from activities at Uniza Technical College and the tree's ability to absorb carbon dioxide through photosynthesis. The primary objective of this study is to determine how the emissions from campus trees can contribute to reducing overall carbon emissions. The methodologies employed at the college include evaluating facilities, analyzing energy consumption and emissions, utilizing CO_2 meters for transportation assessments, monitoring air quality, and tracking goods and services to measure emissions effectively. We also calculated the number of trees on campus that could be used for carbon sequestration to determine the trees' environmental effects. The results of the data analysis showed that the levels of CO_2 inside the college buildings were within the safe range of 700 ppm in most cases. Our research also showed that energy consumption and the use of plastic bottles were significant sources of carbon emissions. We calculated the total carbon footprint to be 521 tCO_2-eq, which is relatively low compared to other universities worldwide. This study demonstrates that decisive intervention is needed, including installing real-time monitoring and energy conservation sensors. These include ensuring that lights and air conditioning are switched off when not in use and reducing plastic bottle use. More trees should be planted on the campus in the future to achieve the goal of carbon neutrality. This research ultimately demonstrates the integration of environmental awareness and sustainability into educational institutions to tackle the challenges posed by climate change.

Keywords

Carbon emissions; CO_2 monitoring; tree contribution; campus sustainability; emission reduction strategies

1. Introduction

The term carbon footprint defined in this study is the total GHG emissions associated with a product or service in its entire life cycle expressed in tons of CO_2e. Wiedmann and Minx [1] stress that such carbon footprints are crucial for assessing environmental impact and applicable in areas including education and construction. The Intergovernmental Panel on Climate Change [2] states that there are eighteen types of GHGs, which have different potentials to contribute to global warming. This underlines the need to build efficient carbon accounting systems to manage emissions on institutional and worldwide levels. In the context of carbon accounting during the Kyoto Protocol and the United Nations Framework Convention on Climate Change [3], other regulations control other substances. However, the commonly used gases include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), as well as sulfur hexafluoride (SF_6) are the only ones [4].

Since human respiration is the primary carbon dioxide (CO_2) source in indoor air, ventilation and occupant density are critical in determining indoor CO_2 concentrations. Indoor environments with insufficient ventilation can accumulate CO_2 to levels several times greater than background values, which could pose health risks [5]. Lu et al. [6] state that inadequate ventilation often results in elevated CO_2 levels, negatively impacting human health and performance. To reduce heat loss and improve energy efficiency, ventilation rates are being reduced due to rising energy costs and growing concerns about the environmental effects of buildings [5]. However, due to this practice, indoor air pollutants like CO_2 are building up to far greater levels than they were under earlier norms. CO_2 levels may be used as proxies to estimate ventilation rates and the presence of human bio-effluents inside due to the relationship between CO_2 concentration, human occupancy, and ventilation rates [6, 7]. Currently, CO_2 is used as a marker to evaluate ventilation since high CO_2 levels indicate inadequate ventilation, which is often associated with worse air quality [8]. As Valls et al. [9] noted, integrating effective ventilation strategies with ecological interventions can mitigate these impacts.

Uniza Technical College was chosen as the study site because it has many different types of buildings, different occupancy patterns, and plants, like trees, that help store carbon. These factors make the campus an ideal model for exploring the relationship between human activities, built environments, and natural carbon mitigation strategies. Additionally, examining these elements offers valuable insights into reducing carbon emissions and promoting sustainability practices in educational institutions.

We often use CO_2 levels as an indicator to assess ventilation rates, as high concentrations indicate poor air quality and insufficient ventilation. Nkwocha and Egejuru [10] associated such high levels with respiratory problems and fatigue. These findings emphasize the importance of managing air quality, especially in educational settings.

According to Leite [11], CO_2 concentrations as high as 4,000 ppm can hurt pupils' ability to focus. Nkwocha & Egejuru [10] did a different analysis, and their findings showed that frequent colds, coughs, phlegm, sinusitis, and bronchitis symptoms linked to elevated CO_2 concentrations are widespread among students. Lethargy, poor coordination, headaches, asthma, and respiratory infections are other symptoms related to insufficient ventilation and high CO_2 levels, according to the Environmental Protection Agency (EPA) [12]. As a result, adequate ventilation and air quality are essential for student's health and academic success [13]. These factors emphasize how crucial it is to use CO_2 as the main indicator for evaluating ventilation and air quality in inhabited rooms.

Despite heightened awareness of carbon emissions, only a few research studies have successfully incorporated carbon footprint evaluations with ecological initiatives like tree planting. In their paper published in 2012, Strohbach et al. [14] stressed that urban green spaces can play a significant role in reducing cities' carbon footprint through biomass sequestration and influencing the energy balance of urban areas, thus helping combat climate change. This study aims to evaluate the effect of tree planting on campus on emissions to fill this gap and provide recommendations for implementing the study.

People increasingly recognize academic institutions as crucial contributors to sustainable development. The United Nations emphasizes the role of universities in achieving the Sustainable Development Goals (SDGs), particularly Goal 4 (Quality Education) and Goal 13 (Climate Action) [15]. This study aligns with these global frameworks by integrating carbon monitoring with green initiatives to enhance air quality, serving as a sustainable model for other institutions.

This research is considered innovative as it establishes a framework for measuring emissions, evaluating the potential for natural mitigation, and aligning with global climate action objectives The findings of Uniza-based Technical College contribute to the existing discourse on sustainability by identifying effective measures that can be taken to achieve carbon neutrality for schools.

