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Assessment of Carbon Footprint for Electricity Generation in Michael Okpara University of Agriculture, Umudike

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Research Article

Abstract

This work forecasts CO_2 emissions from hybrid energy consumption in the Michael Okpara University of Agriculture Umudike. By using primary consumption information from the university to establish carbon emission-based data from grid electricity and fossil energy use, the carbon emission from consumption of energy in MOUAU from January to July 2017 was found to be 705,505.01 kg, of where the carbon emission from fossil and grid electricity consumptions were 609,831.00 kg and 95,674.01 kg, with corresponding proportions of 86.43 % and 13.56 % respectively. The largest amount of carbon emission of 64,079.44 kg was from the Administrative Building with 56,808 kg generated and 7,217.44 kg from the grid. A backward propagation using Artificial Neural Network (ANN) was developed, trained for validation using the CO_2 emission data of MOUAU in predicting the local contribution to global emission data. The results obtained showed that an ANN application is efficient and useful in solving climate pollution problems.

Keywords

Carbon dioxide emissions; greenhouse gases, fossil energy, electricity generation.

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1. Introduction

Worldwide temperature fluctuation is brought about by the uncontrolled increment of ozone harming substances in the environment, for example, carbon dioxide, and it comes about because of the consumption of petroleum derivatives and deforestation (Maslin, 2008). It is one of the most controversial science issues of the 21st century challenging the very welfare of the global society. Some of the resulting major environmental problems include ozone layer depletion, waste accumulation, and rapid climate changes with time (IPCC, 2006, Hulme *et al.*, 2001). These necessitate needs to mitigate the problems arising from the rapidly changing life pattern to preserve the environment and hence the planet. Ozone-depleting substances are vaporous constituents of the air, both regular and anthropogenic, that ingest and produce radiation at explicit frequencies inside the range of warm infrared radiation transmitted by the Earth's surface, the climate itself, and the mists (Stocker et al., 2013). The most recent two centuries have seen a taking-off increment in air centralizations of greenhouse gases (GHGs) resulting from human activities of agriculture, industry, waste disposal, deforestation, and increased use of fossil fuel for electricity generation produces an increase in the amounts of GHGs, for instance, the concentrations of carbon dioxide (CO_2) increased from approximately 280 parts per million volume (ppmv) in pre-industrial age to 372 ppmv in 2001. This continuous increase by about 0.5% per year with the corresponding temperature rise has led to the melting of glaciers, increases sea levels, and submersion of low-lying areas (Kerr, 2007).

Environmental change because of an ascent in the volume of carbon dioxide in the climate was proposed by scientific expert Svante Arrhenius in 1896. Research in climatic change attracted attention on the observation of increasing carbon dioxide present in the atmosphere. Meanwhile human energy consumption and related CO_2 -emissions increased to 429.4 EJ (429.4×10^{18}J) by 2004 (Meadows, *et al.*, 1972). Carbon discharges from modern exercises have additionally become a worry for examination, for instance, Schipper et al. (2001) investigated the carbon outflow power of some assembling areas of known International Energy Agency nations, utilizing the factor deterioration technique and clarified the fundamental explanations behind development in carbon emanations since 1990 and made assessments joined with the objectives of the Kyoto Protocol. Chang and Lin (1998) considered the modern carbon emanation of Taiwan dependent on the info yield approach and decay model. Casler and Rose (1998) and Benyong *et al.* (2009) and Yu and Wang (2009) utilized this strategy to look at the carbon spillage and move in the investigation of carbon discharges typified in worldwide exchange. Generally, changing the industrial space pattern and narrowing the regional differences can have a positive impact on human economic and energy activities on regional carbon cycles.

