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Measures taken by Industries in Increasing their Capacity of Carbon Sink in Tanzania

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Abstract
This paper examined measures taken by industries to increase their capacity for carbon sinks in Tanzania. The study was carried out in the Coast Region of Tanzania. The study design adopted was cross-sectional, whereby a sample of 92 industries was drawn from 1192 industries located in the Coast Region. Industries involved were energy plants, processing industries, and manufacturing industries. Data were collected using documentary review, interview, and observation. Descriptive statistics and content analysis were used to analyze the data collected. The results were presented in the form of charts and percentages. Findings revealed that industries used different strategies to reduce the generation of carbon dioxide such as material substitution, improving resource use efficiency, industrial symbiosis, and fuel switching to electrification. Study found that employed by industries in reducing the emission of carbon dioxide include; producing low-carbon products, investing in low-carbon infrastructures, improving productivity, climate diplomacy, and international cooperation, installing low-carbon technologies. Study recommends that the existing policy should provide clear incentives such as grants, tax incentives, or recognition programs for industries investing in carbon-sinking measures. Industries should invest in research and development to advance carbon capture technologies and practices as a result these technologies will be more accessible and economically viable for industries. Industries should implement capacity-building initiatives through training programs that focus on best practices in carbon sinking and sustainability; this will foster a culture of environmental responsibility. The study concluded that industries are working on reducing the generation of carbon dioxide from their sources.

Keywords: *Industries, climate change, carbon sink, Coast Region, Climate change measures*

1.0 INTRODUCTION

Climate change is a big threat to the whole world (IPCC, 2018). It is considered to be one of the most serious threats to sustainable development and its effects have been a major concern globally (Abolmaali, Tarkesh, & Bashari, 2018;

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Ballew et al., 2019; Jug et al., 2018; Rifkin, Long, & Perry, 2018); ICAO, 2010; URT, 2011). Anthropogenic activities are responsible for almost all of the increase in greenhouse gases in the atmosphere. The global mean surface temperature has increased by 1.0 °C since pre-industrial levels, and is still ongoing at a speed of 0.2 °C per decade (IPCC, 2022). Anthropogenic activities, especially industrial and related activities, have caused a substantial increase in the concentration of carbon dioxide (CO^2) in the atmosphere (Change, 2018; Masson-Delmotte et al., 2021; USGS, 2008). This increase in atmospheric CO^2 from about 280 to more than 380 parts per million (ppm) over the last 250 years is leading to measurable global warming. According to UNEP (2018), worldwide emissions from human activities totaled nearly 46 billion metric tons of greenhouse gases, which were expressed as carbon dioxide equivalents in 2010. Since the beginning of the industrial revolution over 200 years ago, atmospheric concentrations of greenhouse gases such as carbon dioxide (CO^2) and methane (CH4) have significantly increased the atmospheric concentration of carbon dioxide (FAO, 2016). Globally, the Industrial sector contributes 21% of Green House Gases (GHGs) emissions to the atmosphere (FAO, 2016). Global CO_2 emissions from energy and industry increased in 2017, Total annual greenhouse gas emissions, including from land-use change, reached a record high of 53.5 GtCO2e in 2017, an increase of 0.7 GtCO2e compared with 2016, among of reasons for an increase of CO_2 emissions in 2017 was intensive use of fossil fuels in energy and industrial sectors (UNEP, 2016).

Africa is the among of less contributor of greenhouse gases taking third position in the world emitting 3-5% followed by South America and Oceania in second and first position as lesser emitter of greenhouse gases by the rate of 5% and 1-2% consecutively while Asia is the largest emitter which account for 50% of global emissions then followed by North America and Europe that accounts for 20% and 15% of the total global emission of greenhouse gas (IPCC, 2023). The total emissions in Africa have significantly increased by more than twelve-fold since the 1950s, and this level is projected to increase further (Golubski, 2017). Africa continent is the most vulnerable region to climate change in the world due to the fact that the continent has diverse climates and ecosystems making some regions more susceptible to extreme weather, droughts, and floods. In addition, Tanzania has set itself the goals of development through increasing investment in human capital and industrialization (Malenda, 2020; Suru, Seni, & Mbalamula, 2019; UNDP, 2017). The number of industries has increased from 50656 in 2015 to 59133 in the year 2019, with almost 8,477 industries established across the country, including small, medium, and large-scale industries (URT, 2017, 2020). Even though the industrial sector is very important in the country, the sector plays a huge role in the contribution of climate change including through the emission of Greenhouse Gases (GHGs).

The industrial sector in Tanzania contributes approximately 18-20% of the country's total greenhouse gas emissions. This includes emissions from

manufacturing, mining, and construction activities (URT, 2020). The primary contributors within this sector are energy-intensive industries such as cement and processing industries, along with emissions from fossil fuel use and industrial processes (URT, 2020). Tanzania is the second in emissions of greenhouse gas about 0.37% in East African countries which is categorized as among the countries which have lower GHG emissions in the world (WRI CAIT, 2015). Even though industrialization produces a large number of emissions which lead to climate change, industrialization is also an effective means for climate change mitigation. Industrialization is also fundamental in climate change mitigation through technological progress, the retirement of inefficient technologies, changes in the structure of energy systems, and patterns of energy services (Okereke et al., 2019).

