

Estimation of Carbon Footprint Pattern at Nile University of Nigeria: A Technical Campus in Nigeria

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Abstract. This research estimates the amount and pattern of Greenhouse Gas emissions in Nile University of Nigeria, Abuja, Nigeria. Footprint from onsite energy production, transport, gardening and cooking fuels were calculated as major emission sources in university campuses using IPCC's guideline for assessment and reporting GHG. The calculated annual GHGs emission of the university was 5,466.3964tCO₂e. Emission due to transportation was 71%, while 24.7%, 2.7% and 0.8% of the university emissions were from onsite energy generation, cooking fuel and gardening respectively. It was established the university's per capita GHG emissions is lesser than what is suggested by the Kyoto Protocol. Notwithstanding, it can further be reduced by using electricity and LPG more efficiently, provision and incentivizing the use of mass transits.

1 Introduction

From the onset of the industrial revolution in the early 20th century, global average temperatures have been steadily on the rise. The apex of the gradual rise in world temperatures was attained in the year 2016 which on list is the warmest year ever thus far (Boykoff et al., 2019). Recent observations of weather patterns around the world have included widespread glacial melting leading to rising sea levels and the submergence of coastal towns and islands, an increase in the frequency of heat waves, droughts, cyclones, and heavy rainfall events. (Ayanlade et al., 2010; Dodman, 2009; Roeckner et al., 2007). Globally, vehicles are responsible for 23% of all greenhouse gas emissions. In developing nations where older vehicles lacking efficient emission reduction mechanisms are still prevalent, the contribution of vehicles to this total is significantly higher. For instance, in the

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case of Nigeria, vehicles account for 35% of the country's total greenhouse gas emissions. (Mshelia et al., 2021).

Despite the essential role played by renewable technologies, their growth remains sluggish, and they face challenges in keeping pace with global economic expansion and population growth. The International Energy Agency reports that fossil fuels continue to dominate the world's energy landscape and are expected to do so for the foreseeable future. (IEA, 2019). In addition, by 2040 solar energy technologies will provide 50% of the energy demand as stated by the IEA. Increase in the emission of anthropogenic greenhouse gases as a result of increased combustion of fossil fuels has been identified as the major reason for accelerated change in the world's climate (Dodman, 2009). Additionally, satellite instruments employed to gauge solar energy output have shown a slight decrease in solar radiation levels since 1978, suggesting that Earth is not receiving as much energy from the sun for warming. Consequently, it can be inferred that the sun is not responsible for the Global Warming Potential (NASA, 2019).

Institutions of higher learning, including universities, have an important task in mitigating the effect of change in climate by lowering their carbon footprint. Persisting emissions of greenhouse gases will result in a growing trend of global warming. The most likely projection suggests that we could reach a 1.5°C temperature increase in the foreseeable future according to various scenarios and modeled trajectories. Each uptick in global warming will amplify various simultaneous threats. However, if we swiftly and substantially reduce greenhouse gas emissions, we can expect a noticeable deceleration in global warming within approximately two decades, along with observable alterations in atmospheric composition within just a few years. (IPCC, 2023). University Campuses are usually clusters where GHG consumption and emission rate are very high. For instance, in the United States, despite their campuses have less than 1% of the population in the country, college campuses are responsible for approximately 3% of the country's GHGs emission (Sinha et al., 2012). In other countries like Korea and Japan, this rate is up to 5% of the Nation's GHGs emission (Seo et al., 2018; Teah et al., 2019).

Addressing climate change requires a united effort from entities across the globe, as it is a pervasive global challenge. The impact of climate change, driven by human activities, is already manifesting in numerous extreme weather events and climatic shifts in every corner of the world. This has resulted in extensive adverse consequences, causing harm to both ecosystems and human populations. Particularly concerning is the disproportionate impact on vulnerable communities, which have historically had minimal contributions to the current climate change predicament (IPCC, 2023). These changes have far-reaching impacts on the environment, including rising sea levels, increased frequency and intensity of extreme weather events, and threats to ecosystems' sustainability. There is no doubt that human activity has caused the atmosphere, ocean, and land to warm. Between 1901 and 2018, the global mean sea level rose by 0.20 (0.15 to 0.25 m). Between 1901 and 1971, the average annual rate of sea level rise was 1.3 mm (0.6 to 2.1), rising to 1.9 mm (0.8 to 2.9) between 1971 and 2006, and then to 3.7 mm (3.2 to 4.2) between 2006 and 2018. Since at least 1971, human involvement has most certainly been the primary cause of these increases. Since at least 1971, human involvement has most certainly been the primary cause of these increases. Since the fifth assessment report, the case for observed changes in severe events, including heatwaves, heavy precipitation, droughts, and tropical cyclones, has become more compelling. Since the 1950s, human impact has probably increased the likelihood of compound extreme events, such as an increase in the frequency of simultaneous heatwaves and droughts (IPCC, 2023). The American Meteorological Society (AMS) report, state of the climate in 2017, stated that the sea level rose by about 77 millimeters in 2017 compared to 1993, which is a consequence of GWP (Thompson P.R. et al., 2018). Also, an increase in GWP enhances the likelihood of wildfires, primarily due to heat waves. Elevated

