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MACI

MULTIDISCIPLINARY ADAPTIVE CLIMATE INSIGHTS JOURNAL

VOLUME 1, ISSUE 2, DECEMBER 2024

MACI@AAST.EDU

ISSN: 3009-6332

ACADEMY PUBLISHING CENTER
Journal of Multidisciplinary Adaptive Climate Insights (MACI)
First Edition 2024

ACADEMY Publishing Center

MACI
Volume 1, Issue 2, December 2024
E-ISSN: 3009-6332 Online Version
P-ISSN: 3009-7924 Print Version

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MACI JOURNAL OF MULTIDISCIPLINARY ADAPTIVE CLIMATE INSIGHTS

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(MACI) Volume 1, Issue 2, December 2024 - ISSN 3009-6332

http://dx.doi.org/10.21622/MACI.2024.01.2.1027

EDUCATION, TRAINING, AND CAPACITY-DEVELOPMENT FOR THE IMPLEMENTATION OF GLOBAL MARITIME STANDARDS

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EDITORIAL

KEY-WORDS: Global maritime standards, Decarbonization, Education and training, Green transition, Technological advancements.

The role that shipping plays in facilitating trade has been indispensable throughout most of the history of human civilization. Indeed, shipping serves as the lifeblood of the global economy. In recent times it has become abundantly clear that humankind cannot continue to treat the oceans, and nature as a whole, as it has always done – as a pristine and inexhaustible supply of natural resources that can absorb the negative aspects of every operational activity undertaken on it – without giving thought to its state and sustainability.

Climate action aligned with the “Paris Agreement” has compelled the maritime industry to mitigate the negative environmental impacts of shipping activities. Industry needs are rapidly shifting towards the green and ecological operation of ships and ports.

The green transition in maritime energy is inevitable, yet it is also an opportunity for the industry. The maritime industry inherently offers the lowest GHG emissions and energy consumption per transport mode, and has a wide range of technical possibilities for energy saving and replacement of fossil energy with sustainable options. Maritime transport also has great opportunities for adopting carbon-free energy sources, given the dimensions of commercial vessels, and that vast renewable energy resources are available on the world’s oceans.

However, the specific technical issues are not the only issues regarding sustainability as a whole. The concept of greener shipping must be seen as relevant to all aspects of the industry, from maritime education for sustainability, through maritime law, insurance, shipbuilding, repair and operation, financing, regulation, logistics, port operations, bunkering, brokering, Flag State and Port State action, among others.

Given the phenomenal scale of the task ahead, the maritime industry as a whole, stands at the cusp of one of the greatest technical, economic and operational challenges in its modern history. The transition will require unprecedented transformations, adaptations, and changes in the way the industry works as well as the adoption of novel technical innovations. The world is entering an era of fundamental (and often exponential) transformation, perhaps the most profound in human history.

Humankind is already starting to witness the emergence of innovative energy saving measures, net-/zero-carbon renewable fuels, and the use of modern renewable energy technologies, such as wind and solar propulsion technologies. Ports will also no doubt take a central role as energy hubs in this transition.

Maritime education, indeed all education, has a critical role to play in making this current generation and ones to come, appreciate – not only cognitively, but also affectively – the importance of good stewardship of the natural environment in which the maritime industry operates.

The question is what kind of education will support the diverse facets of maritime human resource management and development in this kind of ever-changing global context – and even national context – in light of decarbonization?

One view that could be taken is that education for the future should definitely cover the technical competencies required in the multiple professional areas of the maritime sector, whether in respect of ship operations (seafarers) or in areas such as maritime finance, shipbuilding, and maritime and ocean governance.

Focusing on seafarers, there are many previous and ongoing research efforts to understand the specific skills that will be needed for the medium to long term in ship operations.

The nature of work will change. More sophisticated ships will be deployed, and such sophisticated environments will require a correspondingly high and sophisticated level of skill in future seafarers. On the one hand, demand for seafarers is expected to increase at a steady rate, allaying any initial fears that seafaring jobs would vanish due to automation. However, the technological transition in the maritime industry will affect seafarers differently depending on their rank and job function. Upskilling and reskilling are important interventions in support of seafarers in light of the rapid change in their working environment due to the advancement of smart and green technologies. The pace and nature of technological change brings with it many possibilities and opportunities… but it also presents societal dangers and challenges such as cyber-security concerns, energy demands brought on by cloud-based activities, global inequity, and the risks associated with great pressure for accelerated paces of adaptation.

Furthermore, on top of the specific technical skills needed for the maritime industry today and in the short-term, there is the need for a new paradigm of education that seeks to engender in learners a problem-solving mindset, critical thinking, resilience, adaptability, systems thinking and collaboration (as opposed to the all too pervasive siloed approached taken by maritime actors). Just as important is the kind of education that fosters the important skill of continuous learning.

As the nature of work evolves, massive training will be needed, and the maritime industry will have to consider technological advancements within education and training itself. The question "how" do we educate and train and with "what" brings to mind options such as online/hybrid learning, blended learning mediated by technology, artificial intelligence applications, virtual reality (VR), augmented reality (AR), mixed reality (MR), and extended reality (XR).

Maritime education and training (MET) institutions will be presented with increased pressure to contend with the challenges of –

- educating people for 20- to 40-year career roles in a context of very quick change;
- maintaining awareness at an organizational level of changes in the industry arising from diverse sources – International Maritime Organization (IMO), industry, technology innovators, practices of other MET institutions;
- updating curricula, optimising teaching and learning resources; and
- resource acquisition to support all of the above.

Taking a broader perspective, the world's future maritime leaders will be the architects and the conductors who will determine whether our agreed aspirations today will become the realities of the future. As and when global standards are agreed and adopted at IMO – on decarbonization, ship design and operation, digitalization, automation, among many other areas that will be affected by technological development and innovation – ultimately, success in implementation will depend on strong and concerted partnerships and collaboration between all the stakeholders in the global system of maritime governance. Ultimately, education, training, and capacity-development for all stakeholders will be critical to the successful implementation of global maritime standards.

http://dx.doi.org/10.21622/MACI.2024.01.2.1027

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Professor Maximo Q. Mejia *is an accomplished global leader and scholar in Maritime Governance, Policy, and Administration. With over three decades of professional and academic experience, Professor Mejia is a passionate international advocate for the promotion of safe, secure, sustainable, and efficient shipping on clean oceans.*

Professor Mejia was appointed by the Secretary-General of the International Maritime Organization (IMO), as the eighth President of the World Maritime University (WMU), a university established within the framework of the IMO and a global centre of excellence for maritime and ocean education, research, and capacity building. He is the first President from Asia and the first President who is a graduate of WMU. As the Chief Executive Officer, Professor Mejia oversees and directs the academic programmes, operations, and administration of the University.

Professor Mejia held various positions at WMU, as Director of the PhD Programme, Head of the Maritime Law and Policy Specialization, and Nippon Foundation Professor of Maritime Governance, Policy, and Administration at WMU. He also served as Associate Academic Dean and has been a resident Faculty member since 1998. During his tenure at WMU, Professor Mejia spearheaded the further development of the WMU PhD programme in Maritime Affairs ensuring a cutting-edge curriculum and a growing number of doctoral students. Professor Mejia is author/co-author of more than 70 published articles and book chapters and the editor/co-editor of 12 books. His multi-disciplinary research and teaching include maritime policy, maritime law, maritime labour law and policy, human factors, safety, and security-related issues.

Aside from senior leadership roles within WMU, Professor Mejia served as Administrator/Director-General at the Maritime Industry Authority (MARINA) from 2013 to 2016, heading the government agency responsible for integrating the development, promotion, and regulation of the maritime industry in the Philippines. From 1988 to 1998, he progressively held various positions in the Philippine Navy and Philippine Coast Guard including Deputy Chief of Staff for Navigational Safety and Deputy Executive Director of the Multisectoral Task Force on Maritime Development. In 2013, Professor Mejia was included in the Lloyd's List 100 Most Influential Persons in the Shipping Industry. He served on several senior diplomatic assignments including Head of Delegation of the Philippines to IMO meetings (2013 -2016), Special Envoy of the President of the Philippines to the Inauguration of the Expanded Panama Canal (2016), and Chairperson of the 31st ASEAN Maritime Transport Working Group (2016).

Professor Mejia earned his PhD from Lund University, Sweden, Master of Science from the World Maritime University, Master of Arts in Law and Diplomacy from the Fletcher School, Tufts University, USA, and Bachelor of Science from the United States Naval Academy. Professor Mejia is fluent in Filipino, English, and Swedish and has a knowledge of Spanish and Chinese. He is married to Rebecca Hayes Mejia, with whom he has three children and three grandchildren.

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http://dx.doi.org/10.21622/MACI.2024.01.2.1006

JOURNAL OF MULTIDISCIPLINARY ADAPTIVE CLIMATE INSIGHTS (MACI) Volume 1, Issue 2, December 2024 - ISSN 3009-6332

THE EFFECT OF SUSTAINABLE AGRICULTURE PROGRAMS ON CHEMICAL FERTILIZER CONSUMPTION PATTERNS IN FARMERS

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Received on, 11 September 2024 Accepted on, 02 October 2024 Published on, 09 October 2024

ABSTRACT:

Background: *Fertilizers are essential to achieve food security by enhancing crop growth. The selection of chemical fertilizers over organic fertilizers brings environmental consequences. The government is trying to achieve food security and promote organic fertilizers over chemical fertilizers by implementing various programs.*

Aim: *The study is carried out to understand the effect of government policies on farmers' chemical fertilizer consumption patterns.*

Design: *The publicly available data on the All-India consumption of fertilizer nutrients are collected from The Fertilizer Association of India. All the values from FAI data are in '000 tonnes as used in the text. The data of fifteen years (2007-08 to 2021-22) of chemical fertilizer consumption was divided into three sub-groups of 5-year durations each. Statistical analysis was done to understand the trend of chemical fertilizer consumption by the farmers. The data collected were subjected to tabular analysis and year-wise growth rate analysis. In tabular analysis, the difference in consumption for the current year and the previous year as well as the average consumption of chemical fertilizer per year were analysed and the growth rate was studied.*

Results: *The analysis of data clearly shows the steadily increasing pattern of chemical fertilizer consumption. In the five-years period, from 2007-2012, the total quantity of fertilizer consumed was 129878 tonnes. and the average quantity of chemical fertilizer consumed per year was 25,975.6 tonnes. From 2012 to 2017, the total chemical fertilizers consumed was 128302.4 tonnes, whereas 25,660.48 tonnes were used per year. The results for the year 2017-2022 showed mixed trends.*

Conclusions: *The study clearly shows that there is no effect of sustainable agriculture policies framed by the government on the consumption of chemical fertilizers by farmers. Across the study period, farmers were inclined to use chemical fertilizers, related to a lack of awareness of the principles of appropriate fertilizer management that can limit environmental damage.*

KEY-WORDS: Fertilizers, agriculture, Sustainable Development Goals (SDGs), Environmental Health, Organic fertilizers.

http://dx.doi.org/10.21622/MACI.2024.01.2.1006

1. INTRODUCTION

Sub-Saharan African countries and South Asian countries like India, Bangladesh, Nepal, and Sri Lanka give heavy subsidies on chemical fertilizers to farmers. The main aim of these subsidies is to increase crop yield to increase farmers' income and food security (Ricome et.al., 2024).

India is home to one-sixth of the global population and holds the key to the success of the United Nations 2030 agenda or sustainable development goals (SDGs). The 17 SDGs emphasize the interconnected environmental, social, and economic aspects of sustainable development by putting sustainability at their centre (Schleicher, 2018). SDG 2 is to end hunger, achieve food security and improved nutrition, and promote sustainable agriculture (UNDP, 2020).

SDGs were formulated in 2015 by the United Nations General Assembly (UNGA), but India has been trying to achieve national food security along with sustainable agriculture from the year 2007. The efforts of the Indian government were similar to SDG 2 targets. From year 2007 to 2023, the Government of India launched various programs in this direction. In 2007, the National Agriculture Development Programme (RKVY) was launched. National Project on Management of Soil Health & Fertility (2008-2009), National Mission for Sustainable Agriculture (2014-2015), and recently Paramparagat Krishi Vikas Yojana was launched in 2023. Studying the performance of such programs is necessary for fact-based discussions in sessions of parliament similar to the farmer's issues like pesticide management (Sarkar, 2011) or access to quality seeds (Sarkar, 2012), etc. Consequently, a better policy can be formulated to achieve the desired goals.

The United Nations predicts that India needs to produce 50% more food by 2050 to feed another 2.5 billion people (FAO, 2017b). To achieve food security, improving agricultural production is necessary (Pawlak, 2020). Innovations like farming the sea (Schubel & Thompson 2019; Sarkar, 2021), precision farming (Ericson & Fausti, 2021), permaculture (Kurniawati *et al* 2022), vigour maintaining seeds (Finch-Savage & Bassel, 2016; Sarkar, 2011) and advancing genetic selection technologies (Qaim, 2020; Shabnam et. al, 2011) need to be implemented.

Whatever would be the farming method, fertilizers are one of the important factors affecting agriculture as well as the environment (Li and Wu, 2008; Savci, 2012). The use of organic fertilizer has contributed significantly to environmental sustainability and increasing agricultural production. So, to lessen the negative environmental impact of chemical fertilizers, replacing chemical fertilizers with organic fertilizers is a good choice for farmers (Wang *et. al*, 2018).

Urea, Diammonium phosphate (DAP), and Muriate of potash (MOP) are commonly used chemical fertilizers in India. Urea accounts for 82% of the total consumed nitrogen fertilizers. Not only in India but throughout the world urea is the most widely used chemical fertiliser.

Crops can take up only 30–50% of chemical fertilizers, and many of the applied components are lost in the soil polluting groundwater (Link *et al.,* 2006). Excessive fertilization causes soil salinity, heavy metal accumulation, water eutrophication, and accumulation of nitrate. It gives out gases like nitrogen and sulfur, leading to air pollution and can indirectly lead to the greenhouse effect. Climate change affects how farmers use fertilizer and fertilizer overuse can contribute to further climate change (IFC, 2023).

In such situations, it becomes necessary to understand the patterns of chemical or synthetic fertilizer (NPK) consumption over a period of time. To date, there are few studies available showing the pattern of chemical fertilizer consumption by Indian farmers. But most of these studies are either showing intra-state variations in chemical fertilizer consumption patterns (Bora, 2022; Chand & Pavithra, 2015) or chemical fertilizer consumption patterns for specific states or agricultural zones (Usama & Khalid, 2018; Bagal *et. al*, 2018; Suryawanshi, 2015). Some of the studies are carried out to study the determinants of fertilizer consumption (Jadhav & Ramappa, 2021; Waghmode *et. al*, 2020). However, there is hardly any study available which shows the national level chemical fertilizer consumption pattern specifically after year 2007, when India has decided to achieve food security along with agricultural sustainability.

This study mainly focuses on the exact quantity of chemical fertilizer consumption at the national level on a year-on-year basis specifically after the year 2007. Our main purpose is to comprehend whether there is any impact of the government's sustainable agriculture program on the behavior of farmers while choosing between organic or chemical fertilizers. Consumption pattern of chemical fertilizer mainly after the year 2007 was studied when the government announced various programs for sustainable agricultural development. This study of the trend in the consumption of chemical fertilizers from the year 2007 will help to understand the impact of the government programs on the choice of farmers, to understand factors responsible for the consumption of synthetic fertilizers by farmers, to promote organic fertilizers and to design future policies to achieve food security with agriculture sustainability.

2. METHODS

In the present study, secondary data were used to evaluate the trend in chemical fertilizer consumption in India for the period 2007-2022.

The data on the All-India consumption of fertilizer nutrients are collected from The Fertilizer Association of India https://www.faidelhi.org/general/con-npk.pdf. The Fertilizer Association of India (FAI) is a non-profit and non-trading company representing mainly fertilizer manufacturers, distributors, importers, equipment manufacturers, research institutes, and suppliers of inputs. The Association was established in 1955 with the objective of bringing together all concerned with the production, marketing, and use of fertilizers. This study carried out the analysis of fertilizer consumption in India from the year 2007-08 to 2021-22. For the convenience of the analysis, the total time of the study is divided into three subgroups of 5-year duration each.

The data collected were stored, tabulated, and analyzed. The total quantity of fertilizer ($N+P_2O_5+K_2O$) used per year is considered for the analysis. Keeping in view the study specific objectives, the data collected were subjected to tabular analysis and year-wise growth rate analysis (Wayne & Chad, 2014). In tabular analysis, the difference in consumption for the current year and previous year as well as the average consumption of chemical fertilizer per year were analysed and growth rate was studied by following the formula:

$$\text{Growth Rate} = \frac{\text{Vcurrent} - \text{Vprevious}}{\text{Vprevious}} \times 100$$

The average consumption of chemical fertilizers per year for the period of five years is calculated by the formula:

$$\text{Average} = \frac{\text{Sum of all observations}}{\text{Total number of observations}}$$

$$= \frac{a1+a2+a3\ldots.+an}{n}$$

All the values from FAI data are in '000 tonnes as used in the text.

3. RESULTS

The fertilizer consumption results for the 5 years (2007-2012) of analysis showed increasing trends (Table 1). But the maximum consumption of chemical fertilizer in these five years was in the year 2008-2009. This is the year when the National Project on Management of Soil Health & Fertility (2008-2009) was launched and just a year after the launch of the National Agriculture Development Programme (RKVY, 2007). In the year 2011-2012, fertilizer consumption is reduced as compared to the previous year (2010-2011). In the five-year period, from 2007- 2012, the total quantity of fertilizer Consumed was 129878 tonnes, whereas the average quantity of chemical fertilizer consumed per year was 25,975.6 tonnes (Table 4).

Table 1: Chemical fertilizer consumption pattern in India for the period (2007-2012)

Sr. No.	Year	Quantity of Fertilizer Consumed (´000 tonnes)	Difference from Previous Year 21651.0 (2006-2007) ´000 tonnes	Annual Growth Rate
1	2007-2008	22,570.1	919.1	4.25
2	2008-2009	24,909.3	2339.2	10.36
3	2009-2010	26,486.4	1577.1	6.33
4	2010-2011	28,122.2	1635.8	6.18
5	2011-2012	27,790.0	-332.2	-1.18

When the analysis was done for the period from year 2012 to year 2017, the decreasing consumption trend was noticed (Table 2). In these five years, comparatively lowest quantity of chemical fertilizer (24,482.4 tonnes) was used in the year 2013-2014. In this five-year period of 2012-2017, the total chemical fertilizers consumed was 128302.4 tonnes, whereas 25,660.48 tonnes were used per year.

Table 2: Chemical fertilizer consumption pattern in India for the period (2012-2017)

Sr. No.	Year	Quantity of Fertilizer Consumed (´000 tonnes)	Difference from Previous Year ´000 tonnes	Annual Growth Rate
1	2012-2013	25,536.2	-2253.8	-8.11
2	2013-2014	24,482.4	-1053.8	-4.12
3	2014-2015	25,581.3	1098.9	4.49
4	2015-2016	26,752.6	1171.3	4.58
5	2016-2017	25,949.9	-802.7	-3.00

The results for the year 2017-2022 are showing mixed trends (Table 3). In the years 2017 to 2019, the chemical fertilizer consumption was more or less similar. But the values have shown a dramatic increase in the year 2019-2020 (29,370.4 tonnes) and year 2020-2021 (32,535.6 tonnes). Year 2020-2021 has seen the highest chemical fertilizer consumption in the total study period of fifteen years. Again, in the year 2021-2022, the chemical fertilizer consumption has reduced substantially. The total chemical fertilizer consumed in this period was 145523.9 tonnes, whereas the average quantity of fertilizer consumed per year in this period was 29,104.78 tonnes.

Table 3: Chemical fertilizer consumption pattern in India for the period (2017-2022)

Sr. No.	Year	Quantity of Fertilizer Consumed (´000 tonnes)	Difference from ´000 tonnes	Annual Growth Rate
1	2017-2018	26,593.4	643.5	2.48
2	2018-2019	27,228.2	634.8	2.39
3	2019-2020	29,370.4	2142.2	7.87
4	2020-2021	32,535.6	3165.2	10.78
5	2021-2022	29,796.3	-2739.3	-8.42

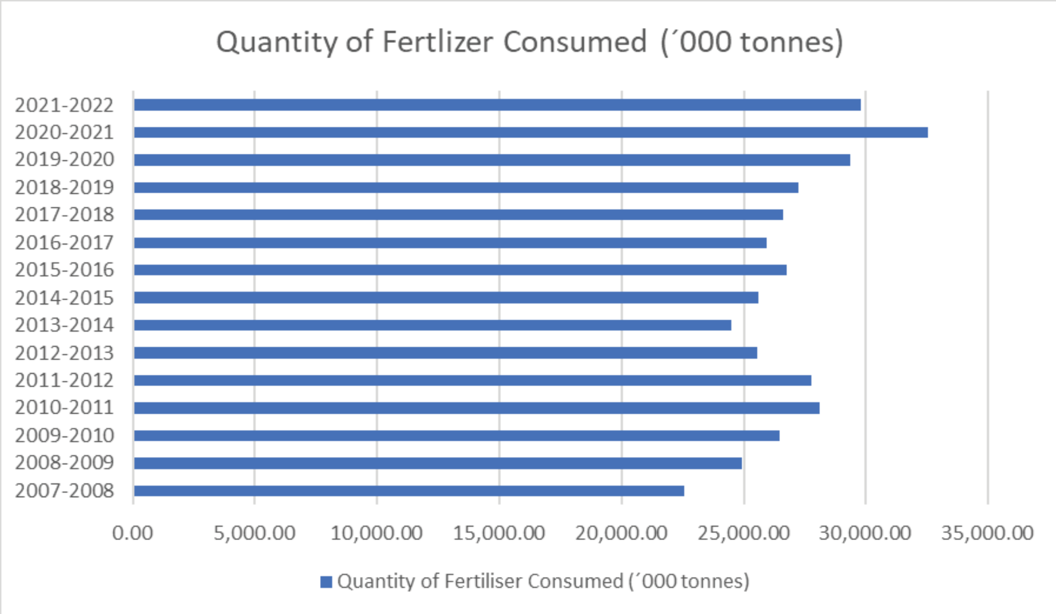

Fig.1. Quantity of fertiliser consumed ('000 tonnes) per year over the period of fifteen years

Table 4: Total quantity of fertilizer consumed in five years and average quantity of fertilizer consumed per year

Sr. No.	Period	Total quantity of Fertilizer Consumed (´000 tonnes)	Average quantity of Fertilizer Consumed per year (´000 tonnes)
1	2007-2012	129878.0	25,975.60
2	2012-2017	128302.4	25,660.48
3	2017-2022	145523.9	29,104.78

4. DISCUSSION

In 2007, National Agriculture Development Programme (RKVY) was launched. The main objective of this program was to increase the productivity of important crops through focused interventions and maximizing returns to farmers. After a year or so in the year 2008-2009, to improve soil health through green manuring, the National Project on Management of Soil Health & Fertility was launched. Both these programs are important from agriculture sustainability and environmental management point of view. The reason behind implementing these programs might be through the XIth – five-year plan, the Government of India was trying to achieve a 4% increase in agricultural growth while focusing on environmental sustainability.

The study is mainly carried out to understand whether the government agriculture programs affect the chemical fertilizer consumption of Indian farmers or not. The results of the study have shown steadily increasing trends in chemical fertilizer consumption in India over the last fifteen years.

The analysis of years 2007-2012 shows, that after launching these two crucial national programs there was an increasing trend in chemical fertilizer consumption. Many studies say subsidy is one of the major reasons for the increasing trend of chemical fertilizer consumption (Chand & Pandey, 2008; Praveen & Singh, 2023). If so, then it is important to consider in the study period, that in certain years, the chemical fertilizer consumption has reduced in India. In the year 2011-2012, chemical fertilizer consumption was reduced by an annual growth rate of -1.18. The possible reason behind this might be, in year 2011–12 India saw extremely dry events or drought (Udmale *et. al*, 2015).

The analysis of data for the year 2012-2017 shows a slight reduction in the consumption of chemical fertilizers as compared to the period 2007-2012. The possible reason behind this trend might be the implementation of National Mission for Sustainable Agriculture (NMSA) in the year 2014-2015. Soil Health Management (SHM) is one of the most important interventions under this Mission. SHM aims at promoting location as well as crop-specific sustainable soil health management, creating and linking soil fertility maps with macro-micro nutrient management, judicious application of fertilizers, and organic farming practices. These efforts of the government might have helped in a slight reduction of chemical fertilizer consumption during this period.

The results for the years 2017-2022 have shown a considerable increase in consumption of chemical fertilizers as compared to the periods 2007-2012 and 2012-2017. Though the analysis shows comparatively lower consumption in the period 2007-2012 and 2012-2017, chemical fertilizer consumption in India in the last fifteen years has increased steadily with slight variations. There is hardly any inclination towards the use of organic fertilizers (manure).

Similar results were found in the comparative study carried out for India, Bangladesh and Nepal for chemical fertilizers used for Rice and Wheat crops (Aryal et. al, 2021). Here, farmers in focus groups indicated that their use of manure was decreasing over time in all three countries. They reported that educated young household members are less interested in carrying manure to plots, and as a result, the use of chemical fertilizer is increasing over time. Economic and elements of social capital are primarily positively correlated with increased chemical fertilizer use. Their study also suggests wealth, gender, education, migration for employment, access to the market, training, and off-farm income sources are some of the key factors influencing the application of chemical fertilizers.

Another study carried out in Iran to analyse the factors affecting the level of water resources pollution caused by the amount of chemical fertilizer consumed by farmers shows that variables such as main activity, farmers' experience, farmers' education, awareness of organic farming, income, price of fertilizers, and irrigation methods have a significant effect on the level of consumption of chemical fertilizers by farmers (Mohammadi *et. al*, 2017).

Understanding the determinants for a farmer's choice of chemical fertilizer over organic fertilizer can help to reduce the consumption of chemical fertilizers. This is relevant for informing policy-making towards the negative environmental impacts and may help to achieve sustainable agriculture development goals, such as the zero growth of chemical fertilizers and pesticides, and recycling of animal and plant waste (MOA, 2015).

A study carried out on Chinese farmers' different fertilizer investment behaviours has discussed interesting facts (Chen *et. al.*, 2018). Environmental friendliness appeared to be unattractive to farmers, who may usually be myopic in developing countries and may need community-level coordination in providing environmental goods that benefit themselves in the long run (Dong et. al., 2013; Huang et. al., 2015).

A study carried out in the Indo-Gangetic Plain (IGP) where the externalities of excessive use of chemical fertilizers for cereal production manifest in pollution highlights an interesting fact. Here, researchers studied the determining factors for the adoption of organic fertilizers in the region. Their study shows that only 32% of the farmers adopted organic fertilizers in the region whereas the rest are dependent on chemical fertilizers. Membership in farmer organizations, training, and education are the key variables that determine the adoption of organic fertilizers over chemical fertilizers. This study suggests the need for efficient extension efforts in organic fertilizers and suggests policy interventions that promote collective learning through farmer groups (Koovalamkadu et. al., 2021).

The adoption rate of organic fertilizer is low compared to the increasing usage of chemical fertilizer because many farmers fear the loss of crop output. Uncertainty can lead risk-averse farmers to apply more fertilizers and generate more pollution than in the certainty case (Isik et. al., 2003). Perceived high cost and long payback periods are also barriers of investment in organic fertilizer (Hou et. al, 2018).

A study was carried out with farmers of Denmark to understand their current use of organic fertilizer, their interest in using alternative types in the future, and their perception of the most important barriers or advantages of using organic fertilizers. Almost three-quarters of respondents (72%) used organic fertilizer, and half of the arable/horticultural farms (without livestock) used unprocessed manures, suggesting significant manure exchange from animal production farms to arable farms in Denmark. The most important barriers to the use of organic fertilizer identified among these respondents were an unpleasant odour for neighbours, uncertainty in nutrient content, and difficulty in planning and use. Improved soil structure was clearly chosen as the most important advantage or reason to use organic fertilizer, followed by low cost to buy or produce, and ease of availability. Consequently, Danish government policies aim to increase in manure processing (Case et. al., 2017).

India, the world's second-largest chemical fertiliser consumer after China, has introduced many policies to regulate or reduce its use. The study at hand clearly shows that national sustainable agriculture policies do not affect farmers' consumption of chemical fertilizers. Across the study period, farmers reported being inclined to use chemical fertilizers. The main reasons for this are farmers' reluctance to take the risk of using organic fertilizers over chemical fertilizers and farmer's income expectations. For increase agriculture production and income, over the decades, the government promoted subsidies on chemical fertilizers which stimulated an increase in the use of chemical fertilizers. But with time, chemical fertilizers negative impacts on the environment have become prominent. Consequently, to minimize pollution and to achieve agriculture sustainability there is a need to reduce chemical fertilizers using multiple government policies.

Government needs to frame different types of policies mainly regulatory, incentive, and awareness policies. There is a need to frame policies related to awareness of the principles of appropriate fertilizer management that can limit environmental damage. The government needs to sensitize farmers by educational programs highlighting measures to improve nutrient-use-efficiency and reduce the negative impact of chemical fertilizer overuse.

The Ministry of Agriculture has to develop a central action plan for achieving 'low to no' chemical fertilizers. Under the guidance of the central policy local governments, every province has to introduce their own action plans to guide and support the farmers in minimizing the chemical fertilizers. The government needs to provide economic incentives to farmers to shift from chemical fertilizers to organic fertilizers. These incentive policies should be supported by publicity or awareness policies.

The success of these policies depends on the farmers' response to these programs. Farmers will accept these policies only if they are convinced of high benefits and low costs of implementation.

Policies framed for reducing chemical fertilizer use need more research work in the future as it will have certain effects. Successful implementation of organic fertilizers will improve soil conditions and increase crop yield. However, these benefits will need a long time to take place. Though this will carry certain levels of risks and uncertainties for farmers, researchers need to work on these risks and uncertainties. They need to convey their research data to the government from time to time to make policy modifications. In-depth research is needed on farmers' individual characteristics, land management methods, and other determinants for farmers' choice of chemical fertilizers.

5. CONCLUSIONS

This study clearly shows that chemical fertilizer consumption has increased steadily over the last fifteen years in India. For the study period, from 2007 to 2022, the chemical fertilizer consumption increased from 22,570.1 to 29,796.3 ('000 tonnes). There is no effect of national sustainable agriculture policies on the choice of chemical fertilizer consumption of Indian farmers. Subsidy on fertilizers is not the only reason behind the increasing use of chemical fertilizers over organic fertilizers. Region-specific determinants for the choice of chemical fertilizers need to be studied. To achieve environmental management and agricultural sustainability goals, policies need to be framed to educate the farmers for long-term gains in their choice of fertilizer. The government should strengthen policies and use comprehensive means to encourage the reduction of chemical fertilizer use. Studies in other countries show farmers' risk attitudes have a significant impact on the choice of fertilizers, hence further programs are recommended to educate the farmers. This can be explored to cover under the agriculture insurance system. The concerns of farmers about how organic fertilizers over chemical fertilizers will affect the crop yield will decide the success or failure of the government policies.

6. DECLARATIONS

- Ethics approval and consent to participate – Not Applicable
- Competing interests- The authors declare no conflicting interests
- Funding - Not Applicable
- Authors' contributions
  1) Conceptualization, methodology, analysis and investigation: - Jaimini Sarkar
  2) Original draft preparation, review and editing- Chiradeep Sarkar
- Acknowledgements - Not Applicable

REFERENCES:

01. Aryal, J. P., Sapkota, T. B., Krupnik, T. J., Rahut, D. B., Jat, M. L., & Stirling, C. M. (2021). Factors affecting farmers' use of organic and inorganic fertilizers in South Asia. *Environmental Science and Pollution Research*, *28*(37), 51480–51496. https://doi.org/10.1007/s11356-021-13975-7

02. Bora, K. (2022). Spatial patterns of fertilizer use and imbalances: Evidence from rice cultivation in India. *Environmental Challenges*, *7*, 100452. https://doi.org/10.1016/j.envc.2022.100452

03. Case, S. D. C., Oelofse, M., Hou, Y., Oenema, O., & Jensen, L. S. (2017). Farmer perceptions and use of organic waste products as fertilisers – A survey study of potential benefits and barriers. *Agricultural Systems*, *151*, 84–95. https://doi.org/10.1016/j.agsy.2016.11.012

04. Chand, R., & Pavithra, S. (2015). Fertiliser use and imbalance in India: Analysis of states. In *Economic and Political Weekly* (Vol. 50, Issue 44).

05. Chand, Ramesh and Pandey, L. M. (2008). Fertiliser Growth, Imbalances and Subsidies: Trends and Implications. *NPP Discussion Paper*, *02*(2008).

06. Chen, X., Zeng, D., Xu, Y., & Fan, X. (2018). Perceptions, Risk Attitude and Organic Fertilizer Investment: Evidence from Rice and Banana Farmers in Guangxi, China. *Sustainability*, *10*(10), 3715. https://doi.org/10.3390/su10103715

07. Cross Chad L., & Daniel Wayne W. (2014). Biostatistics: Basic Concepts and Methodology for the Health Sciences,. *Wiley India Pvt. Ltd.*

08. Dong, G., Mao, X., Zhou, J., & Zeng, A. (2013). Carbon footprint accounting and dynamics and the driving forces of agricultural production in Zhejiang Province, China. *Ecological Economics*, *91*, 38–47. https://doi.org/10.1016/j.ecolecon.2013.04.003

09. Erickson, B., & Fausti, S. W. (2021). The role of precision agriculture in food security. *Agronomy Journal*, *113*(6), 4455–4462. https://doi.org/10.1002/agj2.20919

10. FAO. (2017). FAO and the SDGs Indicators: Measuring up to the 2030 Agenda for Sustainable Development. *FAO and the SDGs*, *1*(1).

11. Finch-Savage, W. E., & Bassel, G. W. (2016). Seed vigour and crop establishment: extending performance beyond adaptation. *Journal of Experimental Botany*, *67*(3), 567–591. https://doi.org/10.1093/jxb/erv490

12. *Goal 2: Zero Hunger*. (2019). Taylor & Francis. https://doi.org/10.4324/SDG-G002

13. Hou, Y., Velthof, G. L., Case, S. D. C., Oelofse, M., Grignani, C., Balsari, P., Zavattaro, L., Gioelli, F., Bernal, M. P., Fangueiro, D., Trindade, H., Jensen, L. S., & Oenema, O. (2018). Stakeholder perceptions of manure treatment technologies in Denmark, Italy, the Netherlands and Spain. *Journal of Cleaner Production*, *172*, 1620–1630. https://doi.org/10.1016/j.jclepro.2016.10.162

14. Huang, J., Huang, Z., Jia, X., Hu, R., & Xiang, C. (2015). Long-term reduction of nitrogen fertilizer use through knowledge training in rice production in China. *Agricultural*

Systems, *135*, 105–111. https://doi.org/10.1016/j.agsy.2015.01.004

15. International Finance Corporation World, B. G. (2023). *Strengthening Sustainability in the Fertilizer Industry*. https://www.ifc.org/en/insights-reports/2023/strengthening-sustainability-in-the-fertilizer-industry

16. Isik, M., & Khanna, M. (2003). Stochastic Technology, Risk Preferences, and Adoption of Site-Specific Technologies. *American Journal of Agricultural Economics*, *85*(2), 305–317. https://doi.org/10.1111/1467-8276.00121

17. Jadhav, V., & Ramappa, K. B. (2021). Growth & Determinants of Fertilizer Consumption in India: Application of Demand and Supply Side Models. *Economic Affairs (New Delhi)*, *66*(3). https://doi.org/10.46852/0424-2513.3.2021.9

18. Koovalamkadu Velayudhan, P., Singh, A., Jha, G. K., Kumar, P., Immanuelraj Thanaraj, K., & Korekallu Srinivasa, A. (2021). What Drives the Use of Organic Fertilizers? Evidence from Rice Farmers in Indo-Gangetic Plains, India. *Sustainability*, *13*(17), 9546. https://doi.org/10.3390/su13179546

19. Kurniawati, I., Dahlan, M. Z., & Faisal, B. (2022). Permaculture Landscape as an Adaptive Strategy towards Food Security at Community-Scale. *IOP Conference Series: Earth and Environmental Science*, *1092*(1), 012015. https://doi.org/10.1088/1755-1315/1092/1/012015

20. Li, D. P., & Wu, Z. J. (2008). Impact of chemical fertilizers application on soil ecological environment. In *Chinese Journal of Applied Ecology* (Vol. 19, Issue 5).

21. Link, J., Graeff, S., Batchelor, W. D., & Claupein, W. (2006). Evaluating the economic and environmental impact of environmental compensation payment policy under uniform and variable-rate nitrogen management. *Agricultural Systems*, *91*(1–2), 135–153. https://doi.org/10.1016/j.agsy.2006.02.003

22. Ministry-of-Agriculture. (2015). National Agricultural Sustainable Development Plan of China (2015–2030). *Beijing, China: Ministry-Of-Agriculture*.

