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Sustainability in Action: Carbon Footprint Assessment of the University of Technology, Jamaica

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Abstract– ***To combat the effects of climate change, anthropogenic greenhouse gas emissions must be reduced. Universities are now starting to increase awareness of this problem and take steps to minimize their carbon footprint, to address the challenges posed by the global climate crisis. This study seeks to illustrate the trajectory for assessing the overall carbon footprint of the University of Technology, Jamaica (UTech, Ja) main campus, identify its stressors to reduce greenhouse gas emissions, and transition towards a greener and more sustainable environment. The Greenhouse Gas (GHG) Protocol methodology was used to categorize emissions into three scopes: direct, indirect, and other indirect emissions. The data from each category was converted to CO_2 emissions, analyzed, and recommendations to reduce UTech's carbon footprint were presented.***

The total CO_2 emissions from UTech Ja's main campus for the academic year 2021-2022 was 4,150.43 tCO_{2e} and 0.36 tCO_{2e} per person (staff and students), with the percentage contributions from scope 1 at 1%, scope 2 at 94%, and scope 3 at 5%. The highest contributor to CO_2 emissions was electricity consumption (94%), followed by paper consumption (3.07%) and waste generated (1.55%). Reduction efforts were focused on emissions from scopes 1 and 2, which the university directly controls. The research team examined the university's energy consumption and travel patterns to find areas where emissions may be reduced by implementing energy-efficient measures, utilizing renewable energy sources such as solar energy and biofuel, as well as other transportation modes that are more environmentally friendly.

Keywords-- Carbon footprint, Carbon emission, Low-carbon economy, Higher education institutions (HEIs), Organizational carbon footprint

I. INTRODUCTION

The Industrial Revolution started in Great Britain in the late eighteenth and early nineteenth centuries when technology powered by new sources of energy started to displace manual labor [1]. The first indication of this transformation was the mechanization of England's textile mills, the advancement of iron-making methods, and the growing reliance on coal for transportation, manufacturing, and heating in place of wood and water power [1]. Carbon dioxide levels in the atmosphere were 280 parts per million in 1750, but by 2005, they had increased to 380 ppm, a growth of more than one-third. As a result, the atmosphere now holds unparalleled levels of carbon dioxide, methane, and nitrous oxide for at least the past 800,000 years [2]. The total amount of carbon dioxide emissions, both directly and indirectly brought on by human actions or accumulated throughout a product's life, is measured by its carbon footprint [3]. These impacts have been observed throughout the climate system, along with those of other anthropogenic factors, and they are very likely to have been the primary factor in the observed warming since the middle of the 20th century [2]. According to Kondash et al [4], the negative effects of a fossil fuel-based economy on the environment have prompted many countries to start working on cleaner energy and transportation options. Several international treaties such as the Kyoto Protocol and Paris Agreement, have been signed to combat global climate change.

A. Paris Agreement

The Paris Agreement calls for countries to take progressively aggressive climate action over five years [5]. The primary goal of the Paris Agreement is to increase the effectiveness of international efforts to combat the threat posed by climate change by limiting the rise in global temperature this century to well below 2 °C above pre-industrial levels and to pursue efforts to limit further temperature increase to 1.5 °C [6]. According to Dawkins [7], with the addition of forestry targets and tighter greenhouse gas emission caps, Jamaica became the first Caribbean nation to submit a more stringent climate plan to the United Nations (UN) in July 2020, as required by the Paris Agreement. Dawkins [7] further mentioned that Jamaica has improved its Nationally Determined Contribution (NDC) to achieve a 60% reduction in greenhouse gas emissions by 2030. This brought about an urge to create a greenhouse gas inventory for our university to show our adherence to these international accords, support the national sustainability goals, and assist in efforts to combat climate change.

B. Greenhouse Gas (GHG) Protocol

For fundamental guidance on GHG accounting concepts, setting inventory boundaries, identifying GHG emission sources, creating and modifying an inventory base year, and tracking emissions over time, organizations are urged to study the GHG Protocol Corporate Standard [8]. Several steps in the greenhouse gas protocol can be used to calculate the carbon footprint. This includes identifying the sources of GHG emissions, selecting a method for calculating greenhouse gas emissions, gathering information on activities, deciding on emission factors, applying calculation tools, and rolling up GHG emissions data to the corporate level [9].

To differentiate between the direct and indirect sources of emissions for enterprises, the GHG Protocol developed a system of scope-based classification [10]. Scope 1 emissions are direct greenhouse gas emissions, Scope 2 emissions are caused by electricity, and Scope 3 emissions are caused by various indirect greenhouse gas emissions [10]. GHG emissions scopes have been created to explain which emissions are taken into consideration by the accounting system of an organization. This aids in understanding gaps in emissions accounting and benchmarking their development across business sectors [11].