temperatures lead to the drying of groundwater and green vegetation, turning them into flammable fuel sources that intensify combustion (Rossiello et al., 2019).

Responding to climate change by the reduction of GHGs emission on an individual and university level requires a strategic approach from policy, regulatory and institutional frameworks to facilitate the identification of priority emission sources and the appropriate reduction measures that can be taken. Nile University of Nigeria, Abuja (NUN), like most other university campuses in Nigeria and other developing countries does not have a record of its GHG emissions. Therefore, for it to be able to monitor and reduce its carbon footprint, it first has to have a record of the sources and pattern of emission on the University campus. This research work intends to provide the University's stakeholders with data which can serve as a baseline for studying and monitoring the University's emissions and a basis for policy formulation to reduce GHGs emissions on University campuses and for further research.

It is expected that at the end of this estimation of GHGs emissions on NUN campus that: the total amount of GHGs emitted on the campus and the amount emitted by each of the major sources on the campus will be determined; GHGs emission level of NUN will be compared to those on other campuses so as to ascertain how ecofriendly the campus is; suitable measures of reducing the GHG emissions of the campus will be suggested.

2. Material and Methods

2.1 Data Collection

Four main emission sources as identified by IPCC (2014) were considered, these are onsite electricity generation; transportation; cooking fuels; and gardening. Data for each of the four sources was collected differently. For onsite electricity generation, a record for the monthly fuel consumption for a period of one calendar year 2022/2023 was obtained from the Electrical Department of the Works and Services Division of the University through a structured interview and data available. A structured interview was carried out with the head of the Sanitation Unit of the University's gardening Division to obtain information about the monthly fuel consumption of the machineries used on campus. Questionnaire and interview were used to collect data for the type and quantity of cooking fuel used at university kitchen, restaurants and university staff quarters from kitchen managers, restaurant owners and resident of staff quarters respectively for 2022/2023 academic session. Since different categories of vehicles have their separate emission factors, vehicles were grouped into five groups and their data collected and analyzed in that manner. The five categories are: Sedans; Sports Utility Vehicles (SUVs)/minibuses; Motorcycles; Tricycles; Trucks. For ease of analysis, emissions from vehicles were gathered in two groups. Firstly, vehicles resident on the campus. Information on the number and category of vehicles resident in the university was obtained using a questionnaire which was issued to the residents of university staff quarters and granted interview by the fleet manager of NUN. The second group of vehicles were vehicles daily entering the university, the numbers and categories in which these vehicles fell into was gotten by observing the volume of traffic from 06:00 hours to 23:59 hours for weekdays and a weekend during school sessions and academic break. The school's academic calendar was then used to calculate the vehicular traffic during school breaks and when school was in session. For this section, the following reasonable assumptions were made:

1. The vehicles that are permanently stationed within the university premises and those that enter the university are surveyed as separate groups.
2. Every vehicle that enters or exits the university utilizes the main entrance.

3. Each vehicle, on average, travels a distance of 2.4 kilometers, which represents the round-trip distance between the main gate and the Administrative Block.

