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RESEARCH ARTICLE

SIMULATION OF THE IMPACT OF HYDROFLUOROCARBON (HFC) EMISSIONS IN TOGO ON GLOBAL AVERAGE TEMPERATURE

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Abstract

Background: Several IPCC scenarios have predicted a global temperature increase of 1.5°C by 2030 attributable to greenhouse gases (GHGs) including hydrofluorocarbons (HFCs) controlled by the Kigali Amendment.

Objectives: Thus, this study aims to simulate the increase in global temperature by 2030 attributed only to HFC emissions in Togo, given that the country is a party to the Kigali amendment and the Paris agreement.

Methods: The methodology applied in this study is based on the projection to 2030 of HFC emissions in 2018 in order to simulate their impact on global average temperature using the LEAP-IBC tool.

Results:HFCs emissions in Togo will reach 2598.13 $GgCO_2$-e and will contribute to the increase in global average temperature by 9.10^{-5}°C representing 18/100000 of the 0.5°C over the period 2018 to 2030 predicted by the IPCC scenarios. This increase attributed to the HFCs sector alone in Togo once again shows the impact of GHG on global average temperature.These results should therefore alert political decision-makers to redouble their efforts in the implementation of mitigation measures.

Introduction:-

HFCs constitute the second product range of substitutes for Ozone-Depleting Substances (ODS) after hydrochlorofluorocarbons (HCFCs) (UNEP, 2011). They are used in many sectors, namely the refrigeration and air conditioning sectors, and as propellants in aerosols. Most HFCs are azeotropic or zeotropic mixtures of several gases in different proportions. The different HFCs are HFC-134a, HFC-32, HFC-125, HFC-143a, HFC-152, and HFC-23 (IPCC, 2005; IPCC, 2006). These HFCs do not deplete the ozone layer (Ravishankara et al., 1994) but are powerful greenhouse gases (GHGs) (Ramanathan, 1975) and are also Short-Lived Climate Pollutants (SLCPs) (WEF, 2014). Their global warming power over 100 years is 150 to 8000 times greater than that of carbon dioxide (CO_2) (WMO, 2014), which brought the Stakeholders to the Montreal protocol (UNEP, 2001; UNEP, 2006; UNEP, 2018)to adopt the Kigali amendment (OzoneAction, 2016; EIA, 2016) in October 2016, the aim of which is to phase out the production and consumption of HFCs. This amendment sets the HFC phase-down schedules for all states divided into three groups. It aims to reduce the consumption and production of HFCs to 15% of their respective reference levels: from 2019 to 2037 for the majority of countries not covered by Article 5 (Developed countries), from 2020 to

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2037 for the other countries non-Article 5 countries (Belarus, Kazakhstan, Tajikistan, Russian Federation, Uzbekistan), from 2024 to 2048 for group 1 of the countries referred to in Article 5 (Developing countries) including China, of which the Togo is a part and from 2026 to 2048 for the developing countries of group 2 (India, Iran, Saudi Arabia, Bahrain, United Arab Emirates, Kuwait, Oman, Qatar). Togo, being a consumer country of HFCs and equipment containing them, has ratified the Kigali amendment. In Togo, HFCs were only introduced in 2013 and are widely used in the refrigeration and air conditioning sectors (Ayassou et al., 2021). During their use, HFCs are released into the atmosphere often due to a lack of good practices and poor management of equipment at the end of their life cycle. These HFCs, once in the atmosphere, will contribute to global warming, resulting in a decline in biodiversity, floods, heat waves, and a drop in agricultural productivity. Togo is also a signatory to the Paris agreement which aims to limit the increase in global average temperature below 1.5°C by 2030 (United, N.; 2015). Thus, the objective of this study is therefore to simulate the increase in global temperature that would be induced by HFC emissions in Togo by 2030. The structure of this paper is as follow: the methodology is described in Section 1 while the results are analyzed and discussed in Section 2 followed by the conclusion.

Methodology:-

Data Collection Method:

The various socio-economic parameters necessary for the calibration of the tool are obtained from the various international and national institutions and on platforms are grouped in the tables 1 and 2.The calculation of HFC emissions also requires the annual quantities of HFCs imported wich are obtained from the National Ozone Office (BNO) of Togo.