C. Method for calculating greenhouse gas emissions

It is uncommon to directly assess GHG emissions through flow rate and concentration monitoring. More frequently, emissions may be estimated using a mass balance or stoichiometric approach that is unique to a facility or process. However, using established emission factors is the most typical method for computing GHG emissions. These variables are mathematical ratios connecting GHG emissions to a fictitious activity indicator at an emissions source [12].

To determine a company's or a product's CO_2 emissions, two fundamental pieces of data are required, activity data and an emission factor. Activity data, which gives more specific information on the activities that cause emissions, is first and foremost required [13]. Examples of activity data include the number of liters of gasoline or kilograms of paper consumed within a specific period. Activity data can be transformed into CO_2 emissions using emission factors [9]. According to the US EPA, factors are typically expressed as the weight of the pollutant divided by the unit weight, volume, distance, or duration of the activity emitting the pollutant [8]. Emission factors can be found in published literature. Country-specific data can also be used to create emission factors, such as the energy content of the fuels used, their carbon content, and carbon oxidation factors [14]. By doing this, the carbon inventory is guaranteed to take regional variations into account while remaining consistent and comparable to international requirements for reporting emissions [14]. Emission factors vary depending on the source. This implies that, for instance, the emissions of electricity generated by coal and nuclear power will differ. The following general equation can be used to calculate emissions [9].

$$CO_2 \text{ emission} = \text{Activity data (kg/km/liters/unit)} \times \text{Emission factor (CO/unit).} \qquad (1)$$

B. Data Collection

An excellent area to start with data collection is the physical plant, facilities office, campus planning office, and local utilities [15]. For "all processes and materials owned, operated or controlled by the footprinting organization," primary activity must be used [16]. Scope 1 GHG emissions can be computed using published emission factors for the majority of small to medium-sized businesses and many larger businesses using the quantities of commercial fuels such as natural gas and heating oil that were purchased [9]. Metered energy consumption data and supplier-specific, regional grid, or other publicly available emission factors will be used to determine the majority of the scope 2 GHG emissions [17]. To determine scope 3 GHG emissions, activity data, such as fuel consumption or passenger miles, as well as public or third-party emission factors, will be predominantly used. When facility-specific emission factors are accessible, they are typically preferred to more broad or generic emission factors [12]. If you can only gather data for 12 months, be certain that the data for each category is for the same 12-month period [18].

B. Mitigation Strategies

An organization may occasionally set specific objectives for reducing emissions over a specific time frame. Setting a CO_2 emission reduction goal will require a baseline to estimate at the stated period if the goal has been achieved [19]. According to preliminary calculations that also account for reductions in 2020, greenhouse gas emissions in the European Union which consists of 27 countries (EU27) have been reduced by nearly a third since 1990. This is mainly due to the implementation of EU and national policies and initiatives, growth in the use of renewable energy sources, a move from coal to gas for power generation, improvements in energy efficiency, and structural changes in the EU economies [20].

Universities can decide to commit to net zero or absolutely zero emissions. Eventually, these promises should encompass emissions reductions from all three scopes (direct, purchased electricity, and indirect), so they should include target dates [13]. These institutions should approach the net zero carbon target by introducing, for example, the conversion of waste to energy. According to Dautremont-Smith (2002) cited by Sprangers [9], the quantity of waste that is burned at an electricity-generating facility can be subtracted from the overall amount of electricity used. When considering the whole environmental impact rather than just focusing on CO_2 emissions, composting is a much better option than incineration and is another option that universities can adopt [21].

In the realm of sustainable energy and the exigent need to reduce carbon footprints, this research undertakes a thorough investigation into the assessment and mitigation strategies for the carbon footprint of a university. By stimulating the creation and use of new or more sustainable, and low-carbon emission technologies, processes, and solutions, carbon footprint assessment and mitigation promote innovation that encourages research and development activities targeted at identifying cleaner and more effective operational methods. Seeking innovative solutions, the study prominently explores the integration of Photovoltaic Cells (PVCs) as a pivotal strategy for carbon footprint reduction. Recognizing the unparalleled potential of PVCs in harnessing solar energy and translating it into a clean power source, the research endeavors to establish a comprehensive baseline for the effective implementation of PVCs across government-owned institutions. By reducing emissions, the institution contributes to mitigating the risks associated with climate change, such as extreme weather events, sea-level rise, and other environmental challenges faced by Jamaica. Reducing GHG emissions will also result in increased productivity and cost-effectiveness, as it allows for improved management of the universities' resources and by extension other schools. Implementing carbon-reduction measures will lower the overall cost of utility bills, whether for electricity, water, or equipment maintenance. By undertaking the assessment and mitigation of its carbon footprint, UTech, Ja can lead government-owned institutions in sustainable practices while contributing to a greener future for the country and the wider Caribbean region.

This research aims to propose a framework that can be used by academic institutions to create a carbon dioxide equivalent baseline and to introduce best practices to reduce carbon emissions sustainably. This structural approach can be used to support local, regional, and international universities in their management of GHG emissions. This framework requires the identification of relevant data sources to categorize and quantify greenhouse gas emissions, using the Greenhouse Gas Protocol methodology. Emission hotspots can then be identified to assess potential mitigation technologies and strategies for effectiveness, viability, and cost-efficiency.