The primary aim is to conduct an exhaustive assessment and evaluation of CO_2 concentrations in several sites around the campus. By doing this, we want to accomplish the following objectives:

1. Quantify CO_2 emissions: To determine the Uniza Technical College's total carbon footprint, measure and record the CO_2 concentrations in various buildings, labs, classrooms, and public areas.

2. Identify emission sources: Identify specific areas or activities within the Uniza Technical College that contribute significantly to CO_2 emissions, such as energy consumption, transportation, and goods and services.

3. Evaluation of the College's Trees' Contribution to Carbon Emission Reduction: accurately assessing every tree on campus's role in lowering carbon dioxide emissions and promoting environmental protection. Consequently, a strategic plan for planting more trees.

2. Methodology

To accomplish these objectives, we propose the following methodology:

2.1 Measurement

During the first semester of 2023, carbon dioxide levels were measured during the training session for four academic weeks, beginning with the first lecture and ending with the eighth lecture. These measurements were taken using the CO_2 Meter Air Quality Monitor Handheld B01966BZDY device across all college facilities, including workshops, classrooms, labs, administrative offices, and trainers' rooms.

We calibrated the CO_2 meters weekly using a standardized CO_2 reference gas to ensure data accuracy. We also conducted cross-validation with independent air quality monitoring devices. We collected data at varying times of the day to capture fluctuations due to occupancy changes, ensuring the representation of peak and non-peak periods.

2.2 Carbon Dioxide Emissions

A. Energy Consumption, B. Transportation, and C. Goods and services related to the training process. Data was connected to the three previously described activities to identify sources of emissions, and patterns and trends indicating increased carbon dioxide levels were observed. The results were then compared with carbon dioxide concentrations at other colleges and academic institutions around the world that use the same methodology.

2.2.1 Energy Consumption

The campus facilities management team tracked electricity consumption monthly from January to December 2022. We analyzed energy usage across different quarters to account for seasonal variations, such as increased cooling demands during the summer. We collected data on electricity consumption from smart meters installed at key distribution points. We recorded the total electricity consumption for the year 2022 at 381.382 MWh. We calculated the emissions using the Saudi Arabian Grid Emission Factor of 0.654 tCO_2/MWh, which we derived from the research by Lari et al. [16].

The following equation (1) was utilized to calculate carbon emissions resulting from energy use:

$$\mathrm{E} = \text{Electricity Consumption (MWh)} \times \text{Grid Emission Factor } (\mathrm{tCO_2/MWh}) \qquad (1)$$

2.2.2 Transportation

We calculated the carbon emissions from transportation using the following equation (2):

$$\mathrm{T} = (\text{Average Fuel Consumption per 100 km} \times \mathrm{CO_2} \text{ Emission per Liter } *) \times \text{Travel Distance (km)}/1000 \qquad (2)$$

*Emission per Liter (Table 1).

Table 1 Carbon Emission Factors Based on Fuel Type Used.

Car Full type	Emission Factors (EF)	Unit	References
Car Diesel Emission	2.7	$kgCO_2$/l	[17, 18]
Car Petrol Emission	2.31	$kgCO_2$/l	

Car Hybrid Emission	0.297	$kgCO_2/l$	[19]

We conducted daily surveys during the first semester of 2023 to gather data on the types of fuel used, travel distances, and vehicle types employed by staff and students. Approximately 95% of the vehicles operated on gasoline, resulting in higher emissions than diesel vehicles. We did not make seasonal adjustments because daily commuting patterns remained consistent throughout the year.

2.2.3 Goods and Services

Based on the following equation (3), it was calculated:

$$G = \text{Quantity of Goods Used} \times \text{Carbon Emission Factor (EF)} \tag{3}$$

Recent research has established emission factors for frequently used commodities such as printing paper, plastic water bottles, and detergents. Bałdowska-Witos et al. [20] evaluated the life cycle of plastic bottle manufacture, emphasizing its considerable environmental effect. Corbett et al. [21] examined the environmental impact of single-use plastics, highlighting their significant role in emissions. This research indicates that plastic water bottles constituted around 99% of emissions associated with these products, highlighting a substantial opportunity for action.

Where the following table's carbon emission factor is found in Table 2:

Table 2 Carbon Emission Factors for College-used Goods and Services.

Items	Emission Factors (EF)	Unit	References
Printing Paper Emission	1.22441	$kgCO_2$-eq/t	[22]
Tissue Products Emission	0.751	$kgCO_2$-eq/t	[22]
Plastic Bottled Water	0.1-0.5	$kgCO_2$-eq/t	[23]
Traditional Waste Bags	0.5	$kgCO_2/t$	[24, 25]
Detergent and Soap	0.76	$kgCO_2$-eq/kg	[26]

2.3 Trees' Carbon Sequestration Potential

Trees use their roots to absorb water and minerals, which they then transfer to their leaves during photosynthesis. Leaves also absorb light and carbon dioxide. After that, leaves use solar energy and chlorophyll to transform carbon dioxide and water into glucose.

