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Article

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Sectoral Contributions to Carbon Dioxide Equivalent Emissions in the Nigerian Economy

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ABSTRACT

In line with the Intergovernmental Panel on Climate Change (IPCC), we estimate the percentage carbon dioxide equivalent (CO_2-eq) emissions by sector in Nigeria. In terms of its emissions, the percentage contribution of carbon dioxide, CH_4 and N_2O to each sector were considered using the 2006 IPCC emission calculation default taking 2012 as the base year projected to 2027. Results revealed that, fugitive emissions from oil and gas accounted for the highest contribution to CO_2-eq emissions with about 75.27% when compared to other sectors. This is due to increased gas flaring employed to dispose of associated gas in major petroleum/oil producing areas in the country. This sector pollutes because of their technology, the remaining sectors were identified as important sectors because of the weight they have on the economy. The study suggests the need for Nigerian government to ensure the security of fuel source for power generation by mandating oil companies to channel their flared gases to power plant.

Keywords: Intergovernmental Panel on Climate Change Sector Contributions, Anthropogenic Gases, Carbon Dioxide Equivalent Emissions, Projections, Nigeria

JEL Classifications: C67, Q40, Q43, Q56

1. INTRODUCTION

From available literature, the increase in population couple with higher living standards which invariably triples the demand for sectors which uses more energy like electricity, transport, petroleum etc., are responsible for the persistent increase in the emission of greenhouse gases (GHGs) in Nigeria (Federal Republic of Nigeria, 2014).

As part of measures towards mitigating these global carbon emissions, the federal government was among the other countries who ratified the Paris agreement geared towards ensuring a rapid and climate smart development. Similarly, the Kyoto protocol to the United Nations Framework Convention on Climate Change (UNFCCC) founded in Japan geared towards the stabilization of GHG concentrations in the atmosphere was revalidated with actions in 2005, with 192 parties to this protocol who ratified it as of June 2013 (Sulaiman et al., 2014). In addition, Nigeria has been registered as a member country of the United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation (UN-REDD), Clean Development Mechanism (CDM) projects, Clean Technology Fund (CTF) of which the World Bank is the trustee (Henrich, 2012b) and the Global Energy Efficiency and Renewable Energy Fund (GEEREF) of the European Union (Gereef, 2012), United States Trade and Development Agency (USTDA), Nigerian Electricity Regulatory Commission (NERC). These amongst other projects were geared towards cutting emissions, not only in the Niger Delta (Ogoniland), but also tackle the problem of drought and desertification in the northern areas. Despite all these measures, GHG emission is still high due to inadequate commitment towards sectoral contributions and their projections.

Several energy related studies using input-output analysis linked to key sectors applications have been developed for emissions in Mexico (Chatellier-Lorentzen and Sheinbaum-Pardo, 2017), Beijing (Lixiao et al., 2014), Brazil (Imori and Guilhoto, 2010), China (Lin and Xie, 2016), Uruguay (Piaggio et al., 2014) and Spain (Alcántara and Padilla, 2006) but dearth is evident in Nigeria, even when she is known to be one of the largest emitter of GHG in Africa (World Resources Institute, 2010). This study employed the Intergovernmental Panel on Climate Change (IPCC) methodology for computing GHG emissions with emphasis on determining sectoral contributions to carbon dioxide equivalent (CO_2-eq) emissions in Nigeria (Intergovernmental Panel on Climate Change (IPCC), 2006).

2. METHODOLOGY

2.1. Data Sources

The study adopted secondary data for its analyses. The contribution of each anthropogenic gases (taking into consideration carbon dioxide [CO_2], CH_4 and N_2O) were calculated based on 2006 IPCC default taking 2012 as the base year projected to 2027.

Table 1: IPCC emission sectors description

IPCC	IPCC description
1A1a	Public electricity and heat production
1A1bc	Other energy industries
1A2	Manufacturing industries and construction
1A3b	Road transportation
1A3c	Rail transportation
1A3d	Inland navigation
1A3e	Other transportation
1A4	Residential and other sectors
1B1	Fugitive emissions from solid fuels
1B2	Fugitive emissions from oil and gas
2A1	Cement production
2A7	Production of other minerals
2B	Production of chemicals
2C	Production of metals
2G	Non-energy use of lubricants/waxes (CO_2)
3A	Solvent and other product use: Paint
3D	Solvent and other product use: Other
4A	Enteric fermentation
4B	Manure management
4C	Rice cultivation
4D1	Direct soil emissions
4D2	Manure in pasture/range/paddock
4D3	Indirect N_2O from agriculture
4D4	Other direct soil emissions
4F	Agricultural waste burning
6A	Solid waste disposal on land
6B	Wastewater handling
6C	Waste incineration
7B	Indirect N_2O from non-agricultural NOx
7C	Indirect N_2O from non-agricultural NH3

Source: Adapted from IPCC methodology guidelines, 2006. IPCC: Intergovernmental Panel on Climate Change, CO_2: Carbon dioxide

2.2. Data Analysis

The data for this study was calculated based on the 2006 IPCC for national GHG inventories, as presented in Table 1.