II. METHOD

A. Organizational Boundary

The GHG Protocol standard was used to compile a greenhouse gas (GHG) inventory for UTech, Ja to thoroughly evaluate and calculate the institution's carbon footprint; for the main campus. UTech, Ja has played a key role in the educational scene, accommodating over 11,000 students and occupying a surface area of 18.2 hectares. An extensive evaluation of the university's carbon emissions for the academic year 2021–2022 was done, which included emissions from sources under scopes 1, 2, and 3.

B. Data Sources and Information Systems

Several steps were taken to obtain activity data and emission factors for the GHG inventory at UTech, Ja to calculate the total CO_2 emissions. A data collection procedure was created, working with numerous university departments such as University Facility Management (FMD), procurement office, Planning Department, Caribbean Sustainable Energy and Innovation Institute (CSEII), Human Resource Department, and Fleet Management Unit. Other data was collected utilizing surveys, annual utility bills, FMD records, and other pertinent administrative sources to gather activity data such as energy consumption, transportation, and waste. This guaranteed thorough coverage of activities and provided the emissions estimation with a solid foundation. Based on the most recent and trustworthy data available, emission factors were then chosen.

The emission factors used were a combination of locally sourced emission factors unique to Jamaica (water treatment and power plants) and globally recognized emission factors from reliable sources such as the United Nations Framework Convention on Climate Change (UNFCCC) and the Department for Environment, Food and Rural Affairs (DEFRA). Local sources such as the National Environmental Planning Agency (NEPA) and National Water Commission (NWC) offered contextual accuracy, taking into consideration local energy production and transportation patterns, while global elements ensured that worldwide reporting requirements were met.

C. *Scope 1*

This encompassed a diverse range of assets, namely stationary equipment, gardening tools, and a university-owned vehicle fleet; the school rental buses were not included. To achieve a nuanced understanding, specific data points were gathered. For vehicles, this involved extracting the distance traveled during the academic year, documented with precision through transportation logs maintained in collaboration with the FMD. Furthermore, the volume of fuel utilized by each piece of equipment, including gardening tools and stationary units, was meticulously recorded. This level of granularity ensured a robust dataset for calculating Scope 1 emissions, taking into account the unique usage patterns and fuel consumption rates associated with each distinct category of equipment. The collaboration with the FMD underscored the commitment to accuracy and completeness in data collection, laying a solid foundation for robust emissions calculations and subsequent sustainability measures.

D. *Scope 2*

The assessment of Scope 2 emissions; with an emphasis on purchased and solar-generated energy, emerged as a crucial component in calculating the carbon footprint of UTech, Ja. Data was provided by Jamaica Public Service Company (JPSCO), using solar records and university electricity bills to derive exact values. These figures, which were provided by JPSCO and were expressed in kilowatt-hours (kWh), served as the foundation for the analysis of the university's electricity usage trends. The estimation of a local emission factor for purchased power derived from the Hunts Bay Power Plant, which is one of the power plants that supplies electricity to the Old Hope Road vicinity, was particularly significant in this study. This factor's calculation took into account the types of fuel used, combustion efficiency, and other pertinent metrics. The emission factor provided a thorough analysis, representing the true environmental impact of electricity generation, by digging into the nuances of the power plant's operations. Using a localized approach, UTech Ja's energy sources were accurately assessed, establishing the framework for focused sustainability initiatives and well-informed decisions to reduce the institution's carbon footprint.

E. Scope 3

To assess scope 3 emissions, water usage, waste generated, and material usage were the emission sources considered. Data from water bills at UTech, Ja, and records from the National Water Commission (NWC) were both used to calculate the carbon footprint of water consumption. These sources offered significant information about the amount of water used by various campus facilities. This strategy includes taking into consideration variables such as the amount of energy needed for water purification and distribution.

Waste generated on campus, such as general and hazardous waste, was considered in assessing the waste produced. The hazardous waste came from laboratories of the College of Health Sciences (COHS) and the School of Engineering (SOE). In contrast, waste from offices, restrooms, hanging baskets, and hallway bins was included in the general waste. With the information gathered from FMD, the size and number of skips used to store waste, as well as the number of days per week that garbage was collected by trucks to be sent to the solid waste disposal site in the Riverton City Landfill, were used to calculate the volume of general waste. The study of material procured also included data on paper consumption, electrical items, plastics, and other stationery and office supplies.

To effectively calculate the environmental impact of water use, a local emission factor for water used was established. For UTech, Ja, the emission factor was calculated using information particularly acquired from the Hope Treatment Plant to the campus, a nearby institution in charge of water treatment and distribution. The energy and resources used to bring water to the university are best understood through the lens of this facility. A localized emission factor that more accurately reflects the carbon footprint attributable to water use at UTech was created by quantifying the carbon emissions linked to these activities.