We categorized the growth stages into saplings, semi-mature, and mature trees. Local climatic conditions, characteristic of a semi-arid environment, were considered to adjust the carbon sequestration rates. These calculations followed the guidelines set by Nowak et al. [27-30]. Following the release of oxygen, the tree uses the glucose to fuel itself:

1. Calculate the tree's overall (green) weight.
2. The tree's dry weight was calculated.
3. The weight of carbon that is contained in the tree.
4. Calculating the mass of carbon dioxide stored within the tree.
5. Every year, the weight of carbon dioxide stored in the tree is determined.

3. Results and Discussions

3.1 Measuring the CO_2 Levels in the Training Facility's Workshops, Training Rooms, Labs, and Administrative Offices

The research indicated that academic buildings' mean carbon dioxide (CO_2) concentration was 499 parts per million (ppm), as shown in Figure 1, a safe level according to international norms. CO_2 concentrations fluctuated around the campus due to several environmental conditions.

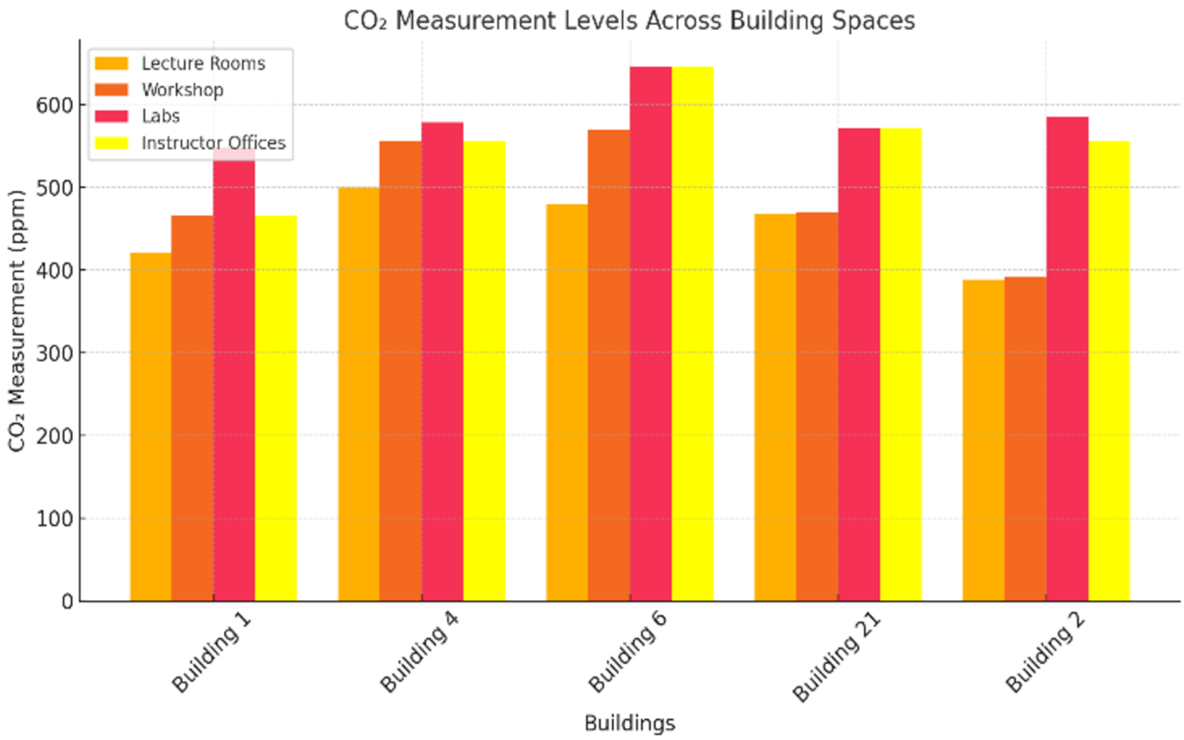

Figure 1 Shows the CO_2 levels in training facilities, workshops, labs, and administrative offices.

1. Ventilation Rates: Effective ventilation systems reduce CO_2 concentrations, while poor ventilation causes higher levels. Proper ventilation regulates indoor CO_2 levels by diluting and eliminating contaminants [31].

2. Occupant Density: Areas of concern include high-traffic areas, such as schools during peak times, where high levels of CO_2 are emitted from human breathing. This information can be used to monitor occupancy and assess ventilation performance [32].

3. The heating, ventilation, and air conditioning (HVAC) systems: Temperature settings can significantly impact indoor CO_2 levels. Demand-controlled ventilation adjusts airflow based on real-time CO_2 concentrations, improving indoor air quality and energy efficiency [33].

These results highlight the importance of considering environmental factors such as ventilation rates, occupant density, and HVAC operations when evaluating indoor CO_2 levels. The average of 499 ppm supports safe circumstances; however, boosting ventilation in busy places could enhance indoor air quality. To fully measure indoor air quality, future research must monitor several environmental indicators in real time.

Carbon dioxide levels are categorized as safe when they are less than 700 ppm (CO_2 < 700 ppm) and dangerous when they exceed 1000 parts per million (CO_2 > 1000 ppm), according to major global environmental and sustainability organizations (Figure 2) [34-37]:

	RISK LEVEL			
	LOW	MODERATE	HIGH	VERY HIGH
CO2 peak concentration or class time average concentration	< 700 ppm	700-800 ppm	800-1000 ppm	> 1000 ppm
Recommended action	No action needed	A If A active, do B If B active, do C If C active, do D	A and B If both active, do C then D If all active, do E	A and C If both active, do D If all active, do E

A: door always open

B: windows open for 10 min at lunch break

C: windows open for 10 min at end of each teaching hour

D: change setting (e.g. windows open longer, reduce number of students per class)

E: infrastructure changes needed (e.g. inbuilt or portable filtration system)

Figure 2 Carbon Dioxide (CO_2) Levels in Indoor Air Risk Classification Diagram [38].