Table 1:- Population data.

Population (hbts)	7352781	source: populationData.net	
Population growth (/year)	2.42 %	source: populationData.net	
Age fraction of the population (Source: World Bank)	Men (%)	Women (%)	Total (%)
0-4 years	15.19	14.95	30.14
5-9 years old	13.97	13.74	27.71
10-14 years old	15.22	12.3	27.52
15-19 years old	10.19	10.5	20.69
20-24 years old	8.93	8.79	17.72
25-29 years old	7.76	7.66	15.42
30-34 years old	6.96	6.9	13.86
35-39 years old	5.96	5.97	11.93
40-44 years old	4.85	4.92	9.77
45-49 years old	3.78	3.9	7.68
50-54 years old	2.89	3.05	5.94
55-59 years old	2.2	2.39	4.59
60-64 years old	1.65	1.84	3.49
65-69 years old	1.19	1.36	2.55
70-74 years old	0.78	0.91	1.69
75-79 years old	0.43	0.51	0.94
Over 80 years old	0.24	0.3	0.54

Table 2:- Socio-economic data.

Household data	Household size	4.5	Source: EDST-III2013-2014
	Less than 5 people per household	57 %	Source: EDST-III2013-2015
	Male child per household	46 %	Source: EDST-III2013-2016
	Child girl per household	43.90 %	Source: EDST-III2013-2017
	Fraction of women by population	51.00 %	Source: QUIBB

Mortality rate and life expectancy in Togo in 2018	Mortality rate	6.90 %	source: populationData.net
	Child mortality rate	43.70 %	source: populationData.net
	Life expectancy	60.80 years	source: populationData.net
GDP and average income per capita in Togo in 2018	GDP	5300000000 $ USD	source: populationData.net
	GDP growth rate	4.80 %	Source: World Bank
	Average income per person	540 $ USD	Source: JDN (Net Journal)
Contribution of different sectors to GDP	Agriculture	40 %	Source: Ministry of Agriculture, Animal Production and Fisheries (MAPAH)
	Services	43.9 %	Source: French Treasury
	Industry	16 %	Source: African Development Bank
Proportion of food products in Togo	Rice	20 %	Source: MAPAH
	But	51 %	Source: MAPAH
	Wheat	0 %	Source: MAPAH
	Sorghum	17 %	Source: MAPAH
Quantity of HFCs imported in 2018	HFC32	303.9metric tons	BNO
	HFC125	478.46metric tons	BNO
	HFC134a	817.1metric tons	BNO
	HFC143a	199.68metric tons	BNO

Key assumptions:
HFC emissions are calculated on the basis of the following assumptions:

1. HFCs are emitted during the operation of equipment, at the end of the equipment's life cycle and during the decommissioning of old equipments.
2. Very few refrigeration technicians have F-gas recovery devices
3. The growth rate of the sale of F-gas is very low in Togo given the standard of living of the population
4. The lifetime of the equipment is relatively short.

Estimation Method:
The study was conducted with the Long-range Energy Alternatives Planning-Inetgrated Benefits Calculator (LEAP-IBC) tool. The LEAP-IBC is a planning tool to help governments assess both emissions of greenhouse gases, SLCPs and other air pollutants as well as to build scenarios for mitigation in the energy and non-energy sectors. HFCs emissions estimated in 2018 were projected until 2030 with IBC application based on the chemical transport model GEOS (Goddart Earth Observing System) from NASA and which contains concentration-exposure-response functions (Malley et al., 2018).In this study, it was assumed that the only greenhouse gases emitted by Togo are HFCs.Based on these assumptions and field survey data (Ayassou et al., 2021), the emission factors or parameters used for the calculation of emissions are grouped together in Table 3. The calculation of the global average temperature increase resulting from radiative forcing for each year; is based on the following equation:

$$dTa(t) = \int_0^t ((k_{SHext,a} * F_{SHext,a}(t') + k_{Tropics,a} * F_{tropics,a}(t') + k_{NHml,a} * F_{NHml}(t') + k_{Artic,a} * F_{artic,a} * F_{artic,a}(t'))/k_{Global,a}) * f(t-t')dt' \quad (1)$$

This equation is published by Shindell in 2012(Shindell et al., 2012); where,dTa(t) denotes the temperature variation in area denoted a between times 0 and t;$k_{x,a}$ represents the response coefficients giving the response of the temperature in area*a* to the forcing in alatitudinal band*x* such as southern hemisphere (SHext), the tropics, the mid-latitudes of the northern hemisphere (NHml), and the artic. These coefficients are given by the GEOS-Chem adjoint model (Malley et al., 2018). TheF_x denotes the radiative forcing (RF) in latitudinal bandx.