2.3. Model Specification

In line with the IPCC emission sectors description, thirty (30) sectors were identified as emission driven sectors in Nigeria from where their emission levels were calculated. The general approach in the estimation of GHG emissions level for CO_2, CH_4 and N_2O were based on 2006 IPCC guidelines, Vol. 4, Ch. 10 and 11, whose formula is presented as:

$$EL = AD * EF \text{ OR } EL = EF_T \times \frac{N_T}{10^6}$$

Where,

EL =GHG emissions level (Gg CH_4/year; Gg CO_2/year; Gg N_2O/year),

AD =Activity data (number of livestock in heads; harvested area in m^{-2}; hectares planted; volumes of fuel used),

EF =Tier 1, default IPCC emission factors, expressed in units of kg/head/metric tons of carbon-dioxide equivalent ($MtCO_2$-eq) per unit of activity/year (Vol. 3, Ch. 4, 4.4),

EF_T = Emission factor for category T animals, kg/head (Table 1a),

N_T = Number of heads for animal in category T,

T = Animal category.

3. RESULTS AND DISCUSSIONS

Estimates of percentage CO_2-eq emissions was calculated based on the 2006 IPCC methodology guidelines. Based on available information adopted from the IPCC, the CO_2, CH_4 and N_2O emissions was calculated for 2012, taking 2012 has the base year projected to 2027 (15 years).

As presented in Table 2a and b, about 15 sectors subsumed into the energy and industrial processess were identified to contribute to CO_2 emissions in the country. Total CO_2 emissions of 416,035 Gg accounting for the highest contributions was emitted from the road transportation sector followed by fugitive emissions from oil/gas sector with a total emissions of 374,347 Gg. The link between CO_2 emissions and transportation arises as a result of emissions by the various modes of transportation which contribute to global warming and climate change. According to IEA (2014)

Table 1a: NB: Refer to 2006 IPCC Guidelines for National Greenhouse Gas Inventories as follows

Default emission factor for CO_2, CH_4 and N_2O emissions for various types of burning, agricultural residues etc.	Volume 4, Table 2.5	Page 2.47
Other default values for all CO_2 emissions in each sector	Volume 4, Table 4.7	Pages 4.53-4.54
Default emission factor for direct N_2O emissions from manure management	Volume 4, Table 10.21	Pages 10.62-10.64
Other default values for all CH_4 and N_2O emissions in each sector	Volume 4, Table 7.6 and 10.19	Pages 7.16 and 10.59
Default values for indirect N_2O from non-agricultural NOx and NH_3	Volume 4, Table 10.22 and 10.23	Pages 10.65 and 10.67
Default emission factors to estimate direct soil emissions	Volume 4, Table 11.1 and 11.2	Pages 11.11 and 11.17-11.18

The activity data for emissions in the agricultural sector were taken directly from FAOSTAT (Domain: Production/Live animals). IPCC: Intergovernmental Panel on Climate Change, CO_2: Carbon dioxide

Table 2a: Sectoral contributions from CO_2 emissions (Gg)

Year	Public electricity and heat production	Other energy industries	Manufacturing industries and construction	Road transportation	Rail transportation	Residential and other sectors	Inland navigation
2012	11770.3023	7599.8033	6081.13	25381.12	22.4523	6901.2194	22.4523
2013	12480.15542	9053.232646	8676.33	25373.63	20.44748163	6955.073151	20.44748163
2014	13088.97962	10383.45673	10761.62	25469.35	18.72799643	7001.262238	18.72799643
2015	13697.80383	11713.68081	12846.90	25565.06	17.00851123	7047.451324	17.00851123
2016	14306.62803	13043.90489	14932.19	25660.78	15.28902603	7093.640411	15.28902603
2017	14915.45223	14374.12898	17017.47	25756.49	13.56954083	7139.829497	13.56954083
2018	15524.27643	15704.35306	19102.76	25852.21	11.85005562	7186.018583	11.85005562
2019	16133.10063	17034.57714	21188.04	25947.92	10.13057042	7232.20767	10.13057042
2020	16741.92483	18364.80123	23273.33	26043.64	8.41108522	7278.396756	8.41108522
2021	17350.74903	19695.02531	25358.61	26139.35	6.691600018	7324.585843	6.691600018
2022	17959.57324	21025.24939	27443.90	26235.07	4.972114816	7370.774929	4.972114816
2023	18568.39744	22355.47347	29529.18	26330.79	3.252629615	7416.964015	3.252629615
2024	19177.22164	23685.69756	31614.47	26426.50	1.533144413	7463.153102	1.533144413
2025	19786.04584	25015.92164	33699.75	26522.22	−0.186340789	7509.342188	−0.186340789
2026	20394.87004	26346.14572	35785.03	26617.93	−1.905825991	7555.531275	−1.905825991
2027	21003.69424	27676.36981	37870.32	26713.65	−3.625311193	7601.720361	−3.625311193
Total emissions	262899.1748	283071.8217	355181.04	416035.71	148.6185783	116077.1707	148.6185783