The training rooms of Building 6 (General Studies) had the highest measured concentration of carbon dioxide (CO_2), with an average of 646 parts per million (ppm). It is still below the typical threshold of 700 ppm despite this increment. It is observed that this location has a 0.33 student density.

However, in other buildings, the carbon dioxide emissions range was 571 to 548 ppm (23%) higher. There was a reported disparity of around 30% in the training workshops and roughly 27% in the training laboratories. With a student density of 0.80, a CO_2 level of 493 ppm was observed in the cafeteria.

As a result, the research suggests the following:

- Sensor Installation: This entails positioning very accurate carbon dioxide monitoring equipment in key areas of colleges, workshops, labs, and office buildings. Additionally, with the appropriate authorities, sensors that detect the degree of danger should be installed and set to open windows and air fans.
- Data collection: Acquiring data on the continuous concentration of carbon dioxide over a long period, recording variations at various periods of the day, week, and year. Regular data recording intervals from the devices will guarantee correctness and dependability.
- Data analysis: examining patterns and trends in the long-term data collection that indicate increases in carbon dioxide levels. Determining the origins of emissions by connecting the data to particular events, actions, or other variables.

3.2 Measure and Calculate the Technical College's Contribution in Onaizah to Carbon Dioxide Levels

3.2.1 Emissions from Energy

The Technical College in Onaizah has implemented efficient carbon emission strategies since it has a total footprint of 521 tCO_2-eq. Compared to institutions of similar size and infrastructure, Onaizah's emissions are relatively low. For example, the University of Cape Town, which has a student and staff population of 2,077, emitted 59,603 tCO_2-eq [39]. Based on the total population, Onaizah's emissions amount to only 1.82% of those at Cape Town, indicating that the college consumes less energy and operates on a smaller scale.

Nevertheless, while this comparison highlights Onaizah's strengths, understanding the complexities requires comparisons with other institutions in similar climate zones and with similar facilities. These comparisons may help identify the most effective and efficient energy management strategies and potential measures for enhancing carbon mitigation.

3.2.2 Emissions Resulting from Transportation

Cars are the primary means of transportation utilized to get to and from the campus. A total of 172 people took part in the survey, administered throughout the morning and evening hours of the first semester of the academic year 2023 to trainers, administrators, and trainees. The distribution of fuel types used for daily transportation to the institution is shown in Figure 3.

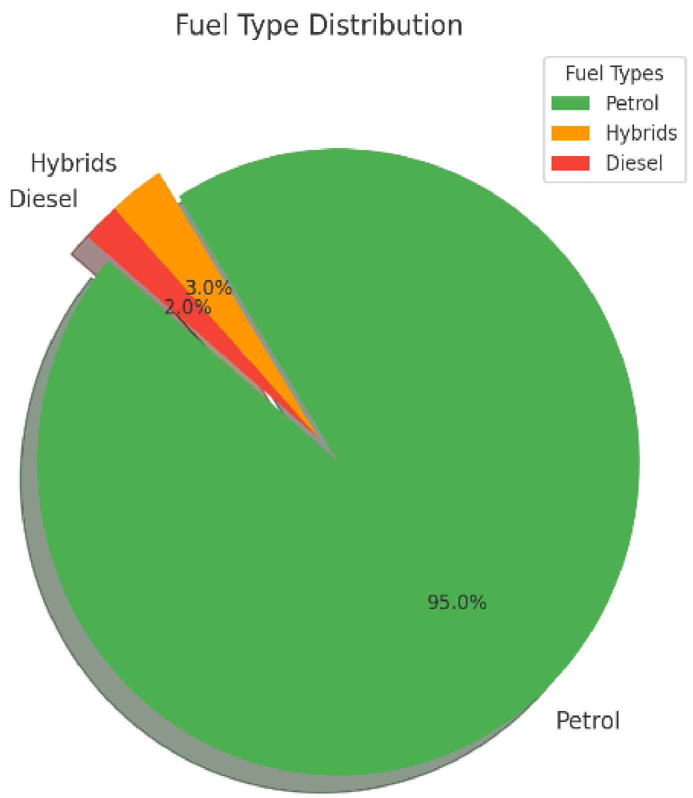

Figure 3 Daily Transportation Mode Distribution by Students and Staff.

Figure 4 illustrates the amount of carbon emissions resulting from car usage as a means of transportation. The total carbon emissions resulting from transportation were 0.79 tCO_2-eq. Since 95% of the transportation used gasoline, the carbon emissions were higher than those from diesel cars.