E. Emissions Calculations

For each scope, the collected data along with local and internationally accepted emission factors from Table 1 were utilized to calculate the carbon dioxide equivalent (CO_{2e}), as outlined in equation (1).

TABLE 1
EMISSION CATEGORIES AND THE SOURCES OF THE EMISSION FACTORS

Scope	**Emission Category**	**Emission Factor (EF)**	**Source of the Emission Factor(s)**
Scope 1	100% Diesel	2.68 kg CO_{2e}/L	DEFRA (2020)
	Gasoline	0.2108 kg CO_{2e}/km	DEFRA (2020)
Scope 2	Purchased Electricity	1.06 kgCO_{2e}/kWh	Hunts Bay Power Plant (JPSCO)
	Generated Electricity	0.046 kg CO_{2e}/kWh	DEFRA (2020)
Scope 3	Water Consumption	0.0001 kgCO_{2e}/L	Hope Treatment Plant (NWC)
	General Waste	0.081 kgCO_2e/kg	DEFRA (2020)
	Hazardous Waste	1.5 kgCO_{2e}/kg 1.26 kgCO_{2e}/kg	DEFRA (2020)
	Paper Consumption	0.919 kgCO_{2e}/kg	DEFRA (2020)
	Purchased Electrical Items	1.148 kgCO_{2e}/kg	DEFRA (2020)

The following equations were utilized to estimate the carbon emissions for Scope 1.

1. Emissions from Generators; 100% Diesel

$$kg\ CO2e\ = Volume\ of\ fuel\ (L)\ x\ emissions\ factors\ (kg\ CO2e/L) \tag{2}$$

where kg CO_{2e} = total CO_2 emissions

2. Vehicle Fleet Emissions: Gasoline

$$kgCO2e\ =\ Distance\ traveled\ (km/yr)\ \times\ EF\ (kgCO2e/km) \tag{3}$$

For Scope 2 the equations utilized are outlined as follows:

1. Emissions from purchased electricity

For the emission factor of purchased electricity: (Hunts Bay Power Plant, JPSCO)

$$EF\ for\ Purchased\ electricity\ =\ \frac{Total\ CO2\ emitted\ (t{-}CO2)}{Total\ Annual\ production\ (Kwh)}. \tag{4}$$

$$tCO2e\ =\ Electricity\ (kWh/yr)\ \times\ EF\ (t/kWh). \tag{5}$$

2. Emissions from generated electricity based on solar energy

$$kgCO2e = Electricity\ (kWh/yr) \times EF\ (kg\ CO2/kWh).$$

For Scope 3, equations 8 to 16 were used to estimate the carbon emission.

1. General waste:

$Volume\ of\ garbage\ (m3/yr) = Volume\ per\ skip \times \#\ of$
$weekly\ pickup \times \#\ of\ weeks/year.$ (7)
$Mass\ of\ garbage\ (kg) = Volume\ (m3) \times density\ kg/m3$

$kgCO2e = EF\ (kgCO2/kg) \times mass\ of\ waste\ generated\ ($

2. Hazardous Waste:

From (COHS)
$kgCO2e = EF\ (kgCO2/kg) \times mass\ of\ waste\ generated\ (k$

From (SOE)
$kgCO2e = Ef\ (kgCO2e/kg) \times mass\ of\ waste\ (kg).$ (11)

3. Purchased materials:

$kgCO2e =$ EF (kgCO2e/kg) × mass of paper (kg). (12)

4. Electrical items

$kgCO2e = EF(kgCO2e/kg) \times electrical\ items\ (kg).$ (13)

5. Water Consumption:

$$EF\ of\ water = \frac{tCO2\ (JPS)}{kWh\ generated} \times \frac{kWh\ consumed}{liters\ of\ water\ treated}\ . \quad (14)$$
$$kgCO2e = EF\ (kgCO2/L) \times Volume\ of\ water\ (L). \quad (15)$$

6. Energy Savings Estimation with the installation of a 1.23 MW Solar PV system

System size: 1.23 MW (1,230 kW)
Number of modules: 1,964
Area covered: 164,000 ft^2
Efficiency of solar panels: 20%
Average peak sun hours: 5 hours

Capacity per module = Total capacity / # of modules *(16)*

Daily energy production = Capacity/module × Average sunlight hrs/day × # of modules *(17)*

Annual energy production = Daily energy production × 365 days *(18)*

CO2 emissions avoided by solar = Energy production from solar × Emission factor *(19)*

*Percentage reduction = (Reduction in emissions / Total emissions before) * 100* *(20)*

F. Emission Reduction Targets

The relationship between campus electricity-induced CO_2 emissions and the corresponding reduction attributed to on-campus solar power generated by (PVC) was examined to estimate the potential CO_2 emissions reduction associated with increased solar energy production from 0.2% to 5%. Data spanning from 2015 to 2019 were analyzed. The analysis was directed by the goal of constructing a 1MW PVC system by 2031, which can be accomplished by adding 300kWh systems every two years. The potential CO_2 emissions offset resulting from the unpredictable nature of solar energy were represented by randomly generated figures, which ranged from 50-70% of the PVC capacity for each corresponding year. This aided in strategic planning and decision-making toward sustainable energy solutions by providing a sophisticated understanding of the CO2 reduction potential associated with increased solar energy output

