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FOREWORD

The Greater Mekong Subregion (GMS) is one of the most dynamic and diverse regions in Southeast Asia. However, it also faces significant challenges, particularly those posed by climate change. As we delve into this special issue of the Journal of Greater Mekong Studies, we aim to shed light on the multifaceted impacts of climate change in the GMS and explore potential strategies for adaptation and resilience. Climate change represents one of the most pressing challenges of our time, with far-reaching implications for ecosystems, economies, and communities worldwide. The GMS is particularly vulnerable due to its geographical and socio-economic characteristics. Rising temperatures, shifting rainfall patterns, and increased frequency of extreme weather events such as floods and droughts threaten agricultural productivity, food security, and water resources. As one of the most biodiverse regions on the planet, the GMS is also home to numerous species that are at risk of extinction as their habitats are altered or destroyed.

Agriculture is the backbone of many GMS economies, employing a significant portion of the population and providing essential food resources. However, the changing climate poses serious threats to agricultural stability. Research indicates that rising temperatures and unpredictable rainfall patterns could lead to reduced crop yields, particularly for staple crops like rice, which is a dietary cornerstone for millions. The potential for increased pest and disease prevalence further complicates these challenges. As a result, the GMS must explore innovative agricultural practices, such as drought-resistant crop varieties and sustainable farming techniques, to ensure food security in the face of climate variability. The economic implications of climate change in the GMS are profound. The region's reliance on agriculture, fisheries, and tourism makes it particularly susceptible to climate impacts. Economic losses could be significant if adaptive measures are not implemented. However, the transition to a green economy presents opportunities for growth and innovation. This special issue explores how sustainable practices can be integrated into various sectors, promoting resilience while also stimulating economic development.

Finally, effective governance and policy frameworks are essential for addressing the complex challenges posed by climate change in the GMS. The importance of cross-border cooperation cannot be overstated; shared water resources, migratory species, and common economic interests necessitate collaborative efforts. At the same time, local communities are often at the frontline of climate change impacts, and their knowledge and experiences are invaluable in crafting effective adaptation strategies. Community-based adaptation initiatives not only foster resilience but also enhance social cohesion and support sustainable development.

I would like to also take this opportunity to thank the journal's co-editors, Drs. Deth Sok Udom and Bradley Jensen Murg for their hard work in making this publication possible and to express CICP's deepest thanks to The Asia Foundation and the Ponlok Chomnes initiative supported by the Australian government for their financial support of the journal.

Huy Kanthoul Vora,
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STRUCTURAL POLICY INTERVENTIONS FOR CLIMATE CHANGE ADAPTATION IN THE GREATER MEKONG SUBREGION

*Dr. Tim Hildebrandt
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Introduction

The Greater Mekong Subregion (GMS) encompasses an expansive area in Southeast Asia and is home to five countries: Cambodia, the Lao People's Democratic Republic (PDR), Myanmar,¹ Thailand, and Vietnam.² These nations are linked by the Mekong River, a vital artery that supports the region's economy (Greater Mekong Subregion Secretariat n.d.).

Agriculture plays a pivotal role in the GMS, underpinning the economies of these countries. It is the lifeblood for over 60% of the subregion's 340 million inhabitants, engaging in small-scale agriculture that directly supports the livelihoods of nearly 200 million people. The GMS's agricultural sector is not just a source of food and income; it also represents a critical challenge in the context of environmental sustainability and climate change (Greater Mekong Subregion Secretariat n.d.a; Greater Mekong Subregion Secretariat n.d.b). The GMS is at a crossroads due to its vulnerability to climate change, which threatens the sustainability of its agriculture and the livelihoods of millions. Issues such as water scarcity, reduced agricultural productivity, and increased vulnerability to extreme weather events are pressing concerns. Due to the prominent role of agriculture within the economic and social structures of the GMS, increasing the climate change resilience of the agricultural sector, both in an economic and social manner, is of the utmost importance. Given these circumstances, the objective of this study is to investigate structural policies that can bolster climate resilience within GMS agriculture. Thus, the study strives to contribute towards the goal of sustaining the GMS as a critical agricultural hub, while ensuring it can withstand the challenges posed by climate change, thereby guaranteeing food security, livelihoods, and environmental sustainability for future generations.