Wiedmann and Minx, (2008) explained carbon impression as a measure of immediate or aberrant CO_2 discharges brought about by a movement or collection of an item in its life cycle. It is dependent on the idea of natural impression and explains the outflow of carbon during human exercises (Wiedmann and Minx, 2008; Ya-Yen et al., 2020). In this view, Weber and Matthews, (2008) used multiregional input-output models in presenting linkages between industries among regions in the United States. Five and a half percent of annual carbon impression in England was found to have been created on a Christmas day (Gary et al. 2008). Similarly, carbon impression in China for fifteen years was estimated to be double that increment in the same period (Qi et al., 2010). Another viewpoint considers carbon footprint as an ecological one, required for absorbing CO_2 emissions from fossil-fuel combustion (Wiedmann and Minx, 2008), measures in the area. Xie *et al.* (2008) investigated the ecological footprint created from energy consumption in China. As a proportion of the effect of human exercises on nature, carbon impression has become a new concentration in the field of biology. Carbon impression as a different class incorporates direct carbon outflows brought about by petroleum derivative burning and aberrant carbon discharges brought by imported products. The results showed that human ecological impact is a result of the development of carbon footprint. Schulz (2010) accepting Singapore as a contextual analysis and evaluated the immediate and circuitous ozone-depleting substance emanation impression of a little open financial framework, and proposed that backhanded weights of urban frameworks ought to be remembered for conversations of viable and reasonable alleviation procedures. Some Chinese researchers documented valuable carbon impression bookkeeping, impression per capita for items, and impact of carbon impression (Huang et al., 2017, Guo and Gifford, 2002; Lai and Huang, 2011). Carbon sink studies when carried out at a small scale give different results. The carbon cycle pressure and carbon footprint of Nanjing city were studied by Zhao *et al.* (2015). Carbon footprints of several districts in India were compared by Lee et al. (2021) using micro consumption data and considering the economic, cultural, and demographic factors. Their results showed that high households expenditure accounted for higher footprint generation and should be held responsible. It has also been observed from studies that carbon footprint homestays in Thailand were low annually due to small size and limited amenities for guests (Jarotwan and Filimonau, 2021). In general, results of research done on a regional scale are jettisoned for global average carbon sink value (Xie *et al.*, 2008), which does not represent the actual situation of various Chinese districts. The African mainland is expected to be affected by environmental factors such as debasement, and desertification (Hummel, 2016). Although with the least concentration of greenhouse gas generated due to low degree of modern turn of events, Africa is helpless against environmental impact and Nigeria is not an exception (Beg *et al.*, 2002).

This work researches carbon – dioxide emanation from different power generation frameworks in the Michael Okpara University of Agriculture, Umudike from an ecological perspective. The carbon emission from generators and grid electricity are studied and compared. Artificial neural network (ANN) built-in MATLAB software was utilized to anticipate the general carbon – dioxide discharge. This work will promote knowledge on the level of environmental degradation and the percentage of carbon emission pollution to global warming within the institution under study.

2. Materials and method

The study was carried out at the Michael Okpara University of Agriculture, Umudike, located in the well-known Agricultural Training and Research community of Umudike in Abia State, South East, Nigeria. The area lies between longitude $\mathbf{7°}$ and $\mathbf{7°\,05'}$ East and latitude $\mathbf{5°\,25'}$ and 6° North, bounded by National Root Crop Research Institute Umudike to the left and Umuahia – Ikot Ekpene Highway to the front (See plate 1).

Plate 1: Area view of Michael Okpara University of Agriculture, Umudike

The source of energy in Michael Okpara University of Agriculture, Umudike is fossil fuel which includes Premium Motor Spirit (PMS), Automotive Gas Oil (AGO), and Grid Electricity. This work computes the carbon emissions from major traditional high-carbon energy sources, covering PMS, AGO, and Grid Electricity. The data used for this study was obtained from various departments, including the Works Department, respective colleges, and offices of Michael Okpara University of Agriculture, Umudike. The carbon emission was estimated from these sources and by a matching relationship between the emission sources and electricity generation sources, those from administrative buildings, colleges, hostels, and commercial centres were obtained.

2.1 Computation of carbon emissions

The sources of carbon emission in Michael Okpara University of Agriculture, Umudike include:

a.) Emissions from power production
b.) Emissions from the imported power (national grid)
c.) Emissions in the exported power

These emissions can be summed up as expressed in equation (1):

$$C_c = C_g + C_{imp} - C_{exp} \quad (1)$$

Where C_c is the CO_2 from power consumption
C_g is the emissions from MOUAU power production.
C_{imp} is emission from imported electricity. This is given as:

$$C_{imp} = \sum_i \left(E_{imp,i} \times F_i\right) + \sum_j \left(E_{imp,j} \times F_j\right) + \left(E_{imp,k} \times F_k\right) \quad (2)$$