2.2 Data Analysis

Formulae and steps as provided and outlined by IPCC (2006) as principles for assessment of GHG footprints were used to evaluate the emission in each of the sector being studied. Fuel consumption data obtained were used with emission factors for stationary combustion engines and were used to calculate the amount of GHGs emitted into the atmosphere due to power generation. The general formula used to determine the emission from power generators on the campus is thus:

$$E_g \text{ (kgCO}_2\text{e)} = \text{AMF} \times \text{FEF (d/p)} \times n \dots\dots\dots (1)$$

Where,
AMF = Average Monthly Fuel Consumption (litres)
FEF = Fuel Emission Factor
Petrol = 2.2862kgCO₂e/l;
Diesel = 2.6924kgCO₂e/l (IPCC, 2006)
n = Number of months being evaluated

For vehicles entering the campus through the main NUN gate and those residents on the campus, the general formula in equation 2 was used to calculate the footprint of each group of vehicle.

$$\text{Emission} = \text{Number of vehicles} \times \text{Average Travel Distance} \times \text{Emission Factor for Vehicle type} \dots\dots\dots (2)$$

Table 1 shows the emission factor for each type of vehicle and the corresponding data source.

Table 1. Emission Factors for Vehicles

Emission Source	Emission Factor	Data Source
Sedans	0.23398kgCO ₂ e/km	(IPCC, 2006)
SUVs	0.88634kgCO ₂ e/km	(IPCC, 2006)
Trucks	0.99976kgCO ₂ e/km	(IPCC, 2006)
Motorcycles	0.12761kgCO ₂ e/km	(WRI, 2008)
Tricycles	0.1860kgCO ₂ e/km	(IES, 2004)

For cooking fuels, the average monthly quantity of fuel type used and its emission factor was used for the estimation. Note that all the households in NUN reported that lpg is the only source of cooking fuel, though the unavailability of firewood as a cooking fuel at NUN, its emissions are considered biogenic emissions therefore they are not accounted for in GHGs estimation (IPCC, 2006). The general equation below was used for the estimation of emissions from cooking fuels.

$$\text{Emission} = \text{Average monthly Quantity used} \times \text{Emission Factor} \dots\dots\dots (3)$$

LPG Emission Factor = 1.6159kgCO₂e/l

Same is applied to gardening machineries that uses petrol to drive the engine, the average monthly fuel consumption and the emission factor of the machineries were used to obtain the emission under this category.

The general formula used to determine the emission from the farm machineries in NUN green area is thus:

$E_p \text{ (kgCO}_2\text{e)} = \text{AMF} \times \text{FEF (d/p)} \times n \dots\dots\dots (4)$

Where,

AMF = Average Monthly Fuel Consumption (liters)

FEF = Fuel Emission Factor

Petrol = 2.2862kgCO₂e/l;

n = Number of months being evaluated

3. Results and Discussions

It was found that the University total average monthly fuel for diesel powered generator on the campus was 80,210 liters, It was noted that there were two sub stations with 8 diesel generators grouped into two; average monthly fuel consumed during academic session and average monthly fuel consumed during academic break. The total average monthly fuel consumed during academic break and academic sessions were 34860 liters and 45350 liters respectively. It was found that the University’s GHG emissions due to electricity usage amounted to 1352.2324tCO₂e. That is about 24.7% of the total GHGs emissions of the campus.

From the head count of vehicles done at the campus’ main entrance and the data obtained from questionnaires issued to residents of the campus, it was found that a total of 5,989,131 trips are made on the campus’ roads annually. The vehicles resident on the campus makes an approximate of 71 trips in 2022/2023 session while those who commute daily in and out of the campus make an approximate value of 5,989,060 trips in 2022/2023 session. The breakdown of the trips made by each category of vehicle is presented in Table 2 below.

Table 2. The Breakdown of the Trips Made by Each Category of Vehicle at NUN 2022/2023 session

Type of Vehicle	Number of Vehicle		Total	Percent age (%)
	Daily Commute	Resident on Campus		
Motorcycles	38,093	12	38105	0.64
Sedans	5,707,193	28	5707221	95.30
SUVs & Buses	216,998	16	217014	3.62
Tricycles	11,389	8	11397	0.19
Trucks	15,387	7	15394	0.26
Total	5,989,060	71	5989131	100

Type of Vehicle	Approx. Annual Traffic Vol. (000)	Emission (tCO ₂ e)
Motorcycles	38105	13.5498
Sedans	5707221	3344.4006
SUVs & Buses	217014	516.2886
Tricycles	11397	6.6578
Trucks	15394	44.8441

GHG emissions estimation done on transportation segment revealed that commuting within the campus was responsible for 3,925.7409tCO₂e, this represents 71% of all GHG emissions and making vehicles the highest sources of GHGs emission on the campus. When it is analyzed based on category of vehicle, it was discovered that the highest emission per number of vehicles was from the Sedan group with 3344.4006tCO₂e, while the least was from Tricycle with 6.6578tCO₂e. Single passenger per car is responsible for the largest share of Sedan emission rate where most student drive to school alone in their car. The estimated annual GHGs emission calculated for sedans, SUVs/buses, motorcycles, trucks and tricycles were 3344.4006tCO₂e, 516.2886tCO₂e, 13.5498tCO₂e, 44.8441tCO₂e and 6.6578tCO₂e respectively.