Source: Author's computation from IPCC, 2019. IPCC: Intergovernmental Panel on Climate Change, CO_2: Carbon dioxide

Table 2b: Sectoral contributions from CO_2 emissions (Gg)

Year	Fugitive emissions from oil and gas	Cement production	Production of other minerals	Production of chemicals	Production of metals	Non-energy use of lubricants/ Waxes (CO_2)	Solvents and other products use: Paints	Other direct soil emissions
2012	28425.73831	5805.6	8.412	683.94	41.6	6.174	112.712	286
2013	27765.82326	6609.862134	8.631580423	706.44	42.9593696	−4.314629825	114.8083708	147.5875374
2014	27093.77404	7481.036027	8.851711579	728.94	46.0380992	−13.31047906	116.9048312	51.90484231
2015	26421.72482	8352.209921	9.071842734	751.44	49.1168288	−22.3063283	119.0012915	−43.77785276
2016	25749.6756	9223.383814	9.29197389	773.94	52.1955584	−31.30217753	121.0977519	−139.4605478
2017	25077.62639	10094.55771	9.512105045	796.44	55.274288	−40.29802677	123.1942122	−235.1432429
2018	24405.57717	10965.7316	9.732236201	818.94	58.3530176	−49.293876	125.2906726	−330.825938
2019	23733.52795	11836.9055	9.952367357	841.44	61.4317472	−58.28972524	127.3871329	−426.508633
2020	23061.47873	12708.07939	10.17249851	863.94	64.5104768	−67.28557447	129.4835933	−522.1913281
2021	22389.42952	13579.25328	10.39262967	886.44	67.5892064	−76.28142371	131.5800536	−617.8740232
2022	21717.3803	14450.42718	10.61276082	908.94	70.667936	−85.27727294	133.676514	−713.5567182
2023	21045.33108	15321.60107	10.83289198	931.44	73.7466656	−94.27312218	135.7729743	−809.2394133
2024	20373.28186	16192.77496	11.05302313	953.94	76.8253952	−103.2689714	137.8694347	−904.9221084
2025	19701.23265	17063.94886	11.27315429	976.44	79.9041248	−112.2648206	139.965895	−1000.604803
2026	19029.18343	17935.12275	11.49328545	998.94	82.9828544	−121.2606699	142.0623554	−1096.287499
2027	18357.13421	18806.29664	11.7134166	1021.44	86.061584	−130.2565191	144.1588157	−1191.970194
Total	374347.9193	196426.7908	160.9994777	13643.04	1009.257152	−1003.109617	2054.965899	−7546.869922

Source: Author's computation from IPCC, 2019. IPCC: Intergovernmental Panel on Climate Change, CO_2: Carbon dioxide

the global CO_2 emissions from the transportation sector are projected to increase by 140% from 2000 to 2050, with the biggest increase in developing countries such as Nigeria. In the study, the road transport sector contributes about 20.67% to total CO_2 emissions caused by anthropogenic activities. With rapidly increasing urban growth and corresponding increases in vehicle ownership and transport use, large (urban) cities in Nigeria like Lagos, Port-Harcourt, Ibadan amongst others are faced with negative environmental impact (pollution) from transportation which not only imposes serious health effect but leads to climate change (Chukwu et al., 2015).

The study carried out by Maceij et al., (2017), revealed that road transport influences air quality in Nigeria. This applies to the cities (especially the thickly populated cities) where there is a large movement of cars, which are often old and do not meet current environmental standards. The noise and carbon-monoxide emissions from the road transportation sector create direct and harmful effects on the environment, along with indirect impacts. According to Onokala (2015), the road transportation contributes significantly to the socio-economic development in Nigeria as it creates new lands for agricultural, industrial and residential development. However, despite the fact that roads changed the orientation of the interior areas of the country from the waterways and the railways to the road network, and its flexibility creates openness/accessibility to the interior parts of the country, as well as employment opportunities to drivers, mechanics thus raising economic standards, its resultant effects in the emission of GHGs cannot be overemphasized.

In a similar study carried out by Daramola (2018), his study revealed that the transport sector is responsible for 23% of energy related CO_2 emissions and 13% of GHGs globally. However, Onokala and Ali (2010) examined the potential contribution of sustainable urban transportation in the reduction of GHG emissions in Nigeria and recommended the use of the methods of Sustainable Transport defined as all forms of transport which minimize fuel consumptions and emissions of CO_2 and pollutants. These methods can reduce traffic congestion and volume of vehicles on the roads.