The National Environmental Policy of 1997 describes that industries are one of the sectors contributing significantly to environmental challenges such as land degradation mainly during the extraction of raw materials and energy resources (NEMC, 2017). According to National Carbon Monitoring Centre (NCMC) in dealing with the carbon reduction campaign Tanzania developing Africa's largest carbon offset project whereby the memorandum of understanding (MOU) agreed between the Tanzania Wildlife Management Authority (TAWA) and Green Cop Development PTE Ltd as Singapore registered company developed the carbon –offset project credit billions to bankroll conservation of territory covering 2.4 million hectares in Southern Tanzania. The project promises substantial new green jobs to implement measures to avoid greenhouse gas emissions (NCMC, 2023). Jiang *et al*., (2021) outlined 20 top countries with the highest land carbon sink with which the implementation range within 45 years from 2005-2050 where the expectation is 62.1pg C. Among them, are Russia, Canada, USA, China, and Brazil. This carbon sink consists of four components production-driven change and turnover-driven change, change in instantaneous carbon storage potential, and interaction between production-driven change and turnover-driven change. The four components account for 49.5%, 28.1%, 14.5%, and 7.9% of the land carbon sink respectively. Despite this truth, little is known about Measures taken by industries in increasing their capacity of carbon sink capacity in Tanzania. Therefore, this study assessed measures taken by industries in increasing their capacity of carbon sink capacity in Tanzania.

2.0 MATERIALS AND METHODS

2.1 The study Area

This study was conducted in the United Republic of Tanzania specifically the Coast Region. The coastal region is located in the Middle East side of Tanzania Mainland between latitudes 6^0 and 8^0 south of the equator and longitude 37^030' and 40^0 east of Greenwich. For the case of climate, the region experiences a tropical climate with an average temperature of 28^0C, and rainfall range from 800mm to 1000mm while the region's topography is within a coastal belt ranging from (0-100m) above mean sea level, and nature of soil is clay, loamy,

silt and alluvial. Water bodies, the region has enough rivers (Rufiji, wami, and Ruvu) that pour their waters along the Indian Ocean. In addition to that, the region is blessed with many economic activities such as; Agriculture, Industries and trade, Beekeeping, Fisheries, Forest, Tourism and wildlife, and mining (URT, 2022). The reason for choosing this region as a study area is because, the region experienced a mushroom rise of industries because of being allocated near Dar es Salaam city, and the majority of industries had shifted from Dar es Salaam to the Coastal region because of the potentiality of resources such as land, and other materials which required by industries. This situation marks the region to have 1192 industries (ranging from large scale to small scale).

2.2 Research Design

The descriptive research design was used in this study to collect information from industries located in coastal regions on the role of industrialization in promoting climate change mitigation. This type of design was used to allow a researcher to collect information, summarize, interpret, and present data for further clarification. Also, Creswell (2015) argued that the descriptive research design is more typically structured and formalized with evaluative questions that are clearly stated. Thus, based on such reason the study selected this design due to its ability to warranty the increased objective and reliability of the evidence collected.

The sampling frame under this study was industries located in the Coast Region. Therefore, respondents were drawn from industries. A representative sample size with known confidence and risk levels was selected, based on the work of Yamane (1967). The Coast region comprises 1192 industries whereby only 92 industries were surveyed by this study. Both probability and non-probability sampling procedures were used to select respondents. Simple random sampling was used to select industries while purposive sampling was used when selecting key informants who were industrial managers, operators, and responsible ministries as well as officers from headquarters of concerning district councils of the Coastal region where industries are being located.

In this case, both primary and secondary data were collected to address the study objectives. Primary data comprises both qualitative and quantitative data and collected direct from the industries through interviews and observation methods. Secondary data was collected from published documents and relevant reports. Multiple methods for data collection were used in this study to make the study valid and free of mistakes and biases, these included interview, observation, documentary review, and questionnaire respectively. The interviews were held with industrial managers, operators, and officers from headquarters of district councils of the Coastal region where industries are located as well as officers from NEMC and responsible ministries. On the other hand, questionnaires were administered to normal industrial workers.

This study used both qualitative and quantitative techniques for data analysis. In quantitative data analysis, descriptive statistic methods were used. Descriptive statistics were used in analyzing data in terms of frequencies and percentages from responses. Statistical Package for Social Science (SPSS) was used to derive descriptive statistics to meet the objectives. The descriptive findings in this study are presented in the form of tables and frequencies as an important part of the process of report writing. On the other hand, qualitative data was analyzed through content analysis thematically, in this case, themes generated from audio records after being transcribed.

3.0 3 RESULTS AND DISCUSSION

3.1 Types and Location of Industries in Coastal Region

The findings of the study indicated that, 92 industries in the study area fall under five types as indicated in Table 1. The table also displays the distribution of the industries in the study area.