¹ Myanmar's position in the GMS is hard to gauge in the aftermath of the February 2021 coup and the ensuing conflict thereafter. Officially, Yangon remains a member of the grouping, despite the ever-deteriorating position of the government. Thus, many of the projects explored in this paper are unlikely to have been implemented in the country, particularly given the suspension of all Asian Development Bank activity as of February 2021 (Asian Development Bank n.d.; Greater Mekong Subregion Secretariat n.d.d).

² China (specifically Yunnan Province and Guangxi Zhuang Autonomous Region) is also part of the GMS. In this analysis Yunnan Province and Guangxi Zhuang Autonomous Region are excluded to simplify the analysis.

Agriculture in the Greater Mekong Region: Economic and Social Dimensions

Agriculture serves as the fundamental economic cornerstone of the GMS, playing an indispensable role in the region's sustenance and employment. As of the year 2000, each country within the GMS reported that over 50% of its workforce was engaged in the agricultural sector. Notably, the less developed nations of Cambodia and Laos exhibited These statistics highlight the significant role of agriculture as a major source of employment and its essential position within the socio-economic structure of the GMS. When comparing the share of employment attributed to agriculture with its contribution to the Gross Domestic Product (GDP) of a GMS country, a conspicuous disparity emerges, indicating that labor productivity in agriculture is markedly lower in comparison to the industrial and services sectors (The World Bank 2022).

This discrepancy between the high employment levels in agriculture and its relatively low contribution to GDP is problematic for several reasons. (1) It underscores the issue of low agricultural productivity, which can limit income growth and poverty reduction efforts in rural areas. (2) The persistence of a large agricultural workforce with low productivity may hinder the reallocation of labor to more productive sectors, such as industry and services, which are critical for economic development and diversification. (3) This discrepancy can exacerbate income disparities and contribute to ongoing challenges in achieving sustainable economic growth and development within the GMS.

figures whereby up to three-quarters of the employed workforce was employed in agriculture. Through dedicated development initiatives over the past decades, significant structural transformations (industrialization) have been realized within the labor markets of all GMS countries (The World Bank 2021). These efforts have resulted in a substantial reduction in the proportion of the workforce employed in agriculture, although all five countries continue to exhibit comparatively high rates of agricultural employment.

Table 1: Key economic indicators of the primary sector, in selected GMS countries, 2000/2010/2020 (World Bank Open Data 2024)

	Agriculture, forestry, and fishing, value added (% of GDP)	Employment in agriculture (% of total employment) (modeled ILO estimate)	Crop production index (2014-2016 = 100)	Arable land (hectares per person)
Cambodia	2000: 35,9% 2010: 33,9% 2020: 22,7%	2000: 73% 2010: 55% 2020: 39%	2000: 36 2010: 80,7 2020: 120,2	2000: 0,31 2010: 0,26 2020: 0,25
Lao PDR	2000: 33,6% 2010: 22,6% 2020: 16,3%	2000: 82% 2010: 71% 2020: 59%	2000: 32,3 2010: 57,9 2020: 101,8	2000: 0,17 2010: 0,22 2020: 0,17
Myanmar	2000: 57,2% 2010: 36,9% 2020: 22,4%	2000: 61% 2010: 52% 2020: 46%	2000: 63,2 2010: 110,8 2020: 96,2	2000: 0,22 2010: 0,22 2020: 0,21
Thailand	2000: 8,5% 2010: 10,5% 2020: 8,7%	2000: 52% 2010: 38% 2020: 31%	2000: 74,3 2010: 91,1 2020: 96	2000: 0,28 2010: 0,26 2020: 0,24
Vietnam	2000: 24,5% 2010: 15,4% 2020: 12,7%	2000: 65% 2010: 49% 2020: 33%	2000: 59 2010: 83,3 2020: 106	2000: 0,08 2010: 0,07 2020: 0,07