G. Correlation Analysis

Data pertaining to scopes 1-3 emissions, population demographics, and surface area were collected for selected universities. The scopes 1-3 emissions data provided insight into direct and indirect GHG emissions associated with the organization's activities, while population demographics and surface area served as proxies for the scale of human activity and land use intensity, respectively. To measure the linear relationship between each parameter and the carbon footprint, Pearson's coefficient was then calculated. Higher carbon footprints are suggested by positive correlations, whereas negative correlations imply opposite outcomes.

IV. RESULTS AND DISCUSSION

The evaluation of the UTech, Ja main campus's carbon footprint has given important insights into the organization's impact on the environment and served as a foundation for converting sustainable practices into actuality. The results of this assessment will help to develop a focused plan of action, enabling the university to put into practice efficient mitigation measures and reinforce its commitment to reducing its carbon footprint in a way that is consistent with previous and present campus dynamics and environmental sustainability objectives. In the academic year 2021-2022, the overall emission at UTech, Ja was 4,150.43 (tCO_{2e}) with 93.95% of these emissions generated by electricity usage. Scope 2 contributed to 94% of the overall emissions, followed by Scope 3 at 5%, as shown in Table 2. Table 2 also shows a breakdown of the emissions sources in each scope. The second highest emission was paper consumption at 3.07%. Paper consumption accounts for 61% of Scope 3 emissions.

TABLE 2
TOTAL CO_2 EMISSIONS GENERATED BY THE UTECH, JA MAIN CAMPUS FOR THE ACADEMIC YEAR 2021-2022

Scope	**Emission Source**	**Type**	**Emissions (tCO_2e)**	**Total CO_2 Emissions (tCO_2e)**	**Total CO_2 Emissions (%)**
Scope 1	Liquid Fuel	100% Diesel	24.12	33.62	0.81
		Gasoline	9.50		
	Vehicle Fleet	Diesel	1.62	6.63	0.17
		Petrol	5.01		
Scope 2	Purchased electricity	Track house	32.23	3899.34	94
		FOSS	50.25		
		Main	3816.86		
	Generated Electricity	Solar Panels	2.28	2.28	0.06
Scope 3	Water consumption	Main campus	13.86	13.86	0.33
	Paper Consumption	Letter size paper	64.10	127.32	3.07
		Legal size paper	63.22		
	Electrical items		0.45	0.45	0.01
	Waste generated	General waste	63.69	64.46	1.55
		SOE	0.50		
		COHS	0.27		
Total				**4,147.96**	**100**

A. Scope 1 - Fuel

Fuel consumption accounted for 0.98% of the university's total carbon footprint. This includes the emissions from diesel used by generators and gasoline used in garden equipment, as well as vehicle fleet emissions. The use of generators, especially those powered by diesel, has a substantial impact on carbon emissions. These emissions are influenced by variables including the generators' size and power output, operating times, and fuel efficiency. Over time, as the number of generators increased, so did the overall emissions from the use of liquid fuel. This can be reduced by switching to low-sulfur diesel or exploring the option of more renewable energy solutions; such as a B20 biodiesel blend which has an emission factor of 2.54 kgCO2e. Regular upkeep and tune-ups of petrol-powered garden equipment can increase their performance and lower emissions, particularly when it comes to the fuel used by such devices. Fuel efficiency can be increased and pollutants can be reduced by properly maintaining engines, cleaning air filters, and making sure blades are sharp. Sharp blades, clean air filters, and regular maintenance of engines can improve fuel economy and reduce emissions.

Biofuels such as ethanol, vegetable oil, biomass, biogas, synthetic fuel, and biodiesel, among others, are gaining significant attention from developed nations [22]. Investigating waste-to-energy technologies offers a chance to transform the organic waste produced on campus into renewable energy. The institution can save waste disposal expenses while also producing sustainable energy by introducing anaerobic digestion or other waste-to-energy technologies. Additionally, we can generate biodiesel from peanut or castor oil to produce B20 fuel which can be used in diesel generators for electricity. B20 fuel can also be used in vehicle fleets to reduce CO_2 emissions. The introduction of B20 to power the generator at the Waste Management Centre will reduce the University's overall carbon emissions from generated electricity by 15-20%.

B. Scope 2 - Purchased Electricity

Purchased electricity emerged as the most significant contributor to the carbon footprint of the university. This is due to a substantial demand for electricity to power various facilities, including classrooms, laboratories, administrative buildings, and student residences. Additionally, electricity purchased by the university is predominantly generated from fossil fuels such as heavy fuel oil, which results in higher carbon emissions per unit of electricity consumed. Reducing power consumption and the carbon footprint on campus requires the implementation of energy conservation measures. Regular energy audits make it easier to locate spaces inside buildings, laboratories, and research facilities where energy-saving solutions can be implemented. Buildings can be retrofitted with energy-efficient insulation, windows, and HVAC systems to reduce cooling needs and energy use drastically. Additionally, occupancy sensors and smart thermostats should be installed in places that aren't consistently occupied to prevent energy waste. Combining these energy-saving techniques will benefit the university financially and environmentally by lowering its carbon impact.