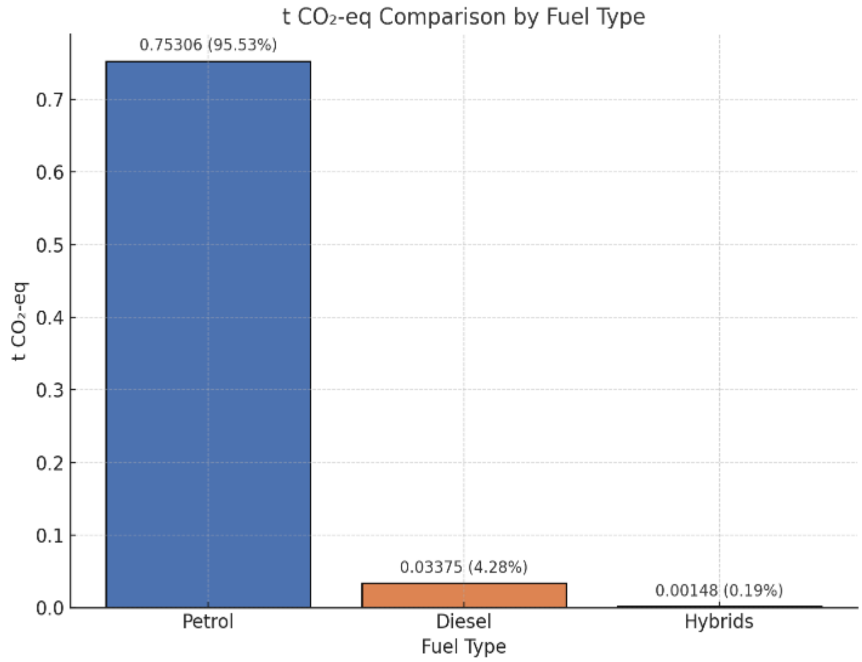

Figure 4 Carbon emissions by Students and Staff.

3.2.3 Emissions Resulting from Goods and Services

A total of 271 tCO_2-eq (Table 3), was emitted from products and services, with approximately 99% of the emissions stemming from plastic water bottles. This presents a significant concern that requires attention. As a result, the study suggests avoiding increasing their use and switching to refrigerators that use readily recyclable or recyclable cups in their place. The report also recommends utilizing recyclable trash bags.

Table 3 Carbon Emission Factors Based on Fuel Type Used.

Total Emissions	unit	Items
0.50	Tone	Paper
0.61	tCO_2-eq	Emissions from Paper
0.20	Tone	Tissue
0.15	tCO_2-eq	Emissions from Tissue
900	L	Plastic Water Bottles
270	tCO_2-eq	Emissions from Plastic Water Bottles
120	Kg	Plastic Waste Bags
0.06	tCO_2-eq	Emissions from Plastic Waste Bags
220	Kg	Soaps and Cleaners
0.17	tCO_2-eq	Emissions from Soaps and Cleaners

The analysis conducted in sections 1, 2, and 3 found that the total carbon emissions amounted to 521 tCO_2-eq, which is considered low compared to 85,000 tCO_2-eq at the University of Cape Town, where the number of students and faculty members was 2077. Additionally, the carbon emissions from the Technical College in Onaizah were compared to several other universities and academic institutions worldwide using the same methodology (Figure 5). The college in Onaizah ranked the lowest at 0.18% [27], calculated by dividing the total carbon emissions by the number of students and staff.

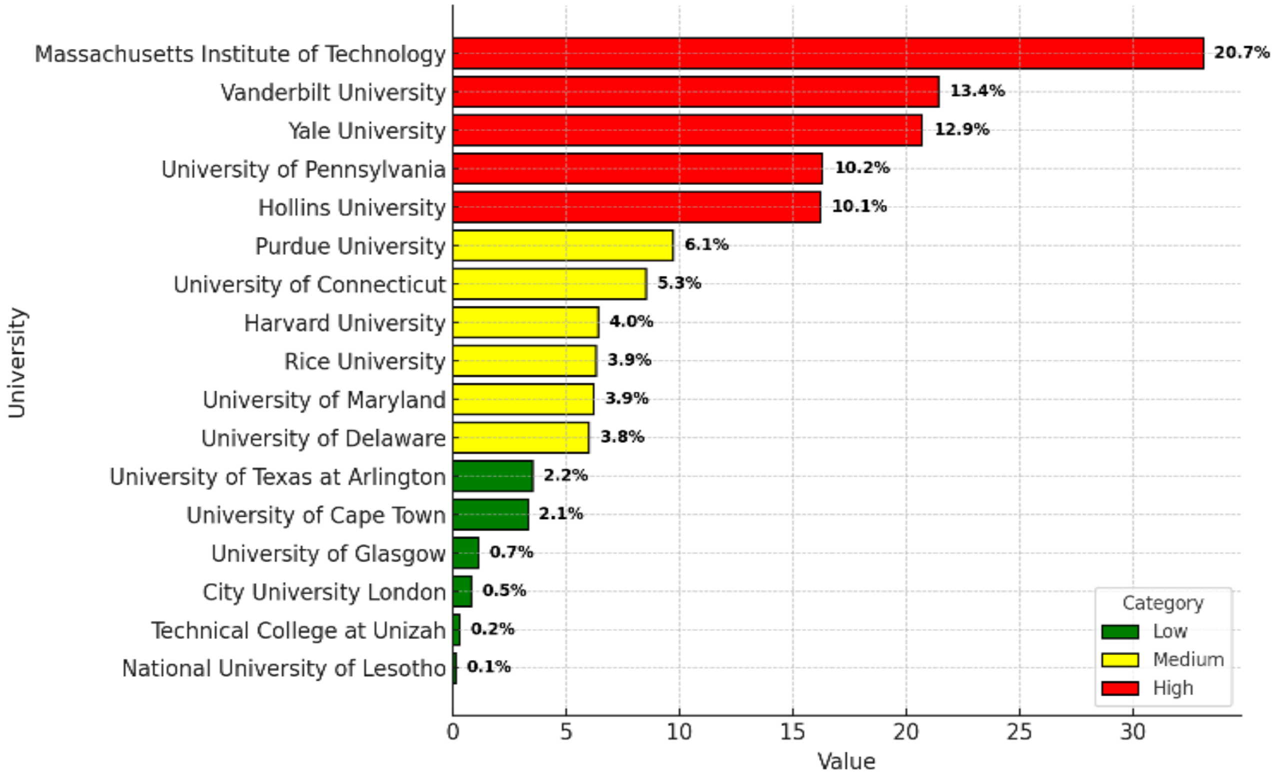

Figure 5 Carbon emissions by Students and Staff.