Where,
i, j, k = indices representing the respective power sources
E_{imp} = imported power

Also, F_i is carbon emissions per unit power of external source *i* while F_j and F_k are the emission factors of external source *j* and *k* respectively.
C_{exp} is the emission from exported electricity and is given by:

$$C_{exp} = \left(\sum_i E_{exp,i} + \sum_j E_{exp,j} + +E_{exp,k}\right) \times F_g \quad (2)$$

Where
$E_{exp,i}$, $E_{exp,j}$ and $E_{exp,k}$ represent power to sources i, j, and k respectively. F_g is the emissions factor for MOUAU. Energy from national or energy exported to grid is given by:

$$E_{imp,k} = max\left(\left(E_c - E_g - E_{imp,i} - E_{imp,j}\right), 0\right) \quad (4)$$

$$E_{exp,k} = -min\left(\left(E_c - E_g - E_{imp,i} - E_{imp,j}\right), 0\right) \quad (5)$$

Where,
E_c is the power consumption in MOUAU and E_g is the power generated from MOUAU. Carbon dioxide emission (CO_2) from imported electricity and generated electricity from petrol and diesel-fired engines are given by equations **Error! Reference source not found.** and **Error! Reference source not found.** respectively.

$$Electricity\ CO_2(kg)\ Emission = E_{used}(kWh) \times EF(kg\ \ CO_2/kWh) \quad (6)$$

$$Fuel\ Use\ CO_2(kg)\ Emission = Fuel\ Used\ (l)\ x\ Fuel\ Type\ EF\ (kg\ \ CO_2/l) \quad (7)$$

2.1.1 Prediction of Carbon Emissions using Artificial Neural Network

The problem of predicting the carbon emission of Michael Okpara University of Agriculture, Umudike has been modeled as a supervised regression problem. It is supervised because the problem has an output and is a regression because the carbon emission is being predicted as a continuous output.

The data was distributed into three sets of the training set, the validation set, and the testing set. The basic adjustment of weight strength takes place in the training phase of the network that makes use of 70% of the data. 15% was used for validation and 15% for testing the network generalization. For a more optimal result and to also avoid complexities, six neutrons were used in the hidden layer since three input variables were identified. The performance of the ANN model was determined using the root mean square error (RMSE) and coefficient of determination (R^2) as given in Equations 8 and 9 respectively:

$$RMSE = \sqrt{\frac{\sum_{j=1}^{N}\left(Y_j, pred - Y_j, expt\right)^2}{N}} \quad (8)$$

$$R^2 = 1 - \frac{\sum_{j=1}^{N}\left(Y_j, pred - Y_j, expt\right)^2}{\sum_{j=1}^{N}\left(Y_j, expt - \bar{Y}\right)} \quad (9)$$

Where; $\bar{Y}$ average of experimental data, $Y_j, expt$ is the experimental output data for input j, $Y_{j,}pred$ is the predictive data of the response for the *j*th trail by the ANN model and N is the number of data.

The coefficient of determination (R^2) indicates how well data fits into the statistical model such as a regression line or curve. The model is said to be accurate when R^2 approaches 1.0.

3. Results and discussion

The result of carbon dioxide emission of the various buildings and clusters in MOUAU for seven months (January - July 2017) is presented in Table 1

Table 1: Energy consumption and carbon – dioxide emission of various buildings and clusters in MOUAU (January – July 2017)