C. Scope 2 - Generated Electricity

Increasing the production of renewable energy is an essential step toward lowering the University's carbon footprint. Currently, the university has a 100kW Solar PV Project that yields up to 100kW of energy per day and offsets the university’s carbon footprint by 0.2-2% per year. The energy generated varies with weather conditions and having all solar units operational. Expanding this project can further contribute to offsetting emissions on campus. For example, decreasing energy consumption emissions on campus to less than 2,800 tCO_{2e} and increasing the amount of solar energy produced on campus to 1 MW per day by 2030. This can be done by installing an additional 300 kW solar PV system every 2 years leading up to 2030, as shown in Figure 1. Figure 1 displays the forecasting of CO_2 emissions reduction if this project is implemented. In the initial phase of this approach, an energy audit was meticulously crafted through comprehensive site inspections, interviews with building engineers, maintenance personnel, and residents, and thorough building assessments. Notably, the parking lots and building rooftops shown in figure 2 emerged as prime locations for solar photovoltaic installation due to their flat surfaces, as identified during the inspection process. The campus facilities can be powered by solar panels mounted on building roofs, which lessens the need for fossil fuel-based grid electricity. Installing solar panels as blinds or on parking lot structures allows the university to make use of space that was previously underutilized for producing electricity and sheltering cars. This makes the campus infrastructure as useful as possible. Purchasing solar panels can eventually result in lower electricity bills as, after the initial installation expenses are paid, solar energy is essentially free. Long-term monetary benefits for the university may arise from this. This analysis encompasses an area of approximately 164,000 square feet. With the integration of fixed tilted mounts and solar canopies, an estimated 1.23 MW of energy will be generated by 1,964 modules [23]. With the expansion of photovoltage usages by the implementation of 1.23 MWh solar PV project, the university can generate 1,127,920kW of electricity per year, which leads to 1,196.47tCO_{2e} less emissions. That is approximately 28.82% reduction than the actual baseline numbers and has to potential to save the university over $318,000 USD per year.

Batteries and other energy storage devices can store excess renewable energy when production is high and release it when demand is at its highest or when renewable energy production is at its lowest. This lessens reliance on non-renewable energy sources and assures a more steady and predictable supply of clean energy.

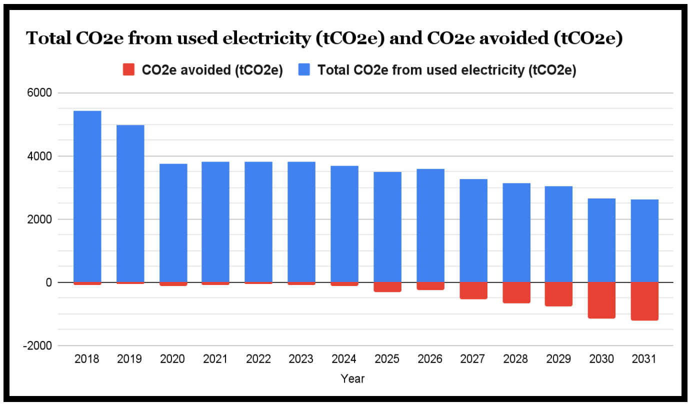

Fig 1. Projected CO_2 emissions target for 2030

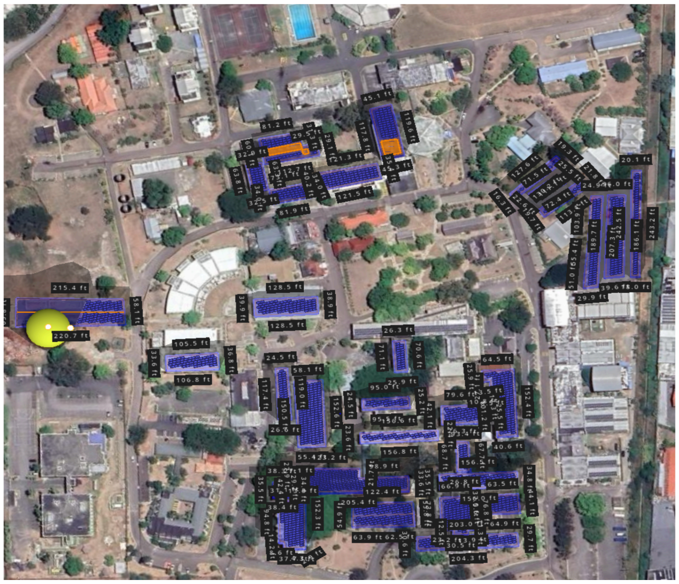

Fig 2. Aerial view of UTech Ja’s campus with the proposed solar layout (Building Roofs and Parking Lots)