Similarly, the unsafe practices and non-maintenance of refineries with the oilfields in the Niger Delta Anomohanran (2012) connected for the transportation of petroleum products from the refineries to the NNPC pumping stations and depots across Nigeria has led to about 18.59% contributions from fugitive emissions from oil and gas sector to CO_2 emissions, thus, suggests the need for existing pipelines to be put back into use and also expanded to other neighboring countries so that Nigeria not only supply petroleum products to them and earn some foreign exchange, but also tankers would no longer be used for long distance transportation of petroleum products in the country. Also, in the study, rail transportation and inland navigation were identified to have one of the least contributions to CO_2 emissions. This suggests that effective mitigation options through the construction of an entirely new railway network across the 36 states of the federation and the development of navigation aids for transportation in riverine communities so that such rivers can function efficiently as waterways for transportation in the country is vital.

Table 3a: Sectoral contributions from methane (CH_4) emissions (Gg)

Year	Public electricity and heat production	Other energy industries	Manufacturing industries/ construction	Road transportation	Rail transportation	Inland navigation	Residential and other sectors	Fugitive emissions from solid fuels
2012	0.493165695	0.37584091	9.398592	7.89711954	0.00125745	0.002121	1068.664125	382.746116
2013	0.519399058	0.450101897	10.35321545	7.802421984	0.001145169	0.001931611	1085.409801	428.5174799
2014	0.541898791	0.518267163	11.30744005	7.766025561	0.001048869	0.001769176	1099.77217	474.8845851
2015	0.564398524	0.586432428	12.26166465	7.729629139	0.000952568	0.001606742	1114.13454	521.2516904
2016	0.586898258	0.654597693	13.21588925	7.693232716	0.000856268	0.001444307	1128.496909	567.6187956
2017	0.609397991	0.722762959	14.17011385	7.656836294	0.000759968	0.001281873	1142.859279	613.9859009
2018	0.631897725	0.790928224	15.12433845	7.620439871	0.000663667	0.001119438	1157.221648	660.3530062
2019	0.654397458	0.859093489	16.07856305	7.584043449	0.000567367	0.000957004	1171.584017	706.7201114
2020	0.676897192	0.927258754	17.03278765	7.547647026	0.000471066	0.000794569	1185.946387	753.0872167
2021	0.699396925	0.99542402	17.98701225	7.511250604	0.000374766	0.000632135	1200.308756	799.4543219
2022	0.721896658	1.063589285	18.94123684	7.474854181	0.000278465	0.0004697	1214.671126	845.8214272
2023	0.744396392	1.13175455	19.89546144	7.438457759	0.000182165	0.000307266	1229.033495	892.1885325
2024	0.766896125	1.199919815	20.84968604	7.402061336	8.58644E-05	0.000144831	1243.395864	938.5556377
2025	0.789395859	1.268085081	21.80391064	7.365664914	−1.04361E-05	−1.7603E-05	1257.758234	984.922743
2026	0.811895592	1.336250346	22.75813524	7.329268491	−0.000106737	−0.000180038	1272.120603	1031.289848
2027	0.834395326	1.404415611	23.71235984	7.292872069	−0.000203037	−0.000342472	1286.482973	1077.656954
Total emissions	10.64662357	14.28472222	264.8904067	121.11	0.008323443	0.014039542	18857.85993	11679.05437

Source: Author's computation from IPCC, 2019. IPCC: Intergovernmental Panel on Climate Change

Table 3b: Sectoral contributions from methane (CH_4) emissions (Gg)