	Total kWh /120days	**Generator Contribution (%)**	**Generator Contribution (kWh/120days)**	**Generated Electricity Carbon Emission CO_2 (kg)**	**Grid Electricity Contribution (kWh/120days)**	**Grid Electricity Carbon Emission CO_2 (kg)**	**Combined CO_2 Emission**	**%Grid CO_2 Contribution**	**%Generated CO_2 Contribution**
Admin Block	150,362.26	89.00%	133,822.41	56,808.00	16,539.85	7,271.44	64,079.44	10.19	89.81
Library, Medical, CASAP, ICT, & Security	397,012.48	89.00%	353,341.11	219,071.48	43,671.37	19,199.31	238,270.79	7.46	92.54
COLPAS	35,025.53	69.00%	24,167.61	14,983.92	10,857.91	4,773.48	19,757.40	19.46	80.54
Works Department	23,369.90	30.00%	7,010.97	4,346.80	16,358.93	7,191.90	11,538.70	38.40	61.60
CAERSE	11,340.84	40.00%	4,536.34	2,812.52	6,804.50	2,991.47	5,803.99	34.01	65.99
CAFST	40,510.54	89.00%	36,054.38	22,353.71	4,456.16	1,959.07	24,312.78	7.46	92.54
CEET	38,738.89	65.00%	25,180.28	15,611.77	13,558.61	5,960.79	21,572.56	21.65	78.35
COLNAS	22,888.32	73.00%	16,708.47	10,359.25	6,179.85	2,716.85	13,076.10	17.20	82.80
CCSS	19,181.83	63.00%	12,084.55	7,492.42	7,097.28	3,120.19	10,612.61	22.72	77.28
CVM	15,999.40	50.00%	7,999.70	4,959.81	7,999.70	3,516.92	8,476.73	29.32	70.68
COLMAS	14,524.53	79.00%	11,474.38	7,114.11	3,050.15	1,340.94	8,455.05	13.69	86.31
COED	6,812.04	41.00%	2,792.94	1,731.62	4,019.10	1,766.92	3,498.54	33.56	66.44
Entrepreneur	39,244.32	53.00%	20,799.49	12,895.68	18,444.83	8,108.93	21,004.61	27.85	72.15
CNREM	19,865.90	74.00%	14,700.77	9,144.48	5,165.13	2,270.75	11,415.23	16.59	83.41
School Hostels	235,658.96	83.00%	195,596.94	171,031.99	40,062.02	17,612.52	188,644.51	8.54	91.46
Computer Village	79,306.92	86.00%	68,203.95	42,286.45	11,102.97	4,881.21	47,167.66	9.38	90.62
Research Computer Cluster	13,266.60	83.00%	11,011.28	6,826.99	2,255.32	991.51	7,818.50	11.25	88.75
Total	**1,163,109.26**	**81.28952598**	**945,486.00**	**609,831.00**	**217,623.26**	**95,674.01**	**705,505.01**	**11.94**	**88.06**

The result shows that a total of 1163109.26 KWh/120days energy was consumed. The use of generators contribute 81.29% (945,486.00 KWh/120days) of the energy utilization while grid electricity contributes 18.71% (217,623.26 KWh/120days). Carbon emission from generators ranges between 1731.62 Kg $\leq$GCE $\leq$ 219,071.48 Kg. The highest emission is attributed to that due to the combination of the library, medicals, CASAP, ICT, and security while the college of education contributes the least (1731.62 Kg). Students' hostel contributed 171,031.99 Kg of emission. This could be due to the running of the generators most evenings as a result of power failure. Also, carbon dioxide emission from grid electricity ranges from 991.51 Kg $\leq$ GECE $\leq$ 19,199.31 Kg. The school hostels and most colleges recorded low carbon emissions from grid supply. This is a result of epileptic supply from the grid in the institution. It was observed that 88.06% of the entire carbon emission is attributed to the frequent use of the generators while 11.94% is allotted to grid electricity supply. The overall carbon dioxide emission was found to be 705,505.01Kg.

The main contributor to carbon dioxide emission in MOUAU is fossil fuel (Table 1) and the major sources are premium motor spirit and automotive gas oil. Figure 1 presents the comparison of the monthly carbon dioxide emission from the premium motor spirit and the automotive gas oil consumption in MOUAU.