Table 1: Types and location of industries

Variables	Frequencies	Percentages
Type of industries		
Steel processing industries	11	12.0
Food processing industries	28	30.4
Construction materials industries	37	40.2
Electronic and motor spare industries	12	13.0
Leather processing industries	4	4.3
Industry location		
Mkuranga	17	18.5
Kibaha Town council	31	33.7
Kibaha District council	22	23.9
Chalinze	16	17.4
Bagamoyo	6	6.5

Source: Field data, 2022

3.1.1 Types of industries

The study findings revealed that about 40.2% of the surveyed industries engaged in the production of construction material, about 30.4% of industries engaged in food processing, and 13% of industries engaged in electronic and motor spare industries. It was found that 12% of industries engaged in steel processing and very few 4.3% industries engaged in leather processing (Table 1). This result implies that the study area is occupied by many industries related to construction materials, spare part making, leather, steel, and food processing. Therefore, the existence of those numbers of industries in the Coastal region had an impact on the environment since greenhouse gases are mainly produced by the industrial sector. According to IPCC (2022), industries are categorized as among of major producers of greenhouse gases because depend much on energy consumption which accounts for 73.2% of global emissions.

3.1.2 Industry location

The study found that about 33% of all industries are located in the Kibaha district council and about 23.9% of them are located in the Kibaha town council. Furthermore, the study noted that 18.5% of industries are located in the Mkuranga district while 17.4% of industries are located in the Chalinze district and a few 6.5% of industries are located in the Bagamoyo district (Table 1). This is an indication that the Coast region has abundant industries in its districts, and statistics indicate that the Coastal region had 1192 total number of industries (URT, 2023). Therefore, those industries located in various districts of the Coastal region are responsible for making sure the environment is kept safe by reducing the emission of greenhouse gases.

3.2 Measures taken by Industries in order to reduce the emission of carbon

The study findings noted that there are measures taken by industry to reduce the generation of carbon dioxide rather than directly improving well-known carbon sink such as de-carbonation, capacity building, and technological transfer strategies. It noted that the implementation of measures involves multiple stakeholders in the chain of industrial production activities. Measures to increase carbon sink capacity included those taken by industries as primary stakeholders in the process of climate change mitigations, also there are measures taken by other stakeholders mainly the government in collaboration with different institutions

3.2.1 De-carbonization strategies

During the survey it was noted that industries play a great role in reducing the generation of carbon dioxide as presented in Table 2.

Table 2: De-carbonization strategies

De-carbonization strategies	Frequencies	Percentages
Material substitution	13	14.1
Improving resource use efficiency	1	1.1
Industrial symbiosis	13	14.1
Fuel switching to electrification	16	17.4
Supporting policy framework	15	16.3
Producing low carbon products	14	15.2
Investing in low carbon infrastructure	10	10.8
Carbon leakage mitigation	10	10.8
Thriving for low carbon materials	7	7.6
Improving productivity	8	8.7

Source: Field data, 2022

Material substitution: The study in Table 2 revealed that, about 14.1% of the industries confirmed material substitution plays a great role reducing emission of greenhouse gases in particular carbon dioxide. Within the study area some industries opted to use alternative material for production to reduce process in

production process. Material substitution in the context of carbon reductions refers to the practice of replacing high-carbon materials with lower-carbon alternatives in industrial processes, this strategy aims to reduce greenhouse gas emissions associated with the production and use of materials. The use of material substitution by industries reduced the level of energy and material used in the production process, also it reduces the use of materials. Study noted that material substitution keeps industrial products and material to be used for long time, this process has benefit to the environment by reducing emission of greenhouse generation. Furthermore, material substitution revealed by study to go directly with improving production designs in order to ensure durability, repair ability and recyclability. Furthermore, materials substitution is using low carbon products or materials than more emission products or materials. Industries are opted to produce low carbon goods by substituting organic fibers for grown fibers. It knows that organic or natural fibers use less energy and have low carbon emissions. TEC (2017) argued that material production and processing require a lot of energy and it is a main driver of GHG emissions in industry production activities. CO_2 emissions can also be reduced substantially through increased material efficiency this included material substitution through the recycling of products and the re-use of materials is an effective way to reduced energy demand and GHG missions. This is due to the fact that the reused material does not need to be augmented as new material; therefore, energy-intensive chemical reactions can be avoided. Moreover, the interview with one of respondent from diamond cement industry confirmed that;

> *"Our industry uses material substitution as strategy to reduce the production of $C0_2$ in several ways such as; replacing carbon-intensive materials, adopting lightweight materials, utilize renewable and recycled materials".* An interview with factory manager, 13/03/2022

Improving resource use efficiency: The study in table 2 found out that, about 1.1% of the industries reduce carbon dioxide generation; industries opted to improve resource use efficiency. Improving resource use accompanied by energy efficiency measures. Study noted that resources and energy use efficiency including reuse of waste products, furthermore, industries recycled waste products as raw material. Through this production of products reduced by number of processes hence reduced energy demand in production process. Improving energy efficiency revealed to consider maintaining the same quality and level of output while using less energy in the process. Furthermore, the findings revealed that improving energy efficiency goes directly with the approaches such as repair, recycling, reuse and reducing quantity of materials used within manufacturing. These findings align with Lv and Qin (2016) who pointed out that improving energy efficiency considered as more effective way of optimal utilization of resources. Energy saving and resources efficiency offer reduction of greenhouses gases emission also offer reduction of production cost by industries. Furthermore, resource efficiency provides financial sustainability

of industries and in carbon-intensive industries, improved resource use efficiency are considered to reduce greenhouse gas emission.