Year	Fugitive emissions from oil and gas	Production of chemicals	Enteric fermentation	Manure management	Rice cultivation	Agricultural waste burning	Solid waste disposal on land	Waste water handling	Waste incineration
2012	3120.43516	0.09642	1152.2235	54.6404916	321.227	29.600813	295.956	801.916968	6.7688
2013	3120.169124	0.09972	1222.949382	57.23268048	336.9648295	31.12446307	311.0455604	821.472102	6.721683881
2014	3116.101867	0.10302	1285.83975	59.57406349	352.258491	32.65342407	326.1978057	841.5736335	6.63034439
2015	3112.034609	0.10632	1348.730117	61.9154465	367.5521526	34.18238508	341.3500511	861.6751649	6.539004899
2016	3107.967352	0.10962	1411.620485	64.25682951	382.8458141	35.71134609	356.5022964	881.7766964	6.447665408
2017	3103.900094	0.11292	1474.510852	66.59821253	398.1394756	37.24030709	371.6545418	901.8782279	6.356325917
2018	3099.832837	0.11622	1537.40122	68.93959554	413.4331371	38.7692681	386.8067871	921.9797593	6.264986426
2019	3095.765579	0.11952	1600.291587	71.28097855	428.7267986	40.29822911	401.9590325	942.0812908	6.173646936
2020	3091.698322	0.12282	1663.181955	73.62236156	444.0204602	41.82719011	417.1112778	962.1828223	6.082307445
2021	3087.631064	0.12612	1726.072322	75.96374457	459.3141217	43.35615112	432.2635232	982.2843537	5.990967954
2022	3083.563807	0.12942	1788.96269	78.30512759	474.6077832	44.88511213	447.4157685	1002.385885	5.899628463
2023	3079.496549	0.13272	1851.853057	80.6465106	489.9014447	46.41407314	462.5680139	1022.487417	5.808288972
2024	3075.429292	0.13602	1914.743425	82.98789361	505.1951062	47.94303414	477.7202592	1042.588948	5.716949481
2025	3071.362034	0.13932	1977.633792	85.32927662	520.4887678	49.47199515	492.8725046	1062.69048	5.62560999
2026	3067.294777	0.14262	2040.52416	87.67065963	535.7824293	51.00095616	508.0247499	1082.792011	5.534270499
2027	3063.227519	0.14592	2103.414527	90.01204265	551.0760908	52.52991716	523.1769953	1102.893543	5.442931008
Total emissions	49495.90999	1.93872	26099.95282	1158.975915	6981.533902	657.0086647	6552.625167	15234.6593	98.00341167

Source: Author's computation from IPCC, 2019. IPCC: Intergovernmental Panel on Climate Change

As presented in Table 3a and b, the fugitive emissions from oil and gas accounted for the highest (49,495 Gg) methane emissions followed by enteric fermentation from the agricultural sector the when compared to other sectors. This could be as a result of CO_2 from liming and urea application, burning of agricultural residues and savanna for land clearing. However, the use of compost has been known to mitigate these emissions. Compost and related products are obtained from recycled organic materials comprising garden and food organics, crop residues, biosolids and manures.

However, the Environmental Protection Agency (2012), identified domesticated ruminant livestock, like cattle, sheep and goats as the greatest agricultural source of methane. From the report, methane was identified to be produced by bacteria in the animal's digestive system that break down fibrous food, which is later released as methane gas into the atmosphere mainly through its mouth and nostrils. However, when these materials are diverted from landfill, methane emissions would be reduced to barest (Table 4). In addition, the application of the products can also help to mitigate climate change through carbon sequestration in the soil, water holding capacity and substitution of nitrogenous and other synthetic fertilizers.

Also, the burning of associated gas in oil fields and over-dependence on oil as the major source of revenue in the country could be associated with the increase in fugitive emissions from oil/gas sector, thus, suggests the need for Nigeria to look beyond oil/reduce economic dependence from the oil sector and adopt other revenue sources from agricultural exports, entertainment/tourism, diversification, liberalization, reshaping our political system, design an automobile policy that encourages the use of electric cars, improve fiscal sustainability over time, in order to ensure sustainable development and shared prosperity in the economy.

Table 4: Methane emissions from enteric fermentation in Nigeria

Parameters	Methane emission level
Animal weight (kg)	250
Milk production (kg/year)	240
Digestibility feed (%)	56
Feed intake (kg/animal/year)	2546
Methane conversion factor from enteric fermentation (kg/animal/year)	59

Source: Adapted from FAO, 2010

As presented in Table 5a and 5b, manure in pasture, range and paddock from the agricultural sector in addition to the emissions from the residential and other sectors accounted for the highest nitrous oxide emissions (with 1013 and 251 Gg respectively) in the country when compared with other sectors. This arises as the a result of increased numbers of livestock and high population growth rate with corresponding increase in per capita energy and other resource consumption. The deposition of manure and urine in the soil by farm animals, increases the emissions of N_2O. According to Cha and Igbokwe (2012), cattle rearing alone generate more global warming GHGs, as measured in CO_2-eq, than transportation. Stephen (2014) in a similar study added that livestock population in Nigeria has been estimated to comprise 1.6 million cattle, 13.5 million sheep, 26 million goats, approximately 2.2 million pigs and 150 million poultry.

Although emissions through the burning of fossil fuels have typically been regarded as one of the major contributors to GHG emissions, FAO (2006) reports the substantial emissions from the farm animal production sector, contributing approximately 18%, or nearly one-fifth of human induced GHG emissions, is a major threat to the environment. Other nitrous oxide emissions are generated from agricultural soils, fertilizer application and agrochemicals. Recently, the use of fertilizer has increased following the introduction of E-wallet, where farmers receive fertilizers and agrochemicals directly from the government.