23. Mohammadi, H., Mohammadi, A. M., & Nojavan, S. (2017). Factors Affecting Farmer's Chemical Fertilizers Consumption and Water Pollution in Northeastern Iran. *Journal of Agricultural Science*, *9*(2), 234. https://doi.org/10.5539/jas.v9n2p234

24. Pawlak, K., & Kołodziejczak, M. (2020). The Role of Agriculture in Ensuring Food Security in Developing Countries: Considerations in the Context of the Problem of Sustainable Food Production. *Sustainability*, *12*(13), 5488. https://doi.org/10.3390/su12135488

25. Praveen, K. V., & Singh, A. (2023). The landscape of world research on fertilizers: a bibliometric profile. *Current Science*, *124*(10). https://doi.org/10.18520/cs/v124/i10/1140-1150

26. Qaim, M. (2020). Role of New Plant Breeding Technologies for Food Security and Sustainable Agricultural Development. *Applied Economic Perspectives and Policy*, *42*(2), 129–150. https://doi.org/10.1002/aepp.13044

27. Ricome, A., Barreiro-Hurle, J., & Sadibou Fall, C. (2024). Government fertilizer subsidies, input use, and income: The case of Senegal. *Food Policy*, *124*, 102623. https://doi.org/10.1016/j.foodpol.2024.102623

28. Sarkar, J. (2011a). Science and higher education-related legislature before parliament. In *Current Science* (Vol. 100, Issue 9).

29. Sarkar, J. (2011b). Vigour maintaining seeds for farmers. In *Current Science* (Vol. 101, Issue 1).

30. Sarkar Jaimini. (2012). Parliament sessions—Planning versus performance. *Current Science*, *102*(9).

31. Sarkar Jaimini. (2021). Farming the Sea for the Future. *Science Reporter*, *58*, 28–31.

32. Savci, S. (2012). Investigation of Effect of Chemical Fertilizers on Environment. *APCBEE Procedia*, *1*, 287–292. https://doi.org/10.1016/j.apcbee.2012.03.047

33. Schleicher, J., Schaafsma, M., & Vira, B. (2018). Will the Sustainable Development Goals address the links between poverty and the natural environment? *Current Opinion in Environmental Sustainability*, *34*, 43–47. https://doi.org/10.1016/j.cosust.2018.09.004

34. Schubel, J. R., & Thompson, K. (2019). Farming the Sea: The Only Way to Meet Humanity's Future Food Needs. *GeoHealth*, *3*(9), 238–244. https://doi.org/10.1029/2019GH000204

35. Shabnam, A. A., Jaimini, D., Sarkar, C., Phulara, R., & Pawar, S. E. (2011). Evaluation of gamma rays-induced changes in oil yield and oleic acid content of niger, Guizotia abyssinica (L. f.) Cass. In *Current Science* (Vol. 101, Issue 4).

36. Singh Bagal, Y., Sharma, L. K., Kaur, G. P., Singh, A., & Gupta, P. (2018). Trends and Patterns in Fertilizer Consumption: A Case Study. *International Journal of Current Microbiology and Applied Sciences*, *7*(04). https://doi.org/10.20546/ijcmas.2018.704.056

37. Suryawanshi, S. D. (2015). Growth of Chemical Fertilizer Consumption in India: Some Issues. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.2571213

38. Udmale, P. D., Ichikawa, Y., Manandhar, S., Ishidaira, H., Kiem, A. S., Shaowei, N., & Panda, S. N. (2015). How did the 2012 drought affect rural livelihoods in vulnerable areas? Empirical evidence from India. *International Journal of Disaster Risk Reduction*, *13*, 454–469. https://doi.org/10.1016/j.ijdrr.2015.08.002

39. Usama, M., & Khalid, M. A. (2018). Fertilizer consumption in India and need for its balanced use: A review. In *Indian Journal of Environmental Protection* (Vol. 38, Issue 7).

40. Waghmode, S. S., Shelake P.N., & Vidhate U.A. (2020). Growth and Determinants of Fertilizer Use in India- An Economic Analysis. *International Journal of Current Microbiology & Applied Sciences*.

41. Wang, Y., Zhu, Y., Zhang, S., & Wang, Y. (2018). What could promote farmers to replace chemical fertilizers with organic fertilizers? *Journal of Cleaner Production*, *199*, 882–890. https://doi.org/10.1016/j.jclepro.2018.07.222

http://dx.doi.org/10.21622/MACI.2024.01.2.1026

JOURNAL OF MULTIDISCIPLINARY ADAPTIVE CLIMATE INSIGHTS (MACI) Volume 1, Issue 2, December 2024 - ISSN 3009-6332

LOBBYING STRATEGIES FOR CLIMATE-AFFECTED FARMERS IN RURAL COMMUNITIES IN GHANA: A CASE STUDY OF KLOTEKPO IN THE VOLTA REGION OF GHANA

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Received on, 20 September 2024 Accepted on, 25 October 2024 Published on, 04 November 2024

ABSTRACT:

Climate change effects such as rising temperatures, and increased frequency of extreme weather events such as droughts and floods significantly impact agriculture in Ghana. These effects threaten crop yields, particularly for rural smallholder farmers who rely on rain-fed agriculture. The case study highlights the significant impact of climate change on agriculture. Informal interviews with farmers revealed their personal experiences with unpredictable weather patterns and prolonged droughts, while a comprehensive review of agricultural policies identified critical gaps in awareness and enforcement. The findings indicate that many farmers lack knowledge of existing agricultural policies and organizations that could support their efforts to advocate for better resources and assistance. To address these challenges, practical lobbying strategies are introduced through training sessions aimed at empowering farmers to effectively communicate their needs to policymakers. This case study underscores the necessity for targeted lobbying efforts to support rural smallholder farmers in adapting to the changing climatic landscape in Ghana.

KEY-WORDS: Adaptation strategies, Climate change, Crop failure, Climate advocacy, Economic impacts, Farming practices, Rainfall patterns, Rural communities, Social vulnerability, Climate justice.

http://dx.doi.org/10.21622/MACI.2024.01.2.1026

1. INTRODUCTION

Globally, agriculture provides livelihoods for 2.5 billion people and accounts for 29% of GDP and 65% of jobs in Low- and Middle-Income Countries (LMICs) (Jayne et al., 2021). Agriculture is vital to Ghana's economy, with about 70% (Darfour, 2016) of the population relying on agriculture for their livelihoods. However, the agriculture sector is highly vulnerable to climate change impacts, such as erratic rainfall patterns and increased temperatures (Desjonqueres, 2024). Given that about 70% of Ghana's population depends directly or indirectly on agriculture, any climate-induced instability in this sector could have far-reaching social and economic consequences (Adom, 2024).

The UNDRIP (2018) provides the need for rural or indigenous communities to have the right to free, prior and informed consent on any changes in existing or creation of new laws or regulations by governments that affect indigenous people. For climate affected farmers in rural communities in Ghana, it is necessary to repeat the centrality of rights in the work on advocacy and lobbying. Looking into the root cause of poverty and marginalization of rural farmers instead of just considering causes is referred to the Rights-Based Approach to development (Cullen, 2024). In Klotekpo, farmers rely predominantly on rain-fed agriculture, making them particularly susceptible to the adverse effects of climate variability. The need for effective lobbying strategies has become paramount as these farmers seek to influence policies that affect their livelihoods and adapt to changing climatic conditions.

This case study aims to discuss the current challenges faced by farmers in Klotekpo due to climate change, identify key agricultural policies, and develop a lobbying strategy that empowers climate affected farmers to advocate effectively for their rights and needs. By understanding the specific impacts of climate change on agricultural practices and engaging with relevant policymakers, this case study seeks to enhance the capacity of local farmers to influence decisions that affect their livelihoods and promote sustainable agricultural practices in their community.

2. METHODS

Klotekpo, is a rural farming community located in the South Tongu District of the Volta Region, Ghana. Majority of community members rely on subsistence farming as a source of livelihood (National Development Planning Commission, 2018-2021). Rice, a crop which mainly grows within the community of Klotekpo, is highly sensitive to the impacts of climate change (Lu, 20214). To understand the challenges faced by farmers, informal interviews and discussions are conducted to gather personal experiences with climate change impacts. A comprehensive review of relevant agricultural policies is performed to identify gaps in policy enforcement and areas for improvement that could better support farmers. Based on these findings, practical lobbying strategies are introduced to farmers through training sessions. These sessions aim to empower climate affected farmers with skills to effectively advocate for their needs and influence policy changes.

3. RESULTS

3.1. Impact of climate change on agriculture

For rural farmers in Klotekpo, the impact of climate change is evident in the year-on-year activities that mainly are dependent on rainfall rather than irrigation as is the case in the developed world (Rifky, 2024). Farmers in Klotekpo reported significant declines in crop yields due to unpredictable rainfall patterns and prolonged droughts. This has heightened food insecurity within the community. According to World Food Programme (2023), approximately one million people in Ghana are food insecure, with rural areas being particularly affected by adverse weather conditions that disrupt agricultural productivity.

3.2. Agricultural policy awareness gaps

Many farmers in Klotekpo lack awareness of existing policies and organizations that could support their lobbying efforts, indicating a critical gap in communication between policymakers and rural communities. This disconnect not only hampers the effectiveness of agricultural policies but also limits farmers' ability to lobby for resources and support systems to enhance their resilience to climate change. Interviews revealed that while some farmers expressed a desire for more information on government initiatives, they often rely on informal networks for knowledge sharing, which may not provide comprehensive or accurate updates on relevant agricultural policies.

4. DISCUSSION

4.1. Vulnerability of smallholder rural farmers

The findings from Klotekpo highlight the profound impact of climate change on rural agriculture, particularly the reliance on rainfall for crop production. The significant declines in crop yields reported by farmers are indicative of the broader challenges faced by smallholder farmers in Ghana, where approximately one million people (WFP, 2023) are currently food insecure due to adverse weather conditions disrupting agricultural productivity. This aligns with research indicating that climate change increases the frequency of extreme weather events, such as prolonged droughts and unpredictable rainfall patterns, which directly threaten food security in vulnerable communities like Klotekpo (Kpenekuu, 2024).

4.2. Agricultural policies in Ghana

Farmers in Klotekpo face significant challenges due to lack of awareness regarding existing agricultural policies and organizations that could aid their lobbying efforts. This gap in communication between policymakers and rural communities limits the effectiveness of agricultural policies and restricts farmers' access to resources designed to enhance their resilience to climate change. Without proper knowledge of available support systems, farmers struggle to lobby for their needs, which can lead to missed opportunities for assistance and improvement in agricultural practices. Strengthening communication channels and raising awareness about these policies are essential steps toward empowering farmers in Klotekpo and improving their ability to adapt to changing climatic conditions. A summary of agricultural policies in Ghana (Sova et al., 2014; Boadu, 2024) is shown in table 1.0 below:

Table 1: Key messages to addressing existing climate change and agriculture policies

Policy	Intent/Focus	Key initiatives	Expected Policy Outcome	Analysis/Challenges
National Agriculture Investment Plan (NAIP)	Transform Ghana's agriculture sector through increased public investment & private sector participation.	Mechanization, irrigation and value chain development.	Effort is to enhance water security, strengthen climate resilience and empower farmers to adapt to changing weather patterns.	NAIP has not significantly reduced food insecurity, malnutrition, and poverty especially among women, the youth, physically challenged, small-scale producers & entrepreneurs.
Planting for Export and Rural Development (PERD)	Promote cultivation of tree crops like cashew, oil palm, and rubber to boost exports and rural incomes.	More seedling distribution and supporting smallholder farmers through subsidizing organic fertilizers.	Effort here is to enhance foreign exchange earnings and promote cash crops growth (cashew) for job creation.	Weak legal framework and lack of effective regulation on cash crop.
One-District-One-Warehouse	Construct warehouses in each of Ghana's 260 districts to reduce post-harvest losses.	Accelerate the construction of one-district-one-warehouse facilities to reduce post-harvest losses.	Establish road networks, especially in rural areas, which impedes the transportation of agricultural produce to and from warehouses.	A number of warehouses in the middle belt and northern parts of Ghana are in operation.
Modernizing Agriculture in Ghana (MAG) Programme	Improve agricultural productivity and competitiveness.	Strengthen the sustainability of interventions and their long-term impact.	Effort here is to enhance crop production.	Lack of processing & storage infrastructure as well as quality standard testing facilities.

4.3. Developing a lobbying strategy

A lobbying campaign for climate-affected farmers in rural communities requires a strategic and comprehensive planning approach that encompasses several critical steps to effectively advocate for their interests and influence policy decisions (Santos et al., 2021). A lobbying campaign planning process involves identifying key stakeholders, conducting thorough research on the policy landscape, developing compelling messages, and building strong relationships with decision-makers. By carefully crafting a targeted campaign, it is possible to mobilize support from key decision makers, raise awareness of smallholder farmers on Ghana's agricultural policy initiatives, and ultimately achieve policy changes that benefit climate- affected farmers. A sample design for building a lobbying campaign is shown in Table 2.0 below:

Table 2: A sample design for building a lobbying campaign

Key Messages	Lobby	Strategies	Suggested Solutions	Responsible/ Collaborating Individuals
Raising awareness of the impact on climate change on agriculture	How is climate change affecting agricultural productivity in Ghana?	Conduct training sessions for rural farmers.	Under changing weather patterns to safeguard food production, Call for urgent adaptation to new farming practices (agroforestry).	Agricultural Extension Officers
				Researchers
				Local NGOs
Enhance Resilience of Farmers	Government to invest in use of technology in agriculture.	Promote climate-smart agricultural practices.	Introduce drought resistant seeds.	Agricultural Advisors
	Provision of financial assistance to farmers.			Financial Institutions
				Government Agencies
Build Alliances for Climate Action through campaigns	Provide financial support for smallholder climate affected farmers.	Collaborate with NGOs and community organizations.	Proactive measures to mitigate the impact of price increases of crops.	Government agencies
				Youth Climate Advocates
	Improve agricultural infrastructure, and implement policies that promote sustainable farming practices.	Engage policymakers in dialogue.		Community Leaders
				Local NGOs

5. CONCLUSION

Climate change poses a significant threat to agriculture, impacting food security and the livelihoods of rural farmers. It is essential for rural farmers to understand their rights and the importance of engaging with policymakers. By organizing and voicing their concerns, rural farmers can influence decisions that affect their lives and communities. Rural farmers must recognize that their voices matter in the decision-making process. Engaging with local and national policymakers is crucial for advocating for the resources and support they need. This engagement can lead to better access to funding, technology, and training programs that help them adapt to changing climate conditions. Additionally, forming alliances with other farmers and community groups can amplify their impact. When rural farmers unite, they create a stronger platform to address common challenges. This solidarity can lead to more effective lobbying efforts and greater visibility for issues such as climate change impacts on agriculture.

6. ACKNOWLEDGEMENT

The Youth Climate Convening + Building Lobbying Capacity of Climate Affected Farmers (YCC + BLOCAF) - a youth-led project, was funded by UMI Fund. Special appreciation to Dr. Vincent Von Vordzogbe, Senior Lecturer, University of Ghana for the technical advisory role played in the

development of the lobbying manual.

REFERENCES:

01. Boadu, E. S. (2024). Evaluating Ghana's Youth-Centered Food-Security Policies: A Collaborative Governance Approach. *Sustainability*, *16*(9), 3830. https://doi.org/10.3390/su16093830

02. Darfour, B., & Rosentrater, K. A. (2016, July 17). AGRICULTURE AND FOOD SECURITY IN GHANA. *2016 ASABE International Meeting*. https://doi.org/10.13031/aim.20162460507

03. Desjonqueres, C., Zhao, H., Kosmidou-Bradley, W., & Corral, P. (2024). *Ghana's climate vulnerability profile*.

04. Government of Ghana. (n.d.).

05. Kpenekuu, F., Antwi-Agyei, P., Nimoh, F., Osei, M. A., & Guodaar, L. (2024). Understanding drought risk management in vulnerable communities in dryland farming systems: Evidence from northwest Ghana. *International Journal of Disaster Risk Reduction*, *100*, 104186. https://doi.org/10.1016/j.ijdrr.2023.104186

06. Lu, M. (2024). Impact of climate change on rice and adaptation strategies: A review. *Advances in Resources Research*, *4*(2), 252–262. https://doi.org/https://doi.org/10.50908/arr.4.2_252

07. Nations, U. (2007). United Nations Declaration on the Rights of Indigenous Peoples. *United Nations Declaration on the Rights of Indigenous Peoples*, 1–32. https://doi.org/10.1353/hrq.2011.0040

08. Rifky, M., Jesfar, M., Dissanayake, K., Ermat, S., & Samadiy, M. (2024). Development and evaluation of an automated irrigation system for ordinary agriculture farm. *E3S Web of Conferences*, *480*, 03013. https://doi.org/10.1051/e3sconf/202448003013

09. Adom, P. K. (2024). The Socioeconomic Impact of Climate Change in Developing Countries in the Next Decades (No. 681).

10. Cullen, B., & Debevec, L. (2024). Integrating social inclusion perspectives in agricultural food systems research for development: a background paper.

11. Santos, S., Ravara, P., & Rodrigues, D. (2021). Guide for Participation in Democratic Environmental Governance.

12. Sova, C., Chaudhury, A. S., Nelson, W., Nutsukpo, D. K., & Zougmoré, R. B. (2014). Climate change adaptation policy in Ghana: Priorities for the agriculture sector. *CCAFS Working Paper.*

13. World Food Population (WFP), Country Brief, Ghana. (2023).

http://dx.doi.org/10.21622/MACI.2024.01.2.1026

APPENDIX I

A general step-by-step guide for lobbying:

1. *Draw up the list of officials/individuals you will lobby and collect information about their background and potential position or stand to your requested action.*

2. *Based on an outlined list, make a plan on how best to approach each of them according to their category (Government, NGO, Academic institutions)*

    - *Examples on different ways to approach officials:*

    - *Request the support of an ally or someone known to the officials to arrange a meeting appointment; or present/discuss your issue to get some initial feedback on the opinion of the official;*

    - *It is not easy to attract the attention of decision-makers. Hence, it is advisable to establish contact to their secretary/ employee who can be sympathetic to your cause/issue. They can be very critical in gaining the support of the official and also influencing the staff of other officials you will also be lobbying.*

    - *Arrange meetings with decision-makers in formal (their office) or informal settings (restaurant or quiet public place) where appropriate; and explore avenues where you can interact with decision-makers by knowing their activities/schedules. For example, you may attend their inauguration of a school, etc. However, do not be intrusive or aggressive as this may cause consternation and be counterproductive.*

3. *When you do lobby work, make sure you have written materials or documents to submit relating to your issue and requested action.*

4. *Lobbying work is not confined in meetings with decision makers, but also includes the court of public opinion. By getting the active support of donors, members of the media and influential individuals, and generating public attention and concern, the advocate is indirectly taking steps to persuade/ exert pressure on decision-makers to take action.*

5. *All types of decision makers can be lobbied! A person or an organisation with the power to make a decision that can benefit or otherwise affect the advocate and his or her goals can be lobbied. They can be traditional leaders, newspaper editor/publisher, church leaders, and representatives of donor agencies/ organisations, NGOs etc. However, use sound judgement when determining whether attempts to persuade particular people and institutions can or should be made.*

http://dx.doi.org/10.21622/MACI.2024.01.2.1016

JOURNAL OF MULTIDISCIPLINARY ADAPTIVE CLIMATE INSIGHTS
(MACI) Volume 1, Issue 2, December 2024 - ISSN 3009-6332

SUSTAINABLE DIET WITHIN GLOBAL FOOD SYSTEM: FROM PEOPLE TO PLANET TO PEOPLE

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Received on, 15 September 2024 Accepted on, 03 November 2024 Published on, 17 November 2024

ABSTRACT:

Sustainability in the global food system is a pressing matter. Healthy and nutritious diet should have Minimal environmental footprints, it is a highly debatable topic. Food scientists, local farmers, food manufacturers, private sectors and governments regularly plan round-tables to dictate new policies. However, one or more party usually oppose the new policy, which is the major conundrum of Sustainable Diet within global food system. This paper deals with Sustainable Diet Notions, tackling food waste and agro-waste, understanding different supply chains in the food system and how circular economy should be effectively implemented. Multiple innovative approaches are introduced from multidisciplinary and circular economy perspectives to: a. Reduce carbon footprints, b. Save resources and huge economic burden of waste control, c. Provide an idea for a new possible merging market based on eco-friendly technology, d. Significantly reduce food waste, e. Significantly reduce food insecurity, hunger and hidden hunger.

KEY-WORDS: Circular economy, Food insecurity, Food waste, GHG emissions, Sustainable diet.

http://dx.doi.org/10.21622/MACI.2024.01.2.1016

1. INTRODUCTION

Sustainable Diet as per UN SDG2 (Zero Hunger), is to provide healthy and nutritious diet which meets sociocultural norms, economically affordable, available throughout the year, and finally with minimal environmental impacts. Sustainable Diet has a pivotal role on reducing Greenhouse Gas emissions (air footprint), Soil footprint (protection of topsoil, low erosion, low intensive farming and reforestation) as well as water footprint with (no physical and chemical pollutants), with minimal exploitation to rangelands, maintaining sustainable fishing methods, adopting regenerative traditional agriculture methods with recent innovative technologies and limiting industrialized conventional agricultural methods, i.e. monoculture (planting one crop in the field such as rice, maize or wheat) with intensive use of insecticides, pesticides and inorganic fertilizers, accompanied by heavy machinery reliance and low labor in the field. (Medicine et al, 2019).

Fig. 1. Elements of sustainable diet (Environmental, Social and Economic) which illustrate the meaning of sustainability in the global food systems.

Obtained from: https://www.researchgate.net/figure/The-key-components-and-determinants-of-a-sustainable-diet-Johnston-et-al-2014_fig1_360239396 The key components and determinants of a sustainable diet (Johnston et al., 2014). Sustainable Diet had environmental, Social and economic aspects.That food has to be healthy, balanced, affordable, available and with minimal ecological impacts.

Green revolution: 1960s is a turning point from traditional farming to industrialized farming (Crain, 2024)

- It increased crops production but also increased insecticides, pesticides and unprecedented rise of new diseases.
- It merged inorganic fertilizers use for more land fertility, but also harmed the environment, as in Eutrophication which reduces the water quality of lakes and rivers, as well as harming aquatic life.
- Machinery replaced labor, but also there is intensive farming, soil erosion, loss of topsoil and land fertility.
- Monocrop and loss of biodiversity: Nowadays 50% of energy crops comes from rice, wheat, and maize.

Theoretically, sustainable diet implementation seems applicable, but in practice it is not easily possible since multiple drivers have to be considered in achieving Global Sustainable Diet System.

Stakeholders of sustainable diet usually make it a very hard controversial choice, it is quite difficult to convince manufacturers, local farmers, private sectors, food banks, governmental and non-governmental institutions to finalize legislations towards achieving Sustainable Diet System (Herens et al., 2022). Civil society and consumers are a major target in achieving Sustainable Diet goals, the challenge is in resistance to adopt Sustainable Diet System. What makes it more challenging is that many people lack awareness of home economics, proper dietary and culinary knowledge. Nevertheless, it is promising that many food industry entities started to have commitments towards applying SDGs in their businesses with circular economy multi-sectorial cooperation to reduce food emissions, enhance livelihood of people and raising proper sustainable diet awareness (Private Sector Engages with FAO on Improving Food Security and Agriculture Sector Sustainability, 2024).

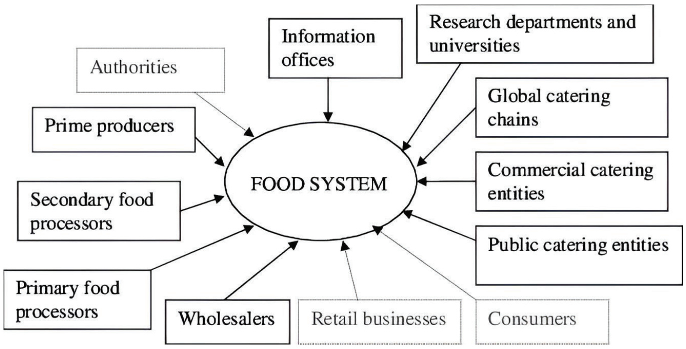

Fig. 2. Stakeholders in the food system.

Obtained from: https://www.researchgate.net/figure/Organisations-represented-in-the-two-empirical-studies_fig1_277204301. Food systems have multiple stakeholders (Governmental & non-governmental organizations, local farmers, private sector, processing factories, research centers, retailers and consumers), each has a profound role in maintaining sustainable food system.

2. A CHALLENGE OF ACHIEVING HEALTHY FOOD SECURITY FOR PRESENT AND FUTURE GENERATIONS

Diet is a interconnected topic. The aspect of healthy food is an enormously studied topic in terms of diet-related diseases, disease-care and prevention (overweight and obesity, severe hunger diseases, i.e. stunting and wasting and hidden hunger diseases, i.e. anemia), in another word non-communicable diseases as in: Cardiovascular diseases, high blood pressure, cancers, osteoporosis and diabetes type 2. In 2024: 695 million people, approximately 10% suffer from mild to severe hunger (HungerMap LIVE, 2024).

JOURNAL OF MULTIDISCIPLINARY ADAPTIVE CLIMATE INSIGHTS
(MACI) Volume 1, Issue 2, December 2024 - ISSN 3009-6332

http://dx.doi.org/10.21622/MACI.2024.01.2.1016

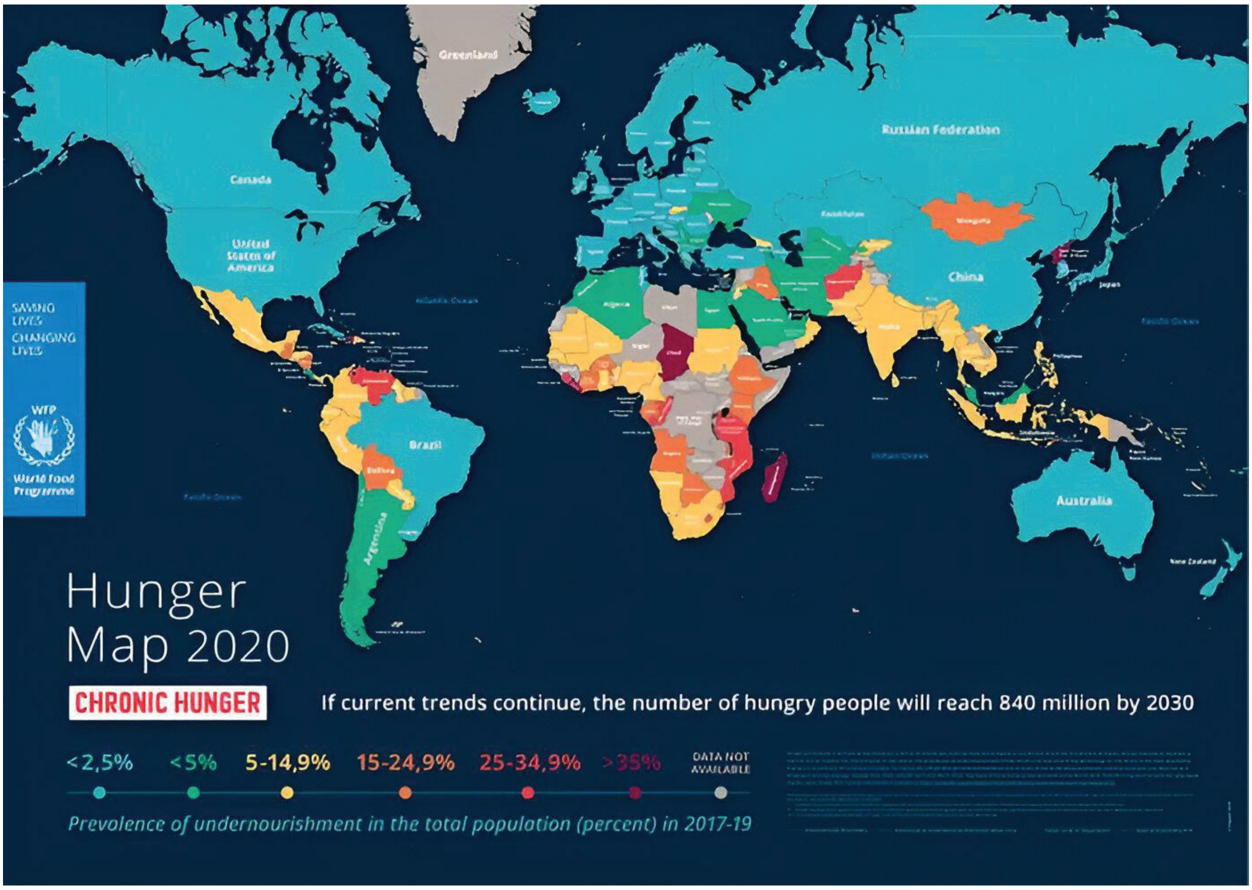

Fig. 3. Hunger map 2020.

Obtained from: https://reliefweb.int/map/world/hunger-map-2020 (WFB, 2020). Blue and Green colors represent countries with low levels of hunger, Yellow and Orange countries indicate mild levels of hunger, Deep Orange and Red represent severe food insecurity and Grey means no data available. As per analytical provisions: hungry people will reach 840 million by 2030 if no further actions taken.

1 billion people suffer from obesity (diabetes 2 and/or CVDs) which costs $2 trillion annually, it is projected to reach 1.53 billion by 2035. (Prevalence of Obesity | World Obesity Federation, 2024).

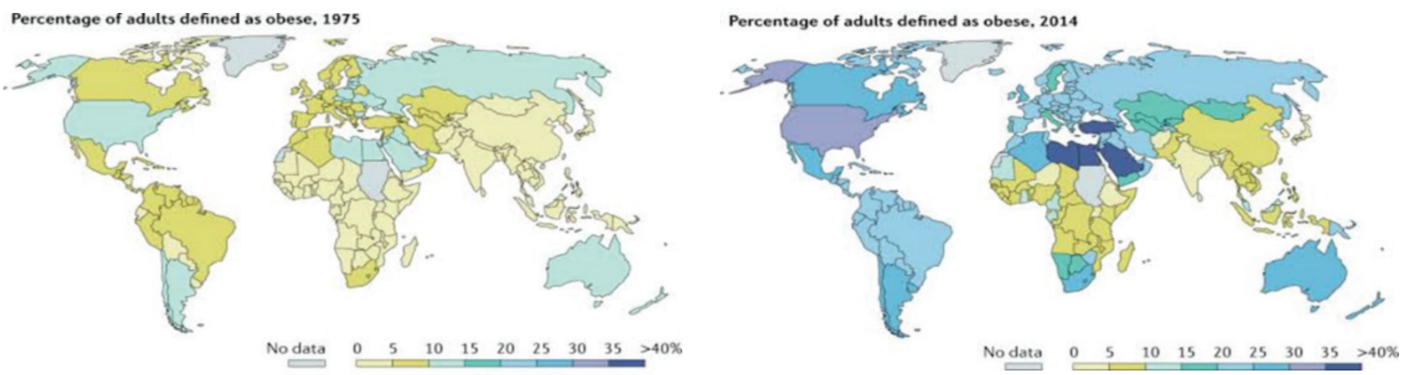

Fig. 4. Obesity prevalence in years 1975 and 2014.

Obtained from: https://www.nature.com/articles/s41574-019-0176-8, (Blüher, 2019). The picture on top shows obesity prevalence between adults in 1975, where there were no obesity levels even in developed countries. In the contrary the picture below illustrates the obesity prevalence between adults in 2014, where obesity has drastically increased in the world especially in the developed countries, where there are surplus of food throughout the year. Deep Blues and Blue colors show extreme and high levels of obesity; deep and light Green colors show low and mild percentages of obesity, White color shows no obesity and Grey color shows no data available.

2 billion people suffer from hidden hunger (lack of one or more essential micronutrients) with continuing rise in mortalities because of diet-related diseases (Micronutrient Forum, 2023).

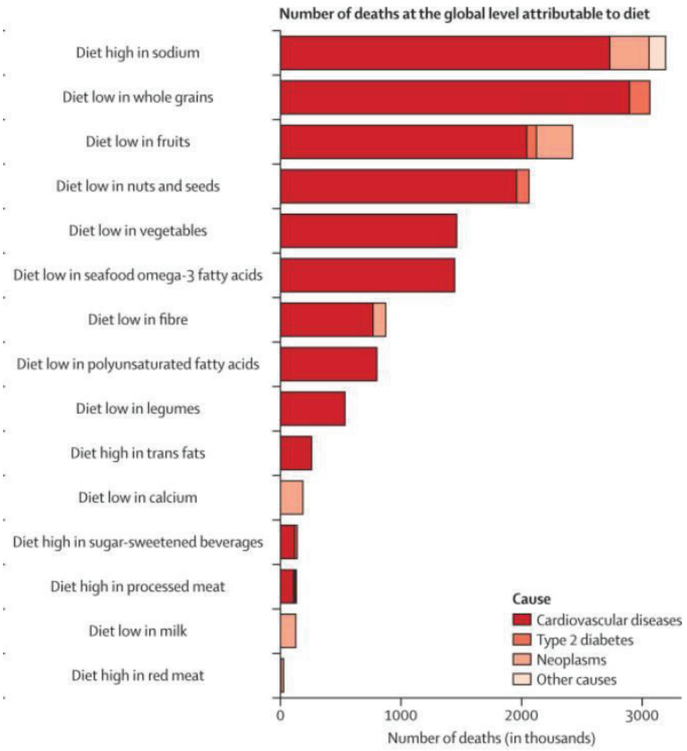

Fig. 5. Diet-related mortality rate and number of deaths in thousands.

Obtained from: http://dx.doi.org/10.1016/S0140-6736(19)30041-8 (Ashkan et. al, 2019). High and low levels of different diets (high sodium, high sugar, high processed meat, low fruits, low whole grains...etc.) cause death between populations from CVDs, Diabetes 2, Neoplasms, and other causes. Statistically cardiovascular diseases have the highest number of deaths because of diet-related complications. For instance, diet low in fibres resulted in approximately 1000 deaths of people due to cardiovascular diseases.

In developed countries there is food surplus because of the continuous breakthroughs in the food production system. However, food need is not limited to availability of food, but it also goes beyond that to the quality of food and availability of essential micronutrients (Vitamins and Minerals), macronutrients (Protein, Fats and Carbohydrates) and other functional food elements for chronic diseases care and prevention, i.e. fruit flow, beta glucan, probiotics & prebiotics...etc.

Research undertaken by Dr. August Dunning (founder of Eco Organics) illustrates that in order to get the amount of iron one uses to get in 1950 from one apple by 1998 one needs to eat 25 apples, nowadays to get the same amount of iron, one needs to eat 36 apples. This reflects the continuing deterioration in nutritional quality of food due to chemical usage in industrial farming with high CO2 emissions, this is compounded by bad eating habits that people tend to eat more refined sugars and saturated fats, which is associated with rise in chronic diseases like: Cardiovascular disease and Diabetes2, and Mineral Deficiencies - Team Dream Extreme (2019).

In developing countries people suffer from mild to severe food insecurity and hunger; food is neither available nor healthy. World population is projected to reach 9.7-9.8 billion by 2050 (Worldometer, 2024). There will be 2 billion people who will not find enough food resources, simply because the amount of natural resources is fixed. So, the challenge here is to increase food resources in the same land size without causing environmental impacts of climate change due to deforestation, land exploitation, destroying ecosystem and reducing biodiversity (The Challenge – Global Food Security, 2023).

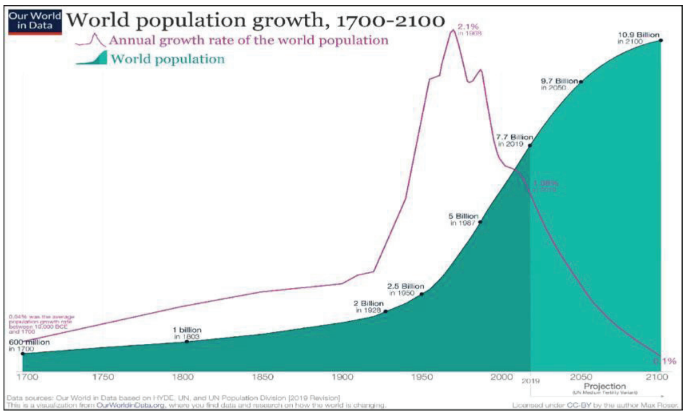

Fig. 6. World population growth from 1700 to 2100,

source: Environmental Conservation Journal, DOI:10.36953/ECJ.2021.SE.2202 (Karamveer et. Al, 2021). The annual growth rate was in a slight increase from 1700 till 1900, then it considerably peaked in 1963 with 2.3% increase rate. As per world population: it elevated substantially after 1950 to reach 8 billion in 2023 with projections of more elevation to reach 9.7 billion in 2050 and 10.43 billion in 2100.

Fortunately, sustainability awareness is considerably rising, many industries began to adopt sustainability commitment in their industries, such as Unilever which is committed to enhancing wellbeing and health for >1 billion people, reducing environmental impacts by half and consolidating livelihood for millions. Tesco is also committed to have a 300% sales increase in meat alternatives by 2025 (Smithers, 2020).

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3. SOCIOCULTURAL ASPECTS OF DIET WITHIN THE GLOBAL FOOD SYSTEM

Sociocultural norms are not easily broken. Has one ever thought of how hard it is to gather all people around the world to accept certain types of food? Food for most people is about culture, beliefs, social activity, joy and traditions. As per Professor Claude Fischer, "Man feeds not only on proteins, fats, and carbohydrates, but also on symbols, myths and fantasies" (Fischler, 1988).

There are gender and age preferences & stigmas; for instance, male teenagers relate meet eating to masculinity. Furthermore, religious beliefs profoundly affect food choices; Muslims do not drink alcohol or eat pork as it is Haram in Islam religion. Geographical locations also have influence on how food is cooked or served; in USA and UK food is individualized. On the contrary, in France, Italy and Switzerland, food is about joy in gatherings, eating takes times as family gather around the table.

Paul Morand (French), in 1937 described New Yorkers lunch: they eat standing up, fast, with their hat on, in a row "like in a stable.", which indicates absence of rules and lack of social exchange.