3.3 Contribution of Trees to Carbon Emission Reduction

Trees play a crucial role in environmental protection, preservation of natural resources, enhancing biodiversity [28], promoting biological security, improving air quality and quality of life, and purifying the air [29]. Additionally, trees contribute to soil stabilization and carbon dioxide reduction through photosynthesis [30].

Based on the calculations in section (c) regarding the contribution of the Technical College in Onaizah to carbon dioxide levels, which amounted to 521 tCO_2-eq, the contribution of trees in the college to reduce these emissions was found to be 2930 kg/year for a total of 303 trees. Therefore, based on the agreement signed between the General Organization for Technical and Vocational Training and the Ministry of Environment, Water, and Agriculture in the Qassim region, the study recommends planting 178 trees to achieve balance. The suggestion of planting 178 trees to counteract the college's carbon footprint of 521 tCO_2-eq is both audacious and viable. However, for this to be effectively achieved and implemented, other factors must be considered, such as the species of trees to be planted, the maintenance required, and whether there is enough space.

To discuss the entire process of selecting and maintaining tree species for sustainability in Onaizah, it is crucial to choose species that are suitable for Onaizah's semi-arid climate. Recommended trees include Acacia tortilis and Ziziphus spina-christi, as they are drought-resistant, require low amounts of water, and have high carbon sequestration potential. The initiative should ensure that only native tree species are used to promote biodiversity, minimize adverse environmental impacts, and ensure that management practices are tailored to local conditions.

Many factors affect tree growth, including water, diseases, pests, and pruning, particularly in the early years. These factors must be incorporated into the college's business processes to ensure that resources and personnel are appropriately allocated to guarantee the success of the initiative.

3.3.1 Considering Several Alternative Strategies for Carbon Mitigation

To this end, this study also looked at several other options that, if implemented, could also help reduce the carbon footprint of the college:

<u>Energy Efficient Technologies.</u> Energy consumption is the most significant factor contributing to college emissions, accounting for 47.9% of the total emissions, which equals 249.42 tCO_2-eq. Some measures include Installing energy-saving lights such as motion sensors in corridors and classrooms and upgrading air conditioning systems to energy-efficient ones, which could also help reduce energy consumption. Also, since the region has high solar irradiance, solar panels are another means of shifting from fossil fuel use.

<u>Transportation Policies.</u> Transportation emissions were estimated at 0.79 tCO_2-eq, reflecting the proximity of students and staff to the campus. To further reduce transportation emissions, measures such as encouraging carpooling, promoting the use of public transport, and supporting the adoption of electric vehicles could be implemented.

<u>Sustainable Consumption Practices.</u> Goods and services were calculated to emit 271 tCO_2-eq, with plastic water bottles alone accounting for 99% of these emissions. Some of the measures include encouraging reusable plastics and ensuring that water refill stations are provided on the campus, which can help reduce these emissions. Such initiatives also contribute to achieving sustainability goals and create awareness of environmental issues among the students and staff.

3.3.2 Addressing Data Uncertainties

The study presents several viable suggestions. However, it also has certain limitations of the data:

- **Emission Calculations:** There is a possibility of errors when using standard emission factors, as the factors set by the standards may need to be revised. For instance, energy generation sources or transportation use may vary and influence the calculations. Real-time monitoring systems could also enhance the accuracy of the data and differentiate between the conditions of planting the proposal areas in detail.
- **Estimated Tree growth Growth rates Variability:** The ability of trees to sequester carbon can be affected by several factors, including soil quality, water intake, and the type of trees used. To mitigate these risks, future research should focus on monitoring tree growth and CO_2 uptake over time.

3.3.3 Strengthening the Proposal

The recommendation to plant 178 trees is still at the forefront of the college's strategy for reducing its carbon footprint. By choosing the drought-tolerant local varieties of trees, including Acacia tortilis and Ziziphus spina-christi, the initiative is feasible given Onaizah's semi-arid climate and low input needs. The feasibility of having sufficient land has been examined, and it has been determined that there are ample spaces on the campus that can accommodate the planting of additional trees. This expansion will not interfere with college operations or other community activities that promote sustainable consumption. Practices will support the tree using planting of ideal energy, thus saving and providing equipment with an overall encouraging approach to carbon management. This approach is consistent with the current international conventions on sustainability and reflects the college's determination to mitigate emissions.