Table 5a: Sectoral contributions from nitrous oxide (N_2O) emissions (Gg)

Year	Public electricity and heat production	Other energy industries	Manufacturing industries and construction	Road transportation	Rail transportation	Inland navigation	Residential and other sectors	Fugitive emissions from solid fuels
2012	0.038835931	0.0200046	1.2537397	1.012029078	0.0086658	0.000606	14.2315983	0.518087
2013	0.043570139	0.022919701	1.380053851	0.999416319	0.00789201	0.000551889	14.45383238	0.580078044
2014	0.047630557	0.025569027	1.506674774	0.99441018	0.007228349	0.000505479	14.64443729	0.642857129
2015	0.051690975	0.028218353	1.633295697	0.989404042	0.006564689	0.000459069	14.83504219	0.705636213
2016	0.055751393	0.030867678	1.759916619	0.984397903	0.005901028	0.000412659	15.0256471	0.768415298
2017	0.059811811	0.033517004	1.886537542	0.979391765	0.005237367	0.000366249	15.216252	0.831194382
2018	0.063872229	0.03616633	2.013158465	0.974385627	0.004573706	0.00031984	15.40685691	0.893973466
2019	0.067932647	0.038815656	2.139779388	0.969379488	0.003910045	0.00027343	15.59746181	0.956752551
2020	0.071993065	0.041464981	2.26640031	0.96437335	0.003246384	0.00022702	15.78806672	1.019531635
2021	0.076053483	0.044114307	2.393021233	0.959367211	0.002582723	0.00018061	15.97867162	1.08231072
2022	0.080113901	0.046763633	2.519642156	0.954361073	0.001919062	0.0001342	16.16927653	1.145089804
2023	0.084174319	0.049412959	2.646263078	0.949354934	0.001255401	8.77903E-05	16.35988143	1.207868888
2024	0.088234737	0.052062284	2.772884001	0.944348796	0.00059174	4.13804E-05	16.55048634	1.270647973
2025	0.092295155	0.05471161	2.899504924	0.939342657	−7.1921E-05	−5.02944E-06	16.74109124	1.333427057
2026	0.096355573	0.057360936	3.026125846	0.934336519	−0.000735582	−5.14393E-05	16.93169615	1.396206142
2027	0.100415991	0.060010262	3.152746769	0.92933038	−0.001399243	−9.78492E-05	17.12230105	1.458985226
Total emissions	1.11873191	0.641979322	35.25	15.48	0.057361557	0.004011298	251.052599	15.81106153

Source: Author's computation from IPCC, 2019. IPCC: Intergovernmental Panel on Climate Change

Table 5b: Sectoral contributions from nitrous oxide (N_2O) emissions (Gg)

Year	Fugitive emissions from oil and gas	Solvent and other product use: Other	Manure management	Direct soil emissions	Manure in Pasture/Range/Paddock	Wastewater handling	Indirect N_2O from agriculture	Indirect N_2O from non-agricultural NH_3	Agricultural waste burning
2012	0.395843	0.00185064	2.69992638	9.50673393	45.3149384	6.61537	6.3878224	6.416816852	0.7674286
2013	0.386710091	0.001898948	2.796047765	8.339516047	47.97298324	6.725832264	6.153503182	6.550696375	0.806930729
2014	0.377417934	0.001947377	2.887719086	7.644634172	50.33666587	6.82057313	6.05143906	6.671445181	0.846570636
2015	0.368125776	0.001995805	2.979390408	6.949752298	52.70034851	6.915313997	5.949374939	6.792193987	0.886210543
2016	0.358833619	0.002044234	3.07106173	6.254870423	55.06403114	7.010054863	5.847310817	6.912942793	0.925850449
2017	0.349541462	0.002092663	3.162733052	5.559988548	57.42771378	7.104795729	5.745246695	7.033691599	0.965490356
2018	0.340249304	0.002141092	3.254404374	4.865106673	59.79139641	7.199536595	5.643182574	7.154440406	1.005130263
2019	0.330957147	0.002189521	3.346075695	4.170224798	62.15507904	7.294277462	5.541118452	7.275189212	1.04477017
2020	0.321664989	0.00223795	3.437747017	3.475342924	64.51876168	7.389018328	5.43905433	7.395938018	1.084410077
2021	0.312372832	0.002286379	3.529418339	2.780461049	66.88244431	7.483759194	5.336990209	7.516686824	1.124049984
2022	0.303080675	0.002334807	3.621089661	2.085579174	69.24612695	7.57850006	5.234926087	7.63743563	1.163689891
2023	0.293788517	0.002383236	3.712760982	1.390697299	71.60980958	7.673240926	5.132861966	7.758184437	1.203329797
2024	0.28449636	0.002431665	3.804432304	0.695815424	73.97349221	7.767981793	5.030797844	7.878933243	1.242969704
2025	0.275204202	0.002480094	3.896103626	0.000933549	76.33717485	7.862722659	4.928733722	7.999682049	1.282609611
2026	0.265912045	0.002528523	3.987774948	−0.693948325	78.70085748	7.957463525	4.826669601	8.120430855	1.322249518
2027	0.256619887	0.002576952	4.07944627	−1.3888302	81.06454012	8.052204391	4.724605479	8.241179661	1.361889425
Total emissions	5.22081784	0.035419885	54.26613164	61.63687778	1013.096364	117.4506449	87.97363736	117.3558871	17.03357975