Data obtained from questionnaires issued out to campus residents showed that 3875 kg of LPG is being used monthly by resident of university quarters, restaurants, and university kitchen. The GHG emissions from burning of cooking fuels on the campus amounted to 147.2731tCO₂e that is approximately just about 2.7% of the campus’ total carbon footprint. Table 3 shows the different cooking fuels used at kitchen, restaurant and staff quarters on the campus and their corresponding carbon footprint.

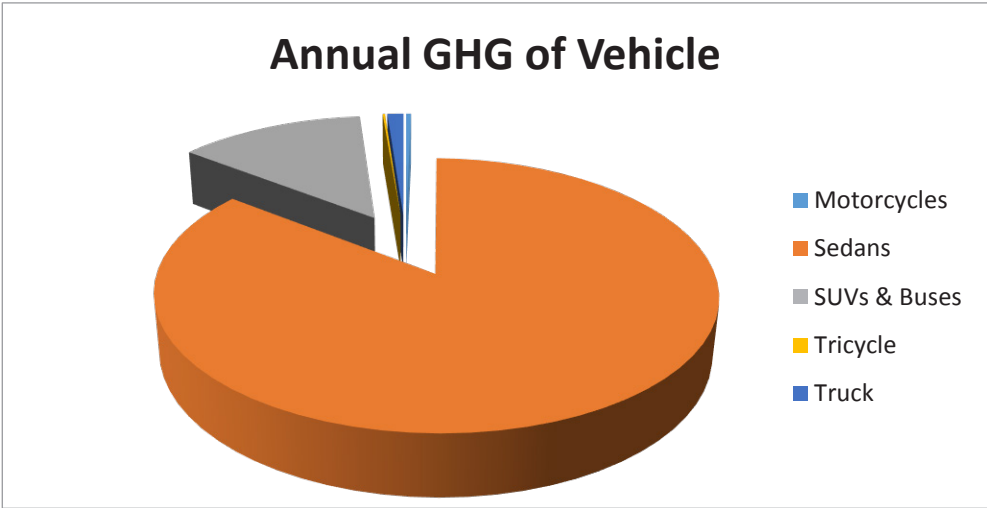


Fig.1. Graphic presentation of annual GHGs emission accrued to each category of vehicle at NUN 2022/2023.

Table 3. Summary of LPG Emission at Nile University of Nigeria 2022/2023 Session

Locations	Cooking Fuel	Carbon Footprint(tCO ₂ e)
Restaurant	LPG	5.090085
University Kitchen	LPG	133.020888
Staff quarters	LPG	4.2756714

The study revealed that the highest emission on University campus comes from the transportation segment, then onsite energy generation. Cooking fuels and gardening are the third and fourth largest sources of emissions on University campus respectively. Table 4 below presents a summary of direct GHG emission of NUN Campus.

Table 4. Summary of GHG Emission Pattern of Nile University of Nigeria 2022/2023 session

S/N	Source	Amount (tCO ₂ e)	Percentage (%)
1	Cooking fuels	147.2731	2.7
2	Electricity Generated on Campus	1352.2324	24.7
3	Transportation	3925.7409	71.8
4	Gardening	41.15	0.8
Total		5,466.3964	100

The total GHGs emission of NUN when compared to the total GHGs emission of other campuses outside the country was found that NUN emission is considerably less. For instance, research conducted in MIT provides that the campus’ calculated annual GHG emission to be 200,000tCO₂e (Groode & Heywood, 2004). In South Africa it was founded by (Letete et al., 2011) that the carbon footprint of the University of Cape Town (UCT) amounted to 83,400tCO₂e annually while in India, the carbon footprint of Rajiv Gandhi South Campus Banaras Hindu University (RGSU) was calculated to be 69,727tCO₂e (Sadhana et al., 2012). While juxtaposing the blanket gross carbon footprint of these campuses might not be a fair comparison, the per capita footprint is a better index for comparison. The estimated per capita footprint of NUN was ascertained to be 0.4555tCO₂e (455.53kgCO₂), while that of MIT, UCT and RGSCU were 17.7tCO₂e, 4tCO₂e and 53.7tCO₂e respectively. Figure 2 is a graphical comparison of the carbon footprint of the campuses.