The first term of the integral represents the RF weighted by regional sensitivities while the second term f(t) describes the inertial response of the climate system. It is described as follows:

$$f(t) = \frac{0.541}{8.4 \exp\left(-\frac{t}{8.4}\right)} + \frac{0.368}{409.5 \exp\left(-\frac{t}{409.5}\right)} \quad (2)$$

With t being the time in years, the first exponential represents the relatively fast response of the land and upper ocean, and the second denotes the slower response (thermal inertia) of the deep ocean (Lacey et al., 2017; Shindell et al., 2012)

Table3:- Emissions parameters.

Settings	Value
Annual bank issue rate (%)	8
Quantity not emitted (tonne/year)/Recovered rate (%)	0
Quantity sold but downgraded after base year (tonne)(rate%)	11
Quantity emitted during the decommissioning of old equipment (tonne/year) (Rate%)	39
Quantity contained in downgraded equipment (tonne) (rate%)	17.1
Age of equipment (year)	5

Results and Discussion:-

Results:-

The results of the projection of HFC emissions according to the Baseline scenario (No mitigation actions) and the simulation of their impact on global average temperature are summarized in Table 9 and 10.

Table 4:- Table of projection results of emissions and temperature increase from 2018 to 2030.

Year	2018	2019	2020	2021	2022	2023	2024
HFC emissions in Gg CO_2-e	641.78	889.29	1117	1326.49	1519.22	1696.53	1859.66
$\Delta\theta$ in $\mathbf{9.10^{-5}}$°C	0	0	0	0	2	2	2

Tableau 5:- Table of projection results of emissions and temperature increase from 2025 to 2030.

Year	2025	2026	2027	2028	2029	2030
HFC emissions in Gg CO_2-e	2009.74	2147.81	2274.84	2391.7	2499.21	2598.13
$\Delta\theta$ in $\times\ \mathbf{10^{-5}}$°C	3	5	6	7	7	9

Results Discussion:-

According to graph 1, the projected emissions of HFCs increase and will reach 2598.13GgCO_2-e, an increase of 305.29%. This strong growth in emissions is explained by the growing demand for cooling for residential air conditioning, automotive air conditioning due to the increase in heat in tropical countries linked to global warming (IPCC, 2018) and the conservation agri-food products.

Still according to graph 1, emissions will have no significant impact on global temperature between 2018 and 2021. This is explained by the fact that emissions have not yet reached the troposphere during this period to be able to warm it. Between 2022 and 2024 because of HFC emissions in Togo; the global temperature would increase by 2.10^{-5} °Cand rises in 2025, 2026, and in 2027 respectively to3.10^{-5} °C, to 5.10^{-5}°C, and to6.10^{-5}°C. In 2028, the temperature drops to 7.10^{-5}°C and keeps the same value until 2029 before going to9.10^{-5} °C in 2030. These results allow us to deduce that from 2018 to 2030, without mitigation measures in the refrigeration sector in Togo, HFCs emissionsare likely to increase the globalaverage temperature up to 9.10^{-5} °C. Moreover, several scientific reports have indicated that the global temperature has increased by 1°C on average compared to the pre-industrial era and that at the rate of current GHG emissions, the global temperature will reach 1.5 °C between 2030 and 2052, i.e., an increase of 0.5°C according to several scenarios (RCP2.4; RCP4.6; RCP6.0) of the IPCC (IPCC, 2014; IPCC, 2018). Thus, this increase of9.10^{-5}°C due to HFC emissions in Togo represents 18 /1000000 of the additional 0.5°C expected. This contribution is therefore very low compared to 0.5°C but should not leave political decision-makers without taking mitigation measures because other sectors of activity contribute to greenhouse gas emissions in Togo and in other countries.