D. Scope 3 - Paper Consumption

Following purchased electricity at 94%, is paper consumption at 3.07% making it the second highest contributor to the university’s carbon footprint. Paper consumption accounts for 61% of Scope 3 emissions. The manufacture of paper uses a lot of resources and energy, which causes greenhouse gas emissions. This involves tasks such as cutting down trees, transportation, and using chemicals to make pulp and paper [24]. Several activities that entail paper use in a university produce emissions, such as printing books, reports, research papers, and other printed items. Although using paper may not be the biggest factor in a university's overall CO_2 emissions, its overall impact should not be understated [25]. Therefore, UTech, Ja needs to adopt sustainable practices like cutting back on paper use, increasing digitalization, putting in place recycling programs, and printing on recycled paper whenever possible. Universities can effectively reduce their carbon footprint and help create a more sustainable future by doing this.

E. Benchmarking UTech, Ja Against National CO_2 Emissions

The CO_2 emissions per person at UTech is 0.36 tCO_{2e}, which is significantly lower than the last estimate for Jamaica in 2019; 3.44 (tCO_{2e}) per capita [26]. According to Chang, Dauwels & Helmers [2], University CFs are 10.47% of the nation's per capita footprints on average (range: 12–37%), with an exception for universities with their own power plant on campus, as shown in Figure 3. As evidence of our dedication to sustainability, our university's carbon footprint is noticeably lower than the national average. The fact that students and staff are normally on campus for up to 8 hours per day is a pivotal factor. Furthermore, only 382 students of the 10,320 student body live on campus, which further contributes to these positive results, as only 3.7% of the school's population's personal carbon footprint was included. While students and staff contribute minimally to our campus carbon footprint, their actions outside the university also play a pivotal role in the grand scheme of personal carbon emissions. Examples of activities such as commuting and household energy consumption for university-related tasks are notable contributors to personal carbon footprints that do not directly reflect on the university's metrics. However, it is important to note that our analysis does not account for all possible emission sources. To ensure accurate accounting, it will be necessary for any employee and student to report their personal consumption from off-campus academic and research activities.

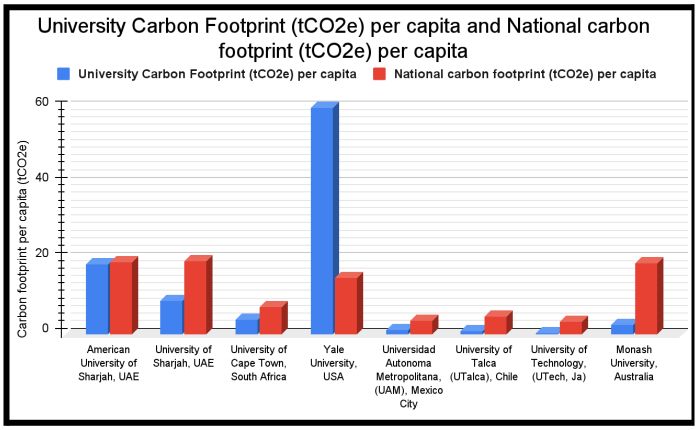

Fig 3. University CFs per capita to national per capita footprints in 2015.

F. Relationship of Measured Parameters

The GHG Protocol was used in all assessments shown in Table 3, which shows a list of selected universities along with their measured CO_2 emissions and the student population. It highlights different studies in different regions and compares various factors to see possible correlations. There are some significant differences between campuses in terms of surface area, energy source, as well as student and staff population. Table 4 shows a low negative correlation between surface area and carbon footprint. Various patterns of land usage, energy-saving techniques in bigger areas, or other mitigating factors that influence carbon emissions could cause this. Surface area may not constitute a good predictor of carbon footprint by itself; other factors are likely to have a greater impact. From the Pearson Correlation coefficients in Table 4, Student population and carbon footprint have a very weak positive correlation. This suggests that changes in the number of students will have a minor impact on the overall carbon footprint.

TABLE 3
Carbon footprint of Universities around the world between 2015-2021 ([13]; Gardner, & McKeon, 2017; Ghengare, et al., 2021)

University	**Population**	**Surface Area (m^2)**	**Total Carbon Footprint (tCO_2e)**	**Carbon Footprint (%)**		
				Scope 1	**Scope 2**	**Scope 3**
American University of Sharjah, UAE	5,122	1,280,000	94,553	0.37	61.12	38.51
University of Sharjah, UAE	14,756	4,000,000	101,404	5.89	93.53	0.58
University of Cape Town, South Africa	21,175	25,000,000	84,926	2	81	17
Yale University, USA	11,701	1,509,000	874,000	66	16	19
Universidad Autonoma Metropolitana, (UAM), Mexico City	2,750	8,093,713	3,000	4	24	72
University of Talca (UTalca), Chile	6,941	1,000,000	5,472	5	35	60
University of Technology, (UTech, Ja)	11,528	182,000	4,150	1	94	5
Monash	70,924	1,100,0	189,592	11.1	57.4	31.5