Industrial symbiosis: The results in Table 2 show that only 14.1% of industries reported using industrial symbiosis as one of their main strategies to mitigate carbon dioxide emissions. Industrial symbiosis involves repurposing secondary by-products from one industrial process as inputs in another, creating interdependence among industries through the exchange of raw materials and enhancing resource efficiency. This strategy reduces doubling of efforts in producing the same kind of raw material. It revealed that most food processing industries does not produce their own package for their product rather they purchase from packaging manufacturing industries. Furthermore, study revealed that other industries depend on by-products and waste products from other industries, this included industries produced goods related to metal products and plastic related products. In his study Boons, Chertow, Park, Spekkink, and Shi (2017) pointed out that industrial symbiosis provides interconnected network which play a great role in functioning on ecosystem by reducing greenhouse gases emission and environmental pollution. Industrial symbiosis reduces the environmental footprint of the industries involved. It reduces the use of virgin raw materials required in production process also it reduce the need waste management and disposal. Furthermore, it reported that, industrial symbiosis allows value of the material to be created and remain in the industrial system for long time of which otherwise would be discarded as waste. Also, the interview with one of respondent from Madoweka Co. Ltd-Vikindu reported that;

> *"We are producing variety of plastic packages such as plastic bottles, and other plastic utensils like water containers, cups, bowels, plates, as well as PVC for construction purposes. Our major customers are food beverage companies which place many orders for plastic bottles that used as packages of drinking water and juice" (*An interview with marketing manager, 27/03/2022)

Fuel switching to electrification: The study findings in table 2 revealed that, only 17.4% of industries opted to switch from fossil fuel to electricity with low carbon play a great role in reduce carbon dioxide which regarded as one of the highly greenhouse gases emitted by industries. Technologies such as electric furnaces are more energy efficient when compared with fossil fueled energy options. Study found out that, electrification technologies reduce energy demand from industrial processes, in particular in low-temperature heat applications. Roelofsen, Somers, Speelman, and Witteveen (2020) supported the findings by reported that, fuel switching to electricity stand as option for reducing the intensity fuel use by industry through moving to lower carbon generation option for example gas use instead of coal use. Fuel switching practiced by industries is the great platform for reducing emission of greenhouse gases from industrial production activities. In Tanzania some industries already opted to switch from heavy fuel oil into the use of National electrical grid which mainly generated by

hydro-electric energy resources, this included Twiga cement, Tanzanian Breweries, Aluminum Africa and Karibu textiles (Pye, Watkiss, & Savage, 2010).

Supporting policy frameworks: Table 2 shows that, only 16.3%of the industries take into consideration the full set of policies related with environmental issues, technologies and resources utilization. This is an indication that, few industries in the study area supported low carbon manufacturing by implementing policies that aiming to encourage green production without significantly impacting the cost to end consumers. These findings align with TEC (2017), which notes that industries adopt various policy measures aimed at minimizing carbon emissions. This included strategic planning, economic instruments, institutional creation and information and education, regulatory instruments, research, development and deployment, and voluntary approaches.

Producing low carbon products: The study findings in table 2 revealed that, 15.2% of the industries within the study area are producing low carbon products as their strategy to reduce emission of greenhouse gases in particular carbon dioxide. Production of low carbon products started from material used in production process, among of the low carbon materials used are organic materials and recycled metal materials. It found out that aluminum and steel making industries products recycled some metal to avoid the production process of metal products which is highly carbon intensive, recycled of metal products are significantly reduce production energy consumption. Also, it noted that recycled metals maintaining metal properties.

Investing in low carbon infrastructures: Findings presented in Table 2 indicate that industries established in the area are increasingly adopting low-carbon infrastructures. This trend is particularly evident in locations with reliable access to environmentally friendly energy sources, such as hydroelectric power and natural gas. According to government data on energy availability in the study area, most industries rely on hydroelectric power as their primary source of energy. Investment decisions regarding low-carbon infrastructure appear to be strongly influenced by the type of energy resources accessible within the area, with industries prioritizing clean and sustainable options. According to TENESCO report of 2021 show that, Tanzania is endowed with diverse renewable energy resources which ranging from biomass, geothermal, HEP, Solar and wind, and current Tanzania total power installed is 1,602 MW of which 48% from natural gas, followed by hydro 31%, 18% petrol, 1% solar, and 1% biofuels (URT, 2021).