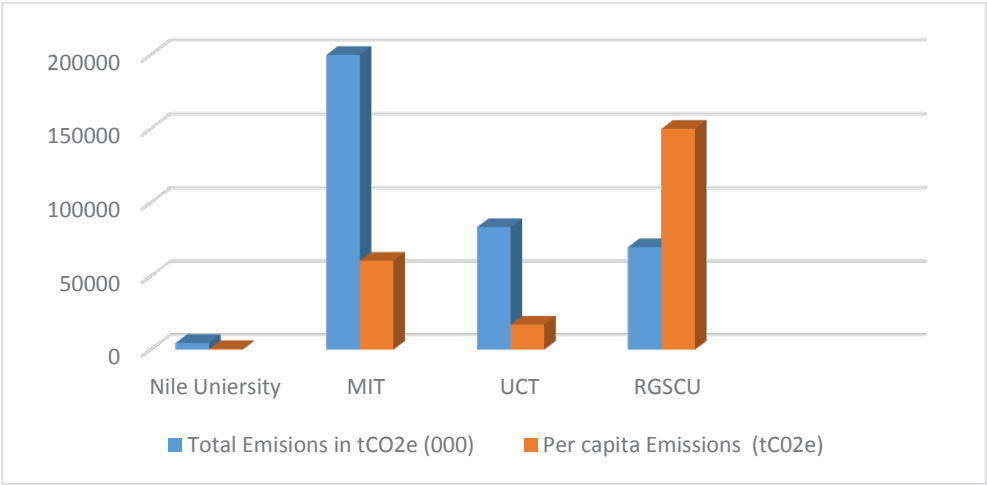


Fig. 2. Comparison of the Total and Per Capita Emissions for NUN and other Campuses

The higher GHG emissions marked by these foreign universities cannot be unconnected to the reason that these campuses are located in technological more inclined and more affluent nations than Nigeria subsequently their per capita fuel consumptions and consequent GHG emissions are naturally higher than that of NUN.

4. Conclusion

Greenhouse gas (GHG) accounting of a typical Nigerian University was done on its major emission sources base year 2022/2023, Nile University of Nigeria Abuja being the case study. After the assessment, it was found that the direct sources of GHG in NUN campus emits an estimated of 5,466.3964tCO₂e annually from electricity generated on campus, transportation segment, gardening and cooking fuels. It was found that emission from transportation segment is responsible for more than half (71.8%) of NUN direct carbon footprint, the next highest emitter was found to be from electricity generated on campus which was found to contribute 24.7% of the campus' emissions. Emissions from gardening and cooking fuels were responsible for only 0.8% and 2.7% of the University direct GHGs emission.

From the result obtained, it was observed that the high GHGs emission due to onsite power generation can be reduced by gradually replacing inefficient gadgets being used on the campus with energy efficient ones, this has the potential of reducing the campus' energy consumption by about 40%, consequently its carbon footprint too. Likewise, the campus can consider supplementing its energy needs with renewable energy sources.

To jack down on the emissions of GHGs due to commuting, efficient public mass transit should be made available by the University authority and its use should be encouraged by incentivizing it so as to reduce the number of personal vehicles. LPG can be used more efficiently by reducing unnecessary burning of it thereby making the emission due to cooking fuel to drop. Finally, the Campus can sequester the amount of CO₂ it emits into the atmosphere by planting more trees on the vast amount of unutilized land it has.