The overall low productivity of the GMS countries' agricultural sectors can also be traced back to the persistent agrarian social structures of the region. Smallholder farms predominate in rural areas, where agriculture supports the livelihoods of a significant portion of the population. These small-scale farms are primarily focused on subsistence farming, although there is a growing trend towards market-oriented production. This trend increases the need for smallholders to adapt to new technologies and market demands, which can be a significant hurdle given the lack of access to information, financial services, and quality inputs. Additionally, the growing market orientation of the overall agricultural sector of GMS countries shows that smallholders are not able to profit in the same way from modern farming practices and economies of scale as larger scale agrarian businesses are able to. (Vorlaufer 2009, 134-142; Snoxell and Lyne 2019, 219-220, 225). The observed shift toward market-oriented agriculture is becoming increasingly evident in crop production patterns within the GMS. While rice remains the preeminent staple, the region is also engaged in the cultivation of cash crops³ including coffee, tea, rubber, pepper, and cashew.

The production of these commodities has seen a notable increase, particularly since the turn of the millennium (Volaufer 2009, 142-150; East-West Center n.d.).

³ Agricultural crops that are planted mainly for sale or export and thus for profit (Eurostat n.d.).

The selection of crops produced is shaped by a combination of internal consumption demands and the prospect of export opportunities, with numerous GMS nations endeavoring to broaden their agricultural export markets. Such endeavors are congruent with policies such as the GMS Economic Cooperation Program Strategic Framework 2030 (GMS 2030). GMS 2030 aims to develop a cohesive agricultural region by improving regional integration, thus fostering economic growth, sustainability, and inclusiveness. It builds upon previous frameworks and plans, focusing on modernizing the economy through digital means, developing trade routes, fostering policy collaboration between the GMS countries, engaging the private sector, enhancing regional partnerships, and implementing a system to monitor progress, while ensuring a business-friendly climate (Greater Mekong Subregion Secretariat n.d.c).

Overall crop productivity in the GMS is influenced by a multitude of factors. A key challenge for the GMS 2030 and for agriculture in the GMS in the coming years are the ramifications of a changing climate. The crop production index illustrates that there has been a general uptick in crop yields within the GMS over the past two decades. However, the trajectory of future developments remains uncertain, with various determinants at play.

Climate Change Risks for Agriculture in the Greater Mekong Subregion

The ongoing structural transformation of agriculture in the GMS is marked by a transition from subsistence farming towards a more commercialized model. This shift is driven by demographic expansion (the total population of the GMS countries has increased by over 19% from approx. 205 million in 2000 to approx. 244 million in 2020 [The World Bank 2020]), societal shifts (increased urbanization and education [ASEAN 2022]), and the dynamics of global trade (Mizik 2021). These shifts accelerated the adoption of four trends in GMS agriculture: greater intensification, specialization, the increased use of agrochemicals, and mechanization.

Table 2: Key trends in GMS agriculture and their ecological ramifications

Production trend	Definition	Ramification
Intensification	Agricultural intensification is defined as the increase in the productivity of crops and livestock per unit of input (Lam, Pham and Nguyen-Viet 2017).	Intensive agriculture can lead to a marked decrease in insect diversity and numbers. This decline can pose a challenge to beneficial insects, potentially negatively impacting productivity (Raven and Wagner 2021).
Specialization	Agricultural specialization is defined as the process of concentrating resources (labor, capital, and land) on producing a limited variety of goods (Abson 2019, 301).	Specialization in farming is often cited as a cause of biodiversity loss and land degradation (Thompson, Barns and Toma 2022).
Use of Agrochemicals	Agrochemicals are generally used to control pests, pathogens, and supply nutrients to the soil (Singh S. I, Singh and Vig 2020, 101).	Increased use of agrochemicals can lead to deteriorating soil health and diminished microbial biodiversity, which impose stress on crop productivity (Phour and Sindhu 2022).
Mechanization	Agricultural mechanization involves employing a range of tools and machinery to carry out farming tasks, from hand-held implements to advanced motorized equipment (Plant Production and Protection Division of the United Nations FAO 2016).	Mechanization can lead to habitat loss and soil compaction due to the use of heavy machinery, which disrupts soil structure and biodiversity. Over time this can impact productivity negatively (Wang et al. 2022, 981).