Uses of automatic production machines: The study findings in table 1 found that, 8.7% of the industries opted to use automatic production machines instead of manual production machines to improve production efficiency. Automatic machines revealed to be connected with computer system which make easy to be

controlled and monitored by operators. It revealed that, automated programmable logic controllers have high ability of monitoring and controlling factors like temperature, gas emitted and waste generated. Automated programmable logic controllers revealed to play a great role in saving energy since it gives opportunity to track and analyze macro-level data which used to determine the need of machines maintenance and optimum performance of the manufacturing process. The use of automatic machines reduced emission of greenhouse gases in particular carbon dioxide by discovering early problem of machines which are likely to generate more carbon dioxide unnecessary and increase energy consumption. The use of automatic technologies on surveyed industries revealed to have high ability to produce consistent high-quality performance in a short period of time which means that industries ramp up production without worrying about a drop in quality.

Climate diplomacy and international cooperation: The study results found that, government and its institutions have been collaborating with industries in climate diplomacy and international cooperation. Government and industrial stakeholders have been attending in number of events intended to discuss reduction of greenhouse emission from industrial sector in particular carbon dioxide gas. Climate diplomacy involves preparation of appropriate strategies for decarbonization which included policy and legal framework. It revealed that, climate diplomacy involved efforts such as mobilizing capacity and strategic focus which aim to ensure effective decision-making related to climate change mitigation by stakeholders in industrial sector, also ensuring effectively allocation of human and funding resources, training and coordination among and between stakeholders. Furthermore, the government has been working together with number of nations and unions such in assisting industrial sector to overcome the challenges facing industries in tackling greenhouse gas emission, also in assisting technological transfer and development by local industries. Climate diplomacy and international cooperation noted by study to be used as tool by industrial stakeholders for setting common goals and objectives due to the fact that climate change and mitigation it is the issue of global concern. In his study Hristova and Chankova (2020) adding that climate diplomacy and international cooperation serve as the engine in climate change mitigation in industrial sector. Climate diplomacy generates assessment of other nations' interest and intentions in finding the agreement in climate change matters. Furthermore, it reported that ultimate goal of climate diplomacy is to create political condition for international agreement, coordination and cooperation in tackling emission of greenhouse gases also implementing UNFCCC.

Installing low carbon technologies: The study results in table 2 found that, industries within the study area shifted to advanced technology which characterized by low carbon generation in the production process, these technologies are electrified with high efficiency when compared fueled technology which involve direct burning of fuel. It revealed that to reduce

energy consumption some industries within the study are installing solar energy technology which mainly used for lighting purposes. Low carbon technology installed by industries possessed number of characteristics included ability to recycle byproduct and reduce the use of raw materials. In industries related production of packaging products such as plastic bottles and bags mainly used plastics material from waste products as raw materials after being gathered from the communities from within the study area also on nearby regions. The use of low carbon technology resulting in low carbon products. Finding from Lv and Qin (2016) reported that for industries to reduce emission of greenhouse gases must opt on the use of low-carbon technologies. In his finding he reported that low carbon technology focusing on reducing or avoiding the use of fossil fuels, evolving new energy, energy conservation and use of alternative energy sources. Furthermore, low carbon technology which adopted by industries must be sustainable and efficient. In country perspective investing in low carbon technologies ensures the sustainability of industries and also a sustainable economy and environment for Tanzania as a country. Low-carbon technologies have the potential to provide Tanzania with more carbon finance which can be used for sustainable industrial investment and sustainable economic growth (Lv & Qin, 2016).

3.3 Capacity Building Strategies

To increase carbon sink industries noted to use capacity building to their workers through different strategies. The study noted that strategies used are both field and off-field strategies as indicated in Table 3.

Table 3: Capacity building strategies

Building capacity strategies	Frequencies	Percentages
Training	16	17.4
Sharing technology information	10	10.9
Outreach program	9	9.9
Field visit	7	7.6
Meetings	18	19.6
Monitoring and evaluation programs	14	15.2
Stakeholder involvement and collaboration	12	13.0
Integrating climate agendas into plans	6	6.5

Source: Field data, 2022

Training: The findings in Table 3 found that the majority of the industries about 17.4% use training strategies to create and extend knowledge and skills about issues related to the environment to their workers, among the issues is climate change and its aspects like climate change mitigation. The study revealed that training on climate change focuses on the appropriate use of machines and energy. Also, it revealed that training covers appropriate waste management generated by the industry during the production process. Furthermore, training and skills upgrading aim to ensure that industry workers are able to absorb

international know-how on all matters related to climate change, technology, and environmental pollution. Also, the narration with one of the respondents from Tazpack Industries limited who confirmed that;

> *"Of course, our industry used different training programs to impart knowledge to the employees on issues regarding climate change and environmental matters. These training programs cover different aspects for instance raising their knowledge of new machines and technologies responsible for low carbon emissions which are installed in our factories. The purpose of these training is to enhance the capacity building among the employees in towards climate change and environmental issues in our industry" (*An interview with training manager, 05/04/2022).