Daniel Lerner (American), in 1956 described French eating habits to be "rigid" and he was surprised to see them eating ritually and at set times: "like in a zoo". Excess of rules, seen as a hindrance to choice (Odile, 2012) as also mentioned in "EATING. French, European, and American Attitudes Toward Food" by Claude Fischler and Estelle Masson. (2008).

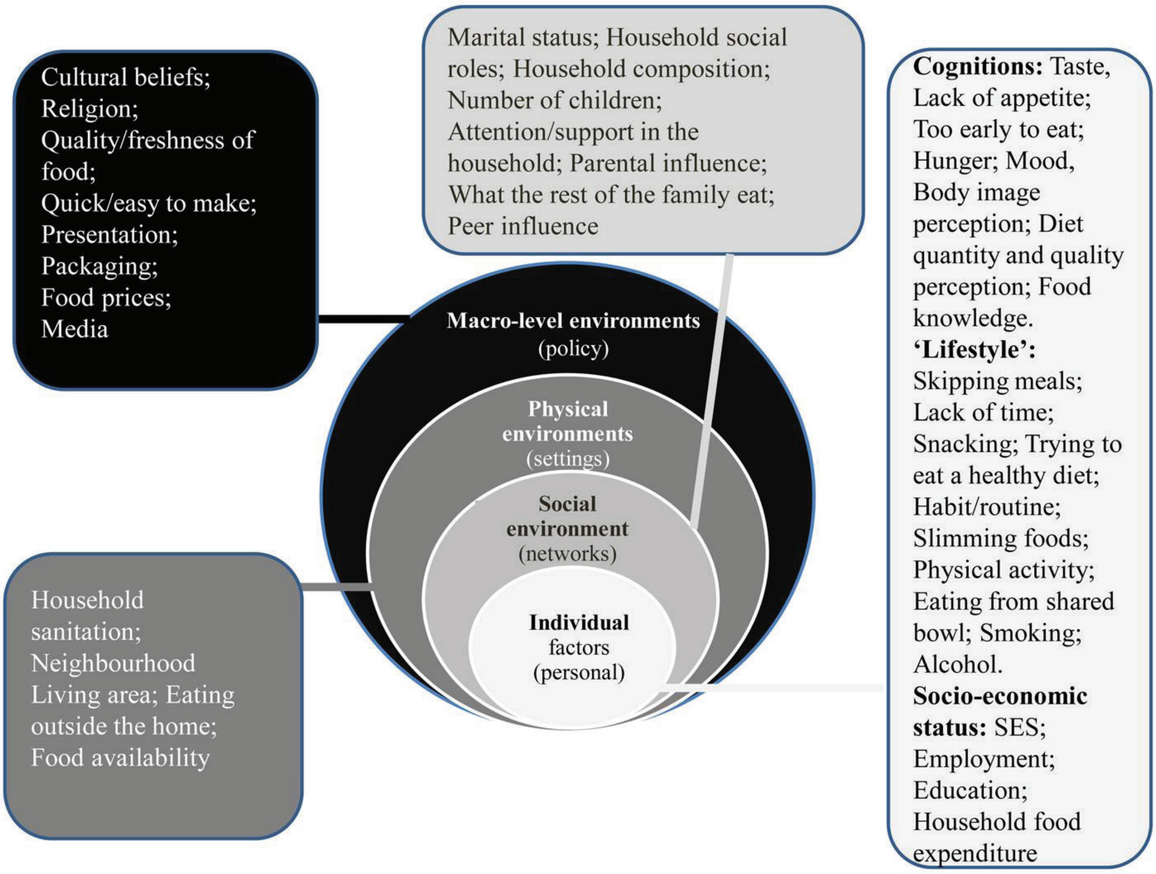

Fig. 7. Investigating different Food environments which affect sociocultural aspects of food.

Obtained from: https://doi.org/10.1017/s0029665118002938 (Holdsworth & Landais, 2019). Factors influencing dietary behaviors from individualistic aspects (physical activity, employment, education…etc.), networks as in peer influence, physical as in (communities & neighborhood) and macro environments as in (country, culture, religion and beliefs).

4. SYNERGIES AND TRADE OFFS WHEN MOVING TOWARDS SUSTAINABLE FOOD SYSTEM

Alternatives to major emitters in the food system have pros and cons, accompanied with diet controversies and debates on both scientific, market and consumer's level.

A. Animal-based Protein Alternatives

Livestock production is a major damage to the environment basically due to deforestation with extremely high levels of GHG emissions and endangering biodiversity. It is estimated that around 60% of environmental resources are already wasted or used unsustainably. In many western countries, people consume higher portions of meat than their daily requirements, by 2050 there must be 70% more food production in the limited food system resources to cover population dietary needs (Valli et al., 2022).

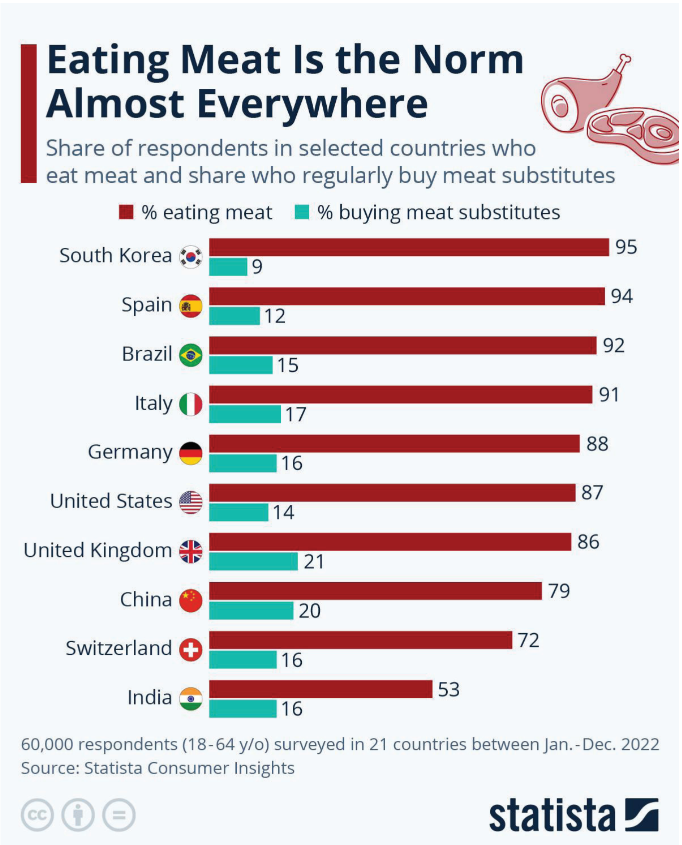

Fig. 8. People who identify themselves as meat eaters in different countries.

Obtained from: https://www.statista.com/chart/24899/meat-consumption-by-country/, (Buchholz, 2023). From 60,000 respondents (9-21%) preferred meat alternatives, compared to (53-95%) who preferred animal protein. South Korea has the highest levels of meat eaters representing 95% and 9% only responded that they adopt meat substitutes in their diet, UK has the highest tendency towards plant-based proteins with 21% and India resembles the lowest meat consumer amongst countries with 53% consumption rates.

Meat alternatives could possibly be a highly recommended solution to this conundrum. Plant-based proteins are an option as in Soy, Legumes and Cereals; Edible Insects are also a recent trend as a sustainable alternative to livestock production; aquaculture, seaweeds and algae are a possible replacement that are part of global diets as in Okinawa Diet in Japan and other Asian cuisines; Finally, cultured meat is widely considered in recent scientific research as a sustainable source of animal protein that gives the same organoleptic as natural meat (Andreani et al., 2023).

All of the abovementioned choices are manufactured in environmentally sustainable ways. However, there is a controversy amongst the population that some options are repulsive, others are not tasty or may be culturally unacceptable.

1. Edible insects:

Entomophagy: Eating insects by humans was popular since the prehistoric age. There are over 1900 species of edible insects. Insects are very high in protein (all of the essential amino acids) and they taste like chicken. Insect's breeding is environmentally friendly and sustainable; there are no fertilizers involved in the process and more importantly with much lower feeding rates than livestock. What is more interesting about the fodder is that it comes from organic waste, so it applies 4R Framework of Circular economy with reducing, reusing, recycling and recovering.

Insects are introduced in the market as crushed, powder, burger, bars, pasta or as a whole. The only barrier nowadays is public acceptance and cultural taboos that many people find eating insects repulsive and culturally unacceptable ("Thinking About the Future of Food Safety," 2022).

2. Cultured meat:

In vitro cultured meat burger was produced for the first time in 2013 with minimum environmental impacts and less land and water consumption compared to livestock breeding. Stems cells of animals are extracted then they grow further into muscle tissues. Burgers, minced meat and meat balls are produced to mimic slaughtered

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livestock meat, but without slaughtering and more importantly, cultured meat can be tailored to be low in fat and meet nutritional needs (Wu, 2022).

The challenge in this business is to convince consumers to replace livestock meat products with cultured meat. There is a debate that although it is promising, it is still coming from animals and production takes so much time and money than conventional methods, at the same time the available options in the market are still limited and expensive.

3. Plant-based meat analogues :

Soy and legumes can be good replacements to animal-based protein. Although most of plant-based proteins lack one or more of essential amino acids such as: Methionine, Lysine and Tryptophan, with proper combinations from different plant sources as in cereals, pseudocereals and legumes, all essential amino acids can be obtained (Wild, 2016).

Recently, German entrepreneurs from Frosta Aktiengesellschaft invented vegan seafood alternatives, they call it “Fish from the Field” with 100% plant-based ingredients.

Legumes fix nitrogen into the soil, so they enhance soil fertility and productivity, especially when they are planted with crop rotations. Legumes lower the risk to chronic diseases, since they are saturated-fat-free and Cholesterol-free.

Soy is the only plant on earth which carries all essential amino acids, it can be used as meat analogues in Tofu or Tempeh. However, the regular consumption of Soy products causes disturbances in thyroid hormones and soy contributes to massive land deforestation and biodiversity loss.

4. Microalgae and seaweeds:

Algae is commonly eaten in Asian cuisine, as Sushi wrapping sheets and Miso soup. They are divided into one cell microalgae; as in spirulina and chlorella supplements, they exist also as macro algae as in seaweeds. Algae contains high amounts of proteins, PUFA (Poly Unsaturated Fatty Acids) and Iodine.

Micro and macro algae are friendly to the environment as they need few resources for production, more interestingly they are fed on organic waste, their reproduction is very fast, twice as fast as soy and corn. Furthermore, algae are very effective in capturing CO_2 through photosynthesis process (Meng et al., 2022).

Mass production still needs further development, as it is susceptible to seasonal and climate changes and mass production requires high economic and ecological costs. Moreover, customer’s acceptance of algae instead of meat products is still unanswerable.

B. Palm Oil: (Elaeis Guineensis)

It is estimated that approximately half of household items contain Palm oil in one way or another; as in food, cosmetics or cleaning products.

Palm oil is the most widely used oil on earth than rapeseed or soy oil, it has very high production rate per hectare compared to other competitors in the global food market, it requires much less fertilizers and pesticides than other oil seeds. Malaysia and Indonesia alone produce 85% of the total global harvest. The palm oil industry has profoundly contributed to improving the livelihood of people and increased the employment of millions of jobseekers around the world (Statista, 2024).

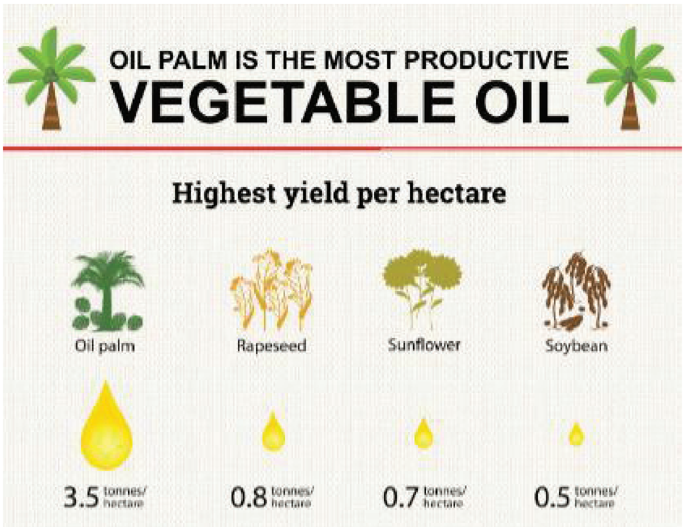

Fig. 9. palm oil production per hectare compared to rapeseed, sunflower and soybean oils.

Obtained from: https://www.smart-tbk.com/en/lima-fakta-utama-2022/ (Smart, 2023). Palm oil production is the most productive and highly competitive amongst other oil seeds that reaches 3.5 tones per hectare of land compared to rapeseed with 0.8 tones per hectare, sunflower with 0.7 per hectare and soybean with 0.5 tones per hectare.

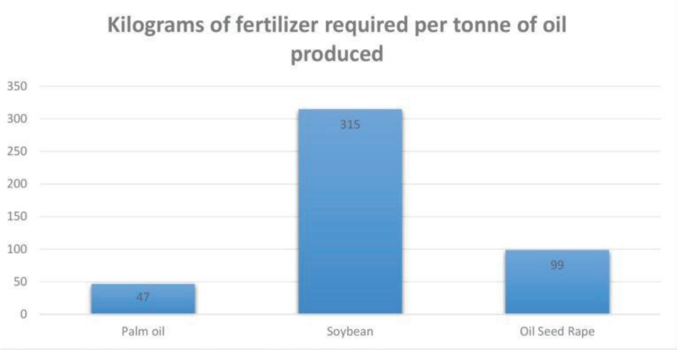

Fig. 10. Number of fertilizers required to produce Palm oil, Soybean oil and Rapeseed oil.

Obtained from: https://www.futurelearn.com/info/courses/engaging-with-controversies-in-the-food-system/0/steps/63415 (EIT FOOD). Palm oil uses relatively low amounts of fertilizers for the production of 1 ton oil compared to rapeseed oil and soybean oil, which is 47 kg per tone compared to 99 kg in rapeseed and 315 kg in Soybean.

Palm Oil has a high melting point and multiple applications in food industries: It is responsible for the smooth and creamy texture in confectionary products, it contains 50% saturated fats and 50% unsaturated fats. In addition to that, it acts as natural preservative in processed & ultra processed foods and has non trans fats, as hydrogenation is not involved in the manufacturing process (Pande et al., 2012).

On the other hand, palm oil industries contribute to deforestation, high GHG emissions, loss of biodiversity and endangering many species (i.e. orangutans). Environmentalists have called it addiction to palm oil, production is escalating vigorously; from 1995 to 2015 production increased from 15.2 to 62.6 million tons and expected to quadruple by 2050. Furthermore, one of palm oil controversies is about labor rights; many original landowners have lost their land because of land acquisition (land-grabbers) for palm oil businesses (Shanahan, 2024).

Palm debates have led global leaders to have roundtables on palm oil production for more pledges on reducing deforestation and moving towards circular economy. Nowadays in Indonesia and Malaysia more than 60 million tonnes of Palm Oil Mill Effluent (POME) are produced each year and used in energy production for both mill operations and providing energy for communities. (Roundtable on Sustainable Palm Oil (RSPO), 2023).

C. Dairy Milk Replacements

Dairy products are resource intensive food products, they are on the top list amongst the highest GHG emitters in the food system. Currently, there are many plant-based dairy replacements in the market, all options have pros and cons related to environmental footprints.

Soy milk is a good alternative since it has all essential amino acids. Also, it causes less water use and Eutrophication than other options. However, it has relatively high GHG emissions after dairy and rice milk (Clinic, 2024).

Almond milk has low GHG emissions and land use. However, it causes death of millions of bees each year through pollination process that is responsible for most of the food produced, it also consumes high amounts of water.

Oat milk is a satisfactory alternative that has relatively low environmental footprints; land, water, GHG emissions and Eutrophication. It also has a nice taste in terms of organoleptic.

Although **Coconut milk** has lower footprints compared to dairy milk, it has high levels of saturated fatty acids, coconut production raises an ethical issue of labor rights as people who work on picking the fruits are usually getting paid with approximately 1 USD per day. Rice milk and Flaxseed milk are widely popular among vegan communities.

Nevertheless, **Rice milk** is ranked as the highest emitter after dairy, rice has an issue of monocrop intensive farming, as well as intensive water consumption, so it should come as the last possible alternative to dairy (Kozicka et al., 2023).

JOURNAL OF MULTIDISCIPLINARY ADAPTIVE CLIMATE INSIGHTS
(MACI) Volume 1, Issue 2, December 2024 - ISSN 3009-6332

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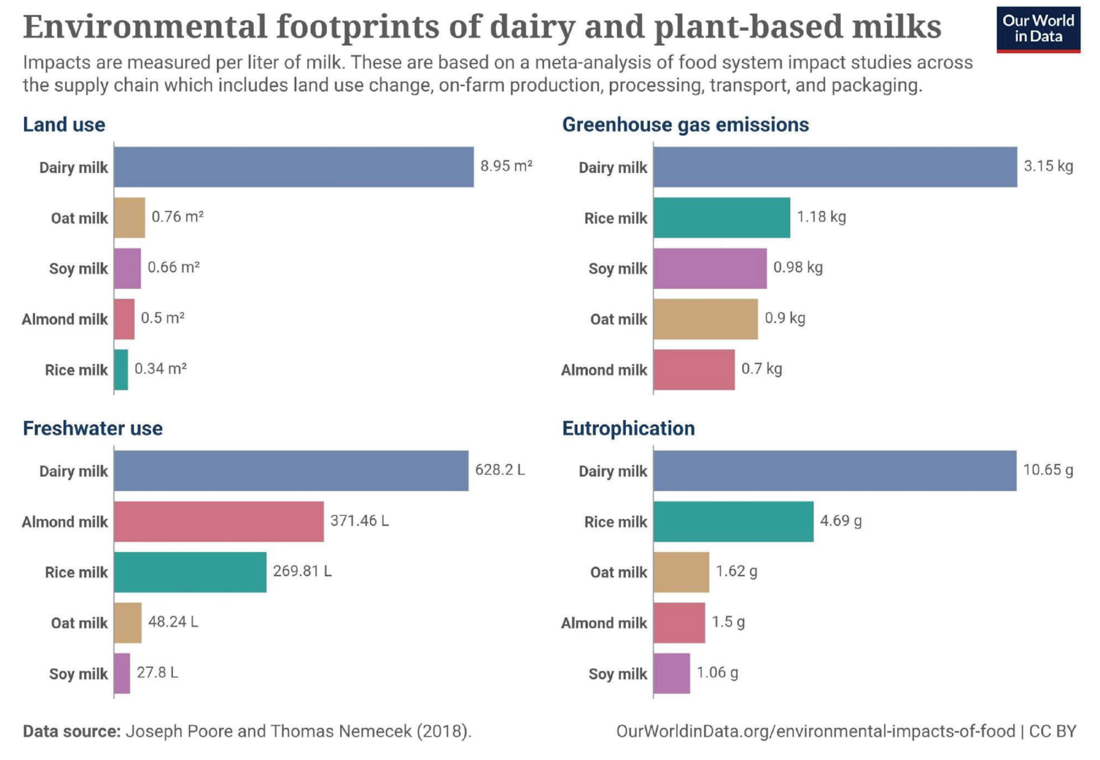

Fig. 11. Comparison of dairy milk vs. plant-based milk in terms of different environmental footprints.

Obtained from: https://doi.org/10.1126/science.aaq0216 (Poore & Nemecek, 2018). Dairy milk has the highest land, air and water footprints compared to plant-based milk alternatives, as in: Almond, Rice, Oat and Soy milks. There is no perfect option amongst non-dairy milks as all have trade-offs; Rice milk has the highest eutrophication after dairy milk, Almond milk contributes to the highest water consumption after dairies, Rice milk has the most greenhouse gas emissions after dairy milk and finally Oat milk contributes to the highest land use after dairy milk.

5. FOOD WASTE

Food valorization is critical in creating sustainable food system, especially because global food system is responsible for 20-30% of greenhouse gas emissions.

When food is wasted or lost, other critical resources are also wasted such as: land, water, labor, energy and capital. For example, half of bread purchased in Britain is almost wasted, which means that all resources used in bread making; wheat planting, flour milling, baking, manpower and transportation are wasted.

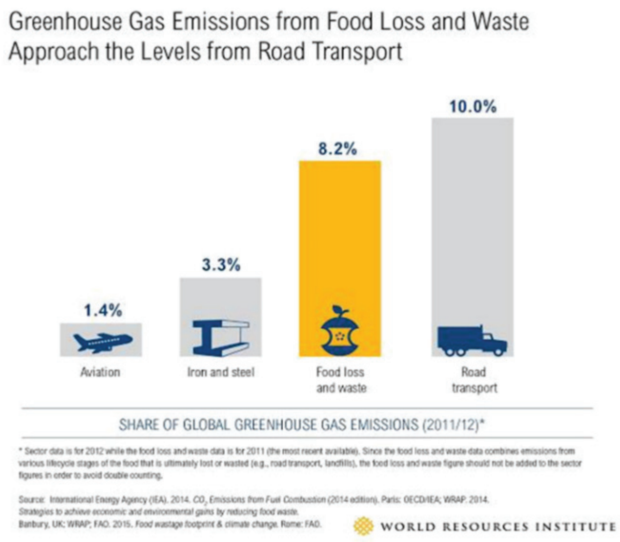

Fig. 12. GHG emissions from Food Loss and Waste approaches emissions of transportation.

Obtained from: https://www.environmentenergyleader.com/2016/01/davos-nestle-unilever-ceos-join-food-waste-reduction-coalition/ (Jessica, 2016). In 2011/2012 food loss and waste had a share of 8.2% GHG emissions which is almost near road transport that contributed to 10% emissions and surpassed aviation emissions and footprints from iron & steel production.

As per FAO Annual Food Report, it is estimated that a third of food produced annually is wasted or lost during one or more stations of the food supply chains. Food waste is considered a huge economic burden, by numbers 143 billion euros are spent as food in EU in 2012 (Food Waste Index Report 2024 | FAO, 2024).

A. The Difference between Food Loss and Food Waste

Food Loss Index (FLI): It occurs at the preliminary stages of the supply chains before food reaches retailers and consumers. For example: Wonky fruits and vegetables are sometimes lost and discarded from the farm or processing factories before reaching the retailers and consumers. (Mingione & Lasinio, 2018). Food products are also lost from the farm because of the contamination which occurs through the intensive use of pesticides and insecticides.

Food Waste Index (FWI): It happens to retailers, supermarkets and households. For example, supermarkets dispose food that reach the expiry date because of low accuracy in managing and handling available stocks, low stakeholder multidisciplinary collaboration...etc. Consumers waste leftover food because of different reasons: Low awareness of the environmental and economic impacts of food waste, lack of culinary skills and lack of home economics skills (Food Waste Index Report, 2024).

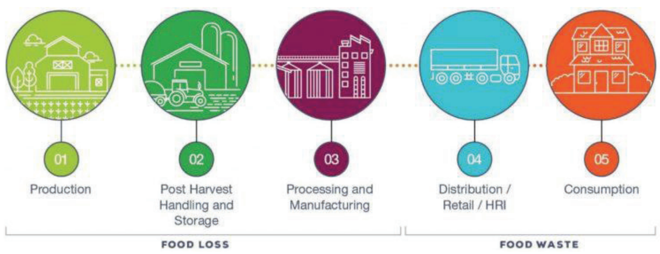

Fig. 13. Food loss and waste in supply chains.

Obtained from https://www.nutriscope.ca/food-waste/ (Food Waste – NutriSCOPE Inc., 2016). Major food losses occur in farms and factories, whereas food waste occurs majorly in supermarkets and consumption in (schools, hospitals, hotels, restaurants and households). The first 3 parts resemble food loss possibilities and food waste occurs in the last 2 steps of the supply chain.

B. Food Loss and Waste in Supply Chains

At the farm, loss can be due to infestation, pests, poor soil handling, climate change i.e. drought or heavy rain seasons...etc.

- **Storage:** Poor logistic management and transportation problems.
- **In transit:** Transportation accidents, human errors or long-time gaps.
- **Processing and packaging:** Losses occur due to human mistakes, machinery malfunction, delivery problems...etc.
- **In the shop:** Most of the food waste in the shop happens when food reaches best before and use by dates.
- **At point of consumption:** Hospitals, restaurants, schools and hotels waste food mainly due to poor food handling, lack of menu planning skills, serving bigger portions and stock management issues.
- **At home:** Waste is due to poor meal planning, lack of home economics and gastronomy skills, lack of home storing and preservation techniques...etc. (Chauhan et al., 2021).

C. Environmental and Economic Burden of Food Loss & Waste

WRAP 2020: If people in UK stop wasting food for one day, it could have an impact on GHG emissions as planting half a million trees!

4.4 G tones of CO_2 are emitted because of food waste process; production, processing, distribution, transportation and disposal (Andrea, 2019).

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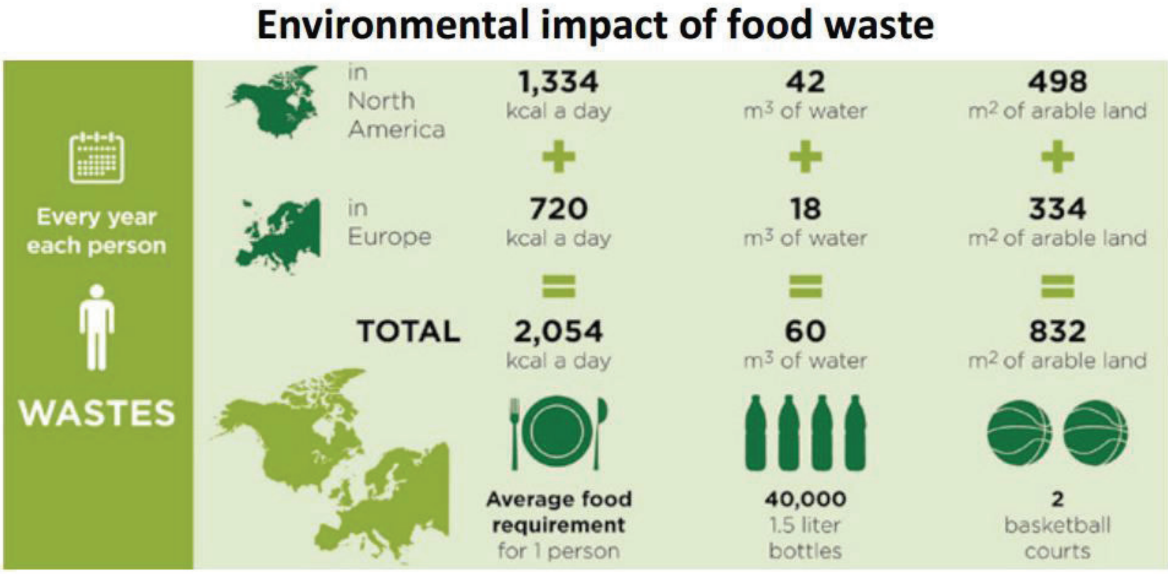

Fig. 14. Environmental impacts of food waste.

Obtained from: https://epthinktank.eu/2014/02/07/tackling-food-waste-the-eus-contribution-to-a-global-issue/ (Ivana, 2016). Annually in Europe and North America each person wastes food equivalent to 2 basketball courts, as 2,054 kcal consumption per day and 60 m³ of water is equivalent to space of 832 m² per day and a size of 2 basketball courts annually.

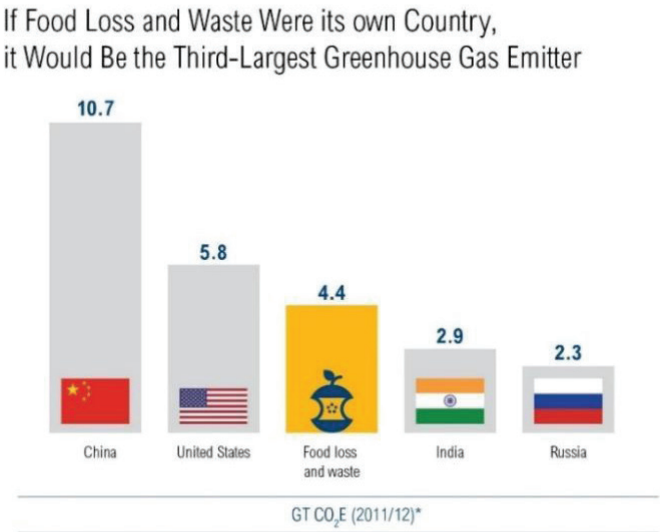

Fig. 15. Food waste is estimated to be the third largest GHG emitter.

Obtained from: https://wri-indonesia.org/en/data/if-food-loss-and-waste-were-its-own-country-it-would-be-third-largest-greenhouse-gas-emitter, (If Food Loss and Waste Were Its Own Country, It Would Be the Third-Largest Greenhouse Gas Emitter, 2018.) Food waste emits 4 billion tons of CO_2 annually, which is estimated to be the third largest GHG emitter after China which emits 10 billion tons of CO_2 and US which produce 6 billion tons of CO_2 each year.

In 2007, 1.4 billion hectares of agricultural land was exploited and wasted to produce food that was not consumed. Furthermore, food waste is one main cause of biodiversity loss and deforestation; 74% of annual deforestation happens to be used in food production.

70% of the earth's fresh water is used in agriculture to produce food, so when one third of food is wasted, water is also wasted. Coffee is a resource intensive food product; just one cup of coffee uses 125 liters of embedded water.

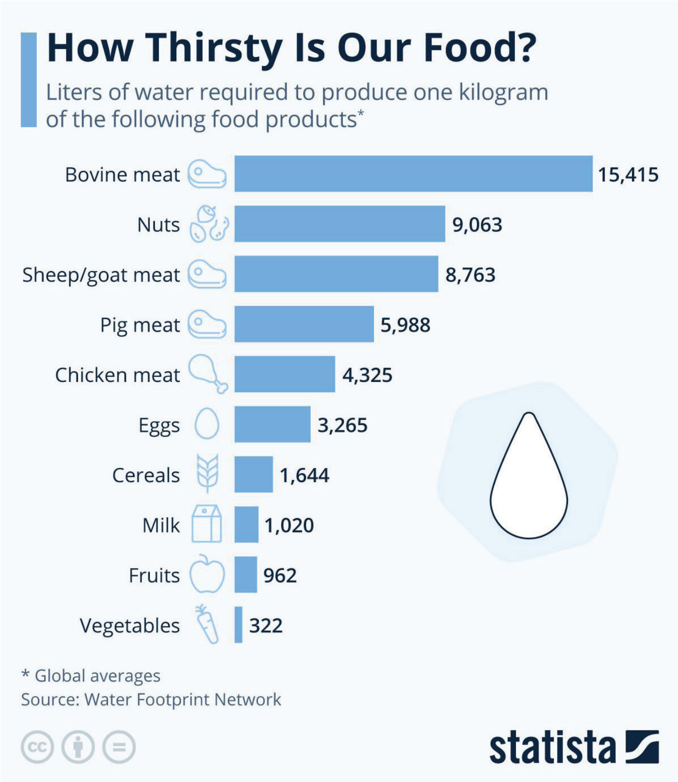

Fig. 16. Amounts of water required for production of some food products.

Obtained from: https://www.statista.com/chart/9483/how-thirsty-is-our-food/ (Armstrong, 2023). Some food products are extremely thirsty to water, bovine meat come on the top of water consumption which requires 15,415 liters of water to produce 1 kg of meat, whereas fruits and vegetables are relatively low in water consumption as 1 kg of fruits requires 962 liters of water and 1 kg of vegetables requires 322 liters of water.

D. Social Impact of Food Loss and Waste

There is an absolute paradox between food production and food waste.

820 million people are undernourished, 1 billion people are overfed. One third of food production is wasted or lost annually, it is estimated that edible food waste can feed all hungry people around the globe.

Now the challenge is not to let food waste reach the landfills, since it releases methane which is 23 times more potent than CO_2. Currently food system stakeholders are moving towards circular-economy approaches by (reducing, reusing, recovering and recycling), with the aim of preventing food from reaching to the incinerator or landfills (Roka, 2020).

Fig. 17. The waste pyramid from the best to the least preferred option.

Obtained from: https://powerknot.com/2021/08/04/the-food-waste-hierarchy-how-to-apply-the-framework-to-your-sustainability-goals (powerknot, 2021). Green colors of Reducing, reusing and recycling food waste come on top as the best options to the environment, yellow and orange colors of recovery by sending waste to the incinerator or disposal into landfills are the worst options for the environment.

E. Successful Example of Governmental Legislations

- In 2005, South Korea banned food from being sent to landfills. Later in 2013 Seoul started an initiative of 'Pay as you Waste' where residents are required by law to discard food waste in biodegradable bags, then bag sizes are measured, by which residents pay tax money as per bag sizes and waste volume. With this initiative food waste was significantly reduced by 80% in Seoul (Mph & Mph, 2020).

- The Netherlands, Qatar, Sweden and Brazil incorporate environmental sustainability into their dietary guidelines based on scientific research and evidence-based policy (Ahmed et al., 2019).

F. Reducing Food Loss and Waste Can Help Achieve Multiple SDGs

SDG1 and 2: No poverty and ZERO hunger; reducing food loss and waste save resources such as: land, water, capital and energy. So, there will be surplus to fight against poverty and food insecurity.

SDG3: Good health: The more the food is required to be produced, the less nutritional quality it possesses and vise versa, achieving resilience in the food system allows food to be energy dense with higher quality than conventional intensive farming.

SDG4 and 5: Quality Education and gender equality; reducing food waste saves money for health, education and other necessities.

SDG6: Clean water and Sanitation; 70% of fresh water goes to the agricultural sector, so managing food waste removes a severe stress on freshwater consumption.

SDG8: Decent work and economic growth: Reducing farm losses saves resources for the farmers to sell more food.

SDG11: Sustainable Cities and Communities: Food waste is a huge economic burden on communities, if food waste is accurately managed and protected from being sent to landfills, a free space will be saved for the sustainability of cities and communities.

SDG12: Sustainable Consumption and Production; Controlling food loss and waste will automatically achieve sustainable production and consumption.

SDG13: Climate Action: Reducing food loss and waste significantly reduces severe GHG emissions.

SDG14: Life under water: The more food is produced, the more eutrophication occurs where fertilizers accumulate in the runoffs. So, reducing food loss and waste helps to keep water resources clean and pure (Food Waste Reduction and Sustainable Development Goals | LIFE FOSTER, 2019).

6. CONCLUSION

Sustainable diet can be one definitive solution to climate change issues, it is hard to achieve but not impossible. Moreover, it can be a key to achieving food security and lower environmental impacts. Food systems are responsible for one third of total environmental issues, the paradox is that with the extreme food insecurity, there is extreme obesity and overfeeding amongst populations, more importantly, food waste can feed all hungry people around the world.

Stakeholders of the food system are the key to achieving sustainable diet goals with collaboration and effective communication agenda.

One legislation can save the planet. Legislations usually take quite long time with many debates between policymakers. However, in the time being a decisive legislation in the food system is an urgent necessity to cut down GHG emissions, preventing food waste and stopping the raising food demands. The more plants are grown, the better public health with more awareness, citizenship and lower emissions.

7. ACKNOWLEDGMENT

I would like to thank my colleagues and supervisors at the National Research Center in Cairo for the continuous support and mentorship, Professor Saeed Hamed and Professor Adel Gabr. I also would like to express my deep appreciation to the team of Sustainable Diet at the University of Aberdeen, Scotland for the great dedication to Climate Change and Sustainable Diet issues.