4. Conclusion

This study thoroughly evaluates carbon emissions at Uniza Technical College, emphasizing its relatively lower emissions than other universities. It underscores the pivotal role educational institutions can play in promoting environmental sustainability. The study, projecting a carbon footprint of 521 tCO_2-eq, underlines the imperative, such as enhancing energy efficiency, reducing single-use plastic usage, and increasing tree planting initiatives. These efforts are not only actionable locally but also align with global sustainability frameworks such as the United Nations' Sustainable Development Goals, particularly Goal 13 (Climate Action) and Goal 15 (Life on Land).

By integrating carbon monitoring with ecological interventions, the study demonstrates a scalable model for other institutions, emphasizing the potential for educational facilities worldwide to adopt similar measures. The proposal to plant 178 trees and select species appropriate for semi-arid regions provides a reproducible strategy for attaining carbon neutrality. This endeavor can inform policy, directing institutions to establish effective environmental management systems suited to their specific circumstances.

This work connects institutional actions with global climate objectives, offering a framework that facilitates the transition to a more sustainable future. Academic institutions must exemplify leadership by cultivating a culture of environmental stewardship and innovation. Subsequent studies should investigate real-time monitoring systems and cross-institutional comparisons to augment the scalability and efficacy of these programs.

Acknowledgment

The author expresses profound gratitude to all members of the college who have contributed to the initiative's success and the hard work to reach its current position. Special recognition goes to the Dean En. Abdullah Al-Saikhan, Mr. Khaled Al-Humaidi, and Eng. Mohammed Al-Samanan for their exceptional support. Additionally, the author would like to thank the head of the department, Eng. Mishal Al-Mutairi, as well as collegemates Eng. Abdullah Al-Fayez, Eng. Mansour Al-Humaidan, and Ms. Mashael Al-Atni. The trainees, including Sami Al-Harbi, Saif Al-Mutairi, and Mohammed Al-Mutairi, are appreciated for their tireless efforts that have helped make this initiative successful. The author extends heartfelt gratitude to everyone involved, as their invaluable contributions have been instrumental in the success of this initiative.

Author Contributions

The author did all the research work of this study.

Competing Interests

The author has declared that no competing interests exist.

References

1. Wiedmann T, Minx J. A definition of 'carbon footprint'. In: Ecological economics research trends. New York, NY: Nova Science Publishers, Inc.; 2008. pp. 1-11.
2. IPCC. Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories [Internet]. Geneva, Switzerland: IPCC; 1996. Available from: https://www.ipcc.ch/report/revised-1996-ipcc-guidelines-for-national-greenhouse-gas-inventories/.
3. UNFCCC. The Kyoto Protocol - Status of Ratification [Internet]. Bonn, Germany: UNFCCC; 1997. Available from: https://unfccc.int/process/the-kyoto-protocol/status-of-ratification.
4. IPCC. Climate Change: The IPCC Scientific Assessment (1990) [Internet]. New York, NY: Cambridge University Press; 2010. Available from: https://archive.ipcc.ch/publications_and_data/publications_ipcc_first_assessment_1990_wg1.shtml.
5. Persily AK, Emmerich SJ. Indoor air quality in sustainable, energy efficient buildings. Hvac R Res. 2012; 18: 4-20.
6. Lu T, Knuutila A, Viljanen M, Lu X. A novel methodology for estimating space air change rates and occupant CO_2 generation rates from measurements in mechanically-ventilated buildings. Build Environ. 2010; 45: 1161-1172.
7. Shriram S, Ramamurthy K, Ramakrishnan S. Effect of occupant-induced indoor CO_2 concentration and bioeffluents on human physiology using a spirometric test. Build Environ. 2019; 149: 58-67.
8. Seppanen OA, Fisk WJ. Summary of human responses to ventilation. Indoor Air. 2004; 14: 102-118.
9. Valls-Val K, Bovea MD. Carbon footprint in higher education institutions: A literature review and prospects for future research. Clean Technol Environ Policy. 2021; 23: 2523-2542.
10. Nkwocha EE, Egejuru RO. Effects of industrial air pollution on the respiratory health of children. Int J Environ Sci Technol. 2008; 5: 509-516.
11. Leite Frandoloso MA. La inserción de la eficiencia energética en los edificios universitarios brasileños: Las políticas y los procesos de toma de decisiones. Barcelona, Spain: Universitat Politècnica de Catalunya; 2018.
12. EPA. Indoor Air Facts No. 4 (revised): Sick Building Syndrome [Internet]. Washington, D.C.: EPA; 1991. Available from: https://www.epa.gov/sites/default/files/2014-08/documents/sick_building_factsheet.pdf.
13. Daisey JM, Angell WJ, Apte MG. Indoor air quality, ventilation and health symptoms in schools: An analysis of existing information. Indoor Air. 2003; 13: 53-64.
14. Strohbach MW, Arnold E, Haase D. The carbon footprint of urban green space-A life cycle approach. Landsc Urban Plan. 2012; 104: 220-229.