Sharing technology information: The study findings in Table 3 revealed that, to extend knowledge and skills on climate change issues, energy issues, and technology, about 10.9% of the industries are sharing information. Sharing information between and among industries is used to address capacity and expertise gaps on matters related to climate change. It noted some industries within the study area are sharing technological information also they are sharing technological information with other industries found inside the country and outside the country. The study found that common information sharing by industries included the availability of new technology for production in the market, also the quality of technology in terms of energy consumption and waste generated by technology. Other information shared included the price of technology, durability of technology, operation, and maintenance of technologies. In his study, Goldar et al. (2019) added that sharing information about climate change mitigations between and among stakeholders related to the industrial sector is very important since it offers formulation and implementation of strategies for climate change mitigations. Industrial stakeholders should prepare information transparently and ensure information is easily accessed by all stakeholders on different platforms such as online documents and media. This plays a great role in industries to tackle climate change through the use of environmentally friendly technologies.

Outreach program: The study findings in Table 3 revealed that about 9.9% of the industries used outreach programs to promote knowledge and skills of workers to climate change issues and their roles towards overcoming the challenge related to climate change and also their role in climate change mitigation. Outreach programs between and among industries aim to help, uplift, and support each other on matters related to climate change. According to Rosen (2015) argued that outreach programs enhance leadership and, a sense of responsibility toward climate change mitigation. It revealed that outreach provides industries opportunities to understand their position in climate change and make them aware of the effort they need to put into reducing the emission of carbon dioxide. Industrial outreach helps industries function better by assessing their needs and guiding them to the appropriate use of resources and technologies for the mitigation of climate change. The industry outreach

programs aim to connect and collaborate with leaders in industries and government to create industry readiness for climate change mitigation and also to foster development in future discoveries of technology and its applications. Outreach programs revealed to focus on influencing the government to make policy changes needed to accommodate them in addressing climate change issues including climate change mitigations.

Field visit: The study findings in Table 3 confirmed that about 7.6% of the industries agreed that field visits among industries play a great role in upgrading knowledge and skills about climate change mitigation and the role of industries in mitigating climate change. The study revealed that industry managers, engineers, and operators have tours to other industries inside the country but mostly outside the country in particular in countries such as China, Malaysia, and India. Their main aim is to gain knowledge and skills on the technologies innovated which are user-friendly to the environment through using less energy while producing high quality and quantity products with minimum waste generated and greenhouse gas emissions such as carbon dioxide. Furthermore, it revealed that field visit helps industrial operators to improve their machines by gaining new formulas for the production process which is less energy consuming and carbon generation. The interview results with one of the respondents from Hill water pure drinking industry;

> *"Our expert team made frequent field visits to collect information that can provide a deeper insight into the environmental impacts posed by our industry to take effective measures. Our team inspects the whole system of our factory to identify the leakages that cause the pollutants, and our team visits the communities that surround our industry to grasp their perceptions on whether there is pollution caused by our industry" (*An interview with the manager, 08/04/2022).

Meetings: The study findings in Table 3 revealed that, the majority of the industries about 19.6% used meetings to upgrade the knowledge and skills of industrial workers on matters related to climate change. It noted that among other industries have environmental engineers while others have invited environmental engineers as their consultants to assist them in understanding the environmental standards required during the production process. It revealed most of the time meetings between and among workers are considered as the best platform for them to strengthen knowledge about environmental issues including climate change issues and the role of industries in mitigating the generation of greenhouse gases, particularly carbon dioxide gas. Also, the interview results with one of the respondents from Sino Tan Kibaha Industrial Park contended that;

> *"We have regular meetings with our workers and stakeholders as the way forward of addressing the climate change. Meetings enable us to make discussions different strategies towards climate change, for instance*

> *making action plans which help in the provision of education on sources of emissions and taking right actions, raising awareness on policies, and regulations, etc." (*An interview with Environmental Engineer Officer, 21/04/2022).

Monitoring and evaluation programs: The findings in Table 3 revealed that about 15.2% of the industries strengthened their knowledge, skills, and practices on climate change mitigation issues by industries to their workers during the production process. The study revealed that the industries within the study area introduced and implemented monitoring and evaluation programs for workers on their performance in operating industrial machines. It noted that monitoring and evaluation of programs introduced by industries focused on industrial operation activities to climate change mitigation by covering energy consumption during the production process, machines maintenance, waste generation, and management. The main target of monitoring and evaluation programs is to ensure industrial operators use their knowledge and skills to ensure there is unnecessary emission of carbon dioxide as a result of machine problems which lead to the increase of carbon dioxide generation. For instance, delaying changing dirty oil to clean oil resulted in increased carbon dioxide emissions at the same time increased energy consumption and sometimes increased raw material consumption. Also, the findings concur with an interview held with one of the respondents from the Soap Manufacturer Industry who argued that;

> *"We have regularly scheduled monitoring and evaluation programs with our workers, especially assessing their effectiveness in operating and utilizing low-carbon machines. In this case, help us to note out the default for training to keep them aware" (*An interview with Program Manager, 28/04/2022).