Source: Author's computation from IPCC, 2019. IPCC: Intergovernmental Panel on Climate Change

Emissions from CH_4 and N_2O are primarily from agriculture making the agricultural sector the largest producer of non-CO_2 emissions. Emissions of N_2O (even in a small quantity) cause significant radiative force due to their global warming potential. Increased soil temperatures coupled with high moisture conditions during cooler months will increase N_2O production in the soil (Ma et al., 2007). However, the need for immediate and far reaching changes in current animal agriculture practices and consumption patterns are both critical if GHGs from the farm animal sector are to be mitigated.

Table 6a and b presents percentage CO_2-eq emissions in line with the IPCC emission sector description obtained by multiplying the emissions by the gas global warming potential (GWP). The results revealed that the fugitive emissions from oil and gas accounted for the highest (75.27%) contribution to CO_2-eq emissions, and was identified as the most polluting sector, known to pollute because of their technology (associated with the discovery of more non-associated gas (NAG) reserves in deeper reservoirs, the development of deep offshore oil fields with huge associated gas (AG) reserves, participation in the gas export business through the Nigerian Liquefied Natural Gas (NLNG) Company, and increasing demand for local gas supply for power generation). This is as a result of increased gas flaring employed to dispose off associated gas in major petroleum/oil producing areas in the country.

Records has it that there were 39 companies directly involved in oil and gas production in Nigeria, producing natural gas from 189 fields with daily AG production of 4.74 bscf/d and NAG production of nearly 3.46 bscf/d in 2015. Ajugwo (2013), in his study reported that Nigeria flares about 17.2 billion m^3 of natural gas per year in conjunction with the exploration of crude oil in the Niger Delta. This high level of gas flaring is equal to approximately one quarter of the current power consumption of the African continent.

From an economic perspective, the main interest of Nigerian government in the oil industry is to maximize its monetary profits from oil production. Oil companies find it more economically expedient to flare the natural gas and pay the insignificant fine than to re-inject the gas back into the oil wells. Additionally, because there is an insufficient energy market especially in rural areas, oil companies do not see an economic incentive to collect the gas.

However, these massive oil exploration and exploitation processes has not only created environmental, health, and social problems in local communities near oil producing fields, but has also resulted in an increased emission which causes climate change. This suggests the need for government to enforce the elimination of routine gas flaring by 2020, with unavoidable gas flaring limited to 2% of total gas production. Similarly, the remaining sectors were identified as important sectors because of the weight they have on the economy.

4. POLICY IMPLICATIONS AND CONCLUSIONS

It can be concluded that the contributions of emission driven sectors based on the 2006 IPCC description to CO_2-eq emissions

Table 6a: Percentage estimates of CO_2-eq emissions by sector using IPCC description

IPCC sector code	IPCC description	CO_2 emissions (Gg)	CH_4 emissions (Gg)	N_2O emissions (Gg)	CO_2-eq (Gg)	%CO_2-eq
1A1a	Public electricity and heat production	262899.1748	10.64662357	1.11873191	263498.7224	0.012294057
1A1bc	Other energy industries	283071.8217	14.28472222	0.641979322	283620.2494	0.013232867
1A2	Manufacturing industries and construction	355181.0382	264.8904067	35.24974435	362790291	16.92670236
1A3b	Road transportation	416035.7093	121.1118249	15.47762932	423675.8378	0.019767439
1A3c	Rail transportation	148.6185783	0.008323443	0.057361557	165.9203973	7.74135E-06
1A3d	Inland navigation	148.6185783	0.014039542	0.004011298	150.1649451	7.00624E-06
1A3e	Other transportation	0	0	0	0	0
1A4	Residential and other sectors	0	18857.85993	251.052599	546260.1745	0.025486855
1B1	Fugitive emissions from solid fuels	0	11679.05437	15.81106153	588664.1975	0.027465299
1B2	Fugitive emissions from oil and gas	374347.9193	49495.90999	5.22081784	1613301473	75.27178795
2A1	Cement production	196426.7908	0	0	196426.7908	0.009164682
2A7	Production of other minerals	160.9994777	0	0	160.9994777	7.51175E-06
2B	Production of chemicals	13643.04	1.93872	0	13691.508	0.000638805
2C	Production of metals	1009.257152	0	0	1009.257152	4.70889E-05
2G	Non-energy use of lubricants/waxes (CO_2)	−1003.109617	0	0	−1003.109617	−4.68021E-05
3A	Solvent and other product use: Paint	2054.965899	0	0	2054.965899	9.58785E-05
3D	Solvent and other product use: Other	0	0	0.035419885	10.55512573	4.9247E-07