Enhanced intensification, specialization, chemical use, and mechanization bolster productivity and value addition in the agricultural sector of GMS countries; however, these approaches may ultimately undermine long-term productivity due to their ecological impacts. These trends, reflective of agricultural modernization which are clearly visible in Table 1 through the simultaneous increase in crop production and decline in arable land and agricultural workforce, are part of a broader socio-economic transformation within the GMS, but they also heighten the sector's vulnerability to climate change risks.

Agriculture, being the primary consumer of water resources, with usage ranging from 68% to 98% in GMS countries, is particularly challenged by the low extent of irrigation and the predominance of rain-fed cultivation, which amplifies its vulnerability to climate change (Johnston et al. 2010, 6). This period of transition necessitates the adoption of adaptive strategies to manage water demand and quality, in the face of climate change projections, including rising temperatures, changes in rainfall patterns, and sea-level rise (Johnston et al. 2010, 19-22,34-38).

The anticipated impacts of climate change, such as altered precipitation patterns and increasing temperatures, pose a significant threat to the productivity of agriculture and fisheries, jeopardizing food security and altering the composition and functionality of the region's ecosystems. Adjustments in agricultural practices, such as the adoption of new crop varieties or changes in cropping patterns, may become necessary. Particularly alarming is the projection that by the century's end, rising sea levels could inundate significant portions of the Mekong Delta's agricultural lands, where a substantial portion of the GMSs rice production occurs, thereby also threatening the region's rice output and overall food security (Johnston et al. 2010; Johnston et al. 2010a).

Climate Change and Agriculture – Wider Ramifications

Within the GMS framework the interrelated consequences of ecological challenges and climate change on agriculture extend across economic, political, and social dimensions, each influencing the others in a complex interplay. The economic implications include a potential decline in agricultural productivity/output due to climatic change, which may result in reduced yields, increasing food prices, and exacerbating poverty – effects that, in turn, could also impact political stability as communities demand government action. This nexus of food security and political unrest was notably observed during the Arab Spring,⁴ where rising food costs contributed to widespread upheaval.

The political dimension is intertwined with economic factors, as a government's legitimacy, often derived from developmental achievements, is threatened by the adverse impacts of climate change. The impact of climate change on GMS agriculture presents a dual challenge: domestically, it threatens political stability and progress, while internationally, it could exacerbate tensions over shared resources like water, particularly as nations grapple with diminishing supplies. The Mekong River, subject to geopolitical discord stemming from China's dam constructions, serves as a case study of how agricultural, environmental, and hydrological concerns are deeply interconnected with regional diplomacy and national sovereignty (Tran 2022; Hirsch 2011).

⁴ *The connection between food prices and political instability, exemplified by the Arab Spring, is underscored by the impact of climate change on agricultural productivity and food availability. Climate change exacerbates existing tensions in fragile states by undermining food security, leading to increased food prices. This dynamic acts as an accelerant of instability, igniting protests and revolutions in regions such as the MENA, where the Arab Spring unfolded as a stark illustration of these effects (Holland 2012).*

Socially, climate-induced ecological changes are precipitating shifts from traditional agrarian practices to urban migration, altering demographics and placing additional pressure on urban infrastructure. This demographic transition may lead to cultural erosion as agricultural and fishing communities, facing a loss of livelihood, are compelled to abandon ancestral practices. Moreover, coastal urban areas like Haiphong, Ho Chi Minh City, Bangkok, and Yangon face their own challenges, such as increased susceptibility to flooding due to rising sea levels (Nicholls et al. 2007).