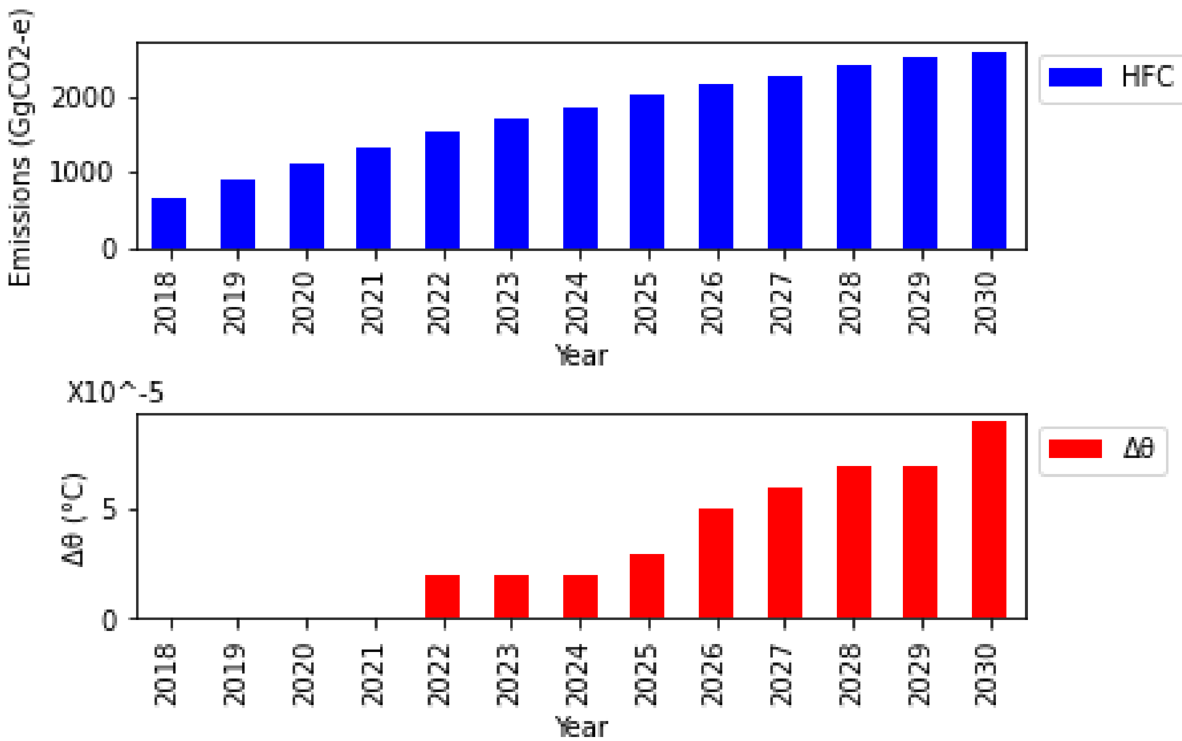

Figure 1:- Projection of HFC emissions (Top panel) and their impact on global temperature (Bottom panel) where Δθ denotes the increase in global temperature.

Conclusion:-

Based on this study based on the LEAP-IBC tool, projected HFC emissions from 2018 to 2030 indicate an upward trend from 641.049 to 2598.13 $GgCO_2$-e. In addition, the simulated increase in global average temperature due to HFC emissions in Togo in 2030 would be 9.10^{-5}°C or 18/1000000 of the 0.5°C simulated by the IPCC scenarios.This increase attributed to the HFCs sector alone in Togo shows once again how GHG emissions contribute to global warming with dramatic consequences. This should therefore alert political decision-makers to redouble their efforts in the implementation of mitigation measures in this refrigeration sector and in other sectors as well to limit the increase in global temperature below 1.5°C recommended by the Paris agreement. Togo, being a signatory to the Paris Agreement, must therefore promote the import of alternative refrigerants such as R-744 (CO_2), propane (R-290), Isobutane (R-600a), R-448A (HFC-HFO), R-455A (HFC-HFO) which have a very low Global Warming Potential (GWP), i.e., which warms the planet less. Also, Togo can encourage the construction of private and public buildings with thermal insulation materials to reduce global warming due to HFCs emissions attributed to residential air conditioning. These measures will constitute, according to Article 6.4 of the Paris Agreement, the country's share in its contribution to compliance with the Paris Agreement in the refrigeration sector.