Stakeholder involvement and collaboration: The results in Table 3 revealed that about 13.0% of the industries involved several stakeholders these included governments and their related institutions; also, it included researchers, technology producers, and traders of technology, innovators, and manufacturing industries. Respondents from the surveyed industries admitted that involving stakeholders in ensuring the production process by industries tends to consider the emission of greenhouse gases in particular decarbonization issues. Industries revealed to collaborate with the government in creating an environmental condition that allows them to import technology that is user-friendly to the environment in terms of energy consumption level of technology pollution also level of raw material consumption. The government takes into consideration issues of tax for those kinds of environmentally friendly technology imported by industries. The findings concur with Detlef et al., (2021) who contended that involving stakeholders is crucial for industries in effectively addressing climate change for several compelling reasons: first of all, stakeholder involvement and collaboration bring diverse perspectives, knowledge, and expertise to the table. This includes environmental NGOs, local communities, governments, consumers, investors, and supply chain partners. Their input can lead to more

comprehensive and innovative solutions to climate challenges. Also, engaging stakeholders helps industries identify and mitigate risks associated with climate change. This includes physical risks from extreme weather events, regulatory risks from changing environmental policies, and reputational risks from perceived environmental impacts.

Integrating climate agendas into plans: The study findings in Table 3 found that, about 6.5% of the industries within the study area integrate climate change issues in particular climate change mitigation in their industrial operation plans. Their main intention of use these strategies to ensure their products are produced under international standards which are highly restricted about the quality of products. It revealed that most industries integrating climate agenda into their plans are those industries that are selling their product in international markets which is highly restricted on the kinds of the products they produce and their process in production. The study noted that mainly this applied to food processing industries and packaging-related industries. Among the issues revealed to be integrated into their plans included energy technology used in production, level pollution, waste management, and raw materials used in production. Also, the study findings related to Dagnachew et al., (2021) who confirmed that integrating the climate agenda within industries' plans involves several key intentions and objectives such as facilitating the integration of climate goals into their plans, industries demonstrate a commitment to sustainable development and environmental stewardship. This includes reducing greenhouse gas emissions, conserving resources, and minimizing environmental impacts.

3.4 Technological transfer and development Strategies

The results in Table 4 indicate technological transfer and development strategies as one among of strategies applicable by industries in reducing greenhouse gas emissions.

Table 4: Technological transfer and development

Technological transfer and development	Frequencies	Percentages
Public-private partnerships	21	22.8
Provision of financial resources and investment	12	13.0
Information development and sharing	21	22.8
Technology cooperation	5	5.4
Human resource and Institutional development	10	10.9
Partnership and networking	9	9.8
Collaborative research and development (R&D).	14	15.2

Source: Field data, 2022

Public-private partnerships: The study in Table 4 found out that, about 22.8% of the industries from the study area have used the public-private partnership approach for technological transfer and development with the main target to help them in climate change mitigation by reducing greenhouse gases generation

mainly carbon dioxide. It revealed that public-private partnerships involve the private sector in public structure, also public sectors are involved in private sector agendas such as technical expertise assistance. Within the study area. The public-private partnership stands as a key element of industries in technology transfer, innovation, and development. Furthermore, public-private partnership was used as a platform for building industrial networks, and technology platforms, also it noted that this approach plays a great role in the development of research about technological transfer, innovation, and development. The public institution is used as a catalyst for supporting the development of science, creating conditions, standards, quality services, and regulatory environment for industries to play their role in reducing carbon dioxide generation while industries implement technological transfers and offer innovative solutions to climate change mitigation. Abu-Lebbeh et al., (2013) added that Public-private partnerships (PPPs) for technology transfer play a crucial role in addressing climate change among industries for several important reasons: First of all, PPPs facilitate the transfer of advanced and sustainable technologies from public research institutions or government agencies to industries. This access allows industries to adopt state-of-the-art solutions for reducing greenhouse gas emissions, improving energy efficiency, and promoting renewable energy sources. Another reason, PPPs encourage Cost Sharing and Risk Mitigation. Technology development and deployment often involve high costs and risks. PPPs enable cost sharing between public and private sectors, reducing financial burdens on industries while mitigating risks associated with technology adoption.

Information development and sharing: The study findings in Table 4 found that about 13.0% of the industries use information development and sharing as a platform for technological transfer with the target of reducing carbon dioxide emissions during the production process. It revealed that common information developed and shared between and among industrial stakeholders included the availability of environmentally friendly technology, characteristics of technology in relationship with energy consumption, and technological compliance to standards rules, and regulations developed by the government to guide technological development and use. The study revealed that different approaches were used by industries in sharing information between and among industries the approaches included advertisements, meetings between industrial stakeholders, and online forums. An interview with one of the respondents from Global Packaging limited who confessed that;

> *"We are not an isolated island, in the dissemination of information regarding various low carbon emissions we are using different platforms with our stakeholders and other industries to learn how others are doing, and it's not bad to learn from business partners and rivalries because the climate change is the country and global issue which needed the collective efforts to address it" (*Environmental Engineer officer, 30/04/2022).