University, Australia		00				

TABLE 4
Relationship between carbon footprint parameters using Pearson's correlation

	Scope 1	Scope 2	Scope 3	Population	Surface Area	Carbon Footprint
Scope 1	1.000	-0.573	-0.167	0.006	-0.215	0.984
Scope 2	-0.573	1.000	-0.712	0.146	0.210	-0.492
Scope 3	-0.167	-0.712	1.000	-0.182	-0.067	-0.251
Population	0.006	0.146	-0.182	1.000	-0.032	0.066
Surface Area	-0.215	0.210	-0.067	-0.032	1.000	-0.172
Carbon Footprint	0.984	-0.492	-0.251	0.066	-0.172	1.000

When reviewing these global carbon footprints in Table 3, similar trends are observed for several universities, with scope 2 emissions being the highest contributor. This was observed for the University of Sharjah at 93.53%, the University of Cape Town at 81%, and the University of Cambridge at 52%. On the other hand, there were some universities with scope 1 being the highest contributor to their overall emission, such as the University of Illinois at 64%, Yale University at 66%, and the University of Alberta at 52%. This can be further supported by Table 4 which shows a very high positive correlation between scope 1 emissions and the overall carbon footprint of these universities. The fact that many colleges, such as Yale University operate their power plants to generate a significant percentage of their electricity from fuel combustion; natural gas or oil [27], resulting in their energy generation being categorized as Scope 1. The same can be said about the University of Illinois, which is regarded as stationary combustion also because it produces its power on-site [28].

UTech, Ja results were most comparable with the University of Talca (UTalca), Chile, with a population of 6,941 students and total emissions of 5,472 tCO$_{2e}$ in 2019-2020. UTalca Chile, student population is significantly lower than that of UTech, Ja; however, their CO$_2$ emissions were higher. Another university that used the GHG Protocol methodology was Monash University, Australia, which has a population 6 times greater than that of the UTech, Ja and higher CO$_2$ emissions. However, this is due to the influence of various factors such as energy use, the climate, and the amount of cooling required. CF values were also influenced by a university's transportation options and the availability of various amenities such as laboratories, a research center, and a hospital on-site.

As a result, comparing the carbon footprint emissions between universities may not always be feasible. All studies agree on one thing, the largest carbon footprint is a result of energy use in terms of electricity and heat output; whether it is purchased or generated, and can be classified as scope 1 or scope 2 emissions.

V. CONCLUSION

The calculated carbon footprint at UTech Ja's main campus for the academic year 2021-2022 was 4,150.43 (tCO$_{2e}$) with scope 2 emissions; purchased electricity in particular was the main contributor at 3899.34 (tCO$_{2e}$). This was done under the guidance of the Greenhouse Gas (GHG) Protocol methodology and included using activities for the various emission sources in the form of utility bills, transportation logs, and invoices which were then converted to CO$_2$ emissions using both local and global emission factors. The CO$_2$ emissions per person at UTech was 0.36 tCO$_{2e}$, which was significantly lower than the last estimate for Jamaica in 2019 at 3.44 tCO$_{2e}$; which is 10.47% of the national CO$_2$ emissions per capita.

This study was able to identify the CO$_2$ emission hotspots on campus. Electricity consumption proved to be the most significant contributor to the university's overall emissions, followed by paper emissions, water consumption, and waste generated in scope 3, and fuel consumption in scope 1. While it is important to have mitigation measures for each emission source, the first step can be to focus on scope 1 emissions that are from sources owned or controlled by the university as well as scope 2 emissions. Even though the university has no control over the type of fuel used to generate purchased electricity, the quantity of electricity purchased can be controlled. With the installation of a 1MW Solar PV system, CO$_2$ emissions generated from purchased electricity can be reduced by 28.82%, with approximately 1,196.47tCO$_{2e}$ avoided. Additionally, it would be helpful to install meters for each building to identify energy-intensive areas and focus efforts on those buildings to reduce emissions. Additional methods of assessment for scope 3 emissions will need to be formulated to improve the accuracy and allow for better monitoring and reporting.

With an emphasis placed on Scope 1 and Scope 2, the overall emissions can be reduced with an increase in the renewable energy generated on campus by adding more solar panels along with storage devices to store energy for periods of low generation. Additionally, biofuel can be produced from collected waste oil on campus as well as peanut or vegetable oil. This can be used in generators and vehicle fleets.

It will require a collective effort of all stakeholders from the university's leadership, staff members, and students as these recommendations will require a willing mindset to commit to reducing the overall emissions on campus. The university can show its dedication to sustainability, lessen its environmental impact, and support international efforts to battle climate change by implementing the suggested activities. This research lays the groundwork for the university to create a comprehensive carbon reduction strategy, improve its standing as a sustainable organization, and spur beneficial change both within and outside of its community.

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