Bibliography:-

1. AR Ravishankara, AA (1994). Do Hydrofluorocarbons Destroy Stratospheric Ozone? Science, 263, 71-75. doi: doi/10.1126/science.263.5143.71
2. ActionOzone. (2016). The Kigali Amendment to the Montreal Protocol: Phase-down of HFCs. ActionOzone.
3. Chris Malley, KH (2018). Quantifying Co-benefits in Asia. Retrieved from https://www.jstor.org/stable/pdf/resrep21865.5.pdf
4. EIA. (2016). Kigali amendment to the montreal Protocol: A Crucial Step in the Fight Against Catastrophic Climate Change. Marrakesh.
5. EMF. (2014). Mitigation of Short-Lived Pollutants: Development Benefits and Integration into Climate Change Strategies. Cancun.
6. IPCC. (2005). Preservation of the ozone layer and the planetary climate system: Issues relating to hydrofluorocarbons and perfluorocarbons.

7. IPCC. (2006). IPCC Guidelines: Emissions of Fluorinated Substitutes of Ozone Depleting Substances.
8. IPCC. (2014). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report. [Edited by the main writing team, RK Pachauri and LA Meyer. IPCC, IPCC, Geneva, Switzerland.
9. IPCC. (2018). Summary for Policymakers, Global Warming of 1.5°C, IPCC Special Report on the Consequences of a Global Warming of 1.5°C above Pre-Industrial Levels and Associated Global Gas Emissions Trajectories.
10. Heaps, C. (2020). Low Emissions Analysis Platform (LEAP). [Software version: 2020.0.12] Stockholm Environment Institute. Somerville, MA, USA. Retrieved from https://www. energycommunity.org.
11. G. Lacey, F., K. Henze, D., J. Lee, C., Donkelarr, A. v., & V. Martin, a. R. (2017). Transiente climate and ambiente health impacts due to national solid fuel cookstove emissions. PNAS. doi: doi/10.1073/pnas.1612430114
12. Koffi, A., Kokou, S., & Moursalou, K. (2021). Trend of anthropogenic emissions of ozone-depleting substances (ODS) and their substitutes in Togo from 1995-2018. International Journal of Innovation and Applied Studies, 33(3), 565-578. Retrieved from http://www.ijias.issr-journals.org/
13. UNEP. (2001). In Protection of the Ozone Layer: ODS Phase-out in Developing Countries; Customs officers training manual.
14. UNEP. (2006). Manual of the vienna convention for the protection of the ozone layer.
15. UNEP. (2017). Handbook of the Montreal Protocol on Substances that Deplete the Ozone Layer. Nairobi: Ozone Secretariat.
16. Ramanathan, V. (1975). Greenhouse Effect Due to Chlorofluorocarbons: Climatic Implications. 190, 50-52. doi: doi/10.1126/science.190.4209.50
17. Shindell, D., Kuylenstierna, J. C., Vignati, E., Dingenen, R. v., Markus A., Klimont, Z., Susan C. A.,Nicholas, M., Greet J-M., Frank, R., Joel S., Greg F., Luca P., Kaarle K., Lena Höglund I., Lisa E., David S., V. R., Kevin H., N. T. Kim O., George, Milly, Martin W., Volodymyr D., David F. (2012). Simultaneously Mitigating Near-Term Climate Change and Improving. Science, 335. doi:10.1126/science.1210026
18. A P. (2011). HFCs: A Critical Link in Protecting Climate and the Ozone Layer.
19. A P. (2018). The Montreal Protocol on Substances that Deplete the Ozone Layer.
20. United, Nations. (2015). Paris Agreement .21st Conference of the Parties.
21. WMO. (2014). Assessment for Decision-Makers: Scientific Assessment of Ozone Depletion. Global Ozone Research and Monitoring Project-Report No.56, Geneva, Switzerland,2014.