Human resource and institutional development: The study findings in Table 4 found that about 10.9% of industries used human resources and institutional development to facilitate technology transfers, utilization, and development. It revealed that institution development included capacities for technological assessment, incubation, testing, and demonstration to reduce the emission of carbon dioxide from industries during the production process. Furthermore, found that institution development goes with human resource development by training industrial workers in adapting, operating, and managing technology for climate change mitigation through reducing greenhouse gases generation in particular emission of carbon dioxide. The study findings concur with OECD and IEA (2003) reported that Human resources and institutional development play pivotal roles in facilitating technology transfer and utilization to address climate change in several significant ways: Human resources development involves training and equipping personnel with the skills and knowledge necessary to understand, implement, and manage climate-friendly technologies. This includes technical training on renewable energy systems, energy-efficient practices, carbon capture technologies, and sustainable production methods.

Technology cooperation: The study findings in Table 4 found that about 5.4% of the industries admitted to enhancing technological cooperation among industries from the study area also from other sides of the country and outside the country proved by a study to be effective in technological transfer for climate change mitigation. Most surveyed large industries have technological relationships with industries from other countries such as China especially those producing similar products. Technological cooperation revealed to maximized efforts for decarbonizing target from industries. The study revealed that technological cooperation included financial and technical assistance that supports technological innovation, utilization, and development for tackling the emission of carbon dioxide from industries. However, it noted that industries from the study area are much more technical than financial. It also revealed climate change mitigation involves a wide range of stakeholders that bring together for low-carbon technological innovation, development, and deployment as a result industries stand as primary stakeholders for implementing international treaties and norms under consideration on the capacities and regulatory frameworks of the country.

Partnership and networking: Successfully of technological transfer and development revealed by study to rely on partnership and networking. The study findings in Table 4 show that, about 9.8% of the industries from the study area use this approach as a means of enhancing technological capabilities, sharing knowledge, and fostering innovation which is necessary for tackling emission of carbon dioxide emissions. It noted partnership and networking play a great role in capacity building among industries, industries reported benefits from the approach, among the benefits included contributing to mobilizing resources,

market access for technology, and technological expertise for technological utilization in tackling carbon dioxide emission. In addition to that, the results interview results held at Silafrica Tanzania-Plant 2: Blow Molding show that;

> *"Sharing of technology is a good step towards addressing climate change, in this case through collaboration in terms of technological aspect is the best way since gives room for exchanging knowledge on energy efficiency, renewable energy, carbon capture and storage, and many other de-carbonation technologies. Additionally, technological collaboration allows us to have joint research on the best technology that can enable our industries to reduce the emission of greenhouse gases, and this will increase our efforts towards addressing climate change" (*An interview with the Electrical Technician, 06/05/2022).

Collaborative research and development (R&D): The study findings in Table 4 found that about 9.8% of the industries from the study area collaborate with local and international institutes in research and development for technological transfers between and among industries from within the country and from outside the country. It reveals that industries from the study are using this approach in accessing technology for production across different parts of the world. Industries reported that research reports give the confidence to utilize technology recommended since it passes through several tests before being suggested by researchers and research institutes. The study results supported by Farooqui & Pawar (2023) who confirmed that Partnerships and networking play critical roles in enhancing technological transfer among industries towards addressing climate change in several key ways like partnerships which allow industries to access specialized expertise, resources, and knowledge that may not be available internally. This includes collaborating with research institutions, technology providers, government agencies, and non-governmental organizations (NGOs) with relevant experience in climate-friendly technologies.

4.0 CONCLUSION AND RECOMMENDATIONS

Based on the results and discussion, industries developed strategies to reduce the generation of greenhouse gases from production activities. Strategies developed by industries differ from one industry to another based on financial, technological, policies, and knowledge reasons. Among the strategies used by industries included capacity building strategies associated with training programs, outreach programs, field visits, meetings stakeholder involvement, monitoring and evaluation programs as well as integrating climate agendas into industrial plans. Also, de-carbonation was another strategy employed by industries as a measure towards the carbon sink. In this case, industries adopted various strategies such as; material substitution, improving resource use efficiency, industrial symbiosis, fuel switching to electrification, supporting policy framework, and investing in low carbon infrastructure.

The study recommended that the existing policy should provide clear incentives such as grants, tax incentives, or recognition programs for those industries that

investing in carbon-sinking measures. Also, the study recommended the promotion of research and innovation, therefor industries should invest in research and development to advance carbon capture technologies and sustainable practices as a result these technologies will be more accessible and economically viable for industries. Also, industries recommended implementing capacity-building initiatives through different training programs and workshops that focused on best practices in carbon sinking and sustainability, fostering a culture of environmental responsibility. Another recommendation is based on the encouragement of collaborative efforts between the government, private sector, NGOs, and local communities to share resources, knowledge, and best practices for effective carbon sinking. On top of that, the study recommended that, industries required to establish comprehensive monitoring systems by creating robust monitoring and reporting frameworks to track carbon sinking efforts, ensuring transparency, and enabling continuous assessment and improvements.

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