REFERENCES:

01. (*Agricultural Waste Facts*, 2024; *Agriculture Innovation: 10 Tech Trends to Watch in 2023 - MassChallenge*, 2023; *Food Waste Index Report 2024 | FAO*, 2024; *Food Waste Reduction and Sustainable Development Goals | LIFE FOSTER*, n.d.; *Mineral Deficiencies - Team Dream Extreme*, n.d.; *New Global Hidden Hunger Estimates*, 2023; *Palm Oil Usage Worldwide 2023/2024 | Statista*, 2023; *Private Sector Engages with FAO on Improving Food Security and Agriculture Sector Sustainability*, 2024; *Thinking about the Future of Food Safety*, 2022; Ahmed et al., 2019; Andreani et al., 2023; Chauhan et al., 2021; Clinic, 2021; Crain, 2024; Earth, 2023; Federation, 2024; Fischler, 1988, 2024; Herens et al., 2022; Ingram, 2016; Kozicka et al., 2023; Leong & Chang, 2022; Meng et al., 2022; Mingione & Lasinio, 2018; O'Donoghue et al., 2022; of Sciences et al., 2019; Pande et al., 2012; Programme, 2020; Rebecca, 2020; Roka,

2020; RSPO, 2023; Seberini, 2020; Sheldon, 2020; UNEP, 2024; Valli et al., 2022; Wild, 2016; Worldometer, 2024; Wu, 2022)

02. *Agricultural Waste Facts*. (2024). https://www.businesswaste.co.uk/sectors/agricultural-waste-management/agricultural-waste-facts/

03. *Agriculture Innovation: 10 Tech Trends to Watch in 2023 - MassChallenge*. (2023). https://masschallenge.org/articles/agriculture-innovation

04. Ahmed, S., Downs, S., & Fanzo, J. (2019). Advancing an Integrative Framework to Evaluate Sustainability in National Dietary Guidelines. *Frontiers in Sustainable Food Systems*, *3*. https://doi.org/10.3389/fsufs.2019.00076

05. Andreani, G., Sogari, G., Marti, A., Froldi, F., Dagevos, H., & Martini, D. (2023). Plant-Based Meat Alternatives: Technological, Nutritional, Environmental, Market, and Social Challenges and Opportunities. *Nutrients*, *15*(2), 452. https://doi.org/10.3390/nu15020452

06. Chauhan, C., Dhir, A., Akram, M. U., & Salo, J. (2021). Food loss and waste in food supply chains. A systematic literature review and framework development approach. *Journal of Cleaner Production*, *295*. https://doi.org/10.1016/j.jclepro.2021.126438

07. Clinic, C. (2021). *What You Need to Know When Choosing Milk and Milk Alternatives*. Cleveland Clinic. https://health.clevelandclinic.org/what-you-need-to-know-when-choosing-milk-and-milk-alternatives

08. Crain, P. (2024). *History of Agriculture | Overview, Importance & Timeline | Study.com*. https://study.com/academy/lesson/history-of-agriculture-overview-importance-timeline.html

09. Earth, D. (2023). *Palm oil: The pros and cons of a controversial commodity* (M. [31] Shanahan, Ed.). https://dialogue.earth/en/food/11627-palm-oil-the-pros-and-cons-of-a-controversial-commodity

10. Federation, W. O. (2024). *Prevalence of Obesity | World Obesity Federation*. https://www.worldobesity.org/about/about-obesity/prevalence-of-obesity

11. Fischler, C. (1988). Food, self and identity. *Social Science Information*, *27*(2), 275–292. https://doi.org/10.1177/053901888027002005

12. Fischler, C. (2024). *France, Europe, the United States: what eating means to us : an interview with Claude Fischler and Estelle Masson, about the new volume published by Odile Jacob. - Le mangeur Ocha*. Le mangeur Ocha. https://www.lemangeur-ocha.com/france-europe-the-united-states-what-eating-means-to-us-an-interview-with-claude-fischler-and-estelle-masson-about-the-new-volume-published-by-odile-jacob/

13. *Food Waste Index Report 2024 | FAO*. (2024). https://www.fao.org/family-farming/detail/en/c/1681058

14. *Food Waste Reduction and Sustainable Development Goals | LIFE FOSTER*. (n.d.). https://www.lifefoster.eu/food-waste-reduction-sustainable-development-goals/

15. Herens, M. C., Pittore, K. H., & Oosterveer, P. J. M. (2022). Transforming food systems: Multi-stakeholder platforms driven by consumer concerns and public demands. *Global Food Security*, *32*, 100592. https://doi.org/10.1016/j.gfs.2021.100592

16. Ingram, J. (2016). *The challenge - Global Food Security*. https://www.foodsecurity.ac.uk/challenge/

17. Kozicka, M., Havlík, P., Valin, H., Wollenberg, E., Deppermann, A., Leclère, D., Lauri, P., Moses, R., Boere, E., Frank, S., Davis, C., Park, E., & Gurwick, N. (2023). Feeding climate and biodiversity goals with novel plant-based meat and milk alternatives. *Nature Communications*, *14*(1). https://doi.org/10.1038/s41467-023-40899-2

18. Leong, Y. K., & Chang, J.-S. (2022). Valorization of fruit wastes for circular bioeconomy: Current advances, challenges, and opportunities. *Bioresource Technology*, *359*, 127459. https://doi.org/10.1016/j.biortech.2022.127459

19. Meng, W., Mu, T., & Marco, G.-V. (2022).

Seaweeds and microalgal biomass: The future of food and nutraceuticals. In *Future Foods* (pp. 183–201). Elsevier. https://doi.org/10.1016/B978-0-323-91001-9.00014-1

20. *Mineral deficiencies - Team Dream Extreme*. (n.d.). https://masterthenewway.com/mineral-deficiencies/

21. Mingione, M., & Lasinio, G. J. (2018). *SDG 12.3. 1: Global Food Loss Index*. unknown. https://www.researchgate.net/publication/348305970_SDG_123_1_Global_Food_Loss_Index

22. *New Global Hidden Hunger Estimates*. (2023). https://micronutrientforum.org/new-global-hidden-hunger-estimates/

23. O'Donoghue, T., Minasny, B., & McBratney, A. (2022). Regenerative Agriculture and Its Potential to Improve Farmscape Function. *Sustainability*, *14*(10), 5815. https://doi.org/10.3390/su14105815

24. of Sciences, E., Division, H., Medicine, Board, F., Nutrition, Forum, F., & Pray, L. (2019). *What Are Sustainable Diets?* National Academies Press (US). https://www.ncbi.nlm.nih.gov/books/NBK540292/

25. *Palm oil usage worldwide 2023/2024 | Statista*. (2023). https://www.statista.com/statistics/274127/world-palm-oil-usage-distribution

26. Pande, G., Akoh, C. C., & Lai, O.-M. (2012). Food Uses of Palm Oil and Its Components. In *Palm Oil* (pp. 561–586). Elsevier. https://doi.org/10.1016/B978-0-9818936-9-3.50022-8

27. *Private sector engages with FAO on improving food security and agriculture sector sustainability*. (2024). FAO. https://www.fao.org/europe/news/detail/private-sector-engages-with-fao-on-improving-food-security-and-agriculture-sector-sustainability/en

28. Programme, W. F. (2020). *HungerMap LIVE*. https://hungermap.wfp.org/

29. Rebecca, S. (2020). Tesco sets 300% sales target for plant-based alternatives to meat. *The Guardian*. https://www.theguardian.com/business/2020/sep/29/tesco-sets-300-per-cent-sales-target-for-plant-based-alternatives-to-meat

30. Roka, K. (2020). *Environmental and Social Impacts of Food Waste* (pp. 216–227). https://doi.org/10.1007/978-3-319-95726-5_17

31. RSPO. (2023). *Who we are*. https://rspo.org/who-we-are/

32. Seberini, A. (2020). Economic, social and environmental world impacts of food waste on society and Zero waste as a global approach to their elimination. *SHS Web of Conferences*, *74*, 03010. https://doi.org/10.1051/shsconf/20207403010

33. Sheldon, M. (2020). *South Korea Recycles Food Waste in Effort to Become Zero-Waste Society*. https://www.nycfoodpolicy.org/food-policy-snapshot-south-korea-food-waste/

34. *Thinking about the future of food safety*. (2022). FAO. https://doi.org/10.4060/cb8667en

35. UNEP. (2024). *Food Waste Index Report 2024*. https://www.unep.org/resources/publication/food-waste-index-report-2024

36. Valli, C., Maraj, M., Prokop-Dorner, A., Kaloteraki, C., Steiner, C., Rabassa, M., Solà, I., Zajac, J., Johnston, B. C., Guyatt, G. H., Bala, M. M., & Alonso-Coello, P. (2022). People's Values and Preferences about Meat Consumption in View of the Potential Environmental Impacts of Meat: A Mixed-methods Systematic Review. *International Journal of Environmental Research and Public Health*, *20*(1), 286. https://doi.org/10.3390/ijerph20010286

37. Wild, F. (2016). Manufacture of Meat Analogues Through High Moisture Extrusion. In *Reference Module in Food Science*. Elsevier. https://doi.org/10.1016/B978-0-08-100596-5.03281-9

38. Worldometer. (2024). *Worldometers - real time world statistics*. https://www.worldometers.info/

39. Wu, J. (2022). *Emerging sources and applications of alternative proteins: An introduction* (pp. 1–15). https://doi.org/10.1016/bs.afnr.2022.06.001

http://dx.doi.org/10.21622/MACI.2024.01.2.1042

JOURNAL OF MULTIDISCIPLINARY ADAPTIVE CLIMATE INSIGHTS
(MACI) Volume 1, Issue 2, December 2024 - ISSN 3009-6332

DEGROWTH IS ESSENTIAL TO ACHIEVE AND SUSTAIN GLOBAL NET ZERO EMISSIONS

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Received on, 01 October 2024 Accepted on, 15 November 2024 Published on, 12 December 2024

ABSTRACT:

This research examines the relationship between carbon emissions and economic growth. The Paris Agreement target of net zero carbon emissions by 2050 is found to be achievable and sustainable but only under very specific conditions. Employing a modified form of the Kaya identity, an analysis of the relationship between carbon emissions and economic growth across a majority of countries shows that carbon emissions cannot be fully decoupled from growth. Emission intensities demonstrate a lower bound of approximately 50g of carbon dioxide equivalent per dollar of Gross Domestic Product (GDP). Further analysis shows that it is not possible to maintain a condition of net zero emissions after 2050 if economic growth continues to rise—even when emission intensities are reduced to a minimum. Carbon inequality in Europe and USA is disaggregated by income cohort to demonstrate that under conditions of sustainable net zero emissions, the bottom 50 percent of the distribution can increase their share of GDP, but the middle 40 percent and especially the top 10 percent of the distribution must substantially reduce their per capita emissions. Economic growth is not constrained in low- and middle-income countries but their emission intensities must be kept to a minimum. This analysis leads to the conclusion that some form of post-growth scenario must be envisaged for high-income countries if the Paris Agreement target of net zero emissions is to be not only achieved but maintained over the second half of the century.

KEY-WORDS: Net-zero emissions, Post growth, Kaya identity, Energy intensity, Negative emission technologies, Carbon inequality.

http://dx.doi.org/10.21622/MACI.2024.01.2.1042

1. OBJECTIVES AND MOTIVATION

The objective of the analysis that follows is to examine in greater detail the claim that greenhouse gas emissions can be completely decoupled from economic growth. This assertion conveys the implication that this degree of decoupling would allow economic growth to continue to rise with no associated increase in the level of greenhouse gas (GHG) emissions.

Many countries have already started to reduce their emissions of greenhouse gases. One projection estimates that nearly 60 countries will have peaked their emissions by 2030, accounting for 60 % of global emissions. Among the countries that have peaked already or have a commitment that implies a peak by 2030 are some of the world biggest emitters, including China, the United States, Russia, Japan, Brazil, Germany and Mexico [1].

The question that arises as emissions continue to decline in countries that are growing economically is: how low can they go? Emissions cannot decline to zero, but they could potentially decline to a condition of *net zero*: where the natural carbon sinks compensate for the residual emissions that remain after the decline bottoms out. However, where does this point lie and can a net zero condition be maintained should economic growth continue, given that the natural carbon sinks are unlikely to increase their capacity to absorb carbon dioxide from the atmosphere? If anything, forest lands may be losing absorptive capacity due to wildfires and infestation by insects, while the capacity of the oceans to absorb carbon dioxide may also be limited. This logic suggests that the ratio of carbon emissions to GDP may continue to decline, but that there is a limit—which would be indicated by a minimum value for this metric. If economic growth continues past this point, carbon emissions will inevitably start to rise once again.

If such a limit can be detected and measured, it can be argued that economic growth should not increase past this point. In other words, since it is incontrovertible that carbon emissions lead to increased global temperatures, for rising global temperatures to eventually decline, economic growth should not be allowed to exceed the level where the ratio of carbon emissions to GDP has declined to its minimum value.

2. INTRODUCTION

Can economic growth be completely decoupled from emissions of greenhouse gases? In his ground-breaking book, *Prosperity without Growth*, economist Tim Jackson stressed the importance of differentiating between relative and absolute decoupling:

- **Relative decoupling** refers to a decline in the ecological intensity per unit of economic output. In this situation, both Gross Domestic Product (GDP) and emissions continue to rise, but emissions rise more slowly.
- **Absolute decoupling** refers to a situation in which emissions decline in absolute terms even as GDP continues to rise [2].

The concept of peaking clearly implies a subsequent decline, so a country that has peaked its emissions is demonstrating absolute decoupling if GDP continues to rise.

More recently, advocates have argued that the relationship between the growth of GDP and carbon dioxide needs to be cut completely. The International Energy Agency has highlighted measures that would enable this transition including phasing out fossil fuels, reducing methane emissions and scaling up financing for emerging and developing economies; proposals that were central to the discussions at COP28 in Dubai [3].

In 2022, global greenhouse gas emissions were approaching 54 billion tonnes (Gt) a year and slowly increasing [4]. Given that emissions in China are starting to flatline [5,6], and with emissions from the USA, Europe, and Japan already on a clear downward path, it is unlikely that future global GHG emissions will exceed 60 Gt a year. This maximum will be reached before 2030; after that time, global GHG emissions will almost certainly decline.

The emission mitigation scenarios presented by the Intergovernmental Panel on Climate Change (IPCC) that have a greater than 67 % probability of limiting global warming to 2C by mid-century show greenhouse gas emissions declining to approximately twenty billion tonnes of CO_2 equivalent (GtCO2e)[1] in 2050 [7].

[1] Carbon dioxide equivalent, CO2e, accounts for emissions of all greenhouse gases (not only carbon dioxide but also methane and nitrous oxide), and aggregates them into an equivalent quantity of carbon dioxide based on their respective global warming potentials.

Twenty gigatonnes of CO_2 equivalent is therefore the level of residual emissions that will have to be compensated by the carbon sinks and negative emission technologies in order to achieve the global balance between emissions and sinks that is the basis for the net zero emissions condition defined in the Paris Agreement [15]. This level of *natural* carbon absorption is certainly possible. According to the Global Carbon Project, over the period 2013-2022, ocean and land sinks absorbed carbon dioxide at a rate of 12.3 and 10.4 Gt/y, respectively [8].

One can therefore define the 2050 emission target: A 67 percent probability of keeping global warming to within 2 C, in terms of *per capita emissions of greenhouse gases.*

The United Nations Department of Economic and Social Affairs (UNDESA) estimates that the world population will be about 9.7 billion in 2050. [9] If the net zero emissions target is to be achieved, on a per capita basis average global emission of carbon will be approximately 20/9.7 = 2.1 tonnes of CO_2 equivalent. **This is the global average per capita GHG emissions target for 2050.**[2]

In 2022, greenhouse gas emissions were approximately 53.8 billion tonnes of CO2e a year [4], which for a population of close to eight billion people [10] gives **average per capita emissions of 6.8 tCO2e per year.** However, there are significant differences both between countries and among the different socio-economic groups within the countries themselves.

For example, per capita emissions in Canada and the US were both greater than 17 tCO2e/yr in 2022 [11]; more than eight times greater that the proposed global per capita target for 2050. Framed in this way, the idea of reducing per capita emissions to 2.1 tCO2e/y by 2050 seems unrealistic.

The European Green Deal

The European Climate Law wrote into law the goal set out in the European Green Deal, which states that Europe economy will become climate-neutral by 2050. The law sets an intermediate target of reducing net GHG emissions by at least 55% by 2030 compared to 1990 levels [12]. The EU27 countries produced approximately 4810 million tonnes of GHG emissions in 1990; per capita emissions were 11.5 tCO2e/y [11].

A 55 percent reduction by 2030 would drive emissions down to 2165 MtCO2e/y. The population of the EU in that year is estimated to be 449.1 million [10] and so per capita emissions, according to this scenario, would be approximately 4.8 tCO2e/y.

However, in February 2024, the European Commission recommended that Europe set a more stringent target of a *90 percent reduction in emissions by 2040* compared to 1990 levels [12,14].

This reduction will bring down emissions to 481 MtCO2e per year in 2040. The population of the EU that year is estimated to be about 446.8 million [13] and so per capita emissions, according to the scenario outlined in the European Green Deal, would be about 1.1 tCO2e in 2040, 52% below the 2050 global target of 2.1 tCO2e per capita. This is a very rapid rate of decline: amounting to a 10% reduction in GHG emissions annually over the period 2022 to 2040.

Post Net Zero

The countries that signed the 2015 Paris Agreement have committed to achieving a “balance between anthropogenic emissions by sources and removal by sinks of greenhouse gases in the second half of this century”, a condition generally referred to as ‘net zero emissions’ [15].

But what happens next? It is a reasonable assumption that countries do not intend to revert to the *status quo ex ante* after having achieved their goal of net zero emissions. That would make no sense. Nor is there any obligation for a country to introduce and maintain additional measures that enable the absorption by the natural sinks to exceed their remaining emissions. This logic implies that once countries achieve their goal of net zero emissions, they strive to maintain this condition but not necessarily to improve it. Under what circumstances is this sustainable steady-state possible, especially when GDP per capita and a country population are very probably still growing?

This study demonstrates first, that per capita GHG emissions can be reduced to a minimum level but not to zero. and second, a condition of global net zero emissions is feasible but to be sustained, economic growth must be constrained.

[2] 2 tCO2e would also be the ideal value of a person’s ‘carbon footprint’.

http://dx.doi.org/10.21622/MACI.2024.01.2.1042

3. METHODOLOGY

To examine in detail the relationship between economic growth as denominated by GDP and emissions of GHGs, it is useful to recall the identity developed by energy economist Yoichi Kaya in 1993 [16]. Known as the Kaya identity, it formulates emissions of carbon dioxide as the product of the emission intensity of energy, the energy intensity of GDP, GDP per capita, and population. Although the factors cancel out (hence the term 'identity') the constituent elements are easily measured and analysed. It can be written as:

$$CO2 = \frac{CO2}{E} x \frac{E}{GDP} x \frac{GDP}{pop} x\ pop$$

where CO_2 is annual emissions of carbon dioxide; CO_2/E is the emission intensity of energy consumption; E/GDP is the energy intensity of GDP; and GDP/pop is per capita GDP.

Globally, both energy intensity and emission intensity have been decreasing, reflecting a widespread shift to renewable sources of energy, the increased efficiency of electrical energy compared to fossil fuels, and the electrification of key economic sectors. However, in most countries both GDP and population have continued to slowly rise; so, the question is: Can carbon emissions be held at a minimum level should GDP and population continue to trend upward?

To address this question a modified version of the Kaya identity will be employed: one that explicitly accounts for electrification and GHG emissions on a *per capita* basis. It can be written as:

$$\frac{CO2e}{pop} = \frac{CO2e}{elec} x \frac{elec}{E} x \frac{E}{GDP} x \frac{GDP}{pop}$$

Where,

- CO2e/pop is emissions of CO_2 equivalent per capita, tCO2e
- CO2e/elec is the total emissions of CO2e per unit of electricity generated, tCO2e/GWh
- elec/E is the electricity generated per unit of total energy consumption (both in GWh)
- E/GDP is the energy intensity of GDP, GWh/$GDP, where E is total energy consumption
- GDP/pop is per capita gross domestic product, $GDP/cap

In a sustainable steady-state of net zero emissions, the product of all four factors on the right-hand side of the identity has to be constant, and approximately equal to 2.1 tCO2e per capita, if the net zero condition is to be maintained.

The product of the first three factors can be called the *emission intensity factor*, EIF. Its value depends on the degree to which GHG emissions are reduced as fossil fuels are phased out (CO2e/elec); the level of electrification of the economy (elec/E); and the energy intensity of GDP. One can therefore state:

$$GHG\ emissions\ per\ capita\ = EIF\ x\ GDP\ per\ capita$$

Where,

$$EIF = \frac{CO2e}{elec} x \frac{elec}{E} x \frac{E}{GDP} \qquad \boldsymbol{tCO2e/\$GDP}$$

In a country committed to reducing its carbon emissions, empirical data should show a clear decrease in the value of the emission intensity factor over time. In many countries, EIFs are falling. Globally, the metric declined from 730 gCO2e/$GDP in 1990 to 390 gCO2e/$GDP in 2022. In the European Union, the EIF declined from 400 to 160 gCO2e/$GDP over the same period.[3] Figure 1 shows how the EIF has declined in Europe over the last 30 years compared to the USA, UK and Canada [17].

[3] All GDP and GHG emission data discussed in this report are taken from the Our World in Data website. The GDP data are based on World Bank 2023 data, and expressed in "international dollars at 2017 prices adjusted for inflation and cost of living differences between countries." https://ourworldindata.org/grapher/gdp-per-capita-worldbank and https://ourworldindata.org/grapher/per-capita-ghg-emissions

http://dx.doi.org/10.21622/MACI.2024.01.2.1042

JOURNAL OF MULTIDISCIPLINARY ADAPTIVE CLIMATE INSIGHTS
(MACI) Volume 1, Issue 2, December 2024 - ISSN 3009-6332

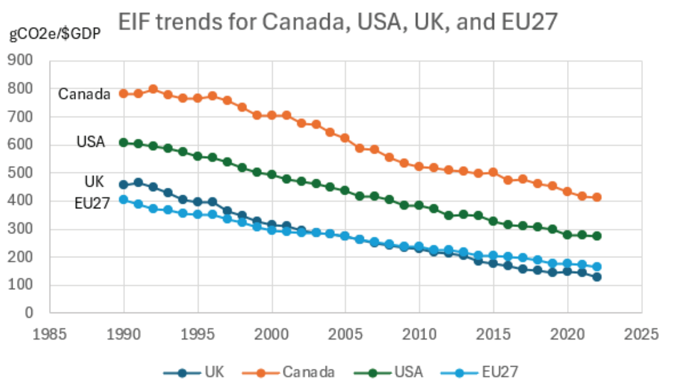


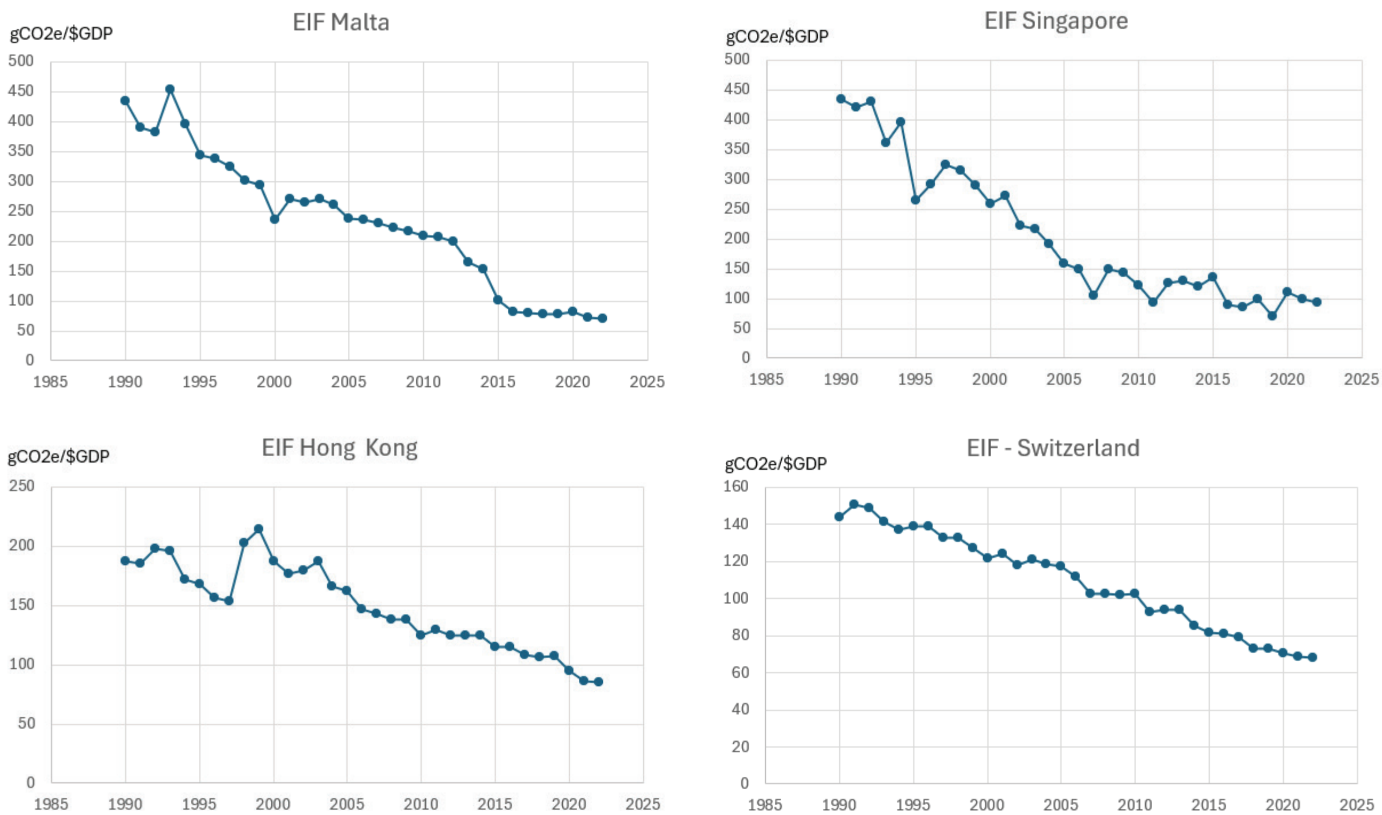
Fig. 1. EIF trends for Canada, USA, UK and Europe.

Emission intensity factors, gCO2e/$GDP, for Canada, USA, UK, and Europe from 1990 to 2022. EIF values have significantly declined in all regions: Canada by 47%; USA 55%; UK 72%, and EU27 by 60%. Source: https://ourworldindata.org/grapher/gdp-per-capita-worldbank and https://ourworldindata.org/grapher/per-capita-ghg-emissions.

The three EIF components aggregate to the ratio of CO2e/GDP which is the reciprocal of the ratio that indicates the degree of decoupling. Even with a fully electrified economy powered by renewable sources of energy and operating at unprecedented efficiency, carbon emissions per dollar of GDP cannot fall to zero. GHG emissions come from agriculture, land use change, waste disposal, industrial processes, biogenic methane, and other sources unrelated to electricity generation. This implies that EIF will decline to a minimum value which it reaches asymptotically over time.

There is no clear indication in Figure 1 that the EIFs for the four countries shown decline asymptotically to a minimum value. This is because few countries approach this limit. However, the tendency can be seen in data from the five jurisdictions that had EIF values below 100 gCO2e/$GDP in 2022: Hong Kong, Malta, Singapore, Macao and Switzerland. The EIF downwards trend for these four countries and Macao is shown in Figure 2 [18].

For most governments, it is axiomatic that GDP must not only increase over time, but that the growth of GDP must exceed population growth, so that GDP per capita should continually rise. However, if per capita emissions are to be held at a level commensurate with net zero emissions, when the EIF declines to its minimum value, **GDP per capita must be held constant.** If not, the net zero emissions condition cannot be maintained and GHG emissions starts to rise.



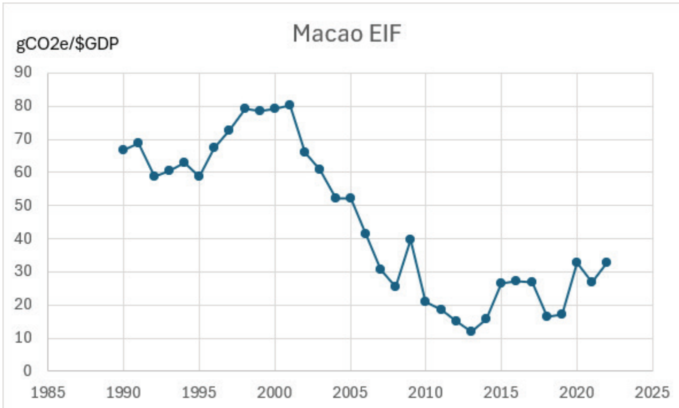


Fig. 2. Energy Intensity Factors for Malta, Singapore, Hong Kong, Switzerland, and Macao.

Emission intensity factors for Malta, Singapore, Hong Kong, Switzerland and Macao show a downward trend towards a theoretical minimum value. Analysis of the constituent factors of the EIF suggest that its value is unlikely to decline below 50 gCO2e/$GDP. Macao is an unusual case given its status as a 'special administrative region'. Source: https://ourworldindata.org/grapher/per-capita-ghg-emissions?tab=chart&country=HKG~MLT~MAC~SGP~CHE https://ourworldindata.org/grapher/gdp-per-capita-worldbank?tab=chart&country=HKG~MLT~MAC~CHE~SGP

The lower bound

It is crucial to estimate the lower bound of the emission intensity factor; the minimum value defines the lowest possible value of per capita GHG emissions for a specified per capita GDP.

Among the four countries and one region shown in Figure 2, Macao has the lowest EIF at 33 gCO2e/$GDP in 2022 (although it fell to 12 gCO2e/$GDP in 2013). But Macao is an unusual case. It is a 'special administrative region' of China; the most densely populated region in the world, with over 90 percent of its electricity imported from the mainland. More typical are the other four countries: where the lower bound for EIF appears to be between 50 and 70 gCO2e/$GDP. Given that the EIF values are still slowly declining in the four countries showcased, for the purpose of the following discussion the researcher assumes that the lower bound on the emission intensity factor, $EIF_{min,}$ is closer to 50 gCO2e/$GDP.

The theoretical minimum for a country GHG emissions per capita can be calculated from this value. **It is simply equal to EIF_{min} x GDP per capita.**

The EIF_{min} is not a 'universal' constant. Every country minimum EIF is slightly different because all economies have different structural and socio-economic characteristics; but there is a universal rule: **the value of the EIF tends to a minimum.**[4]

Note that the countries shown in Figure 2 are all modern economies with per capita GDP values over $50,000. Low-income countries do <u>not</u> have low EIFs. Although their emissions may be minimal, GDP per capita is also very low. For example, the average EIF for low-income and lower middle-income countries is 1420 and 420 gCO2e/$GDP, respectively.

If GDP per capita is to be held constant from mid-century, this does not mean that the economic growth of low-income countries is impeded or curtailed. On the contrary, if their EIF is reduced to a minimum, the per capita emissions target of approximately 2 tCO2e allows for a developing country per capita GDP to rise to $40,000, about the same level as Spain, and greater than Italy, Poland, and Portugal [18].

The per capita GDP of all low-income developing countries could theoretically rise to this level by mid-century--if they introduce policies that reduce EIF to a minimum of approximately 50 gCO2e/$GDP. Few low-income countries may achieve this target; but nothing in the transition to a global condition of sustainable steady-state emissions at a level of 2 tCO2e per capita by 2050 prevents this scenario from becoming possible. In reality, the required rates of economic growth are very high: the GDP per capita of low-income countries would need to increase at 11.4% a year to reach $40,000 in 2050; while for lower middle-income countries, the required annual rate of growth is 6.4 %.

[4] Strictly speaking: a non-zero positive value.

These growth rates are challenging but not impossible; for example, annual GDP growth in China averaged 7.8% from 2000 to 2022 [18].

Minimising the EIF

The Emission Intensity Factor can be disaggregated into three components, each of which should be the focus of a specific and targeted set of energy policies. In many countries, the value of EIF is slowly declining, but measures to accelerate its decline are essential if values close to 50gCO2e/$GDP are to be achieved before mid-century.

1. **The component, *CO2e/elec,*** is substantially reduced by phasing out all fossil-fuel electricity generation ideally before 2030. The generation of electrical power must not produce *any* emissions of carbon; which means that all generation is from renewable sources of energy: primarily hydropower, solar energy and wind power (but not biomass). Other renewable sources such as geothermal energy may also become more important over the next 25 years. Nuclear power is also carbon-free and some countries will undoubtedly invest in this technology despite its abysmal track record in terms of cost overruns, lengthy construction delays, and the still intractable problem of radioactive waste management. [19, 20] This component cannot decline to zero. In all modern economies, there are diffuse emissions of carbon dioxide, methane, and nitrous oxide from biogenic sources, and these cannot be entirely eliminated. The Our World In Data (OWID) database shows six countries with values below 100 gCO2/kWh (Iceland, Norway, Macao, Malta, Singapore and Sweden) with an arithmetic mean of 61 gCO2/kWh [18]. The other GHGs raise this value by about 20 percent, so the minimum value for this component may be estimated as approximately 73 gCO2e/kWh.

2. **The degree of electrification, *elec/E,*** is a ratio that approaches unity as economic activity becomes increasingly electrified. Policies should initially focus on the transport and building sectors. But progress will be slow (as it is now) unless governments incentivise, *inter alia,* the transition to electric vehicles and the electrification of heating and cooling systems in buildings and industry by the deployment of heat pumps. The electrification of steel-making and other heavy industry is essential, as is the production of industrial-scale electrolytic hydrogen powered by renewables. Aviation and marine transportation are responsible for a significant percentage of global GHG emissions, and these sectors will either electrify or operate on carbon-neutral biofuels.

3. **The energy intensity of GDP, *E/GDP,*** is a measure of the efficiency of economic activity as measured by GDP. Its value declines with the improved energy efficiency of buildings and transport, decarbonisation, and electrification. The minimum value among high-income countries (for example Switzerland) is 0.52 kWh/$GDP [18].

The values of the EIF components referenced above lead to an estimate of EIF_{min} of approximately 37 gCO2e/$GDP. But this value is only theoretically possible if each of the EIF components are reduced to their absolute minimum. Setting a target of 50gCO2e/$GDP is more realistic, and one that has already been achieved in at least one jurisdiction: Macao.

4. RESULTS AND DISCUSSION

For the countries of EU27, population growth is forecast to be close to zero up to mid-century and then to slowly *decline* at 0.13% per year [13]. In 2022, per capita emissions had declined to 7.5 tCO2e, but GDP per capita was still rising at about 1.3% a year.

A constantly increasing GDP per capita will fatally undermine European emission targets no matter how forceful the transition to fully electrified, highly energy-efficient economies is. For example, at current rates of 1.3 % a year, EU27 GDP per capita will reach $67,000 in 2050, at which time per capita emissions at an EIF_{min} of 50gCO2e/$GDP will be 3.3 tCO2e, well short of the target aimed at limiting global temperatures to its less stringent value.

Similarly, in the case of the United States, at current rates of growth, GDP per capita will rise to $93,352 by 2050. Even if the EIF falls to 50 gCO2e/$GDP, per capita emissions will be about 4.7 tCO2e/y, more than twice the value of the global target.

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This analysis shows that for developed countries with per capita GDPs above $40,000, policies aimed at achieving compliance with the Paris Agreement target by mid-century must confront an unpalatable truth: **Compliance is impossible if GDP per capita is allowed to constantly rise.**

Many developing countries face no such constraints. Nigeria, for instance, forecasts an annual population growth of 2.4 % through to 2050 which means that the country economy could grow at this rate if it maintains its currently low level of emissions at approximately 2 tCO2e per capita [21].

China, which alone accounts for a quarter of global GHG emissions, has nonetheless reduced its EIF from 1130 gCO2e/$GDP in 2000 to 540 gCO2e/$GDP in 2022. It has a long way to go; but the pace of the transition to renewable sources of energy is extraordinary: 180 GW of utility-scale solar and 159 GW of wind power are currently under construction, twice as much as the rest of the world combined [22]. However, the country has also constructed new coal-fired power plants, often as back-up for variable solar energy and wind power. Longer term, pumped hydropower storage may be the key to phasing out coal and reducing per capita emissions--which in 2022 were 9.8 tCO2e/y [18].

The preceding argument confirms that the concept of an absolute decoupling of economic growth and emissions which would allow for unrestrained growth is not plausible. In such a scenario, the ratio of GDP to carbon emissions would continue to increase indefinitely. However, as we have noted, the ratio of $GDP to gCO2e is the reciprocal of the Emission Intensity Factor--which has a lower bound of approximately 50 gCO2e/$GDP. We may therefore deduce that the ratio of GDP to carbon emissions is limited by an upper bound of approximately 20 $GDP/kgCO2e. Economic growth can never be fully decoupled from carbon emissions. The ratio can be substantially increased but it is limited by an upper bound.

Negative Emission Technologies

The technologies that could potentially change this pessimistic forecast are the so-called negative emission technologies (NETs). These technologies absorb carbon dioxide from the atmosphere and lock the carbon away in a variety of substrates: biomass, seawater, and geologic formations[5]. In principle, if these technologies can withdraw substantial amounts of carbon dioxide from the atmosphere, this would allow for a higher level of emissions than the 20 GtCO2e target judged to be necessary by the IPCC for limiting global temperatures to 2C above pre-industrial levels by 2050.

The most comprehensive evaluation of NETs was conducted by the Science Advisory Council of the European Academies in 2018 [24]. The EASAC evaluated seven NETs: afforestation and reforestation; land management to increase soil carbon; bioenergy with carbon capture and storage (BECCS); enhanced weathering; direct air capture and carbon storage (DACCS); ocean fertilisation; and carbon capture and storage.

The report is not encouraging. The EASAC concludes that *"these technologies offer only limited realistic potential to remove carbon from the atmosphere and not at the scale envisaged in some climate scenarios (as much as several billion tonnes of carbon each year post 2050). Negative emission technologies may have a useful role to play but, based on current information, not at the level required to compensate for inadequate mitigation measures"[23].*

The Science Advisory Council went on to say *"Scenarios and projections of NET's future contribution to CDR (carbon dioxide removal) that allow Paris targets to be met thus appear optimistic on the basis of current knowledge and should not form the basis of developing, analysing and comparing scenarios of longer-term energy pathways for the European Union."*

More recent reports on BECCS and carbon capture and storage technologies have confirmed this negative assessment [25]. Moreover, the contribution of forests, previously thought to be reliably effective as carbon sinks, has been called into question by the way rising global temperatures have provoked a greater frequency of increasingly intense and destructive wildfires. Many forested regions are now carbon *sources* not carbon *sinks* [25, 26].

[5] How long the carbon is locked away depends on the technology. Carbon stored in biomass is sequestered for several decades, whereas carbon fixed chemically in seawater and geologic strata is held longer in the 'slow' carbon cycle. Carbon dioxide stored underground is in principle permanently sequestered—assuming the storage system doesn't leak.

This realistic assessment of the limitations of negative emission technologies leads to the conclusion that measures to *directly reduce greenhouse gas emissions* must be the foundation of all country policies aimed at limiting global temperatures to less than 2C above pre-industrial levels.

Increasing Population

The questions remains whether global steady-state emissions of around 2 tCO2e *per capita* will hold *total* emissions at a level commensurate with the Paris accords. In other words, sustainable per capita emissions may be a *necessary* condition but not necessarily a *sufficient* one.