References

1. ASTM. (2004). Standard test method for gross calorific value of refuse-derived fuel by the bomb calorimeter. Annual Book of ASTM Standards ASTM International, 105.
2. Ayanlade, S., & Adeoye, N. O. (2010). Climate Change and Menace of Floods in Nigerian Cities : Socio-economic Implications. *Advances in Natural and Applied Sciences*, 3(3), 369–390.
3. Boykoff, M., Katzung, J., & Nacu-Schmidt, A. (2019). Media and Climate Change Observatory Monthly Summary: The Earth is facing a climate change deadline-Issue 26, February 2019.
4. Brander, M., Sood, A., Wylie, C., Haughton, A., Lovell, J., Reviewers, I., & Davis, G. (2011). Electricity-specific emission factors for grid electricity. *Ecometrica*.
5. Dodman, D. (2009). Blaming cities for climate change? An analysis of urban greenhouse gas emissions inventories. *Environment and Urbanization*, 21(1), 185–201.
6. Duan, A., Wu, G., Zhang, Q., & Liu, Y. (2006). New proofs of the recent climate warming over the Tibetan Plateau as a result of the increasing greenhouse gases emissions. *Chinese Science Bulletin*, 51(11), 1396–1400.
7. Groode, T. A., & Heywood, J. B. (2004). A Methodology for Assessing MIT 's Energy Use and Greenhouse Gas Emissions. Cambridge. Retrieved from <http://fee.mit.edu/publications/reports>
8. Hiller, A. (2011). Climate change and individual responsibility. *The Monist*, 94(3), 349–368.
9. IES. (2004). Integrated Environmental Strategies– Philippines Project Report/Metropolitan Manila: A Focus on the Transport Sector. Manila: Citeseer.
10. IPCC, 2023: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate

- Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, 184 pp., doi: 10.59327/IPCC/AR6-9789291691647.
10. IPCC. (2014). Climate Change 2014 Mitigation of Climate Change Working Group III Contribution to the Fifth Assessment Report of the Intergovernmental Panel on ClimateChange.
 11. IPCC. (2006). IPCC Guidelines for National Greenhouse Gas Inventories. New York: Cambridge University Press.
 12. Letete, T. C. M., Mungwe, N. W., Guma, M., &Marquard, A. (2011). 2011 - Carbon footprint of the University of Cape Town. *Journal of Energy in Southern Africa*, 22(2), 2–12.
 13. Mishelia, R. B., Jibatswen, T. Y., Babarinde, F., & Yusuf, R. (2021). Assessment of vehiculargreenhouse gas emissions and potentials for reduction in a university campus: Case studyofBayerouniversity Kano.
 14. *International Journal of Environment and Geoinformatics*
 15. ,8(3) 301-306. <http://doi.org/10.30897/ijegeo.837262>
 16. NASA (2019), <http://climate.nasa.gov/causes/>
 17. Roeckner, K. G., Hansen, J., Schnitzler, K. G., Strassmann, K., &Doney, S. (2007). *Climate Change and Trace Gases*. Phil Trans and Roy Publishers.
 18. Rossiello,M.R.,Anthony,S.(2019) Health Effects of Climate Change-induced Wildfires and Heatwaves,Cureusvol.11,5e4771. 28 May. 2019, doi:10.7759/cureus.4771Petr Havlík,HugoValin, Mario Herrero et al. (2014), Climate Change Mitigation through Livestock System Transitions.” *Proceedings of the National Academy of Sciences*10: 3709–3714.
 19. Sadhana, C., Vijai, K., Juli, K., Gandhi, M., &Gramodaya, C. (2012). Assessment Of Carbon Footprint Of Rajiv Gandhi South Campus Banaras Hindu University, Mirzapur, India. *Journal of Environmental Research And Development*, 7(2).
 20. Seo, Y.-K., Hong, W.-H., Na, W.-J., Ryu, J.-H., & Kim, Y.-C. (2018). Analysis of Energy and Greenhouse Gas Emissions Before and After Implementation of a Greenhouse Gas Emissions Trading Scheme in University Buildings. *International Journal of Pure and Applied Mathematics*, 120(6), 5109–5122.
 21. Sinha, P., Schew, W. A., Sawant, A., Kolwaite, K. J., & Sarah, A. (2012). Greenhouse Gas Emissions from U.S. Institutions of Higher Education. *Journal of the Air & Waste Management Association*, 60(5), 568–573. <https://doi.org/10.3155/1047-3289.60.5.568>
 22. Teah, H. S., Yang, Q., Onuki, M., &Teah, H. Y. (2019). Incorporating External Effects into Project Sustainability Assessments: The Case of a Green Campus Initiative Based on a Solar PV System. *Sustainability*, 11(20), 5786.
 23. Weitzman, M. L. (2012). GHG targets as insurance against catastrophic climate damages. *Journal of Public Economic Theory*, 14(2), 221–244.
 24. WRI. (2008). World Resources Institute Carbon Dioxide (CO₂) Inventory Report For Calendar Years 2006 & 2007. Washington, DC.