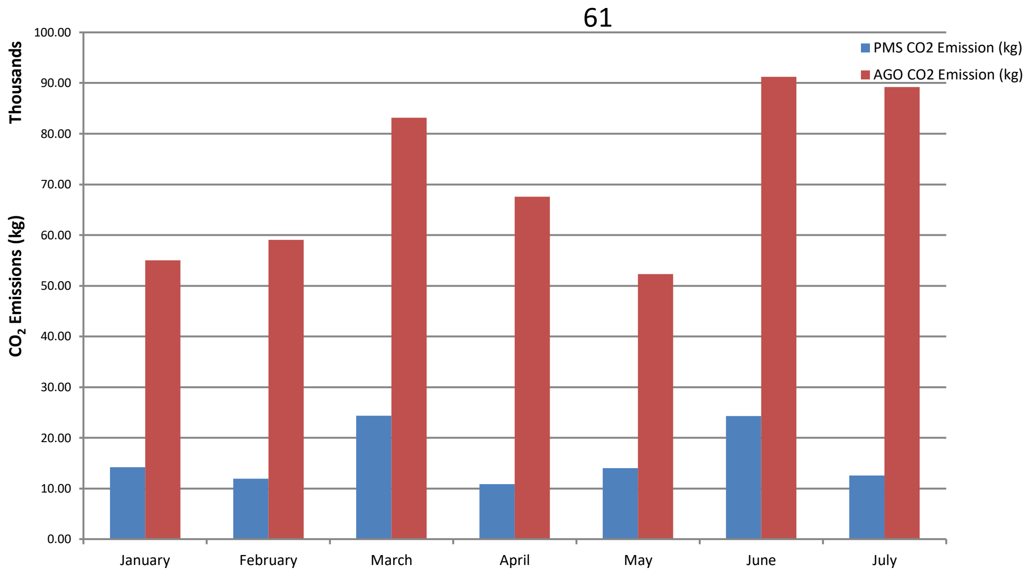

Figure 1: Comparing CO_2 Emission from PMS and AGO consumption in MOUAU

The total carbon emission by the premium motor spirit and the automotive gas oil are 112,287.60Kg and 497,543.40Kg respectively. The emission from premium motor spirit was high in March and June and relatively stable in other months. Also, the highest emission from automotive gas oil was in June, almost the same in March and July, and relatively stable for other months. The months of March and June must have recorded higher emissions probably because of final year students' seminar and project defense that usually falls within these months respectively.

CARBON EMISSION PREDICTIONS FROM ARTIFICIAL NEURAL NETWORK

Table 1: CO_2 Emission for January to August, 2017 in MOUAU

Month	PMS Consumption (litres)	AGO Consumption (litres)	Grid Electricity Consumption (kWh)	Combined CO_2 Emission (kg)	Predicted CO_2 Emission (kg)
January	6,397.00	20,912.00	28,687.00	81,811.60	81,941.60
February	5,391.00	22,450.00	29,735.00	84,083.96	85,607.65
March	10,982.00	31,620.00	32,224.00	121,707.32	120,710.38
April	4,902.00	25,695.00	34,985.00	93,840.79	93,270.95
May	6,308.00	19,890.00	32,794.00	80,731.73	81,339.14
June	10,945.00	34,683.00	26,037.00	126,960.87	126,589.47
July	5,655.00	33,930.00	33,162.00	116,369.06	116,260.99

The neural network prediction of the carbon dioxide emission is shown in Table 2. The RMSE = 772.35 is not very small compared to the mean of the field data. The plot of the ANN-predicted data and the field survey data of the carbon emission demonstrated the goodness of the proposed ANN with R^2 = 0.9983.

4. Conclusion

The carbon – dioxide footprint sources of power supply in MOUAU were assessed. The main sources of energy in the institution were identified to be fossil and grid electricity supply. The result shows that the use of generators constitutes 81.29% of the energy utilization while 18.71% attributed to the grid supply. On average, the overall carbon dioxide emission was 705,505.01Kg of which 88.06% is due to the usage of generators and 11.94% of grid electricity supply. The reason is attributed to the poor supply of electricity from the grid in the campus. The research suggests an improvement in the supply from grid and adherence to the statutory maintenance procedure of the available generators in use. This will reduce the rate of pollution to the environment by the emitted carbons thereby making the environment friendly, habitable, and conducive for learning.

Nomenclature

CAERSE: College of Agricultural Economics, Rural Sociology, and Extension
CAFST: College of Food and Science Technology
CASAP: College of Animal Science and Animal Production

CCSS:	College of Crops and Soil Sciences
COED:	College of Education
CEET:	College of Engineering and Engineering Technology
CNREM:	College of Natural Resources and Environmental Management
COLMAS:	College of Management Sciences
COLNAS:	College of Natural and Applied Sciences
COLPAS:	College of Physical and Applied Sciences
CVM:	College of Veterinary Medicine
ICT:	Information Technology & Communication

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