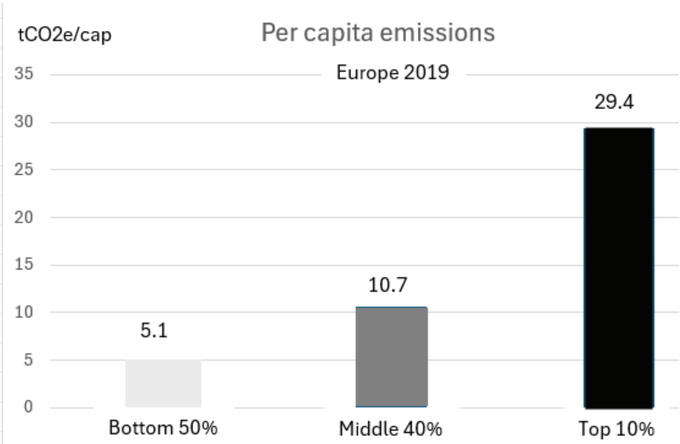
The UN Department of Economic and Social Affairs projects that the world population is likely to peak within the current century. The 2024 population of 8.2 billion is forecast to grow to about 10.3 billion people in the mid-2080s, before gradually declining to 10.2 billion by the of the century [9]. The annual rate of increase over the period to the mid-1980s is only 0.38 percent.

Recall that the global target for GHG emissions in 2050 is 20 GtCO2e. Global emissions may therefore rise to 21.2 GtCO2e by the mid-2080s before declining slightly to 21.0 GtCO2e by the end of the century. These projected minor increases in global emissions after mid-century are inconsequential compared to the significant challenge of reducing total emissions from the current level of approximately 54 GtCO2e to 20 GtCO2e by 2050.

If the target of reducing global emissions in line with the Paris Agreement is redefined as maintaining annual GHG emissions post-2050 at 20 tCO2e (±1 tCO2e), the requirement of steady-state *per capita* emissions becomes a *sufficient* condition.

Emission Inequality

The linear relationship between per capita emissions and per capita GDP enables a new perspective on the latter metric which can now be disaggregated over a range of demographic cohorts. The work of Lucas Chancel has highlighted the substantial difference in per capita GHG emissions across population cohorts in several regions of the world [27, 28]. Figure 3 shows per capita emissions in Europe and the USA for three population groups: the bottom 50%; the middle 40%, and the top 10% of the income distribution.



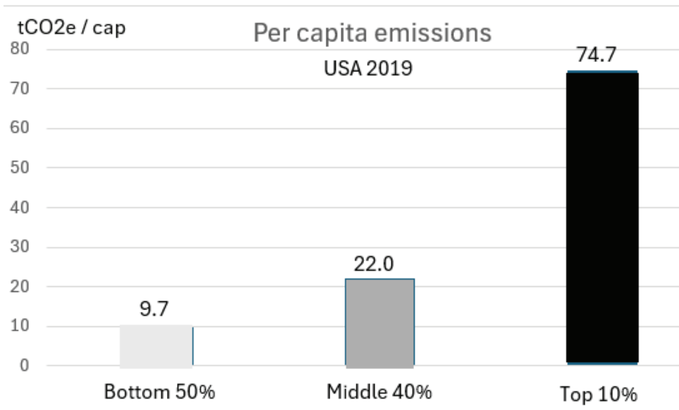


Fig. 3. Emission inequality in Europe and USA.

Per capita GHG emissions from the top 10% of the income distribution in Europe and the USA are roughly 6 to 7 times higher than the bottom 50%. The middle 40% also emits twice as much per capita as the bottom 50%. Source: Chancel, L. Global carbon inequality over 1990-2019. [24] and World Inequality Report 2022 [28].

It is notable that the top ten percent of the income distribution in Europe emits almost 6 times more greenhouse gases than the bottom 50 percent and almost 3 times more than the middle 40 percent on a per capita basis. In the USA, the inequality in per capita emissions is even more pronounced. In sum, the top ten percent are responsible for 30 percent of all greenhouse gas emissions in Europe and 35

http://dx.doi.org/10.21622/MACI.2024.01.2.1042

percent in the USA. This emission inequality is seen in every region analysed by Chancel [27], and points to the need to reduce emissions by focusing specific mitigation policies on each demographic cohort and particularly on the top 10 percent of the income distribution.

These data enable one to calculate Emission Intensity Factors for Europe and the USA from per capita GDP and per capita GHG data [17].

Table 1: Emission and GDP data for EU27 and USA (2019)

	EU27	USA
GDP per capita, $GDP/cap	$44,371	$64,623
Emissions per capita, tCO2e/cap	9.77	21.12
Emission Intensity Factor, gCO2e/$GDP	220	327

GDP per capita can now be calculated for each population group. The results are shown in Figure 4.

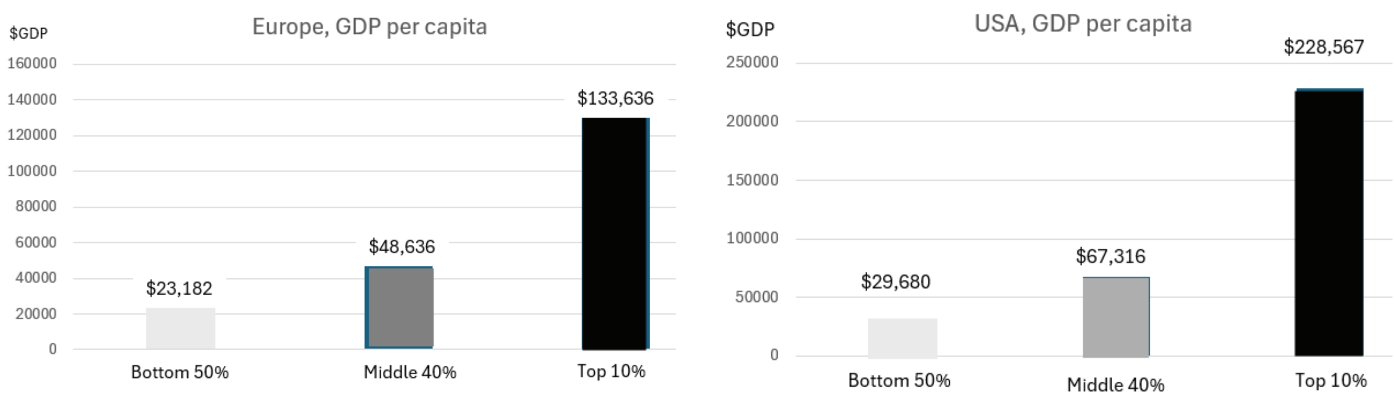


Fig. 4. Per capita GDP per demographic cohort in Europe and USA (2019).

Per capita GDP values mirror per capita emissions because of the linear relationship between the two variables. Based on EIF=220 gCO2e/$GDP for Europe and 327 gCO2e/$GDP for USA.

Figure 4 underscores the fact that the top 10 percent of the distribution are responsible for a disproportionate amount of the economic and environmental impacts of GDP growth: 30 percent in Europe and 35 percent in USA.[6]

The condition for sustainable net zero emissions depends first, on reducing the emission intensity factor, EIF, to its minimum value--which the researcher has estimated as being close to 50 gCO2e/$GDP; and second, on reducing per capita GDP to approximately $40,000. Under these conditions, per capita emissions can be held at approximately 2.1 tCO2e/yr which is the global target for holding rising temperatures to no more than 2 C above pre-industrial levels from 2050 onwards.

It is instructive to examine the impact of these conditions on the structure of disaggregated GDP. Figure 5 shows the per capita GDP threshold of $40,000 in relation to 2019 values for each cohort for Europe and USA.

[6] Based on the *total* GDP for each cohort, equal to population x per capita GDP.

http://dx.doi.org/10.21622/MACI.2024.01.2.1042

JOURNAL OF MULTIDISCIPLINARY ADAPTIVE CLIMATE INSIGHTS (MACI) Volume 1, Issue 2, December 2024 - ISSN 3009-6332

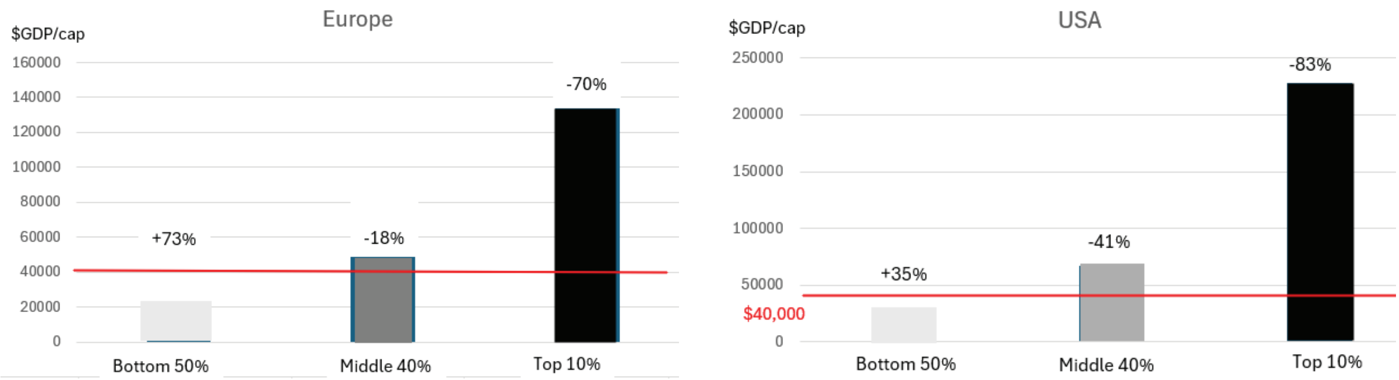


Fig. 5. Changes in per capita GDP at net zero emissions.

If the EIF is reduced to its minimum value, the bottom 50% of the income distribution in Europe and the USA may increase their per capita GDP to the target level of $40,000. Modest reductions in GDP per capita are required of those in the middle 50%. However, substantial reductions in per capita GDP are required of the top 10%.

If per capita GDP is to be held at $40,000 across all cohorts, in Europe these changes would amount to a 72.4% *increase* in the per capita GDP of the bottom 50%; a *reduction* of 18% in the per capita GDP of the middle 40%; and a *reduction* of 70% in the per capita GDP of the top ten percent. In the USA, the bottom 50% can still grow their economies by one third. But the middle 50% see a reduction of 41 percent, and the top 10% are looking at a reduction in per capita GDP of more than 80 percent if the US is to reduce its emissions to a level commensurate with the Paris Agreement target.

National emission-reduction policies should therefore focus primarily on the top 10 percent of the population. The paper by Chancel [27] discusses one such option which is the imposition of a tax on investments proportional to their carbon content. According to his estimates, such a tax would impact close to 100% of the top 10% of the global population, but the bottom 77% of the US population and the bottom 90% of the European population would be unaffected. Other fiscal instruments are likely to be necessary, but the essential point is that government policies to reduce GHG emissions should take account of the inequality of emissions in order to better target the economic and environmental impacts of their policies.

How these redistributive measures are to be designed and implemented is beyond the scope of this paper. A comprehensive review of the theory and practice can be found in the works of Picketty [29].

5. INTERNATIONAL CONTEXT AND RELEVANCE

At the 2023 European 'Beyond Growth' conference, the post-conference declaration (signed by over 1180 participants) agreed to set a pathway to a "post-growth" world in which the economy and society would "thrive while operating within the established planetary limits" [30]. One of these limits is the atmospheric concentration of carbon dioxide [31].

The 'beyond growth' scenarios include **Green/ inclusive growth**, where growth is still a central policy, but adjustments are made to ensure sustainability and inclusivity; **Degrowth,** which takes an opposing view and envisions a steady-state or shrinking economy; and **post-growth**, which is agnostic about growth, instead focusing on a "more rounded vision of social and economic progress" [32].

It is axiomatic in all three scenarios that planetary limits should not be breached--which means that **a condition of net zero emissions at approximately 2 tCO2e per capita must be achieved and maintained.**

If there is to be a realistic possibility of keeping global temperatures from exceeding 2 C above pre-industrial levels, all countries must design and implement measures to reduce the value of their *emission intensity factors* to the minimum level of approximately 50 gCO2e/$GDP. These measures include the complete phase-out of fossil fuels; the electrification of all sectors of the economy; and the reduction of the energy intensity of GDP by *inter alia* investing in more efficient and less carbon-intensive industrial processes and by taking stronger steps towards an economy with much lower rates of extraction, consumption, and waste.

Low-income and developing countries should also follow these energy and industrial policies. They may continue to grow their economies, but in a way that limits greenhouse gas emissions to the greatest possible extent. Higher levels of electrification based on rural mini grid systems are essential and all forms of transport should be electrified. Also essential is the transition away from biomass fuels used for cooking. The analysis set out in this paper suggests that GDP per capita should not rise above $40,000 a year, a level approximately the same as Spain. This strategy provides considerable GDP headroom for low- and middle-income countries which have average per capita GDPs below $5000 and $20,000 respectively [18].

High-income countries face a highly consequential choice, with implications of global even existential importance. They can continue to grow their economies; or they can decelerate and curb economic growth and reduce their emissions to a sustainable steady-state aligned with Paris Agreement targets. But they cannot do both.

REFERENCES:

01. *2040 climate target - European Commission*. (n.d.). https://climate.ec.europa.eu/eu-action/climate-strategies-targets/2040-climate-target_en

02. Agency, I. E. (2024). *The relationship between growth in GDP and CO2 has loosened; it needs to be cut completely – Analysis*. https://www.iea.org/commentaries/the-relationship-between-growth-in-gdp-and-co2-has-loosened-it-needs-to-be-cut-completely

03. Bearak, M. (2024). Why the Era of China's Soaring Carbon Emissions Might Be Ending. *The New York Times*. https://www.nytimes.com/2024/07/18/climate/china-greenhouse-gas-emissions-plateau.html

04. Beyond Growth Conference 2023. Post-Conference Declaration. (2023). *Annuaire International de Justice Constitutionnelle*, *38*, 475–526. https://doi.org/10.3406/aijc.2023.3088

05. *Bloomberg - Are you a robot? Top Polluter China's Shrinking Emissions Put Carbon Peak in Play* . (2024). https://www.bloomberg.com/news/articles/2024-07-15/top-polluter-china-s-shrinking-emissions-put-carbon-peak-in-play

06. Byrne, B., Liu, J., Bowman, K. W., Pascolini-Campbell, M., Chatterjee, A., Pandey, S., Miyazaki, K., van der Werf, G. R., Wunch, D., Wennberg, P. O., Roehl, C. M., & Sinha, S. (2024). Carbon emissions from the 2023 Canadian wildfires. *Nature*, *633*(8031), 835–839. https://doi.org/10.1038/s41586-024-07878-z

07. Chancel, L. (2022). Global carbon inequality over 1990–2019. *Nature Sustainability*, *5*(11), 931–938. https://doi.org/10.1038/s41893-022-00955-z

08. Commission, E. (2019). *The European Green Deal*. European Commission. https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en

09. Contributors, W. (2019). *Kaya identity*. Wikimedia Foundation. https://en.wikipedia.org/wiki/Kaya_identity

10. *European Academies Science Advisory Council. Forest bioenergy, carbon capture and storage, and carbon dioxide removal: an update*. (2019). https://www.qualenergia.it/wp-content/uploads/2019/02/EASAC_Commentary_Forest_Bioenergy_Feb_2019_FINAL.pdf

11. *European Parliamentary Research Service From growth to 'beyond growth': Concepts and challenges*. (2023). https://www.europarl.europa.eu/RegData/etudes/BRIE/2023/747107/EPRS_BRI(2023)747107_EN.pdf

12. *Eurostat. The EU's population projected up to 2100* . (n.d.). https://ec.europa.eu/eurostat/web/products-eurostat-news/-/DDN-20190710-1

13. Flyvbjerg, B., & Gardner, D. (2023). *How Big Things Get Done*. Signal Books .

14. *Global Carbon Budget*. (2022). Page: Changes in the budget over time. https://globalcarbonbudget.org/wp-content/uploads/GCP_CarbonBudget_2022_slides_v1.0.pdf

15. Ihédate. (2023). *World Nuclear Industry Status Report 2023*. https://www.worldnuclearreport.org/-World-Nuclear-Industry-Status-Report-2023-.html

16. IPCC. (2022). *Summary for Policymakers*. IPCC 6th Assessment Report WG III. Figure SPM-4. Global GHG emissions of modelled pathways. Panel a. Global GHG emissions. https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_SummaryForPolicymakers.pdf

17. Jackson, T. (n.d.). *Tim Jackson*. https://timjackson.org.uk/ecological-economics/pwg/

18. Levin, K., Rich, D., & Institute, W. R. (2017). Turning Point: Which Countries' GHG Emissions Have Peaked? Which Will in the Future? *Www.Wri.Org*. https://www.wri.org/insights/turning-point-which-countries-ghg-emissions-have-peaked-which-will-future

19. *Nigeria: Population 1950-2020*. (2021). https://www.statista.com/statistics/1122838/population-of-nigeria/

20. *Our World in Data. GDP per capita* . (2017). https://ourworldindata.org/grapher/gdp-per-capita-worldbank?tab=chart&country=HKG~MLT~MAC~SGP~CHE

21. *Per capita greenhouse gas emissions*. (2024a). https://ourworldindata.org/grapher/per-capita-ghg-emissions?tab=chart&country=

22. *Per capita greenhouse gas emissions*. (2024b). https://ourworldindata.org/grapher/per-capita-ghg-emissions?tab=chart&country=HKG~MLT~MAC~SGP~CHE

23. Piketty, T. (n.d.). *Capitalism in the Twenty-first Century*. Harvard University Press.

24. Popkin, G. (2017). Tropical forests may be carbon sources, not sinks. *Nature*. https://doi.org/10.1038/nature.2017.22692

25. Richardson, K., Steffen, W., Lucht, W., Bendtsen, J., Cornell, S. E., Donges, J. F., Drüke, M., Fetzer, I., Bala, G., von Bloh, W., Feulner, G., Fiedler, S., Gerten, D., Gleeson, T., Hofmann, M., Huiskamp, W., Kummu, M., Mohan, C., Nogués-Bravo, D., … Rockström, J. (2023). Earth beyond six of nine planetary boundaries. *Science Advances*, *9*(37). https://doi.org/10.1126/sciadv.adh2458

26. Ritchie, H., Rosado, P., & Roser, M. (2023). CO_2 and Greenhouse Gas Emissions. *Our World in Data*. https://ourworldindata.org/co2-and-greenhouse-gas-emissions

27. the. (2018). *Negative emission technologies: What role in meeting Paris Agreement targets?* https://interacademies.org/publication/negative-emission-technologies-what-role-meeting-paris-agreement-targets

28. UNFCCC. (2015). *United Nations Framework Convention on Climate Change, Paris Agreement. Article 4 paragraph 1.* https://unfccc.int/files/meetings/paris_nov_2015/application/pdf/paris_agreement_english_.pdf

29. *United Nations Department of Economic and Social Affairs. World Population Prospects 2024. Summary of Results*. (2024). https://population.un.org/wpp/Publications/Files/WPP2024_Key-Messages.pdf

30. *United Nations Population Division. Day of eight billion*. (2022). https://www.un.org/development/desa/pd/events/day-eight-billion

31. *World Inequality Report 2022*. (2021). https://wid.world/news-article/world-inequality-report-2022/

32. Yu, A., Lu, S., O'Malia, K., & Prasad, S. (2024). China continues to lead the world in wind and solar, with twice as much capacity under construction as the rest of the world combined. *Globalenergymonitor.Org*. https://globalenergymonitor.org/report/china-continues-to-lead-the-world-in-wind-and-solar-with-twice-as-much-capacity-under-construction-as-the-rest-of-the-world-combined/

JOURNAL OF MULTIDISCIPLINARY ADAPTIVE CLIMATE INSIGHTS
(MACI) Volume 1, Issue 2, December 2024 - ISSN 3009-6332

http://dx.doi.org/10.21622/MACI.2024.01.2.1035

EVALUATING THE EFFECTIVENESS OF THE EU ETS IN REDUCING GREENHOUSE GAS EMISSIONS IN THE SHIPPING SECTOR

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Received on, 28 September 2024 Accepted on, 26 October 2024 Published on, 03 December 2024

ABSTRACT:

The European Union Emissions Trading System (EU ETS) is designed to reduce greenhouse gas (GHG) emissions by setting a cap on the total emissions allowed from included sectors and allowing companies to buy and sell emission allowances, to meet their compliance obligations. Expanding the EU ETS to cover the maritime shipping sector, already in use from start of 2024, could be an effective tool for reducing GHG emissions in maritime transport. The EU ETS can be an effective mechanism for reducing GHG emissions in the maritime shipping sector, especially when combined with other decarbonization strategies such as technology investment, fuel innovation, and regulatory frameworks. Based on case studies the paper examines the cost aspect of the EU ETS implementation on the various ship types and shipping companies, showing that the success of the newly introduced framework depends on several factors that must be considered. This paper reveals that while the system holds potential, the financial impact on shipping companies varies significantly depending on ship size and route. Additionally, the success of the EU ETS relies on overcoming challenges related to carbon leakage, administrative complexity, and global cooperation.

KEY-WORDS: Decarbonization in maritime shipping, GHG, CO_2 emissions, EU Emission Trading Systems.

1. INTRODUCTION

The concept of emissions trading began to take shape in the United States during the 1970s with the Clean Air Act Amendments. The Environmental Protection Agency (EPA) experimented with emissions trading to control air pollution, which led to the establishment of the US Acid Rain Program under the Clean Air Act Amendments of 1990. This became one of the first large-scale applications of emissions trading in the world at the time. The program is aiming at reducing sulfur dioxide (SO_2) and nitrogen oxides (NOx) emissions from power generation plants1[1].

Building on the success of earlier emissions trading systems, the EU ETS was introduced in 2005 to target greenhouse gas emissions across various sectors, and as of 2024, it includes the maritime shipping sector. On the other hand, the European Union Emissions Trading System (EU ETS), already in place since 2005[2], is a key policy instrument for reducing greenhouse gas (GHG) emissions in the EU, and it has been increasingly considered for the maritime shipping sector as well. The EU ETS is a cap-and-trade system where a cap is set on the total amount of GHG emissions that can be emitted by companies operating in sectors included in the scheme. Companies receive allowances for free (each allowance provides the right to emit 1 ton of CO_2 equivalent green-house gases within a year) or must purchase them via auctions or in secondary market, selling their surplus allowances or purchasing more depending on their annual emissions needs. Over time, the total cap is reduced, leading to lower emissions across the covered sectors.

EU ETS currently covers more than 10,000 industrial and power installations and airline companies operating flights in and between EU airports only, across the 27 EU member states, Iceland, Norway, and Liechtenstein (and there is a link with the Swiss ETS framework)[3].

The objective of the ETS is to reduce GHG emissions from power generation installations and other energy intensive industries by a certain percentage every year (referencing the key scheme variable called the Linear Reduction Factor – LRF, essentially setting the overall cap reduction rate per year)[4]. As of 2013, the annual LRF was set at 1.74% to achieve an overall reduction of GHG emissions in the included sectors of 21% by 2020, compared to 2005 levels.

The central question this paper aims to explore is: Is the EU ETS an effective mechanism for reducing greenhouse gas emissions in the maritime shipping sector[5], and what are the economic implications for different types of shipping companies? This research analyzes the system potential impact and assess its success in reducing maritime emissions.

2. METHODOLOGY

Authors apply a structured approach that combines comprehensive and systematic literature review of the Institutional Framework[6], as it is applied and affects real operating and voyage costs. Primary data retrieved for indicative vessel sizes and routes[7], as monitored via the established and approved MRV procedures for certain shipping companies. Geographical trading areas cover Trans-Atlantic and Trans-Pacific trading routes to EU and from EU countries, to explore all the possible trading routes that EU ETS is applied[8]. This approach allows for an in-depth, contextual exploration of EU ETS implementation in the shipping industry, as limited by the institutional framework.

By exploring real case studies, authors prove that - considering real time costs associated with the EU ETS provisions - different ship types absorb the increased costs in a different way, raising the issue of fair competition between various ship segments. Comparative data analysis among tonnage segments, prove that smaller ships are likely to face greater financial strain under the EU ETS. The cost of compliance, including purchasing

[1] https://www.epa.gov/clean-air-act-overview/1990-clean-air-act-amendment-summary

[2] Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a system for greenhouse gas emission allowance trading within the Union and amending Council Directive 96/61/EC

[3] https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets/scope-eu-ets_en

[4] Directive (EU) 2018/410 of 14 March 2018 amending Directive 2003/87/EC to enhance cost-effective emission reductions and low-carbon investments, and Decision (EU) 2015/1814

[5] Regulation (EU) 2023/957 of the European Parliament and of the Council of 10 May 2023 amending Regulation (EU) 2015/757 in order to provide for the inclusion of maritime transport activities in the EU Emissions Trading System and for the monitoring, reporting and verification of emissions of additional greenhouse gases and emissions from additional ship types

[6] Review of the existing EU and IMO legislative framework

[7] Reference to private shipping operating companies that provided real yet confidential figures from various chartered vessels

[8] Round voyages from / to EU countries as well as intra EU trading

http://dx.doi.org/10.21622/MACI.2024.01.2.1035

emissions allowances and implementing emission-reduction measures, could be a higher percentage of operational expenses for smaller vessels. Larger ships, which are generally more fuel-efficient per unit of cargo, may have an easier time absorbing the additional costs.

3. THE EVOLUTION OF EMISSION TRADING SYSTEMS – EU ETS I & EUTS II

Maritime shipping is responsible for approximately 3% of global carbon dioxide (CO_2) emissions, with around 90% of global cargo transported by sea. As the shipping industry is essential for global trade, its emissions contribute significantly to climate change. Given its international nature, regulating emissions in the sector presents unique challenges, making it a key focus for decarbonization strategies under international and regional frameworks like the EU ETS.

Between 2021 and 2030 the LFR was set to decrease at an annual rate of 2.2%. The Linear Reduction Factor was set in 2018 to align with the previous EU targets of cutting all greenhouse gas emissions by at least 40% by 2030 compared with 1990 levels.

Importantly, however, the 2023 reform of the ongoing phase 4 of the EU ETS (2021-2030) introduced more ambitious goals. The new goals target an overall emissions reduction of 62% by 2030, compared to 2005 levels. Therefore, the annual LRF is raised to 4.3% for the 2024-2027 period, and then to 4.4% from 2028 onwards.

This trajectory is envisaged that it will bring the cap to zero by 2039 (this does not account for small batches of allowances for the aviation and maritime sectors). Once the EU decides on a climate target for 2040, it will also set out to further adjust the ETS[9].

In 2023, the EU decided to extend the ETS to the maritime sector, which is responsible for about 3% of global CO_2 emissions, and for transporting around 90% of global cargo volumes. The inclusion of maritime shipping in EU ETS is decided to take place via a phase-in approach (instead of providing a % of free allowances as was the case with other industries in the past) starting in 2024, with full implementation by 2026. The shipping industry will be required to purchase allowances to cover a portion of their emissions from voyages within the European Economic Area (EEA) and half of their emissions from international voyages into and out of the EEA.

This phased approach mirrors the way other sectors, such as aviation and power generation, were gradually integrated into the EU ETS. For instance, the aviation sector was included in the ETS in 2012, but only intra-European flights are currently covered. Lessons learned from the aviation sector's integration can be valuable for the maritime industry, particularly in managing carbon leakage and monitoring emissions across jurisdictions. Similarly, the power sector's experience with emissions trading highlights the importance of adapting to the evolving carbon market and investing in cleaner technologies to remain competitive. The maritime industry may face similar challenges, such as the risk of carbon leakage, where shipping companies reroute activities to non-EU ports to avoid compliance costs, and the high initial costs of implementing cleaner technologies (Christodoulou et al., 2021).

In mid-2021, the European climate law came into force. It set a binding target of a net greenhouse gas emissions reduction (emissions after deduction of removals) by at least 55% by 2030 compared to 1990 levels.

To achieve this new ambitious goal, the EU presented its "Fit for 55"[10] package of new rules and legislative proposals in July 2021 – including a renewal of the EU ETS.

After negotiations, the European Parliament, member state governments in the EU Council, and the Commission reached a deal in December 2022 to reform the existing ETS I and introduce a second system for transport and heating fuels, namely ETS II. The final acts were signed in the middle of 2023.

The key changes that increase the uncertainty regarding the decarbonization targets, technologies and impact, are summarized below:

- Amended 2030 target for ETS emissions is -62% (previously -43%) compared to 2005 levels.

[9] https://www.cleanenergywire.org/factsheets/understanding-european-unions-emissions-trading-system

[10] European Commission, Communication on 'Fit for 55': delivering the EU's 2030 climate target on the way to climate neutrality, COM/2021/550 final

http://dx.doi.org/10.21622/MACI.2024.01.2.1035
JOURNAL OF MULTIDISCIPLINARY ADAPTIVE CLIMATE INSIGHTS
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- New Linear Reduction Factor of 4.3% from 2024 to 2027 and 4.4% from 2028 to 2030.

- Member States should spend the entirety of their emissions trading revenues on climate-related activities.

- Maritime Shipping emissions are to be included within the scope of the EU ETS. While the emissions for ships arriving from outside the EU or departing to a port outside the union will only be covered by half (50%), any emissions from intra-EU maritime transport are fully covered under the ETS (100%). The EU agreed on a gradual phase-in of obligations for shipping companies to surrender allowances: 40% for verified emissions for 2024, 70% for 2025, and 100% for 2026 onwards. Currently, only offshore vessels of 5,000 gross tons and above will be included in the scheme, but there are discussions to lower this threshold going forward.

- **Free allocations and CBAM:** The rules for companies receiving free emission allowances will change, phasing these out step by step for products that fall under the Carbon Border Adjustment Mechanism (CBAM) by 2034. These product categories include for example cement, steel, and fertilizers (2026: 2.5%, 2027: 5%, 2028: 10%, 2029: 22.5%, 2030: 48.5%, 2031: 61%, 2032: 73.5%, 2033: 86%, and 2034: 100%). From 2026, free allocation of emission allowances should be conditional on investments in techniques to increase energy efficiency and reduce emissions.

- In the Aviation sector, currently, the EU ETS applies only for intra-European flights. The EU decided to phase out the free allocation of allowances to aircraft operators and to move to full auctioning of allowances by 2026 to create a stronger price signal. In addition, the so-called non-CO_2 effects of aviation will be included in the ETS I from 2025, initially through monitoring and later probably also with the obligation to surrender allowances. To deal with extra-European flights to and from third countries, the global Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) will be integrated into the ETS.

- Emissions from burning waste are to be monitored from 2024 onwards and likely included in the ETS from 2028 (member states can push this to 2030).

- **Market Stability Reserve reform:** 24% of all ETS allowances will continue to be placed in the Market Stability Reserve – MSR. This mechanism is intended to reduce the historical surplus of allowances available in the market, and on the other hand, enables the EU ETS I to be more flexible to future supply and demand shocks. Based on the total number of allowances in circulation, the MSR mechanism removes allowances from the market or distributes them by adjusting the auction volumes in subsequent years[11].

4. FACTORS THAT AFFECT THE EFFECTIVENESS OF THE EU ETS FOR THE SHIPPING MARKET

The inclusion of the maritime shipping sector in the EU ETS is a step towards combating GHG emissions. It offers market-based incentives to reduce emissions and promotes innovation. However, its overall effectiveness will depend on how it is implemented, the cooperation of global shipping actors, and how it interacts with other policy measures (like fuel standards or port regulations). To achieve concrete decarbonization in the shipping sector, the EU ETS will likely need to be complemented by other regulatory or technological initiatives.

The effectiveness of the EU ETS for the shipping industry has become a matter of ongoing debate and depends on several factors, such as:

- **Incentives for Emission Reductions:** By putting a price on emissions, the ETS encourages shipping companies to adopt more efficient technologies, use cleaner fuels (like LNG or biofuels), or reduce operational inefficiencies. This could accelerate the sector's shift towards decarbonization.

- **Cap on Emissions:** The ETS sets a limit on emissions that decrease over time, helping ensure that absolute reductions are achieved. This regulatory framework provides certainty to companies and investors about the future direction of climate policy.

[11] https://www.cleanenergywire.org/factsheets/understanding-european-unions-emissions-trading-system

- **Scope and Global nature of Shipping:** The shipping industry is inherently global, with ships frequently operating outside the EU's jurisdiction. This could create loopholes, where companies reroute shipping to avoid EU waters or emissions monitoring. Since only voyages within or into the EEA are covered, the system leaves much of global shipping emissions unchecked.

- **Expanding on Solutions to Carbon Leakage and Administrative Complexity:** To address the risk of carbon leakage, where companies may reroute shipping activities to avoid EU waters and regulations, a potential solution lies in fostering international collaboration. The EU could work more closely with other major shipping nations and regions to harmonize emissions trading schemes or introduce a global carbon pricing mechanism for shipping. For example, aligning the EU ETS with the International Maritime Organization (IMO) decarbonization efforts could create a more comprehensive, global system that reduces the incentive for companies to avoid compliance by rerouting vessels (Lagouvardou et al., 2022). Additionally, strengthening the monitoring, reporting, and verification (MRV) framework through digital solutions such as blockchain and artificial intelligence could reduce administrative burdens while ensuring accurate tracking of emissions across global routes. This would simplify comply with shipping companies and ensure a more transparent, tamper-proof reporting process.

- **Potential Mitigation Strategies:** Another approach to mitigating carbon leakage is to introduce incentives or rewards for shipping companies that go beyond compliance, such as offering reduced fees or faster port clearance for ships that adopt green technologies or alternative fuels. Moreover, introducing transitional financial support, such as subsidies or tax incentives, for smaller shipping companies or developing regions could ensure that compliance with the EU ETS does not disproportionately burden certain players in the market, thereby avoiding unfair competitive disadvantages. Global initiatives, like the proposed Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), which is designed to tackle aviation emissions, may serve as a model for similar initiatives in the shipping sector. A harmonized or global emissions trading system would make it harder for companies to exploit regional regulatory differences, creating a more level playing field internationally.

- **Risk of Carbon Leakage:** If the EU ETS makes shipping within the EEA more expensive, companies might shift their activities to non-EU ports, leading to "carbon leakage" where emissions are not reduced but simply moved outside the EU.

- **Administrative Complexity:** Monitoring, reporting, and verifying emissions from ships, especially across multiple jurisdictions, could be administratively burdensome and costly for both regulators and shipping companies.

- **Limited Immediate Impact on Fuel Prices:** The ETS price signal might not be strong enough in the short term to make more expensive zero-carbon fuels (e.g., hydrogen, ammonia) competitive with conventional fuels like heavy fuel oil. This means that while the ETS may incentivize incremental efficiency improvements, it might not lead to a rapid transition to zero-emission fuels without additional policy measures.

- **Revenue Generation for Innovation:** The auctioning of allowances generates revenue that can be reinvested into green technologies, including sustainable shipping solutions and alternative fuels like LNG, methanol, or ammonia. In 2023, the EU ETS generated a total of 43.6 billion euros in auction revenue. For instance, the revenues generated from EU ETS auctions are being reinvested into the EU Innovation Fund, which supports the development and deployment of cutting-edge low-carbon technologies. In the maritime sector, this has resulted in projects focused on alternative fuels, such as hydrogen and ammonia, which have the potential to significantly reduce the industry carbon footprint. A notable example is the Horizon 2020-funded project 'HySHIP,' which is building a demonstration vessel powered by liquid hydrogen, intended to showcase the feasibility of zero-emission shipping.

Additionally, some of the revenue has been used to support port infrastructure upgrades that accommodate alternative fuel bunkering, enabling ships to refuel with cleaner energy sources like liquefied natural gas (LNG). Ports in Rotterdam and Hamburg, for example, have already begun investing in LNG bunkering facilities, reducing the carbon intensity of shipping operations.

Beyond fuel innovations, part of the revenue is also allocated to initiatives aimed at improving vessel efficiency, such as retrofitting older ships with more efficient engines and propulsion systems. This reinvestment strategy helps shipping companies, particularly smaller operators, reduce compliance costs by giving them access to newer technologies that lower emissions and improve fuel efficiency.

Looking ahead, auction revenues are expected to play a pivotal role in accelerating research into next-generation maritime technologies, such as carbon capture and storage (CCS) systems on vessels and autonomous, fully electric ships. These investments not only support the decarbonization of the shipping sector but also create opportunities for economic growth by positioning the EU as a global leader in maritime innovation.

To illustrate these points, case studies from early adopters of EU ETS regulations in shipping provide valuable insights. For example, Maersk has introduced an "Emission Surcharge" for voyages subject to the EU ETS to cover the costs of emissions allowances, but also offers customers "eco delivery" options, using greener fuels to minimize emissions for specific bookings. This adjustment is designed to help them meet stricter environmental regulations while controlling operational costs. Hapag-Lloyd has similarly incorporated emissions surcharges, adjusting pricing based on emissions-related costs. Similarly, Vale, which operates a fleet of bulkers, has begun investing in energy-efficient technologies and exploring alternative fuels like LNG to meet the regulatory requirements (Ajsa Habibic, Offshore Energy, 2022).

On the Rotterdam–Tubarao route, initial estimates suggest that the cost of compliance with the EU ETS will add approximately 5-15% to the overall cost of transporting dry bulk cargo, depending on the price of emission allowances. Larger vessels, such as Capesize ships, are better positioned to absorb these additional costs due to economies of scale, while smaller ships, such as Supramax vessels, may face more significant economic burdens (Bernacki. D 2021). Similarly, based on the real costs the authors examined in the paper, in a scenario where the price of EU emission allowances (EUAs) reaches €80-100 per tonne, the cost of compliance per tonne of cargo transported on these vessels is projected to range from €1.40 to €1.80, depending on the ship size and the phase-in level of emissions covered.