15. United Nations. Social Development for Sustainable Development: Transforming our world: The 2030 Agenda for Sustainable Development [Internet]. New York, NY: United Nations; 2015. Available from: https://social.desa.un.org/2030agenda-sdgs.
16. Clean Development Mechanism. Baseline Determination for the Electricity Grid in the Kingdom of Saudi Arabia: Grid emission factor (GEF) according to CDM regulations [Internet]. Riyadh, Kingdom of Saudi Arabia: Clean Development Mechanism, Inc.; 2010. Available from: https://cdmdna.gov.sa/content/files//e179cf72596d15213c8772bf7a9dab64.pdf.
17. NCR. Natural Resources Canada [Internet]. Ottawa, Canada: NCR; 2014. Available from: https://natural-resources.canada.ca/sites/nrcan/files/performancereports/files/dpr-2013-14/NRCan-DPR2013-14_e.pdf.
18. Beér JM. Stationary combustion: The environmental leitmotiv. Symp Int Combust. 1989; 22: 1-16.
19. Strapasson A, Woods J, Donaldson A. Bulb calculator: An independent review [Internet]. London, UK: Imperial College London; 2020. Available from: https://www.researchgate.net/publication/341878409_Bulb_Calculator_An_Independent_Review.
20. Baldowska-Witos P, Kruszelnicka W, Kasner R, Tomporowski A, Flizikowski J, Mrozinski A. Impact of the plastic bottle production on the natural environment. Part 2. Analysis of data uncertainty in the assessment of the life cycle of plastic beverage bottles using the Monte Carlo technique. Przem Chem. 2019; 98: 1668-1672.
21. Schnurr RE, Alboiu V, Chaudhary M, Corbett RA, Quanz ME, Sankar K, et al. Reducing marine pollution from single-use plastics (SUPs): A review. Mar Pollut Bull. 2018; 137: 157-171.
22. Ta Thi Y, Thi Anh TN. Determination of life cycle GHG emission factor for paper products of Vietnam. Green Process Synth. 2020; 9: 586-594.
23. Makov T, Meylan G, Powell JT, Shepon A. Better than bottled water? Energy and climate change impacts of on-the-go drinking water stations. Resour Conserv Recycl. 2019; 143: 320-328.
24. Filimonau V. Life cycle assessment: Past, present and future. In: The Routledge Handbook of Tourism and Sustainability. London, UK: Routledge; 2015. pp. 209-220.
25. Ma X, Li C, Li B. Carbon emissions of China's cement packaging: Life cycle assessment. Sustainability. 2019; 11: 5554.
26. Shahmohammadi S, Steinmann Z, Clavreul J, Hendrickx H, King H, Huijbregts MA. Quantifying drivers of variability in life cycle greenhouse gas emissions of consumer products-a case study on laundry washing in Europe. Int J Life Cycle Assess. 2018; 23: 1940-1949.
27. Neema MN, Karashima K, Junichiro A, Ohgai A. Correlation between GA-based optimization of green spaces and air pollution reduction: A case study on Dhaka City. Berlin, Germany: ResearchGate GmbH.; 2016. Available from: https://www.researchgate.net/profile/Akira-Ohgai-2/publication/308980269_Correlation_between_GA-based_optimization_of_green_spaces_and_air_pollution_reduction_A_Case_Study_on_Dhaka_City/links/57fc519a08ae6ce92eb2b762/Correlation-between-GA-based-optimization-of-green-spaces-and-air-pollution-reduction-A-Case-Study-on-Dhaka-City.pdf.
28. EcoTree. How much CO_2 does a tree absorb? [Internet]. Copenhagen, Denmark: EcoTree; 2025. Available from: https://ecotree.green/en/how-much-co2-does-a-tree-absorb.
29. Pearson TR. Measurement guidelines for the sequestration of forest carbon. Newtown Square, PA: US Department of Agriculture, Forest Service, Northern Research Station; 2007.

30. Nowak DJ, Crane DE. Carbon storage and sequestration by urban trees in the USA. Environ Pollut. 2002; 116: 381-389.
31. ASHRAE. Indoor Carbon Dioxide Concentrations and Ventilation Effectiveness [Internet]. Washington, D.C.: ASHRAE; 2022. Available from: https://www.ashrae.org/file%20library/about/position%20documents/pd_indoorcarbondioxide_2022.pdf.
32. ASHRAE. Indoor Carbon Dioxide, Ventilation, and Indoor Air Quality [Internet]. Washington, D.C.: ASHRAE; 2023. Available from: https://www.ashrae.org/file%20library/about/government%20affairs/public%20policy%20resources/briefs/indoor-carbon-dioxide-ventilation-and-indoor-air-quality_2023.pdf.
33. Mysen M, Berntsen S, Nafstad P, Schild PG. Occupancy density and benefits of demand-controlled ventilation in Norwegian primary schools. Energy Build. 2005; 37: 1234-1240.
34. Bekiashev KA, Serebriakov VV. World Meteorological Organization (WMO). In: International Marine Organizations: Essays on Structure and Activities. Dordrecht: Springer Netherlands; 1981. pp. 540-552.
35. Reinman SL. Intergovernmental panel on climate change (IPCC). Ref Rev. 2012; 26: 41-42.
36. EPA. U.S. Environmental Protection Agency [Internet]. Research Triangle Park, North Carolina: EPA; 2012. Available from: https://www.epa.gov/.
37. ASHRAE Board of Directors. ASHRAE Position Document on [Internet]. Peachtree Corners, GA: ASHRAE; 2012. Available from: https://www.ashrae.org/about/position-documents.
38. Greenhalgh T, Katzourakis A, Wyatt TD, Griffin S. Rapid evidence review to inform safe return to campus in the context of coronavirus disease 2019 (COVID-19). Wellcome Open Res. 2021; 6: 282.
39. Letete T, Mungwe NW, Guma M, Marquard A. Carbon footprint of the University of Cape Town. J Energy South Afr. 2011; 22: 2-12.