Source: Author's computation from IPCC, 2019. IPCC: Intergovernmental Panel on Climate Change, CO_2: Carbon dioxide, CO_2-eq: Carbon dioxide equivalent

Table 6b: Percentage estimates of CO_2-eq emissions by sector using IPCC description

IPCC sector code	IPCC description	CO_2 emissions (Gg)	CH_4 emissions (Gg)	N_2O emissions (Gg)	CO_2-eq (Gg)	CO_2-eq (%)
4A	Enteric fermentation	0	26099.95282	0	26099.95	0.001217745
4B	Manure management	0	1158.975915	54.26613164	45145.70723	0.002106363
4C	Rice cultivation	0	6981.533902	0	174538.35	0.008143434
4D1	Direct soil emissions	0	0	0	0	0
4D2	Manure in pasture/range/paddock	0	0	1013.096364	301902.7165	0.014085872
4D3	Indirect N_2O from agriculture	0	0	87.97363736	26216.14393	0.001223166
4D4	Other direct soil emissions	−7546.869922	0	61.63687778	10820.91966	0.000504872
4F	Agricultural waste burning	0	657.0086647	17.03357975	21501.22427	0.001003182
6A	Solid waste disposal on land	0	6552.625167	0	163815625	7.643143699
6B	Wastewater handling	0	15234.6593	117.4506449	415866.7922	0.019403092
6C	Waste incineration	0	98.00341167	0	2450.08525	0.000114314
7B	Indirect N_2O from non-agricultural NOx	0	0	54.90147791	16360.64042	0.000763338
7C	Indirect N_2O from non-agricultural NH_3	0	0	117.3558871	34972.05436	0.001631691
Total					2143301650	100

Source: Author's computation from IPCC, 2019. IPCC: Intergovernmental Panel on Climate Change, CO_2: Carbon dioxide, CO_2-eq: Carbon dioxide equivalent

in Nigeria cannot be over-emphasized. Improvement in techniques and practices is an important mitigation options for sectors that pollutes through its own production process. But for sectors that are regarded as 'important' because they make other sectors pollute, this option may only be effective when there is a reduction in the demand for intermediate products from direct polluters like fugitive emissions from oil and gas as it accounted for the highest contribution of percentage CO_2-eq emissions when compared to other sectors. However, increases in methane and nitrous oxide emissions especially from the agricultural sector, suggests the need to lower stocking densities as well as inputs of concentrated feed in order to contribute to better energy balances in the agricultural sector.

5. RECOMMENDATIONS

Technological improvements and best practices would be an effective emission mitigation measure for sectors that pollutes through its own production process but for other sectors that are important because they make other sectors to pollute, these measures would only be effective if they reduce intermediate demand to directly polluting sectors.

The absence of good and adequate policy has an undesirable effect on the environment and therefore the quality of the agricultural sector. Hence, policies geared towards encouraging the planting/maintaining of efficacious plants, candlenuts as well as the broad leaves of banana plants; discouraging deforestation and soil erosion due to over cropping would not only minimize environmental degradation but will also mitigate emissions in the agricultural sector.

Creation of awareness on the need to practice organic farming (since it has the potential to use less energy) will not only prohibit the use of synthetic fertilizers and pesticide that leads to increased emissions, but will also improve energy efficiency in the agricultural sector.

There is need to adopt the use of compost, as it not only offers environmental and societal benefits towards the mitigation of CO_2-

eq emissions directly and indirectly through carbon sequestration in soil and substitution of nitrogenous and other synthetic fertilizers, but also helps in enhancing long term agricultural productivity and production.

The result of the study also revealed increases in methane and nitrous oxide emissions especially from animal manure, thus, suggests the need for government to support waste management in all the states in Nigeria to have a sequel structure to safe disposal of organic matter from cattle. Also, there is need to lower stocking densities as well as inputs of concentrated feed in order to contribute to better energy balances in the agricultural sector.

Finally, the result of the study also reveals increases in emissions in the fugitive emissions from oil and gas, as well as the manufacturing, energy and construction industries by 2027. This suggests the need for the Nigerian government to ensure the security of fuel source for power generation by mandating oil companies to channel their flared gases to power plant. In addition, there is need for government, Federal Environmental Protection Agency (FEPA) as well as the Department of Petroleum Resources (DPR) to enforced environmental regulations, implement anti-flaring policies for natural gas waste from oil production, monitor the emissions and ensure effective compliance by the citizenry.

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