5. CASE STUDY: THE IMPACT OF EU ETS ON THE OPERATIONAL COSTS OF VARIOUS SEGMENTS

In the below comparative table[12], the authors depict the total cost evolution for each chosen round voyage and dry cargo vessel type, but also the EU ETS compliance cost per tonne of cargo for different EUA price levels, for all current and future phase-in eligible emissions levels.

[12] Tubarao in Brazil is a major loading port region for Iron Ore but also other dry bulk commodity cargoes, serviced depending on commodity category by Capesize (~180k dwt), Kamsarmax (~82k dwt) and Supramax (~54k dwt, geared) dry bulk vessels). **Round Voyage:** vessel ballasts from Rotterdam to Tubarao, load in Tubarao, transport laden to Rotterdam, discharge to Rotterdam and deliver to owner again in Rotterdam.

http://dx.doi.org/10.21622/MACI.2024.01.2.1035

Table 1: The Cost of emissions for the round trip Tubarao – Rotterdam (several segments)

Rotterdam to Tubarao Round Voyage (NL->BR->NL)									
	2024 40% Emissions			2025 70% Emissions			2026 100% Emissions		
EUA Price (EUR)	69.55	80	100	69.55	80	100	69.55	80	100
	Total costs (USD. EUR/USD = 1.1)								
Capesize	68,997	79,364	99,205	120,745	138,887	173,609	172,493	198,411	248,013
Kamsarmax	37,682	43,344	54,180	65,944	75,852	94,815	94,205	108,360	135,450
Supramax	30,982	35,637	44,547	54,219	62,365	77,957	77,456	89,094	111,367
	As % of Cargo (per t)								
Capesize	0.43	0.49	0.61	0.75	0.86	1.07	1.06	1.22	1.53
Kamsarmax	0.51	0.58	0.73	0.89	1.02	1.28	1.27	1.46	1.82
Supramax	0.54	0.62	0.78	0.95	1.09	1.36	1.36	1.56	1.95

Source: data based on the round trip Tubarao - Rotterdam, as compiled by Authors

As one can see from table 1, in the very moderate scenario of a price of EUAs between 80 and 100 EUR in the future, and after the full phase-in of the scheme in the year 2026, the cost per tonne of cargo transported for EU ETS compliance, will range from 1.40 to 1.80 USD, which for the specific route chosen, it is anything between 5-15% of the per tonne of cargo transportation cost. This is a significant and inelastic increase in all cases, being around 2 to 3 times higher than the current expected EUA cost under the 40% - 2024 emissions phase.

As is obvious from the economies of scale in shipping, the larger vessels (Capesize vessels in this example) will deliver a lower per tonne of cargo EU ETS compliance cost at all times, but the flexibility and choice of vessel type, have much more to do with vessel availability, general freight levels, port restrictions and other operational parameters, and less to do with the cost of EU ETS compliance per tonne of cargo, at least for now.

While larger vessels benefit from economies of scale, smaller shipping companies, particularly those operating Supramax and Kamsarmax vessels, face greater financial pressure from the EU ETS compliance costs. These smaller companies are often less able to absorb the costs associated with purchasing allowances or investing in new, energy-efficient technologies, making them more vulnerable to rising operational expenses. For instance, a small shipping company with a limited fleet may see the cost of compliance rise by 10-20% of its operating budget, significantly affecting its profitability.

The increased cost of compliance is likely to trickle down through the supply chain, ultimately impacting the cost of goods for consumers. In the dry bulk market, for example, higher shipping costs driven by the EU ETS could lead to increased prices for essential commodities such as iron ore, coal, and agricultural products. This is especially critical for routes heavily dependent on shipping, like those between Europe and developing countries, where such price increases could have broader economic implications, potentially affecting trade balances and consumer prices globally.

Furthermore, large multinational shipping companies with diversified fleets and access to more capital may be better equipped to manage these increased costs by passing them on to customers or investing in cleaner technologies. In contrast, smaller companies may struggle to remain competitive unless they receive financial support or incentives to make necessary adjustments. This raises concerns about market consolidation, where smaller players could be forced out of business, leading to reduced competition and higher costs across the board.

6. CONCLUSION

With regards to the EU ETS framework, which is by far the most extensive and far-reaching for the Maritime industry, simply put, compliance is another cost item in the value chain that must be appropriately monitored, calculated and assigned to market participants cost list.

The maritime industry despite some initial friction and uncertainty with regards to implementation, seems to have been very efficient in adopting the necessary technical parts of the regulation, as well as effectively operating to fully comply with the regulation.

At a micro level, the industry seems to have almost entirely decided to pass the cost down the value ladder to the final consumer of the goods transported, even though the regulation essentially points to the EU compliance entity, the ship registered owner.

BIMCO clauses and market practice via data exchange on verified emissions essentially monitor, calculate and verify the appropriate cost items that must be transferred across the value chain.

At the shipowner level, the EU ETS, already essentially initiated via the MRV regulation, is a regulatory and operational burden, with data collection and management a key part of the process. The operational burden is required not only to comply with the regulation, but also to efficiently pass through the final cost to the end user of the transportation service.

While the EU ETS provides a framework for reducing greenhouse gas emissions in the maritime sector, its long-term success depends on several key policy adjustments. Firstly, to ensure that carbon leakage does not undermine the effectiveness of the system, the EU could work towards greater international cooperation, particularly with non-EU shipping nations, to create a more harmonized global carbon pricing mechanism. Additionally, incentives for the early adoption of alternative fuels and low-carbon technologies should be expanded, especially for smaller shipping companies that may face financial challenges during the transition period.

Policymakers should also consider creating more flexible mechanisms for addressing the unique challenges of global shipping, such as including more international routes and emissions within the ETS scope. This would prevent companies from rerouting to avoid compliance and encourage broader decarbonization across the industry.

Given that most shipping companies have already familiarized themselves with the adoption of new regulations and the increased need to monitor reporting and verification of data systems, the future is probably less demanding from an operational point of view. The picture is, however, different with regards to the future costs of compliance, but also the additional operating costs that forthcoming regulatory frameworks like FuelEU Maritime will necessitate.

Further research is needed to explore the long-term economic impacts of the EU ETS on different segments of the shipping industry, particularly smaller operators and companies based outside the EU. Investigating the effectiveness of specific alternative fuels, such as hydrogen or ammonia, in the context of large-scale maritime operations will also be crucial for determining the most viable pathways for the industry decarbonization. Additionally, research into the potential for integrating carbon capture and storage technologies on ships could open new avenues for reducing maritime emissions.

By addressing these policy and research gaps, the EU ETS can evolve into an even more effective tool for decarbonizing the global shipping industry, ensuring that it aligns with the broader goals of reducing global emissions and mitigating climate change.

REFERENCES:

01. Bernacki, D. (2021). Assessing the Link between Vessel Size and Maritime Supply Chain Sustainable Performance. *Energies*, *14*(11), 2979. https://doi.org/10.3390/en14112979

02. Christodoulou, A., Dalaklis, D., Ölçer, A. I., & Ghaforian Masodzadeh, P. (2021). Inclusion of Shipping in the EU-ETS: Assessing the Direct Costs for the Maritime Sector Using the MRV Data. *Energies*, *14*(13), 3915. https://doi.org/10.3390/en14133915

03. *Directive (EU) 2018/410 of the European Parliament and of the Council of 14 March 2018 amending Directive 2003/87/EC to enhance cost-effective emission reductions and low-carbon investments, and Decision (EU) 2015/1814*. (2018).

04. *Directive (EU) 2023/959 of the European Parliament and of the Council of 10 May 2023 amending Directive 2003/87/EC establishing a system for greenhouse gas emission allowance trading within the Union and Decision (EU) 2015/1814 concerning the establishment and operation of a market stability reserve for the Union greenhouse gas emission trading system*. (n.d.).

05. Emmanouil, N., & Marina, M. (2024). Is Cold Ironing (Onshore Power Supply, or Alternative Maritime Power, or Shore-to-Ship Power) a viable solution for reducing greenhouse gas emissions in ports? EU / Greek Ports perspective. *Journal of Multidisciplinary Adaptive Climate Insights (MACI)*, *1*(1), 27–32.

06. *EP Legislative Observatory (2021), Procedure file on Monitoring, reporting and verification of carbon dioxide emissions from maritime transport: inclusion of maritime transport activities in the EU ETS and of other greenhouse gases than CO2, 2021/0211B(COD)*. (n.d.).

07. *EP Legislative Observatory (2021), Procedure file on Revision of the EU Emissions Trading System, 2021/0211A(COD)*. (2021).

08. *EU Regulation (EU) 2023/957 of the European Parliament and of the Council of 10 May 2023 amending Regulation (EU) 2015/757 in order to provide for the inclusion of maritime transport activities in the EU Emissions Trading System and for the monitoring, reporting and verification of emissions of additional greenhouse gases and emissions from additional ship types*. (n.d.).

09. *European Commission (2021), Communication on "Fit for 55": delivering the EU's 2030 climate target on the way to climate neutrality, COM/2021/550 final*. (n.d.).

10. *European Commission (2022), Supporting study for the implementation of Regulation (EU) 2015/757 on the monitoring, reporting and verification of CO2 emissions from maritime transport*. (n.d.). https://doi.org/doi:10.2834/402169ML-05-23-370-EN-N

11. *European Commission, Directorate-General for Climate Action, Budaragina, M., Paroussos, L., Kwon, H., De Vita, A., et al., Study on EU ETS for maritime transport and possible alternative options of combinations to reduce greenhouse gas emissions : final report, Publications Office of the European Union, 2021*. (n.d.). https://data.europa.eu/doi/10.2834/27271

12. *European Committee of the Regions (2021), Making ETS and CBAM work for EU cities and regions, CDR 4546/2021*. (n.d.).

13. *European Economic and Social Committee (2021), EESC opinion: Revision of the EU Emissions Trading System (ETS), including maritime transport and Market Stability Reserve, NAT/833-EESC-2021*. (n.d.).

14. *European Parliament (2022), Amendments adopted by the European Parliament on 22 June 2022 on the proposal for a directive of the European Parliament and of the Council amending Directive 2003/87/EC establishing a system for greenhouse gas emission allowance trading within the Union, Decision (EU) 2015/1814 concerning the establishment and operation of a market stability reserve for the Union greenhouse gas emission trading scheme and Regulation (EU) 2015/757 (COM(2021)0551, 2021/0211(COD)*. (n.d.).

15. Faber, J., Leestemaker, L., Roy, van den B., & Delft. (n.d.). *" Maritime shipping and EU ETS: An assessment of the possibilities to evade ETS costs" Maritime shipping and EU ETS*. https://www.portofrotterdam.com/sites/default/files/2022-03/ce-delft-maritime-shipping-eu-ets.pdf

16. Fit for 55 package Proposal for a Directive of the European Parliament and of the Council amending Directive 2003/87/EC establishing a system for greenhouse gas emission allowance trading within the Union, Decision (EU) 2015/1814 concerning the establishment and operation of a market stability reserve for the Union greenhouse gas emission trading scheme and Regulation (EU) 2015/757

- General approach, 10796/22. (2015). *EU Council* .

17. Flodén, J., Zetterberg, L., Christodoulou, A., Parsmo, R., Fridell, E., Hansson, J., Rootzén, J., & Woxenius, J. (2024). Shipping in the EU emissions trading system: implications for mitigation, costs and modal split. *Climate Policy*, *24*(7), 969–987. https://doi.org/10.1080/14693062.2024.2309167

18. Lagouvardou, S., & Psaraftis, H. N. (2022). Implications of the EU Emissions Trading System (ETS) on European container routes: A carbon leakage case study. *Maritime Transport Research*, *3*, 100059. https://doi.org/10.1016/j.martra.2022.100059

19. *Maritime Forecast to 2050 – an update on shipping's decarbonization journey*. (2024). https://www.dnv.com/maritime/webinars-and-videos/on-demand-webinars/access/maritime-forecast-to-2050-an-update-on-shippings-decarbonization-journey/

20. *On-demand webinar: The commercial implications of the EU MRV, EU ETS, FuelEU regulations*. (2024). https://www.dnv.com/maritime/webinars-and-videos/on-demand-webinars/commercial-implications-EU-MRV-EU-ETS-FuelEU-regulations/

21. Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL amending Directive 2003/87/EC establishing a system for greenhouse gas emission allowance trading within the Union, Decision (EU) 2015/1814 concerning the establishment and operation of a market stability reserve for the Union greenhouse gas emission trading scheme and Regulation (EU) 2015/757 COM/2021/551 final . (2015). *European Commission* .

22. Register, L. (2024). *EU ETS and FuelEU call for proactive risk management*. Lloyd's Register. https://www.lr.org/en/knowledge/insights-articles/eu-ets-and-fueleu-call-for-proactive-risk-management/

JOURNAL OF MULTIDISCIPLINARY ADAPTIVE CLIMATE INSIGHTS
(MACI) Volume 1, Issue 2, December 2024 - ISSN 3009-6332

http://dx.doi.org/10.21622/MACI.2024.01.2.1041

INTERSECTING VULNERABILITIES: CLIMATE JUSTICE, GENDER INEQUALITY, AND COVID-19'S IMPACT ON RURAL WOMEN IN EGYPT

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Received on, 30 September 2024 Accepted on, 06 November 2024 Published on, 04 December 2024

ABSTRACT:

This review explores the intricate interactions between climate justice, gender inequality, and COVID-19 pandemic, with a particular focus on rural women in Egypt. As a result of integrating findings from several literature, it examines how rural women face increased vulnerabilities as a result of these intersecting issues, compounding their socio-economic disadvantages and limiting their ability to participate in climate adaptation. As a result of systemic gender inequality, as well as the effects of climate change and the pandemic, rural women have been marginalized significantly, exposing critical gaps in current policies and interventions. Research and policies fall short in addressing context-specific needs and applying intersectional approaches. In order to empower rural women, the review emphasizes the importance of education, skill development, and access to resources. In addition, it makes policy recommendations for promoting gender-sensitive climate and pandemic responses, enhancing rural women's economic participation, and empowering them. Overall, the review emphasizes the importance of developing inclusive and equitable policies that address the unique challenges faced by rural women in Egypt. These policies include simplifying land registration processes, offering microfinance and credit tailored to rural women's needs, and integrating gender-sensitive training programs for climate-resilient agriculture. These measures aim to improve women's economic participation and resilience. This review seeks to promote a more nuanced understanding of climate justice, gender inequality, and pandemics to improve rural women's resilience, equality, and sustainability.

KEY-WORDS: Climate justice, Gender, COVID-19, Rural women, Vulnerability, Resilience.

1. INTRODUCTION

Climate change presents a pressing global challenge, with a broad scientific consensus recognizing human activities as primary contributors to its progression. The impacts of climate change, however, are not uniformly experienced across different social groups; instead, they are intricately linked to existing social structures, particularly gender dynamics. In many contexts, including rural Egypt, gender significantly influences vulnerability to climate impacts, disaster risk, and the effectiveness of adaptation and policy responses. COVID-19 pandemic has further illuminated and exacerbated pre-existing social vulnerabilities, inequities, and injustices, underscoring that these crises are not gender-neutral but are profoundly shaped by patriarchal and socio-cultural frameworks (Glazebrook et al., 2020; Campbell, 2020; Coll et al., 2020).

Rural women globally face numerous inequalities that severely limit their access to social, economic, and political opportunities. In Egypt, these disparities are intensified by climate change and health crises, which disproportionately undermine their livelihoods and well-being (Brown et al., 2020; Botreau & Cohen, 2020; Gressel et al., 2020). Case studies from various regions, particularly within the Nile Delta coastal areas, illustrate how climate change disrupts rural women's livelihoods—who often play crucial roles in agriculture and resource management—while the added pressures of COVID-19 pandemic further compound these challenges (Dokhan, 2021; Monshipouri & Ramaswamy, 2024).

This review aims to investigate the intersections of climate justice, gender inequality, and COVID-19 pandemic and their collective impacts on rural women in Egypt. Recognizing the significant reliance of rural women on natural resources for their livelihoods, the research highlights the importance of addressing these intersecting vulnerabilities through targeted policy recommendations. The methodology employed in this review involves a systematic literature analysis over 30 peer-reviewed articles, books, and reports. The selected studies span the past two decades and are gathered using academic databases with search terms such as "climate justice," "gender inequality," "COVID-19," "rural women in Egypt," and "intersectionality."

This analysis aims to elucidate the specific challenges faced by rural women in Egypt and identify gaps in current research. The review is grounded in three theoretical frameworks: climate justice, which advocates for addressing the unequal distribution of climate impacts; gender inequality, which examines socio-economic disparities that exacerbate women's vulnerabilities; and intersectionality, which explores how overlapping forms of discrimination interact to create unique challenges for rural women. Collectively, these concepts offer a comprehensive understanding of the compounded effects of climate change, gender inequality, and global health crises, guiding the formulation of effective policy recommendations and future research directions.

2. UNDERSTANDING CLIMATE JUSTICE, GENDER INEQUALITY, AND THEIR IMPACTS ON RURAL WOMEN IN EGYPT

The interwoven concepts of climate justice and gender inequality offer a critical lens through which to examine the experiences of rural women in developing nations like Egypt. Climate justice underscores the imperative for equitable solutions to the climate crisis, focusing on the disproportionate impact climate change has on those who contribute minimally to its causes. In Egypt, rural women exemplify this vulnerable group, facing compounded challenges due to both environmental impacts and gender-based structural inequalities. Their limited access to resources, decision-making power, and opportunities heightens these challenges, particularly as global health crises, such as COVID-19 pandemic, intensify pre-existing vulnerabilities. This section outlines the frameworks of climate justice and gender inequality, including their intersectionality, to provide a nuanced understanding of how these issues converge to affect rural women in Egypt.

2.1. Gender Inequality in Egypt

Gender inequality in Egypt is embedded within structural and socio-cultural frameworks that restrict rural women's access to economic, political, and social participation. Legal frameworks and national policies, such as the Egyptian National Action Plan for Women (2001) and the National Strategy for the Empowerment of Egyptian Women (2017), demonstrate Egypt's commitment to gender equality, aligning with international standards like the Convention on the Elimination of All Forms of Discrimination Against Women (CEDAW). However, these initiatives have not translated into consistent, effective changes, particularly in rural areas where the impact of legislation is often limited (Takieldin, 2023; ElMorally, 2024).

Legal measures aimed at gender equality, such as Egypt's Family Law of 2000, have advanced women's rights in certain areas, like family and divorce matters. Nonetheless, these measures remain inadequate in addressing economic disparities that limit rural women's access to land, income, and other assets essential for resilience in the face of climate change (El-Harazi, 2023; Siddiqui, 2023). COVID-19 pandemic highlighted these gaps, with rural women disproportionately affected due to their exclusion from social safety nets and reliance on informal labor (Farrag, 2021). This exclusion underscores the limitations of existing gender-sensitive policies in addressing the specific vulnerabilities rural women face in crisis contexts.

2.2. Climate Justice

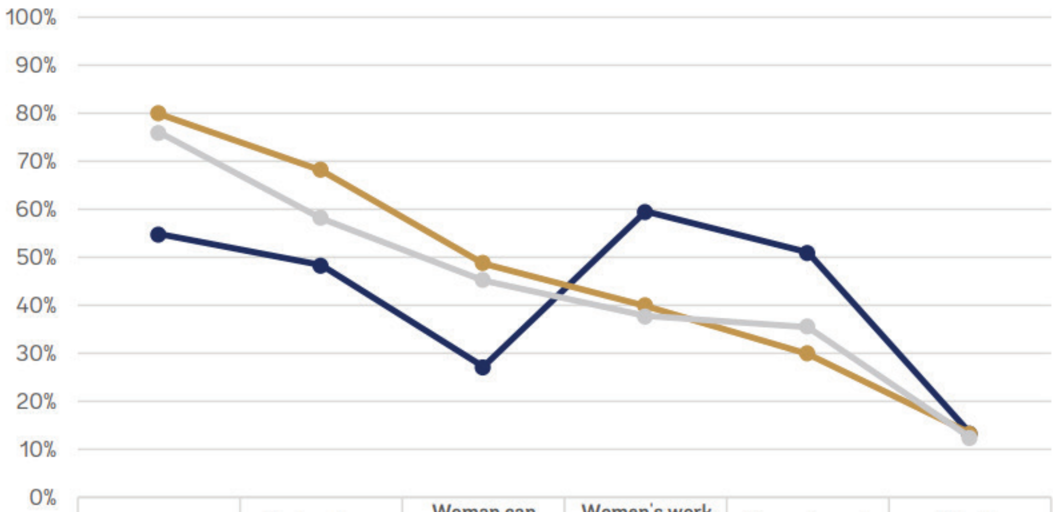
Climate justice integrates principles of human rights and environmental stewardship, advocating for the fair distribution of both the burdens and benefits associated with climate change. It is especially pertinent to marginalized communities, including rural women in developing countries, who often contribute minimally to climate change but endure its most severe impacts (Boom et al., 2016). In rural Egypt, women's livelihoods heavily depend on natural resources, making them particularly susceptible to climate-induced challenges such as droughts and floods, which threaten agricultural productivity and increase economic instability (Hafez, 2020).

Given their role in managing household resources, these women bear additional burdens during climate crises, yet remain largely excluded from climate policy and decision-making processes. This exclusion is compounded by limited access to education, a key factor that restricts their ability to influence policy. Although there is potential for rural women to contribute insights into localized climate adaptation, their low levels of formal education and restricted access to knowledge-sharing platforms make meaningful participation challenging (Eastin, 2018). Ensuring that climate justice initiatives include rural women would require structural adjustments, such as enhancing educational and economic resources to enable their informed participation (Schlosberg & Collins, 2014).

2.3. Economic Participation and Decision-Making

Economic participation for women in Egypt remains constrained by several structural barriers, particularly in rural areas where unpaid labor, such as caregiving and subsistence agricultural work, predominates. This labor is often undervalued and unrecognized in formal economic statistics, exacerbating economic inequalities faced by women (El-Baz, 2020; Altuzarra et al., 2021). Rural women's limited access to critical resources, including land, credit, and education, further hinders their economic empowerment and restricts their decision-making power within households and communities.

Traditional gender norms that prioritize male economic roles compound these challenges, creating a persistent gender wage gap and limiting opportunities for rural women (Aggestam & True, 2020). Empirical data suggest that rural Egyptian women are largely confined to low-status occupations, while men continue to dominate higher-paying roles and decision-making positions (Krafft et al., 2021; Assaad et al., 2020). This disparity reflects a trend of de-feminization in Egypt's labor force, despite improvements in women's educational attainment.



	Right to work	Husband can spend wife's money*	Woman can request/hire assistance with childcare to work	Women's work increases problems with husband/family*	Women's work exposes her to harassment*	Man is responsible for HH income*
Empirical expectations	54.70%	48%	27.10%	59.34%	50.81%	13.20%
Personal beliefs	79.8%	68.1%	48.6%	39.8%	29.90%	13.30%
Normative expectations	75.90%	58%	45.20%	37.70%	35.40%	12.40%

Fig. 1. Comparison of personal beliefs and social expectations on female labor force participation (World Bank, 2023).

Figure 1 compares personal beliefs, empirical expectations, and normative expectations concerning female labor force participation among male and female respondents in Egypt. It highlights disparities between individual beliefs and perceived societal expectations, illustrating support for Female Labor Force Participation along with the enduring societal concerns about the implications of women's employment. It aligns with the analysis of how societal expectations influence rural women's economic opportunities and decision-making power, highlighting the need for targeted interventions to reconcile personal beliefs with social expectations. This approach would help foster an environment that not only supports FLFP in principle but also mitigates the social and cultural barriers that currently limit women's economic empowerment in Egypt.

2.4. Intersectionality

Intersectionality, a concept introduced by Kimberlé Crenshaw (1989), provides a critical framework for understanding how overlapping social identities—such as gender, socioeconomic status, and geographical location—compound the vulnerabilities experienced by marginalized groups. For rural women in Egypt, these intersecting identities intensify their exposure to climate impacts and limit their adaptive capacities. Women from lower-income, marginalized communities face distinct challenges, as they are often excluded from social safety nets and last to receive aid during crises like COVID-19 (Fletcher & Reed, 2022).

Intersectionality also highlights the need for policies that address the specific needs of diverse groups of women, as a one-size-fits-all approach may overlook the unique challenges faced by the most vulnerable. By designing climate adaptation policies that account for factors such as socioeconomic status and geographical location, policymakers can better ensure that no group of rural women is disproportionately disadvantaged (Singh et al., 2022).

2.5. Linking Gender Inequality to Climate and COVID-19 Impacts

The structural gender inequalities faced by rural women in Egypt are intrinsically linked to the broader impacts of climate change and COVID-19 pandemic. Dependent on natural resources for their livelihoods, these women are disproportionately affected by climate variability, which threatens agricultural productivity and heightens economic exclusion (UN Women Watch, 2009; Hafez, 2020). The added caregiving responsibilities during

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climate and health crises further intensify these burdens, often exposing women to health risks and exacerbating their economic vulnerabilities.

During COVID-19 pandemic, rural women faced amplified challenges, including job losses in the informal sector and increased caregiving responsibilities (Singh et al., 2022). These compounded vulnerabilities reveal how climate change, gender inequality, and economic exclusion converge, with rural women bearing the brunt of these overlapping crises. Addressing these issues within a climate justice framework, particularly through targeted interventions and structural reforms, could provide rural women with the resources and decision-making power necessary to enhance their resilience in the face of environmental and socioeconomic challenges.

As established, rural women in Egypt face distinct social, economic, and health challenges due to longstanding gender inequalities and resource limitations. These inequities have been further strained by recent crises, such as COVID-19 pandemic, which exacerbated vulnerabilities already present in their lives. Analyzing these impacts, particularly in the domains of healthcare, economic stability, and caregiving roles, provides a deeper understanding of the compounded challenges rural women face and highlights the need for targeted, gender-sensitive interventions.

3. CHALLENGES FACED BY RURAL WOMEN IN EGYPT

Rural women in Egypt shoulder responsibilities across household and agricultural domains, yet they lack equal access to the resources, protections, and opportunities needed to thrive. These roles became increasingly demanding during COVID-19 pandemic, which amplified disparities in healthcare access, economic stability, and caregiving obligations. In contrast, the pandemic impact on rural men, while significant, often did not entail the same dual burdens of unpaid caregiving and limited access to critical services. This section discusses the specific ways in which rural women's experiences during the pandemic diverged from those of men, emphasizing the intersecting challenges they continue to confront.

3.1. Socio-Economic and Caregiving Challenges

Rural women in Egypt have long faced barriers due to deep-seated gender inequalities, insufficient policies, and limited access to essential services. They often manage a dual workload of domestic tasks and agricultural labor, a situation intensified during the pandemic. As schools closed and healthcare became less accessible, rural women faced an increased caregiving load while also contending with reduced agricultural output and income (Altuzarra et al., 2021; El-Baz, 2020). Unlike men, whose primary roles typically focus on wage-earning activities, rural women found themselves responsible for both household management—such as childcare, collecting water, and maintaining livestock—and diminished economic opportunities (Boca et al., 2020; Mubenga-Tshitaka et al., 2023).

The ongoing shift from traditional agriculture to light industry in rural Egypt further restricts economic opportunities for women, whose skill sets are often not aligned with available industrial jobs (Jabeen et al., 2020). While rural men are more likely to find employment in these sectors, women remain economically marginalized and continue to rely on undervalued contributions to the rural economy, including unpaid or informal work that remains unrecognized (Ariffin et al., 2020).

3.2. Healthcare Disparities

While COVID-19 pandemic underscored healthcare disparities in rural Egypt, access to adequate healthcare has long been a challenge, particularly for rural women. Gender and geographic inequalities mean that rural women often lack access to maternal and reproductive healthcare, essential services that are more readily available in urban centers. During the pandemic, accessing skilled medical care became even more difficult, compromising maternal health outcomes and further limiting access to reproductive health services (Adatara et al., 2020).

Rural women in underserved regions, particularly in southern Egypt, were especially affected, with limited access to midwifery and family planning services compared to their urban counterparts. In contrast, rural men, while also affected by healthcare access issues, did not face the same level of gender-specific health needs or barriers (Adatara et al., 2021). The pandemic compounded these disparities, as rising healthcare costs forced many women to rely on inadequate public services, further endangering their health and increasing their vulnerability (Hulsbergen & van der Kwaak, 2020).

3.3. Economic Impacts

The economic fallout of COVID-19 pandemic disproportionately impacted rural women in Egypt, particularly those employed in informal sectors with limited protections. As economic activity slowed, rural women in agriculture, hospitality, and retail—sectors heavily affected by the crisis—faced significant reductions in income and job security, in addition to increased caregiving responsibilities (Botreau & Cohen, 2020).

While rural men also experienced economic challenges, their roles generally remained within more stable, traditionally male-dominated sectors. In contrast, rural women, who are frequently responsible for household food provision, experienced heightened stress and insecurity, managing both the financial and physical needs of their families (Shibata, 2021). Additionally, the closure of schools and overwhelmed healthcare systems meant that caregiving roles expanded, with rural women balancing homeschooling, increased household tasks, and care for sick family members. This added burden increased risks for mental health issues, domestic violence, and poverty, underscoring the necessity of gender-sensitive interventions to address these compounded inequalities (Khamis et al., 2021).

Building on the previous discussion, it is evident that rural women in Egypt face a unique set of compounded challenges rooted in both gender-based inequities and systemic neglect. As these challenges intersect with the impacts of climate change and COVID-19 pandemic, they exacerbate existing vulnerabilities and reinforce economic and social marginalization. This next section provides a deeper analysis of how climate justice, gender inequality, and pandemic recovery interrelate, underscoring the importance of integrated, intersectional approaches for supporting rural women in Egypt.

4. INTERSECTIONAL ANALYSIS: CLIMATE JUSTICE, GENDER INEQUALITY, AND COVID-19

This section examines the compounded impact of climate justice, gender inequality, and COVID-19 pandemic on rural women in Egypt. By exploring how these factors intersect, it highlights the long-term consequences for women's health, economic opportunities, and socio-political inclusion in rural communities. Understanding these layered vulnerabilities is essential for crafting holistic and sustainable policy interventions.

4.1. Climate Change: A Gendered Impact

Rural women in Egypt disproportionately experience the adverse effects of climate change due to their reliance on natural resources and limited adaptive capacity. Climate-related challenges such as erratic rainfall, rising temperatures, and water scarcity have immediate repercussions for food security and household responsibilities, which are traditionally managed by women (Hafez, 2020). These pressures further restrict women's participation in economic activities and decision-making, as caregiving and household management demand more time during environmental crises.

The structural gender inequalities that limit women's access to resources, such as land ownership and financial credit, exacerbate the impact of climate change on their livelihoods. These entrenched disparities, combined with their vital roles in agriculture and family care, heighten rural women's vulnerability to climate stressors in ways that differ markedly from men's experiences (Aggestam & True, 2020).

4.2. Gender Inequality and COVID-19 Pandemic

COVID-19 pandemic has underscored and intensified gender-based economic and social disparities among rural women in Egypt. While rural women contribute extensively to agricultural work, their roles often remain informal and unrecognized, preventing them from accessing the financial and social protections needed during economic crises (Tonbol, 2024). This gendered division of labor, combined with structural inequalities in access to credit, education, and technology, limits women's productivity and economic security compared to their male counterparts.

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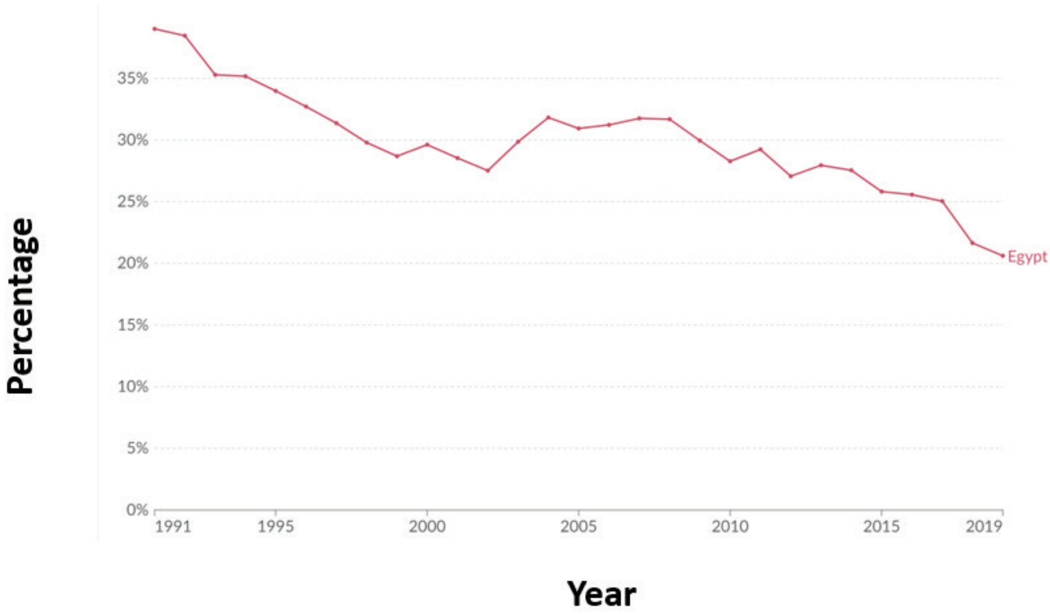

Fig. 2. Agriculture Value Added Per Worker (World Bank).

Figure 2 captioned "Agriculture Value Added Per Worker" illustrates the disparity in productivity levels within the agricultural sector. Although rural women play a critical role in agriculture, their contributions often yield lower productivity compared to men, not due to lack of skill, but because of systemic barriers. Limited access to modern farming technology, irrigation systems, and training curtails their productivity and restricts their income potential (El Baz, 2018). These constraints contrast with the resources more readily available to men, who often have formal land ownership and better access to credit and technology.

Figure 2 also underscores the need for policies that bridge these productivity gaps by addressing gendered barriers in resource access. Enhancing rural women's access to land titles, technology, and financial services can significantly improve agricultural productivity and support gender equality. Such policy reforms not only empower rural women economically but also contribute to national agricultural output and poverty alleviation goals (Fletcher & Reed, 2022).

4.3. Compounded Vulnerabilities and Long-term Impacts

The intersection of climate change, gender inequality, and COVID-19 pandemic has created a unique set of compounded vulnerabilities for rural women in Egypt (Ibrahim, 2021). These crises reinforce each other, forming a cycle of disadvantage that further constrains rural women's economic independence and social standing. For instance, the caregiving burdens exacerbated by the pandemic reduced women's capacity to cope with climate-related losses in agriculture, such as decreased yields and water shortages (Byers et al., 2020).

Moreover, rural women's limited access to healthcare, social protection, and education compounds these challenges, leaving them with fewer resources to manage or recover from crises. The long-term impacts include heightened poverty, food insecurity, and adverse health outcomes for women and their families, further entrenching gender inequality within households and communities (Ibrahim, 2021). The pandemic also amplified existing limitations on women's decision-making power, reducing their capacity to seek support or advocate for their rights, deepening their socio-economic exclusion.

Addressing these intersecting challenges requires a holistic approach that integrates gender equality, climate adaptation, and pandemic recovery. Policies focusing solely on one dimension, such as climate resilience or economic empowerment, may yield only partial solutions. A more comprehensive, intersectional strategy is crucial to fostering sustainable development, improving livelihoods, and promoting resilience for rural women in Egypt's agricultural sector.

5. ECONOMIC PARTICIPATION AND DECISION-MAKING. FOR RURAL WOMEN

The structural barriers limiting rural women's participation in Egypt's labor market are deeply entrenched in both legal frameworks and socio-cultural norms that restrict equal access to economic opportunities. Although Egypt has ratified international agreements such as the Convention on the Elimination of All Forms of Discrimination Against Women (CEDAW), the enforcement of these laws is often inconsistent, particularly in rural areas.

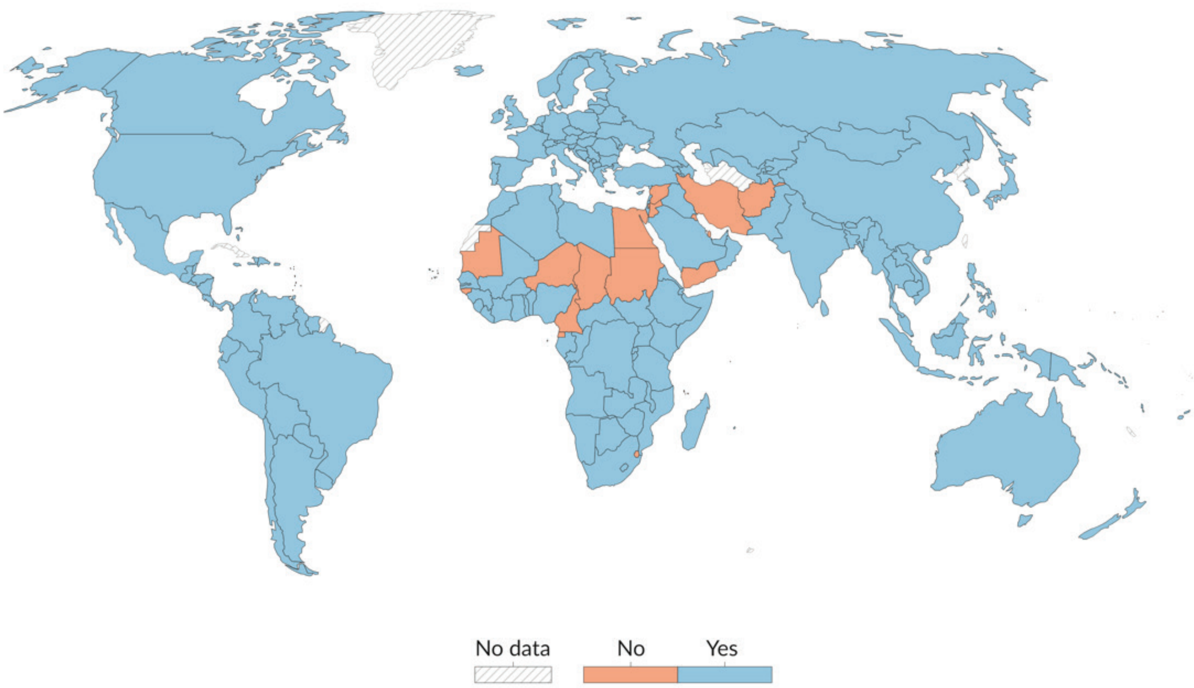

Fig. 3. Law Mandate for Equal Opportunities (World Bank, 2024).

Figure 3 titled "Women Can Take the Same Jobs as Men (Law Mandate for Equal Opportunities)" from *Our World in Data* illustrates the discrepancy between legal mandates for gender equality and their practical implementation within the workforce. This visual representation reveals persistent inequalities in employment sectors, emphasizing the limitations on women's access to various occupations, particularly in rural Egypt (*Our World in Data*, 2024).

As a result, many rural women remain confined to unpaid agricultural labor, which reflects their undervalued contribution to the economy. El-Baz (2020) notes that this economic marginalization is perpetuated by inadequate legal protections and cultural norms that reinforce traditional gender roles. Such barriers impede women's access to vital resources and limit their participation in decision-making processes related to climate adaptation efforts. Addressing these disparities is crucial for enhancing rural women's economic agency and promoting equitable development in Egypt's agricultural sector.

5.1. Education and Skill Development

Education is one of the most powerful tools for rural women's empowerment, serving as a foundation for greater socio-economic participation and resilience to climate-related challenges (Malwade, 2020). Investing in rural women's education helps break the cycle of poverty and enhances their ability to participate in decision-making processes related to climate adaptation and community development. This not only improves their livelihoods but also positions them as key contributors to local and national development (Shaikh & Ramchandra, 2020).

Research has shown that women with higher levels of education are better equipped to cope with environmental crises, manage agricultural resources sustainably, and advocate for their

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rights (Ibrahim, 2021). In the Egyptian context, the educational divide between urban and rural women remains stark, with rural women facing additional barriers such as early marriage, gender-based discrimination, and limited access to schools. Empowering rural women through education must therefore include tailored programs that consider their specific circumstances, including adult literacy programs, vocational training, and climate-resilient agricultural skills (Farrag, 2021).

Beyond formal education, skill development initiatives are essential for building rural women's economic independence and enabling them to participate in climate adaptation efforts. These initiatives should focus on equipping women with skills in sustainable agriculture, renewable energy technologies, and small-scale entrepreneurship, sectors that are critical for climate resilience and economic recovery in rural areas (Mapanje et al., 2023). By providing women with access to knowledge and technologies that promote environmentally sustainable practices, these programs can empower them to take active roles in mitigating climate change impact on their communities.

5.2. Access to Resources and Technology

One of the primary barriers preventing rural women from becoming agents of change is their limited access to essential resources such as land, credit, and technology. Addressing this requires a concerted effort to reform land ownership laws and credit systems that disproportionately favor men. Ensuring rural women have equal access to these resources is fundamental to enhancing their capacity to contribute to both household and community climate adaptation strategies (Hafez, 2020).

For example, rural women's exclusion from land ownership prevents them from making critical decisions related to agricultural productivity and resource management. In Egypt, where agriculture remains a key source of livelihood for rural families, this exclusion limits women's ability to adopt climate-resilient farming practices or diversify their income sources (Daoud, 2021). Providing rural women with equal access to land not only boosts their economic standing but also fosters a sense of agency in environmental stewardship.

Technology also plays a pivotal role in empowering rural women, particularly in the context of climate adaptation. Access to climate-smart technologies—such as drought-resistant crops, solar-powered irrigation systems, and mobile weather forecasting tools—can significantly enhance rural women's ability to manage climate risks. Coupling these technological advancements with targeted training and support ensures that women can fully utilize them to improve agricultural productivity and safeguard their livelihoods in the face of climate volatility (Singh et al., 2022).

5.3. Enhancing Decision-Making Power

Rural women's empowerment cannot be fully realized without addressing their exclusion from decision-making processes at both household and community levels. Traditional gender roles and patriarchal structures often marginalize women's voices, preventing them from contributing to critical discussions on climate adaptation, resource allocation, and development planning (Aggestam & True, 2020). However, research indicates that when women are involved in decision-making, communities are more likely to adopt sustainable practices and prioritize social well-being (Ibrahim, 2021).

To enhance rural women's decision-making power, empowerment strategies must include legal and institutional reforms that ensure women have an equal voice in governance structures. Community-based organizations, women's cooperatives, and rural councils should be supported to include women in leadership roles, giving them a platform to influence local climate adaptation strategies and resource management decisions. Additionally, national policies should prioritize women's participation in climate-related decision-making at higher levels, ensuring that their perspectives are integrated into broader environmental and socio-economic policies (Altuzarra et al., 2021).

5.4. Building Resilience Through Social Protection

Social protection programs tailored to the specific needs of rural women are critical for enhancing their resilience to climate shocks, economic crises, and health emergencies like COVID-19. These programs should offer financial assistance, healthcare access, and employment support, with focus on women in the most vulnerable communities. Cash transfer programs, for example, can help alleviate the immediate economic impacts of climate-related disasters, while healthcare subsidies ensure that rural women have access to essential medical services, particularly in times of crisis (Takieldin, 2023).

Moreover, social protection mechanisms that integrate climate risk management can provide a safety net for rural women, reducing their vulnerability to environmental and economic shocks. For example, crop insurance schemes, disaster relief funds, and climate-adaptive infrastructure investments can mitigate the risks associated with climate change, empowering women to rebuild their lives and continue contributing to their communities even in the face of adversity (UNDP, 2016).

6. RECOMMENDATIONS AND CONCLUSION

6.1. Recommendations

Addressing the complex challenges faced by rural women in Egypt necessitates targeted, scientifically informed policy interventions. To integrate gender-sensitive approaches into climate adaptation strategies effectively, policies should ensure the inclusion of rural women in community-level adaptation programs and provide equitable access to climate-smart technologies. Expanding their access to land, financial services, and technology, while promoting the adoption of climate-resilient agricultural practices, is critical for enhancing their adaptive capacity.

Educational initiatives must prioritize literacy, vocational training, and STEM programs for rural girls to equip them for roles in climate innovation and sustainable development. Concurrently, strengthening social protection systems with gender-sensitive safety nets will mitigate the adverse effects of climate change and health crises.

Promoting women's leadership within climate governance structures and ensuring their representation in local decision-making processes are vital for effective policy outcomes. Furthermore, implementing robust monitoring and evaluation frameworks, including gender-specific indicators, is essential for assessing the impact of interventions and ensuring they effectively support rural women's empowerment and resilience.

6.2. Conclusion

This review highlights the urgent need for intersectional policies that tackle the challenges of climate justice, gender inequality, and health crises, particularly in rural Egypt. The compounded effects of these issues on rural women demand targeted interventions that enhance their access to resources, education, and leadership opportunities. Implementing these gender-sensitive strategies is crucial for building the resilience of rural women, positioning them as key agents in sustainable development and climate adaptation efforts in Egypt.

REFERENCES:

01. Achcar, G. (2020). On the 'Arab Inequality Puzzle': The Case of Egypt. *Development and Change*, *51*(3), 746–770. https://doi.org/10.1111/dech.12585

02. Adatara, P., Amooba, P. A., Afaya, A., Salia, S. M., Avane, M. A., Kuug, A., Maalman, R. S.-E., Atakro, C. A., Attachie, I. T., & Atachie, C. (2021). Challenges experienced by midwives working in rural communities in the Upper East Region of Ghana: a qualitative study. *BMC Pregnancy and Childbirth*, *21*(1), 287. https://doi.org/10.1186/s12884-021-03762-0

03. Adatara, P., Strumpher, J., & Ricks, E. (2020). Exploring the reasons why women prefer to give birth at home in rural northern Ghana: a qualitative study. *BMC Pregnancy and Childbirth*, *20*(1), 500. https://doi.org/10.1186/s12884-020-03198-y

04. Adenutsi, D. E. (2023). Entrepreneurship, Job Creation, Income Empowerment and Poverty Reduction in Low-Income Economies. *Theoretical Economics Letters*, *13*(06). https://doi.org/10.4236/tel.2023.136089

05. Agarwal, B. (1992). The Gender and Environment Debate: Lessons from India. *Feminist Studies*, *18*(1). https://doi.org/10.2307/3178217

06. Aggestam, K., & True, J. (2020). Gendering foreign policy: A comparative framework for analysis. *Foreign Policy Analysis*, *16*(2). https://doi.org/10.1093/fpa/orz026

07. Altuzarra, A., Gálvez-Gálvez, C., & González-Flores, A. (2021a). Is gender inequality a barrier to economic growth? A panel data analysis of developing countries. *Sustainability (Switzerland)*, *13*(1). https://doi.org/10.3390/su13010367

08. Altuzarra, A., Gálvez-Gálvez, C., & González-Flores, A. (2021b). Is Gender Inequality a Barrier to Economic Growth? A Panel Data Analysis of Developing Countries. *Sustainability*, *13*(1), 367. https://doi.org/10.3390/su13010367

09. Ampaire, E. L., Acosta, M., Huyer, S., Kigonya, R., Muchunguzi, P., Muna, R., & Jassogne, L. (2020). Gender in climate change, agriculture, and natural resource policies: insights from East Africa. *Climatic Change*, *158*(1). https://doi.org/10.1007/s10584-019-02447-0

10. Arezki, R., Lederman, D., El-Mallakh, N., Islam, A. M., Harb, A. A., Fan, R. Y., Nguyen, H. M., & Zouaidi, M. (2020). *Where Missing Data Hurts the Most: Low Growth, Macroeconomic Vulnerability, and Labor Market Outcomes in Middle East and North Africa*. World Bank Publications.

11. Ariffin, A. S., Baqutayan, S. M. S., & Mahdzir, A. M. (n.d.). Enhancing women entrepreneurship development framework: Policy & institution gap and challenges in the case of Malaysia. *Journal of Science, Technology and Innovation Policy*, *6*(2), 22–33.

12. Assaad, R., Hendy, R., Lassassi, M., & Yassin, S. (2020). Explaining the MENA paradox: Rising educational attainment yet stagnant female labor force participation. *Demographic Research*, *43*. https://doi.org/10.4054/DEMRES.2020.43.28

13. Atukunda, E. C., Mugyenyi, G. R., Obua, C., Musiimenta, A., Najjuma, J. N., Agaba, E., Ware, N. C., & Matthews, L. T. (2020). When women deliver at home without a skilled birth attendant: A qualitative study on the role of health care systems in the increasing home births among rural women in southwestern uganda. *International Journal of Women's Health*, *12*. https://doi.org/10.2147/IJWH.S248240

14. Auer, D. (2022). Firing discrimination: Selective labor market responses of firms during the COVID-19 economic crisis. *PLoS ONE*, *17*(1 January). https://doi.org/10.1371/journal.pone.0262337

15. Birkmann, J., Jamshed, A., McMillan, J. M., Feldmeyer, D., Totin, E., Solecki, W., Ibrahim, Z. Z., Roberts, D., Kerr, R. B., Poertner, H. O., Pelling, M., Djalante, R., Garschagen, M., Leal Filho, W., Guha-Sapir, D., & Alegría, A. (2022). Understanding human vulnerability to climate change: A global perspective on index validation for adaptation planning. *Science of the Total Environment*, *803*. https://doi.org/10.1016/j.scitotenv.2021.150065

16. Boom, K., Richards, J.-A., & Leonard, S. (2016). Climate Justice: The International Momentum Towards Climate Litigation. *Climate Change and Social Justice*, *2*(4).

17. Botreau, H., & Cohen, M. J. (2020a). *Gender inequality and food insecurity: A dozen years after the food price crisis, rural women still bear the brunt of poverty and hunger* (pp. 53–117). https://doi.org/10.1016/bs.af2s.2020.09.001

18. Botreau, H., & Cohen, M. J. (2020b). *Gender inequality and food insecurity: A dozen years after the food price crisis, rural women still bear the brunt of poverty and hunger* (pp. 53–117). https://doi.org/10.1016/bs.af2s.2020.09.001

19. Brown, K., Ellis, K., & Smith, K. (2020). *Vulnerability as lived experience: Marginalised women and girls in the UK*. Routledge.

20. Bullard, R. D. (1990). *Dumping in Dixie: Race, Class, and Environmental Quality*. Boulder, CO: Westview Press.

21. Buyukkececi, Z., & Engelhardt, H. (2021). On the relationship between fertility, development and gender equality: A comparison of western and mena countries. *Comparative Population Studies*, *46*. https://doi.org/10.12765/CPoS-2021-09

22. Byers, E. A., Coxon, G., Freer, J., & Hall, J. W. (2020). Drought and climate change impacts on cooling water shortages and electricity prices in Great Britain. *Nature Communications*, *11*(1). https://doi.org/10.1038/s41467-020-16012-2

23. Campbell, C. (2020). Social capital, social movements and global public health: Fighting for health-enabling contexts in marginalised settings. *Social Science and Medicine*, *257*. https://doi.org/10.1016/j.socscimed.2019.02.004

24. Chiwona-Karltun, L., Amuakwa-Mensah, F., Wamala-Larsson, C., Amuakwa-Mensah, S., Abu Hatab, A., Made, N., Taremwa, N. K., Melyoki, L., Rutashobya, L. K., Madonsela, T., Lourens, M., Stone, W., & Bizoza, A. R. (2021). COVID-19: From health crises to food security anxiety and policy implications. *Ambio*, *50*(4), 794–811. https://doi.org/10.1007/s13280-020-01481-y

25. Coll, C. V. N., Ewerling, F., García-Moreno, C., Hellwig, F., & Barros, A. J. D. (2020). Intimate partner violence in 46 low-income and middle-income countries: An appraisal of the most vulnerable groups of women using national health surveys. In *BMJ Global Health* (Vol. 5, Issue 1). https://doi.org/10.1136/bmjgh-2019-002208

26. Crenshaw, K. (1989). Demarginalizing the Intersection of Race and Sex: A Black Feminist Critique of Anti-Discrimination Doctrine, Feminist Theory and Antiracist Politics. *University of Chicago Legal Forum*, 139–167.

27. Dang, H. A. H., & Viet Nguyen, C. (2021). Gender inequality during the COVID-19 pandemic: Income, expenditure, savings, and job loss. *World Development*, *140*. https://doi.org/10.1016/j.worlddev.2020.105296

28. Daoud, M. (2021). Is vulnerability to climate change gendered? And how? Insights from Egypt. *Regional Environmental Change*, *21*(2). https://doi.org/10.1007/s10113-021-01785-z

29. Del Boca, D., Oggero, N., Profeta, P., & Rossi, M. (2020). Women's and men's work, housework and childcare, before and during COVID-19. *Review of Economics of the Household*, *18*(4). https://doi.org/10.1007/s11150-020-09502-1

30. Dokhan, N. (2021). The Impact of Global Crises on Women: The Case of Covid-19 in Egypt. *Theses and Dissertations*.

31. Eastin, J. (2018). Climate change and gender equality in developing states. *World Development*, *107*, 289–305. https://doi.org/10.1016/j.worlddev.2018.02.021

32. El Bari, H., Habchi, S., Morchid, M., & Cherqaoui, M. (2024). *Climate Change Vulnerability and Sustainable Tools for Mitigation and Adaptation Achievement in MENA Region* (pp. 1–18). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-91260-4_33-1

33. El Khorazaty, N. (2021). Egyptian Women's Agriculture Contribution; Assessment of the Gender Gap for Sustainable Development. *Aucegypt.Edu*.

34. El-Baz, S. (2020a). The Impact of Social and Economic Factors on Women's Group Formation in Egypt. In *Organizing Women* (pp. 147–171). Routledge. https://doi.org/10.4324/9781003136026-7

35. El-Baz, S. (2020b). The Impact of Social and Economic Factors on Women's Group Formation in Egypt. In *Organizing Women* (pp. 147–171). Routledge. https://doi.org/10.4324/9781003136026-7

36. El-Fiky, S. (n.d.). *Gendered Entrepreneurship Contextualization in Egypt: An Empirical Study on Policies for Women Entrepreneurship Empowerment* .

37. El-Harazi, M. (2023). Navigating a Human Rights Roadblock: Making the Case for the Women's Equality Act. *U. Pa. J. Int'l L.*.

38. ElMorally, R. (2024). *Recovering Women's Voices: Islam, Citizenship, and Patriarchy in Egypt*. Emerald Publishing Limited. https://doi.org/10.1108/9781836082484

39. El-Saharty, S., Nassar, H., Shawky, S., Elshalakani, A., Hamza, M., Zhang, Y., & Zeltoun, N. (2022). *Achieving the Demographic Dividend in the Arab Republic of Egypt: Choice, Not Destiny* (S. El-Saharty, H. Nassar, S. Shawky, A. Elshalakani, M. Hamza, Y. Zhang, & N. Zeltoun, Eds.). The World Bank. https://doi.org/10.1596/978-1-4648-1811-0

40. Enarson, E., & Fordham, M. (2001). From women's needs to women's rights in disasters. *Environmental Hazards*, *3*(3), 133–136. https://doi.org/10.3763/ehaz.2001.0314

41. Farrag, S. A. S. (2021). Policies of Women Empowerment in Decision Making Positions: The Case of Egypt 2014- 2020. *Journal of Law, Policy and Globalization*. https://doi.org/10.7176/JLPG/112-12

42. Fletcher, A. J., & Reed, M. G. (2022). Different Experiences, Diverse Knowledges: Gender, Intersectionality, and Climate Change in Rural and Resource Contexts. In *Gender and the Social Dimensions of Climate Change: Rural and Resource Contexts of the Global North*. https://doi.org/10.4324/9781003089209-1

43. Gill, D. A., Blythe, J., Bennett, N., Evans, L., Brown, K., Turner, R. A., Baggio, J. A., Baker, D., Ban, N. C., Brun, V., Claudet, J., Darling, E., Di Franco, A., Epstein, G., Estradivari, Gray, N. J., Gurney, G. G., Horan, R. P., Jupiter, S. D., … Muthiga, N. A. (2023). Triple exposure: Reducing negative impacts of climate change, blue growth, and conservation on coastal communities. In *One Earth* (Vol. 6, Issue 2). https://doi.org/10.1016/j.oneear.2023.01.010

44. Glazebrook, T., Noll, S., & Opoku, E. (2020). Gender matters: Climate change, gender bias, and women's farming in the global south and north. *Agriculture (Switzerland)*, *10*(7). https://doi.org/10.3390/agriculture10070267

45. Gressel, C. M., Rashed, T., Maciuika, L. A., Sheshadri, S., Coley, C., Kongeseri, S., & Bhavani, R. R. (2020). Vulnerability mapping: A conceptual framework towards a context-based approach to women's empowerment. *World Development Perspectives*, *20*. https://doi.org/10.1016/j.wdp.2020.100245

46. Hafez, M. R. (2020). Impacts of Climate Change on Agriculture, Livelihoods, and Women in Nile Delta, Egypt. In *Handbook of Climate Change Resilience* (pp. 765–784). Springer International Publishing.

47. Hassan, M. (2024). Islamic Feminism and Gender Equality in Modern Egypt. *Journal of Philosophy, Culture and Religion*, *7*(2), 13–23. https://doi.org/10.47604/jpcr.2605

48. Hulsbergen, M., & van der Kwaak, A. (2020). The influence of quality and respectful care on the uptake of skilled birth attendance in Tanzania. *BMC Pregnancy and Childbirth*, *20*(1), 681. https://doi.org/10.1186/s12884-020-03278-z

49. Ibrahim, S. (2021). The dynamics of the Egyptian social contract: How the political changes affected the poor. *World Development*, *138*. https://doi.org/10.1016/j.worlddev.2020.105254

50. ICJN. (2002). Bali Principles of Climate Justice. *World*, *August*.

51. Jabeen, S., Haq, S., Jameel, A., Hussain, A., Asif, M., Hwang, J., & Jabeen, A. (2020a). Impacts of rural women's traditional economic activities on household economy: Changing economic contributions through empowered women in rural Pakistan. *Sustainability (Switzerland)*, *12*(7). https://doi.org/10.3390/su12072731

52. Jabeen, S., Haq, S., Jameel, A., Hussain, A., Asif, M., Hwang, J., & Jabeen, A. (2020b). Impacts of Rural Women's Traditional Economic Activities on Household Economy: Changing Economic Contributions through Empowered Women in Rural Pakistan. *Sustainability*, *12*(7), 2731. https://doi.org/10.3390/su12072731

53. Jackson, M. O. (2021). Inequality's Economic and Social Roots: The Role of Social Networks and Homophily. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3795626

54. Khamis, M., Prinz, D., Newhouse, D., Palacios-Lopez, A., Pape, U., & Weber, M. (2021). The Early Labor Market Impacts of COVID-19 in Developing Countries: Evidence from High-Frequency Phone Surveys. *Jobs Working Paper*, *58*.

55. Kleven, H., Landais, C., Posch, J., Steinhauer, A., & Zweimüller, J. (2021). Do Family Policies Reduce Gender Inequality? Evidence from 60 Years of Policy Experimentation. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3731251

56. Krafft, C., Assaad, R., & Rahman, K. W. (2021). Introducing the Egypt Labor Market Panel Survey 2018. In *IZA Journal of Development and Migration* (Vol. 12, Issue 1). https://doi.org/10.2478/izajodm-2021-0012

57. Lee, S., Schmidt-Klau, D., & Verick, S. (2020). The Labour Market Impacts of the COVID-19: A Global Perspective. *Indian Journal of Labour Economics*, *63*. https://doi.org/10.1007/s41027-020-00249-y

58. Mahfouz, E. M., Mohamed, E. S., Alkilany, S. F., & Rahman, A. A. (2021). Food Insecurity and Intimate Partner Violence among Rural Women, Minia, Egypt. *The Egyptian Journal of Community Medicine*, *39*(3), 82–92. https://doi.org/10.21608/ejcm.2021.187679

59. Malwade, V. A. (2020). Rural Women's Education in India. *Journal of Emerging Technologies and Innovative Research.*

60. Mapanje, O., Karuaihe, S., Machethe, C., & Amis, M. (2023). Financing Sustainable Agriculture in Sub-Saharan Africa: A Review of the Role of Financial Technologies. In *Sustainability (Switzerland)* (Vol. 15, Issue 5). https://doi.org/10.3390/su15054587

61. Monshipouri, M., & Ramaswamy, K. (2024). The COVID-19 pandemic, climate change, and internally displaced persons: constraints and opportunities. In *Public Policy in the Arab World* (pp. 45–66). Edward Elgar Publishing. https://doi.org/10.4337/9781035312696.00012

62. Mubenga-Tshitaka, J. L., Dikgang, J., Muteba Mwamba, J. W., & Gelo, D. (2023). Climate variability impacts on agricultural output in East Africa. *Cogent Economics and Finance*, *11*(1). https://doi.org/10.1080/23322039.2023.2181281

63. Neumayer, E., & Plümper, T. (2007). The gendered nature of natural disasters: The impact of catastrophic events on the gender gap in life Expectancy, 1981-2002. *Annals of the Association of American Geographers*, *97*(3). https://doi.org/10.1111/j.1467-8306.2007.00563.x

64. Schlosberg, D., & Collins, L. B. (2014). From environmental to climate justice: Climate change and the discourse of environmental justice. In *Wiley Interdisciplinary Reviews: Climate Change* (Vol. 5, Issue 3). https://doi.org/10.1002/wcc.275

65. Shaikh, R. B., & Ramchandra, P. (2020). Obstacles in rural women's education from Gosavi community. *Journal of Emerging Technologies and Innovative Research.*

66. Shibata, I. (2021). The distributional impact of recessions: The global financial crisis and the COVID-19 pandemic recession. *Journal of Economics and Business*, *115*. https://doi.org/10.1016/j.jeconbus.2020.105971

67. Siddiqui, S. (2023). Status of Muslim women in modern family and personal law. In *The Oxford Handbook of Islam and Women*. https://doi.org/10.1093/oxfordhb/9780190638771.013.26

68. Singh, P., Tabe, T., & Martin, T. (2022). The role of women in community resilience to climate change: A case study of an Indigenous Fijian community. *Women's Studies International Forum*, *90*. https://doi.org/10.1016/j.wsif.2021.102550

69. Takieldin, R. (2023). Political Empowerment of Egyptian Women (2005-2022). *American Journal of Youth and Women Empowerment*, *2*(2). https://doi.org/10.54536/ajywe.v2i2.2183

70. Tonbol, K. (2024). Climate change: interdisciplinary solutions for a global challenge. *Multidisciplinary Adaptive Climate Insights*, *1*(1), 1. https://doi.org/10.21622/MACI.2024.01.1.907

71. Tóth, G., Wachs, J., Di Clemente, R., Jakobi, Á., Ságvári, B., Kertész, J., & Lengyel, B. (2021). Inequality is rising where social network segregation interacts with urban topology. *Nature Communications*, *12*(1). https://doi.org/10.1038/s41467-021-21465-0

72. UN, W. (2020). *Issue brief: COVID-19 and ending violence against women and girls | Digital library: Publications*. https://www.unwomen.org/en/digital-library/publications/2020/04/issue-brief-covid-19-and-ending-violence-against-women-and-girls

http://dx.doi.org/10.21622/MACI.2024.01.2.1041

73. *UN Women Watch Women, Gender Equality, and Climate Change*. (2009).

74. *UNDP Overview of linkages between gender and climate change. New York, USA: United Nations Development Programme.* (2016).

75. *World Bank. Social norms and female labor force participation in Egypt. International Bank for Reconstruction and Development / The World Bank.* . (2023).

76. *World Bank. (2024). Women, Business and the Law. Retrieved from* . (2020). https://ourworldindata.org/grapher/women-can-take-the-same-jobs-as-men?tab=chart&country=~EGY

77. *World Bank. Our World in Data based on International Labor Organization (via the WorldBank) and historical sources. Retrieved from*. (2024). https://ourworldindata.org/grapher/share-of-the-labor-force-employed-in-agriculture?tab=chart&country=~EGY

http://dx.doi.org/10.21622/MACI.2024.01.2.1070

JOURNAL OF MULTIDISCIPLINARY ADAPTIVE CLIMATE INSIGHTS
(MACI) Volume 1, Issue 2, December 2024 - ISSN 3009-6332

REGENERATIVE FACADES FOR HOTEL RETROFITTING IN HOT-DRY CLIMATE

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Received on, 26 October 2024 Accepted on, 19 December 2024 Published on, 25 December 2024

ABSTRACT:

Nigeria, despite its vast oil and gas resources, faces significant challenges in electricity generation, resulting in an average daily power supply of only nine hours. This inadequate power supply poses a major obstacle to economic diversification in non-oil-producing states like Kebbi. The hospitality sector in Birnin Kebbi struggles with high operational costs due to reliance on diesel generators, contributing to environmental degradation and hindering investments. This study evaluates the regenerative energy potential of retrofitting hotel facades in a Hot-Dry climate. Energy audits in target hotel and data collection on electricity bills, diesel consumption, and building characteristics reveal significant energy-saving opportunities. The data collected are used to simulate regenerative energy facade strategies for retrofitting hotels, including shading, glazing, thermal mass, and insulation. Base-case modelling shows that wall improvements and insulation materials like rock wool or glass wool can reduce energy consumption by over 30%. Using lighter-coloured wall surfaces with higher Solar Reflectance Index (SRI) can further enhance energy savings. Additionally, implementing windows with improved insulation properties and shading devices can reduce energy consumption. These findings underscore the importance of incorporating regenerative energy facade strategies in building designs and policies in Nigeria to promote sustainable development. Further research should focus on long-term performance evaluations and cost-benefit analyses of these strategies.

KEY-WORDS: Climate change, Energy efficiency, Energy use, Tourism, Hospitality facilities.

http://dx.doi.org/10.21622/MACI.2024.01.2.1070

1. INTRODUCTION

About 95% of Nigeria's income is generated from exporting crude oil [1]. However, despite Nigeria's abundant oil and gas resources, electricity generation hovers around 7000MW for over 200 million population (National Bureau of Statistics) [2] with an average power supply of only nine hours daily. This is grossly inadequate and especially challenging for the non-oil-producing states to diversify their economies.

Birnin Kebbi is the capital city of Kebbi state. Like most state capitals in Nigeria, enjoys the privilege of being the seat of governmental administration. The state borders Sokoto, Zamfara and Niger states (Figure 1). On the international level, it borders Niger Republic and Benin Republic to its North and West, respectively. This makes it a centre of trade at both national and international levels.

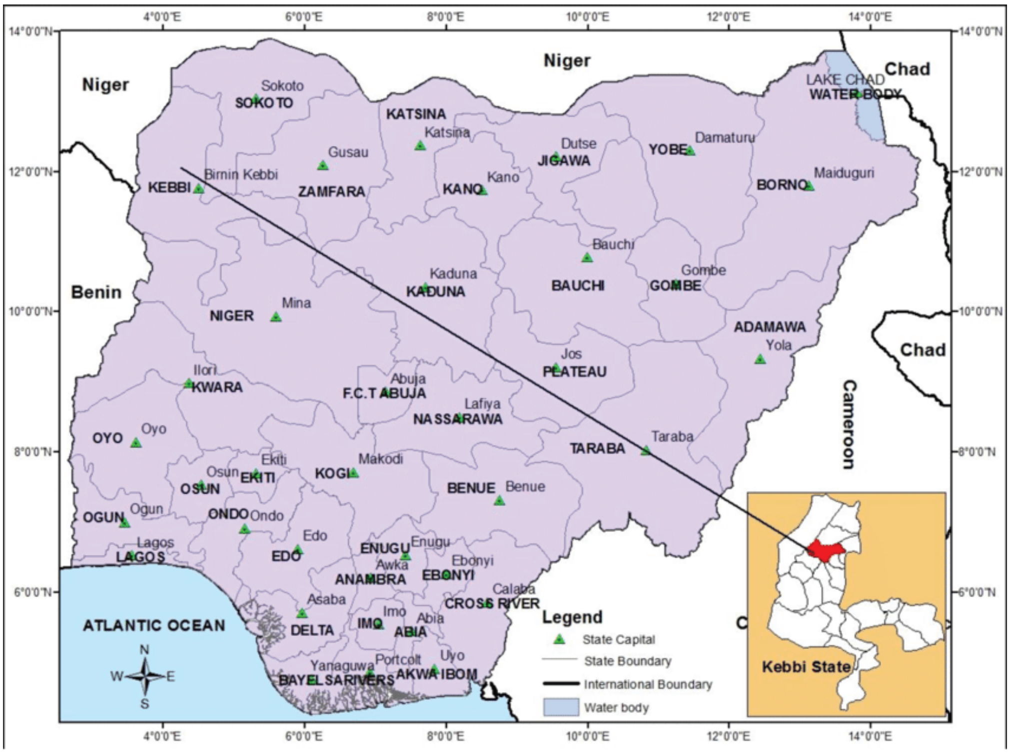

Fig. 1. Geographical location of Kebbi State. [3]

Kebbi state is internationally recognised as the location for three renowned festivals; Argungu International Fishing Festival, Uhola Agric Festival Zuru, and Yauri Rigata Agricultural Show [4]. As a result of these, Birnin Kebbi witnesses a constant influx of visitors throughout the year adding to the need to invest in providing accommodation facilities within and around the metropolis.

Tourism has been identified as a potential source of Internally Generated Revenue (IGR), especially for the non-oil-producing states in Nigeria like Kebbi [5] [6]. However, hospitality facilities require a steady power supply to operate [7] [8]. This further challenges the diversification of the hospitality sector and hinders investments across the region due to the enormous cost involved in operating or maintaining facilities.

From a global perspective, Heating Ventilation and Air Conditioning (HVAC) and Transportation are the major consumers of energy, with demand estimates of over 80% [9]. This is a cause for concern and likely a potential focus for stakeholders in the building industry in catalysing new ideas that would substantially reduce energy demand in buildings, particularly HVAC loads, through design, materials, and construction techniques in all phases of the building life cycle.

According to the European Commission [10], non-residential buildings are 40% more energy intensive, and they consume up to 250kWh/m² of energy as against 180kWh/m² for residential buildings [10] [11]. The energy use in hotels plays a crucial role in both environmental degradation and poverty. Many hotels in this region heavily rely on conventional energy sources such as diesel and petrol generators, due to inconsistent power supply from the national grid. This heavy use of fossil fuels contributes to environmental degradation not only through the exploration and refining of fossil fuels which exacerbates the effects of climate change, but also through air and noise pollution. Additionally, the high operational costs associated with diesel generators often result in increased hotel prices, limiting access to accommodation for those in lower-income brackets and perpetuating poverty. The environmental and economic impacts of unsustainable energy practices in hotels are interconnected, with vulnerable communities experiencing the harshest consequences [12].

Transitioning to cleaner and more sustainable energy sources in the hotel industry is not only essential for mitigating environmental degradation but can also contribute to poverty alleviation by reducing operational costs and making accommodations more affordable.

There is a significant research gap in the analysis of retrofitting the building façade to achieve higher thermal efficiency [13] and this research aims to evaluate the regenerative energy potential of retrofitting the facades of hotels in Hot-Dry Climates, with a focus on Birnin-Kebbi, Nigeria.

Literature shows that shifting to regenerative energy is capital intensive and requires a longer payback period [11], as such there is a need to devise means of retrofitting old stock of buildings. Retrofitting hotel facades with regenerative technologies presents a promising approach to enhance energy efficiency and reduce environmental impact.

2. LITERATURE REVIEW

Hotel buildings consume large amounts of energy to provide the best service possible for guests [11] [14] [15]. The energy used in running hotels is largely from fossil fuels, which not only aggravates Climate Change but also reduces profits due to high energy costs [16].

From the available data on energy consumption of hotels in North America, Europe, and Asia between the years 1990 to 2000 [17] an average of 401kWh/m² of energy is consumed in the United States per year, out of which about 41% is electricity. In Canada, an average annual energy consumption between 612 kWh/m² to 689kWh/m² is consumed over the same period, out of which electricity accounts for about 29%. In Europe, hotel energy consumption accounts for 1% of the total (39TWh), 50% of which is electricity [18]. In Singapore, a study conducted in 1993 on energy consumption of hotel buildings indicates that an annual average of 468 kWh/m², is consumed annually, and a later study in the same location of 29 hotels conducted between 2005 and 2006 reported an annual electricity consumption of 361 kWh/m² per annum. In Hong Kong, two-year research conducted between 1995 and 1997 indicates that consumption of energy in hotels in that location ranges between 406 kWh/m² to 564 kWh/m² per annum.

Studies conducted in Nigeria show similar results. In 2015, six hotels were audited in northern Nigeria. It was estimated that an average of 303 kWh/m² is consumed annually [19]. In the south-eastern part of Nigeria, an assessment conducted in 2019 estimated a higher annual consumption of 403 kWh/m² [20], with a total average of 438 kWh/m² seen in the cases mentioned. Results (Figure 2) indicate that electricity is the main form of energy used to power these hotels.

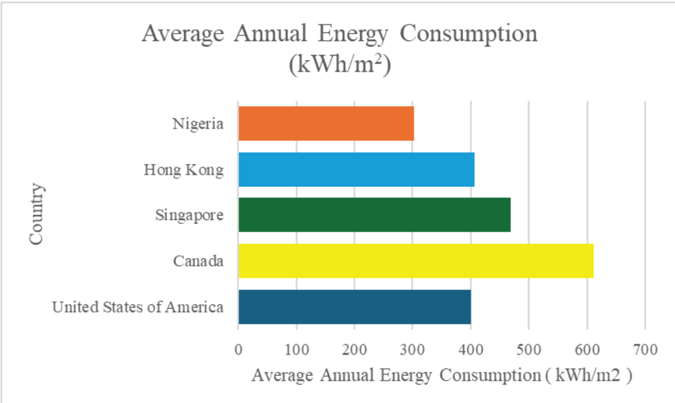

Fig. 2. Bar-Chart diagram showing different countries and their hotel annual average energy consumption with a total average of 438 kWh/m².

There is a need for hotels to have energy-efficient facades that can reduce heat gain, enhance natural ventilation, regulate daylight, and provide insulation [21]. Some of the possible solutions include smart facades that can adapt to environmental conditions, ventilated facades that can create an air gap between the inner and outer layers, and integrated glass facades that can incorporate films, coatings, or frit patterns to control solar radiation [22]. By having energy-efficient facades, hotels can benefit from lower energy bills, higher guest satisfaction, better indoor air quality, and lower environmental impact. Moreover, they can contribute to the national and global goals of reducing greenhouse gas emissions and mitigating climate change [23].

Wang et. al [24] utilised 15 existing hotels in Jiangsu Province as case studies for implementing energy-saving retrofits. The top five energy-saving retrofit technical measures, applied most frequently, were heating, ventilation and air conditioning, monitoring, lighting, domestic hot water, and building envelope systems. A study by Tushar [12] examines methods to enhance thermal efficiency by retrofitting building façades, focusing on adding extra insulation to floors and walls, both internally and externally, and replacing old windows with new ones that have lower U-values. Table 1 lists the most common and suitable insulation materials for a Nordic climate. Reducing the U-value of the building envelope through insulation leads to lower final energy use, which in turn reduces primary energy use and heating costs. However, achieving a constant decrease in U-value necessitates thicker insulation and resulting in increased primary energy use and costs [26].

Table 1: Retrofit materials for a Nordic Case Study [26]

Insulation materials	Thermal conductivity (W/mK)	Density (kg/m³)
Glass wool	0.042,	20
Rock wool	0.037	40
Wood fibre	0.038	40
Extruded polystyrene XPS for basement walls	0.030	32
Double-glazed windows having a single low-e coating, and argon and krypton gas fills	1.2 and 1.0	
Triple-glazed windows with double low-e coating, and argon or krypton gas fills	0.8 and 0.6	

The general design guidelines for comfort in this type of climate in literature [27] [28] [29] [30] [31] show the variables recommended for a composite climate include: shading, geometry, orientation, glazing, thermal mass, internal gains minimization, outdoor living and insulation.

Excellence in Design for Greater Efficiencies (EDGE) is a no-cost software tool, a standard for green buildings, and a global certification system for sustainable construction. EDGE is developed by the International Finance Corporation (IFC), and is part of the World Bank Group, to demonstrate green buildings financial benefits and stimulate investment in such projects EDGE [32]. EDGE calculations are based on climatic conditions of the location already built in the software, the building type, and occupant use. In this instance, the hotel category is selected for the research. Assumptions for area, occupancy, and the type of support services are based on the star rating of the property which is 3-star for Saffar Guest Inn and Conference Centre.

The thermal properties of the building envelope reflect the typical practice in Nigeria.

Simulations, such as those supported by EDGE, are a critical tool in designing and retrofitting buildings, particularly in the context of sustainable and energy-efficient practices [33]. Before implementing retrofitting measures, it is essential to simulate the potential outcomes to understand their effectiveness and impact. This is particularly relevant in the case of regenerative facades for retrofitting hotels, where energy efficiency and environmental sustainability are paramount.

The use of simulation tools, such as the Excellence in Design for Greater Efficiencies (EDGE) software, can provide valuable insights into the potential benefits of retrofitting measures [34]. EDGE is specifically designed to assess the environmental impact of building designs and retrofitting strategies, allowing designers and architects to optimize their solutions for maximum efficiency and sustainability.

By simulating the results of retrofitting measures, stakeholders can make informed decisions about the most effective strategies to implement. This not only ensures that the retrofitting process is cost-effective but also minimizes the environmental impact of the building [35]. In the context of regenerative facades for hotels, simulation can help identify the most suitable materials, technologies, and design strategies to improve energy efficiency and sustainability.

EDGE assessment uses 'a monthly quasi-steady-state calculation method based on European Committee for Standardization (CEN) and International Standards Organization (ISO) 13790 standards to estimate annual energy consumption for heating and cooling in both residential and non-residential buildings'. In order to better illustrate efficiency improvements to users, energy usage outputs are shown as delivered energy, rather than primary energy or carbon dioxide emissions. Further details on the EDGE methodology can be found in EDGE [32]. The calculation methodology was verified using dynamic simulation software (eQuest11) for buildings across nine different locations.

EDGE has advantages, compared to other building performance methodologies [35] [36], as it is free, relatively easy to use, and has an interactive and instant response. However, the most attractive benefit is that it has an extensive and expanding built-in database that is customized adaptively to a location determined by the user and suited to developing economies with data for sub-Saharan Africa. Despite Leadership in Energy and Environmental Design (LEED) being the most certified green building certification system in the world, for example, the list of top ten countries with the most LEED-certified projects (US excluded) does not include any African country.

3. METHODOLOGY

This study focuses on Saffar Guest Inn and Conference Centre, a 65-room hotel located within Birnin Kebbi metropolis. Recognized by state authorities as a prominent hotel in the area, it is selected for an energy audit. The hotel classification as a medium-class establishment guided the audit scope.

During the audit, the following data are collected:

1. One year electricity bills.
2. Diesel consumption data from fuel log book.
3. A log of average daily power outage from the grid.
4. A log of average monthly patronage from the guest register.
5. Gross floor area of the facility.
6. Floor area of the conditioned space.
7. Energy rating of all electrical devices used in a facility.

The Energy Commission of Nigeria (ECN) is the foremost research institute in Nigeria. The energy audit model adopted is based on the ECN energy audit format [37]. However, while comparing its adequacy introduced to improve both the economy and the quality of life with other standard models, it is observed that this model lacks a behavioural aspect and formulae to estimate demand and supply.

Therefore, this study adapts the ECN model by adding a behavioural section. Another addition is required to account for power supply inadequacy in Nigeria. Within the data collection process, there is a notable difference between the demand and supply. The model is further adapted to accommodate this inconsistency as shown in the results section.

http://dx.doi.org/10.21622/MACI.2024.01.2.1070

Considering the power inadequacy experienced in Nigeria, a methodology [38] is presented to account for this inadequacy. However, it is updated to include water supply in the disaggregated energy demand end.

The data estimated from the audit are used to analyze the current situation; and then used as input data for the simulation of regenerative energy facade strategies for the retrofit potential in the hotel industry in north-western Nigeria:

1. Shading
2. Glazing
3. Thermal mass
4. Insulation

The regenerative energy facade strategies are categorised under walls and windows in Table 1.

Table 2: Building components, strategies, and thermal conductivity

Building component	Strategies	Thermal conductivity (U-Value)			Cost (NGN*)
		Existing 230mm + 12mm render on both sides	Retrofit mat. (w/m²K)	Total (w/m²K)	
Exterior wall improvements/insulation					
• Single leaf exterior wall with synthetic insulation	Retrofitting of existing exterior wall with cladding filled with a 50mm thick **rock-wool** batt.	2.75 W/m²K	0.037W/m²K	0.0365 W/m²·K.	98,000.00
• Single leaf exterior wall with organic insulation	Retrofitting of existing exterior wall with: Cladding filled with **rice husk** batt.	2.75 W/m²K	1.067Wm²K	0.7685Wm²K	79,300.00
• Single leaf exterior wall with interior insulation	Retrofitting with **polystyrene** sandwiched in interior decorative pvc wall panels.	2.75 W/m²K	0.038W/m²K	0.0375 W/m²·K	24,000.00
• Double leaf exterior wall with dynamic air layer insulation	Construction of additional wall leaf on the exterior façade with **static air layer** as the insulation medium.	2.75 W/m²K	2.75 W/m²K	1.6 W/m2K	7,000.00
• Double leaf exterior wall with dynamic air layer insulation	Construction of additional wall leaf on the exterior façade with **horizontal air vent.**	2.75 W/m²K	0.18 w/m²k	0.169W/m²K	7,000.00
• Green wall insulation	Exterior wall **vine planting**.	2.75 W/m²K	2.9w/50mm²K	0.5131W/m²K	2,000.00
Exterior wall surface improvements					
• Light Reflectance Value (LRV)	Using Light Reflective Index (RI) of most common exterior wall paint shades on the exterior wall.	-	-	**Light Reflectance Value (%) Colours**	
				- White = 85%	700.00
				- Off-White =72%	700.00
				- Cream = 69%	700.00
				- Brown = 57%	700.00

Window					
• Single pane glazing	Using **anti Ultra violet single pane** glass on windows along sun path.	-	-	7 Wm^2K	2,280.00
• Double pane glazing	Use of **double pane glazing filled with argon gas** on all windows.	-	-	1.3 W/m^2K	3,280.00
• Double pane glazing	Use of double pane glazing with **vacuum space.**	-	-	- 0.5 W/m^2K	1,725.00
Shading device					
• Steel horizontal shading device	Installing **horizontal steel grill shading device** on windows along the sun path direction.	-	-	**Solar Shading Coefficient (SSC)** 0.2969 SSC @ 65% window coverage	21,700.00
• Vertical shading device	Installing **vertical steel shading device** on windows situated along sun path.	-	-	0.4931 SSC @ 42% window coverage	21,700.00
• Horizontal & Vertical shading devices	Installing a combination of **horizontal and vertical shading devices** on windows.	-	-	0.068 SSC @ 92% window coverage	31,750.00
Roof					
• Light reflectance Value	Trying different colour shades on the roof. The colours are:	-	-	Light Reflectance Value (%)	
				- White = 85%	3,300.00
				- Off-White =72%	3,300.00
				- Cream = 69%	3,300.00
				- Brown = 57%	3,300.00
Roof insulation					
• Roof insulation	Install roof installation in the attic space, this includes	-			
	• Rockwool			- 0.035 w/m^2K	27,000.00
	• Glass wool			-0.032w/m^2K	19,000.00
Green roof					
• Intensive	Replacing the existing conventional roofing sheets with an **intensive green roof.**	-	-1.325W/m^2K	-1.325W/m^2K	17,000.00

** Cost of items and installations per square meter in Nigerian Naira (NGN)*

Source: Authors Field work, 2024

4. RESULTS AND DISCUSSION

This section analyses the base-case modelling and simulation results to achieve the objectives of the study and to analyse the regenerative energy facade strategies.

4.1. Base Case Modelling

Design and specifications: Other input data for the modelling of the base case include:

1. Exterior Wall Improvements/ Insulation.
2. Exterior Wall Surface (Solar Reflectance Index).
3. Fenestrations (Windows).
4. Shading Device.
5. Roof (Insulation / Green Roof).

JOURNAL OF MULTIDISCIPLINARY ADAPTIVE CLIMATE INSIGHTS
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4.1.1. Exterior Wall Improvements/Insulation:

The analysis under the Exterior Wall Improvement/ Insulation table compares different wall types and their energy use in kWh/m2/year, as well as the percentage of energy savings compared to the base case.

The base case, which consists of a 230mm hollow sancrete wall with 12mm screeding, has an energy use of 60.01 kWh/m²/year and no energy savings.

Other wall types such as rockwool + clad had savings of 4.9%, rice husk insulation showed energy savings of 3.16%, polystyrene + PVC cladding had energy savings of 4.9%, cavity + stat air had energy savings of 4.62%, cavity + vent had energy savings of 4.59%, and vine on wall showed energy savings ranging from 3.75% (Figure 3).

These findings suggest that certain wall improvements and insulation materials can contribute to reducing energy consumption in buildings.

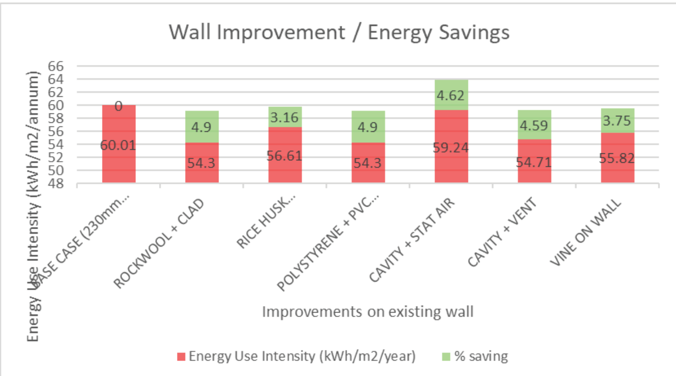

Fig. 3. Wall Improvement/energy Savings.

4.1.2. Exterior Wall Surface (Solar Reflectance Index):

The analysis under the Exterior Wall Surface (SRI) figure, compares various wall surface colors based on their Solar Reflectance Index (SRI), energy use (kWh/m²/year), and percentage savings relative to the base case.

The results show that the white wall surface with SRI 100 reduces the base case consumption to 47.17 kWh/m²/year, leading to 9.99% energy savings; Off-white wall surface with SRI 72 reduces the base case consumption to 53.87 kWh/m²/year with potential energy saving of 5.08%; Cream colour wall surface which has SRI 69 reduces the base case consumption to 54.6 kWh/m²/year, corresponding to 4.54% energy savings; similarly, Beige (base case colour) has SRI 53, which is 60.01 kWh/m²/year and is used as yard stick for the possible colour choices.

Conversely, Brown colour wall surface has SRI 25, which tends to go higher than the base case, with 65.59 kWh/m²/year, increasing the energy consumption when compared to base case with up to 3.49% (or -3.49%).

As illustrated in Figure 4, these findings suggest that selecting lighter-colored wall surfaces with higher solar reflectance indices can significantly reduce energy consumption in buildings.

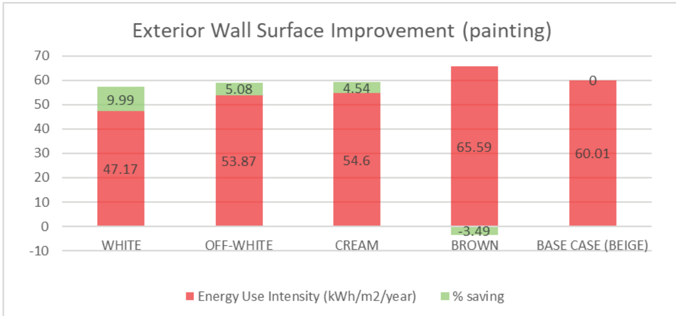

Fig. 4. Exterior surface improvement (painting).

4.1.3. Fenestrations (Windows):

Table 2 is a presentation of the data gotten from fenestration (windows) which compares different types of windows in terms of their energy use in kWh/m²/year and the percentage of energy savings compared to the base case, which is a single pane clear glass window. The base case, which is the single pane clear glass window, has an energy use of 60.82 kWh/m²/year and no energy savings.

Other window types such as anti-UV single pane glass, double pane with argon gas, and double pane with vacuum space show varying levels of energy savings ranging from 0.17% to 2.82%.

These findings (Figure 5) suggest that using windows with improved insulation properties, such as double pane windows with argon gas or vacuum space, can contribute to reducing energy consumption in buildings.

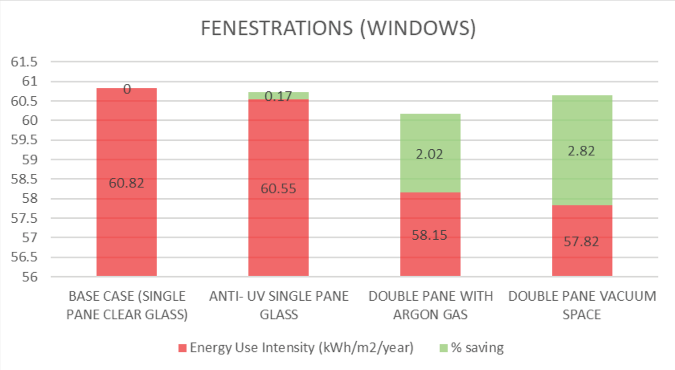

Fig. 5. Exterior Wall Improvement/Insulation.

4.1.4. Shading Device:

The analysis under the Shading Device table compares different types of shading devices in terms of their energy use in kWh/m²/year and the percentage of energy savings compared to the base case, which has no shading device. Figure 6 shows that steel horizontal shading device recorded 60 kWh/m²/year, providing just 0.6% energy savings. 59.46 kWh/m²/year is recorded from steel vertical shading device intervention, which is 1% energy savings, while combination of horizontal and vertical shading devices recorded 58.19 kWh/m²/year, equivalent to 4.26% energy savings. These results can be seen graphically in Figure 6.

The findings suggest that using shading devices, such as steel horizontal or vertical shades, can contribute to reducing energy consumption in buildings, although with relatively modest energy savings compared to the base case without any shading devices.

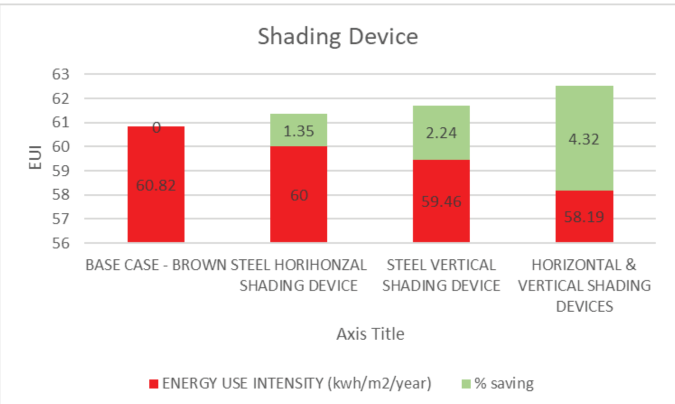

Fig. 6. Shading Device.

4.1.5. Roof (Insulation)

Under the roof (insulation/green roof) this analysis compares different types of roof insulation and the energy savings they provide in kWh/m²/year.

The base case, which is a brown roof without any insulation, has an energy use of 60.82 kWh/m²/year and no energy savings. Rockwool insulation reduces energy use to 19.28 kWh/m²/year, resulting in a 31.07% energy savings. Glass wool insulation also reduces energy use to 19.17 kWh/m²/year, with a slightly higher energy savings of 31.16%. The green roof, specifically an intensive green roof with a thickness of 300mm, has an energy use of 40.95 kWh/m²/year and provides a 14.85% energy savings, as highlighted in Figure 7. Similarly, a general overview of the all the energy saving potentials is indicated in Figure 8.

These results suggest that both rock wool and glass wool insulation can significantly reduce energy consumption in buildings, with energy savings exceeding 30%. Additionally, implementing a green roof can also contribute to energy reduction, although to a lesser extent as compared to insulation options.

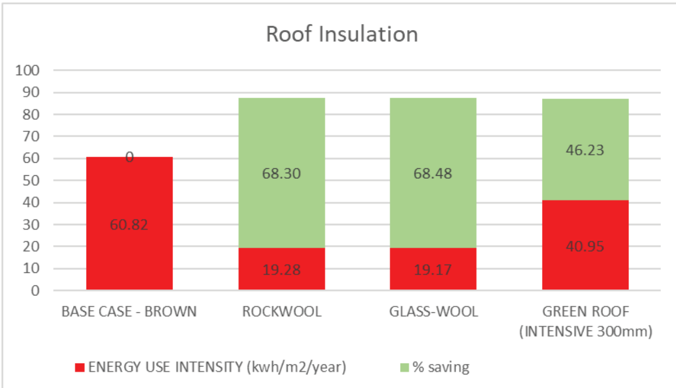

Fig. 7. Roof Insulation.

4.1.6. Cost analysis:

Table 2, gives breakdowns of tree potential intervention (Wall, Windows and Roof) strategies to reduce energy consumption in hotels located in Birnin Kebbi, a region within a tropical hot-dry climate. The proposed interventions focus on optimizing thermal performance and minimizing cooling energy loads.

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For walls, retrofitting options include synthetic insulation using cladding filled with 50mm rock-wool batt, which achieves a U-value of 0.0365 W/m²·K at a cost of ₦98,000, and organic insulation with rice husk batt, offering a U-value of 0.7685 W/m²·K for ₦79,300. Interior insulation, using polystyrene sandwiched in decorative PVC panels, is a cost-effective solution at ₦24,000 with a U-value of 0.0375 W/m²·K. Double-leaf walls with a horizontal air vent provide efficient insulation (U-value of 0.169 W/m²·K) for ₦7,000, while green walls improve insulation (U-value of 0.5131 W/m²·K), which is relatively cheaper than previous interventions, but require continuous maintenance at ₦2,000.00. For enhanced heat reflectivity, light reflective paint coatings, such as white with a light reflectance value (LRV) of 85%, offer an economical option at ₦700 per square meter.

For windows, double-pane glazing with vacuum space is the most efficient, with a U-value of 0.5 W/m²·K and a cost of ₦1,725, while argon-filled double-pane glazing provides a U-value of 1.3 W/m²·K for ₦3,280. Anti-UV single-pane glazing is less efficient (U-value of 7 W/m²·K) but is priced at ₦2,280. Shading devices, including horizontal, vertical, and combined options, are effective in reducing solar heat gain. Combined shading devices, offering a solar shading coefficient (SSC) of 0.068 at 92% coverage, are the most effective but cost ₦31,750.

Roof treatments include reflective coatings in shades like white (LRV of 85%), off-white (72%), and cream (69%), priced at ₦3,300 per square meter. Roof insulation options include rock wool and glass wool, achieving U-values of 0.035 W/m²·K and 0.032 W/m²·K, at costs of ₦27,000 and ₦19,000, respectively. Intensive green roofs provide superior thermal performance (U-value of -1.325 W/m²·K) at ₦17,000. These strategies offer a range of options for hotel owners to balance cost and performance in improving energy efficiency.

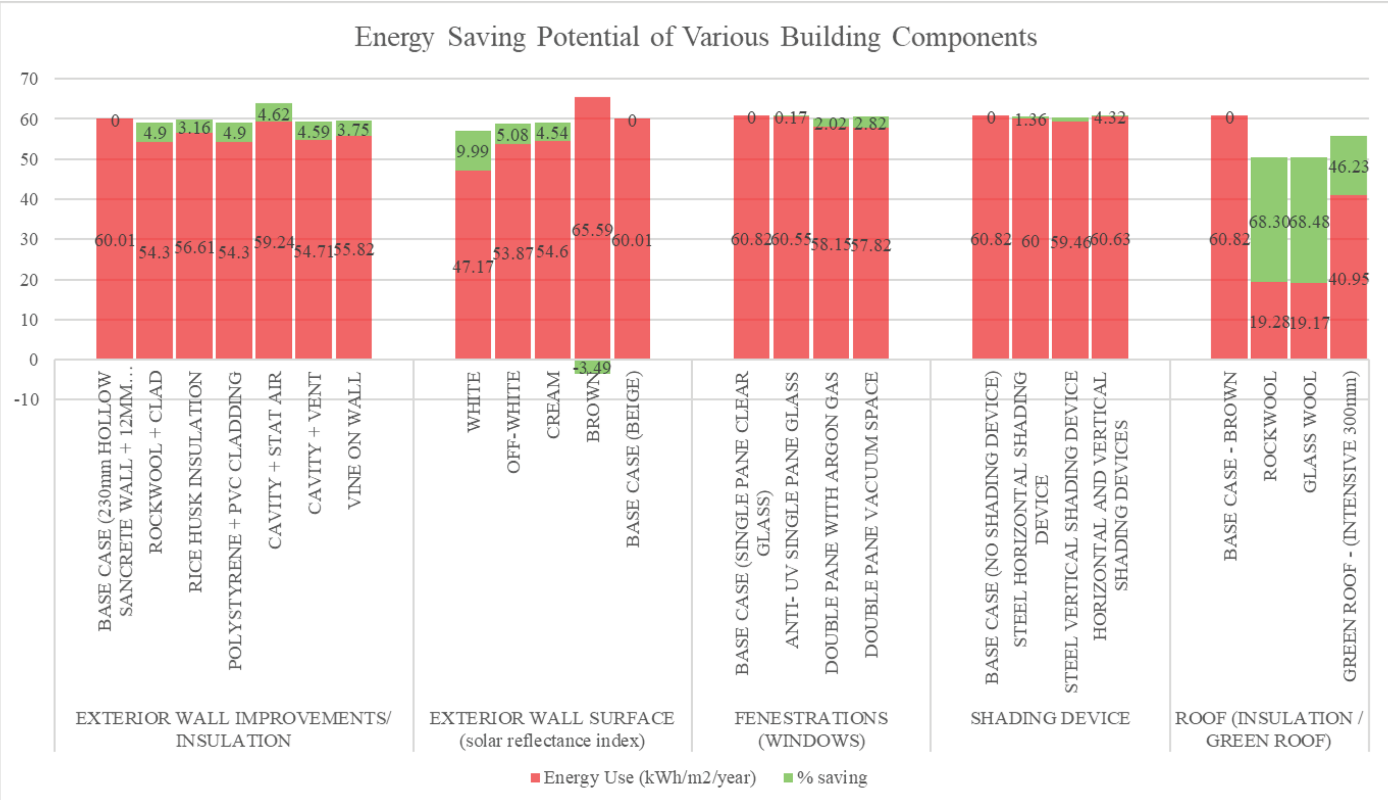

Fig. 8. Energy Saving Potential of Various Building Components.

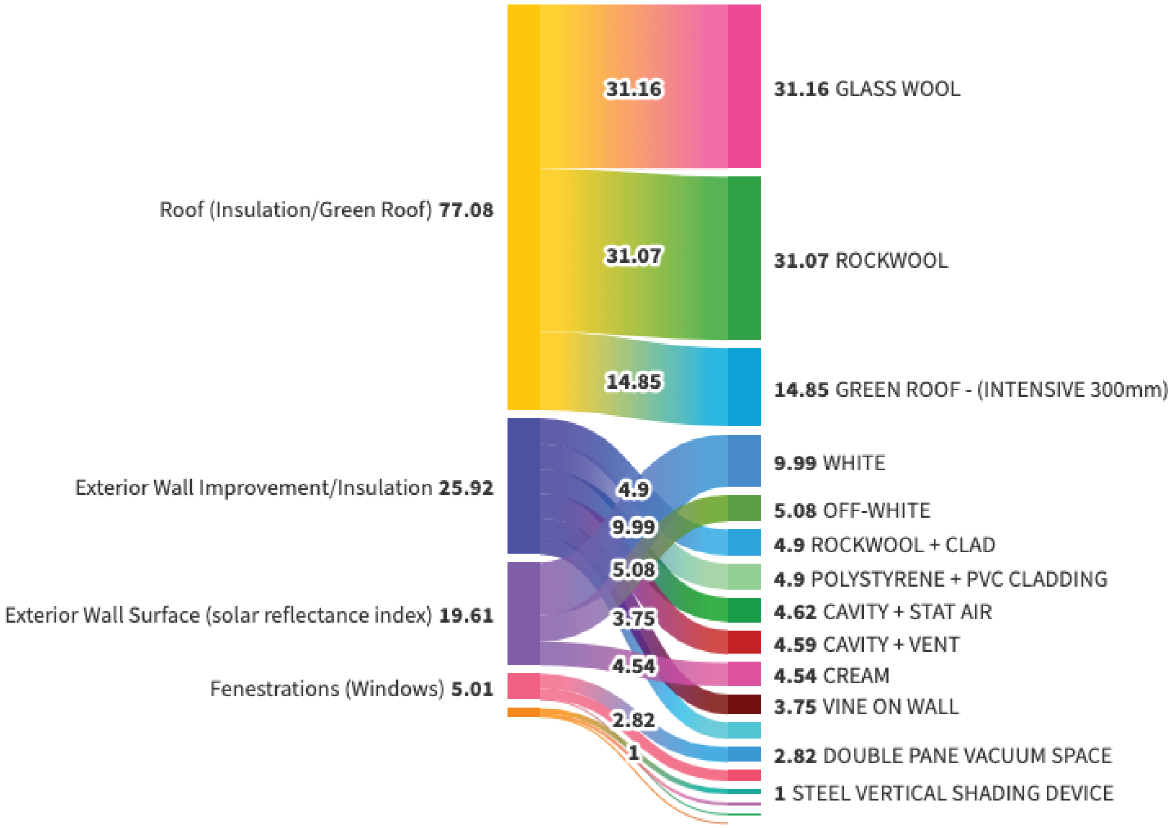

Fig. 9. Sankey diagram showing optimized cases for various building components in kWh/m²/year.

5. CONCLUSION

The results of the study highlight the potential of regenerative energy facade strategies in reducing energy consumption in buildings. The analysis of base-case modelling revealed that certain wall improvements and insulation materials can lead to significant energy savings. For example, using rock wool or glass wool insulation can reduce energy consumption by over 30% compared to the base case.

Similarly, choosing lighter-colored wall surfaces with higher solar reflectance index (SRI) can also contribute to energy savings. The study found that wall surfaces with higher SRI values had lower energy use and higher energy savings compared to darker-colored surfaces.

Furthermore, the analysis of different types of windows and shading devices showed that using windows with improved insulation properties, such as double-pane windows with argon gas or vacuum space, and implementing shading devices, can also help in reducing energy consumption in buildings.

Through detailed analysis of different building components, including exterior walls, fenestrations, shading devices, and roofs, the study highlighted the significant energy savings that can be achieved through the implementation of these strategies. Stakeholder perceptions gathered during the study revealed widespread support for regenerative energy facade strategies, particularly among architects, policymakers, and building owners who recognized their potential to balance energy efficiency with long-term economic benefits. However, stakeholders also emphasized the importance of addressing challenges such as upfront costs, material availability, and user education to maximize adoption and effectiveness.

The findings suggest that designers and policymakers in Nigeria and similar regions should consider incorporating regenerative energy facade strategies in building designs and policies to promote sustainable development. The findings also suggest that implementing regenerative energy facade strategies can play a significant role in reducing energy consumption in buildings and moving towards more sustainable building

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practices. However, it is essential to consider the specific context and requirements of each building to determine the most suitable strategies for energy efficiency and sustainability.

Researchers can look into conducting long-term studies to evaluate the performance and effectiveness of regenerative energy facade strategies in different climatic regions and building types and explore the integration of regenerative energy facade strategies with smart technologies to enhance energy efficiency and user comfort.

REFERENCES:

01. Abdou, A. H., Hassan, T. H., & Dief, M. M. El. (2020). A description of green hotel practices and their role in achieving sustainable development. *Sustainability (Switzerland)*, *12*(22). https://doi.org/10.3390/su12229624

02. Administration, I. T. (2023). *Electricity. Power Systems and Renewable Energy*. https://www.trade.gov/country-commercial-guides/electricity-power-systems-and-renewable-energy

03. Ajani, F., & Kalu, K. E. (2017). Economy diversification: a potent tool for tourism development in Nigeria. *AFRREV STECH: An International Journal of Science and Technology*, *6*(2). https://doi.org/10.4314/stech.v6i2.7

04. Alghamdi, S., Tang, W., Kanjanabootra, S., & Alterman, D. (2023). Optimal configuration of architectural building design parameters for higher educational buildings. *Energy Reports*, *10*. https://doi.org/10.1016/j.egyr.2023.08.066

05. Alhuwayil, W. K., Almaziad, F. A., & Abdul Mujeebu, M. (2023). Energy performance of passive shading and thermal insulation in multistory hotel building under different outdoor climates and geographic locations. *Case Studies in Thermal Engineering*, *45*. https://doi.org/10.1016/j.csite.2023.102940

06. Arenhart, R. S., Souza, A. M., & Zanini, R. R. (2022). Energy Use and Its Key Factors in Hotel Chains. *Sustainability (Switzerland)*, *14*(14). https://doi.org/10.3390/su14148239

07. Batagarawa, A. (2013). *Assessing the thermal performance of phase change materials in composite hot humid/hot dry climates: An examination of office buildings in Abuja-Nigeria.* [Unpublished doctoral dissertation.].

08. Boakye, K. A. A., Adams, I., & Adongo, C. A. (2017). Analyzing Ghana's Tourism Operating Environment A Political Economy Perspective. *Journal of Business and Enterprise Development*, *7*(2017). https://doi.org/10.47963/jobed.2017.01

09. Bohdanowicz, P., & Martinac, I. (2007). Determinants and benchmarking of resource consumption in hotels-Case study of Hilton International and Scandic in Europe. *Energy and Buildings*, *39*(1). https://doi.org/10.1016/j.enbuild.2006.05.005

10. Ebimobowei, A. (2022). Oil Revenue and Economic Growth of Nigeria: 1990 – 2019. *African Journal of Economics and Sustainable Development*, *5*(1). https://doi.org/10.52589/ajesd-jwzxifnw

11. *Energy Commission of Nigeria*. (2020). https://www.energy.gov.ng/

12. *European Commission , Second Report on the State of the Energy Union*. (2017).

13. Farrou, I., Kolokotroni, M., & Santamouris, M. (2012). A method for energy classification of hotels: A case-study of Greece. *Energy and Buildings*, *55*. https://doi.org/10.1016/j.enbuild.2012.08.010

14. Gössling, S., & Lund-Durlacher, D. (2021). Tourist accommodation, climate change and mitigation: An assessment for Austria. *Journal of Outdoor Recreation and Tourism*, *34*. https://doi.org/10.1016/j.jort.2021.100367

15. Haase, M., & Amato, A. (2006). Ventilated façade design in hot and humid climate. *PLEA 2006 - 23rd International Conference on Passive and Low Energy Architecture, Conference Proceedings*.

16. Idris, U. B. (2023). *Assessment of the implementation of demographic aspect of Nigeria's national population policy in Kebbi State* [Unpublished master's thesis.].

17. Isimbi, D., & Park, J. (2022). The Analysis of the EDGE Certification System on Residential Complexes to Improve Sustainability and Affordability. *Buildings*, *12*(10). https://doi.org/10.3390/buildings12101729

18. james_admin. (2022). *EDGE - Excellence in Design for Greater Efficiencies (EN) - EDGE Buildings*. https://edgebuildings.com/edge-excellence-in-design-for-greater-efficiencies/.

19. Kadrić, D., Aganović, A., & Kadrić, E. (2023). Multi-objective optimization of energy-efficient retrofitting strategies for single-family residential homes: Minimizing energy consumption, CO2 emissions and retrofit costs. *Energy Reports*, *10*. https://doi.org/10.1016/j.egyr.2023.08.086

20. Latha, H., Patil, S., & Kini, P. G. (2023). Influence of architectural space layout and building perimeter on the energy performance of buildings: A systematic literature review. *International Journal of Energy and Environmental Engineering*, *14*(3). https://doi.org/10.1007/s40095-022-00522-4

21. MacAskill, S., Becken, S., & Coghlan, A. (2023). Engaging hotel guests to reduce energy and water consumption: A quantitative review of guest impact on resource use in tourist accommodation. *Cleaner and Responsible Consumption*, *11*. https://doi.org/10.1016/j.clrc.2023.100156

22. Marzouk, O. A. (2023). Zero Carbon Ready Metrics for a Single-Family Home in the Sultanate of Oman Based on EDGE Certification System for Green Buildings. *Sustainability (Switzerland)*, *15*(18). https://doi.org/10.3390/su151813856

23. Musa, A. B., Batagarawa, A., & Mohammed, A. L. (2015). Assessment of energy consumption in some selected hotel buildings in Northern Nigeria. *Architects Colloquium. Abuja: ARCON.*

24. Mustafa, Z. (2011). Climate change and its impact with special focus in Pakistan. *Pakistan Engineering Congress, Symposium*, *33*(290).

25. Ogunsote, O. O. (1991). An introduction to building climatology-a basic course for architecture students. *Zaria: Ahmadu Bello University Press Limited*.

26. Oyedepo, S. O. (2012). Energy and sustainable development in Nigeria: The way forward. In *Energy, Sustainability and Society* (Vol. 2, Issue 1). https://doi.org/10.1186/2192-0567-2-15

27. Pan, Y., Zhu, M., Lv, Y., Yang, Y., Liang, Y., Yin, R., Yang, Y., Jia, X., Wang, X., Zeng, F., Huang, S., Hou, D., Xu, L., Yin, R., & Yuan, X. (2023). Building energy simulation and its application for building performance optimization: A review of methods, tools, and case studies. In *Advances in Applied Energy* (Vol. 10). https://doi.org/10.1016/j.adapen.2023.100135

28. Peiris, S., Lai, J. H. K., Kumaraswamy, M. M., & Hou, H. (Cynthia). (2023). Smart retrofitting for existing buildings: State of the art and future research directions. In *Journal of Building Engineering* (Vol. 76). https://doi.org/10.1016/j.jobe.2023.107354

29. Piccardo, C., & Gustavsson, L. (2023). Deep energy retrofits using different retrofit materials under different scenarios: Life cycle cost and primary energy implications. *Energy*, *281*. https://doi.org/10.1016/j.energy.2023.128131

30. Raju, A. A., Prabha, A. A., J., B., Nivya, V. J., & Sing, M. A. S. (2018). Energy audit and energy management - an overview. *Available in SSRN ELibrary of ELSEVIER, April 2018*.

31. Sam-Amobi, C., Ekechukwu, O. V., & Chukwuali, C. B. (2019). A preliminary assessment of the energy related carbon emissions associated with hotels in Enugu Metropolis Nigeria. *AFRREV STECH: An International Journal of Science and Technology*, *8*(2), 19–30. https://doi.org/10.4314/stech.v8i2.2

32. Sayed, M. A. A. E. D. A., & Fikry, M. A. (2019). Impact of glass facades on internal environment of buildings in hot arid zone. *Alexandria Engineering Journal*, *58*(3). https://doi.org/10.1016/j.aej.2019.09.009

33. Shehu, A., Inuwa, I., Husseini, I., & Yakubu, I. (2019). Relationship of Hotel Energy Management Strategies and Hoteliers' Perception on Sustainable Energy Management in Abuja Nigeria. *Journal of Resources and Environment*, 19–26.

http://dx.doi.org/10.21622/MACI.2024.01.2.1070

34. *The International Renewable Energy Agency (IRENA) , Renewable Energy Roadmap Nigeria*. (2023). Publications@irena.org.

35. Tushar, Q., Zhang, G., Bhuiyan, M. A., Giustozzi, F., Navaratnam, S., & Hou, L. (2022). An optimized solution for retrofitting building façades: Energy efficiency and cost-benefit analysis from a life cycle perspective. *Journal of Cleaner Production*, *376*. https://doi.org/10.1016/j.jclepro.2022.134257

36. Usman Kaoje, I. (2016). Site Suitability Analysis for Municipal Solid Waste Disposal in Birnin Kebbi, Nigeria. *IOSR Journal of Humanities and Social Science*, *21*(07). https://doi.org/10.9790/0837-02107030110

37. Wang, Y., Dong, L., & Li, H. (2022). Economic Evaluation of Energy-Saving Retrofit of Existing Hotels. *Energies*, *15*(3). https://doi.org/10.3390/en15030757

38. Yüksek, I., & Karadayi, T. T. (2017). Energy-Efficient Building Design in the Context of Building Life Cycle. In *Energy Efficient Buildings*. https://doi.org/10.5772/66670

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JOURNAL OF MULTIDISCIPLINARY ADAPTIVE CLIMATE INSIGHTS
(MACI) Volume 1, Issue 2, December 2024 - ISSN 3009-6332