Structural Policy for Agriculture

To avoid the outlined socio-economic worst-case scenarios, GMS governments need to tackle the challenges climate change poses for agriculture, as well as address the ecological challenges for agricultural productivity posed by the ecological fallout of agricultural modernization, such as intensification and specialization. These challenges can only be sufficiently addressed in the long term through agricultural structural policy.

Agricultural structural policy refers to a subset of agricultural policies aimed at modifying the structural aspects of the agricultural sector to achieve goals such as long-term efficiency and sustainability (Marsh 1991). These policies can encompass a wide range of interventions designed to support the transformation and modernization of agriculture, address rural development, or facilitate adjustments to the socio-economic fabric of rural areas. The intention behind these policies can vary depending on the given contexts. Often, they aim to enhance agricultural productivity, ensure food security, improve rural livelihoods, or contribute to environmental sustainability.

The most prominent example of agricultural structural policy is the Common Agricultural Policy (CAP) of the European Union. The CAP was initially established in 1962 to support agricultural production and ensure a stable supply of affordable food to support political stability in Europe. Since then, the CAP operates through two main pillars: direct payments to farmers to support income (Pillar I) and rural development measures (Pillar II), which together seek to address the structural challenges faced by the agricultural sector and rural areas. Over time, the CAP has evolved to include a stronger focus on rural development (the second pillar). This includes measures aimed at improving the competitiveness of the agricultural sector, promoting sustainable farming practices, and supporting rural economies and communities (European Commission n.d.).

In the context of developing countries and emerging economies, agricultural structural policies may target the modernization of agriculture through strategies that aim to reduce poverty. Such policies might include improvements in agricultural productivity, better access to markets, the use of sustainable practices, and measures to ensure that equitable growth benefits all segments of society, particularly the most vulnerable. Currently, the agricultural structural policy in the GMS focuses on three areas:

Climate-Resilient and Inclusive Value Chains: The Greater Mekong Subregion Sustainable Agriculture and Food Security Program (GMS SAFSP), initiated in 2019, is a

program designed to address the challenges posed by climate change to agriculture in the GMS countries. It aims to transform the GMS into a leading provider of safe, quality, and climate-friendly agri-food products; to enhance climate-adaptive agriculture, while considering the water-energy-food nexus; and to harmonize safety and quality systems for crops and livestock across the region. The measures to achieve the outlined goals include developing climate-friendly, inclusive, and gender-responsive agri-food value chains and agribusiness; promoting environmentally sustainable production practices along the value chain; and strengthening value chain integration by involving smallholder farmers, rural women, and small to medium-sized agro-enterprises. The GMS SAFSP is being carried out by the Working Group on Agriculture (WGA), which is tasked with executing priority projects under the Core Agriculture Support Program, as well as by the Asian Development Bank, which plays a pivotal role in providing technical assistance, funding, and guiding the program's strategic direction (Asian Development Bank 2019, 1-11; Greater Mekong Subregion Secretariat n.d.a).

Harmonization and Safety: This is exemplified by the GMS Cross-Border Livestock Health and Value Chains Improvement Project, which is a comprehensive initiative designed to mitigate the risks from trans-boundary animal diseases (TADs), enhance food safety, and strengthen livestock value chains. The project is set to improve the health of livestock, the integrity of value chains, and the formal trade of livestock and livestock products in the Greater Mekong Subregion (GMS). The overarching goal of the project is to support the GMS vision of becoming a leading supplier of safe and environmentally friendly agriculture products. This specifically includes reducing risks from transboundary animal diseases, zoonotic diseases, and antimicrobial resistance, while simultaneously building up animal health monitoring and service delivery, enhancing food safety, and promoting subregional cooperation. The project strives to achieve this goal through several comprehensive measures, such as establishing Disease Control Zones (DCZs) with facilities for feedlots, quarantine, laboratories, and health inspection, upgrading livestock health and value chain infrastructure in a climate-friendly manner, enhancing capacities for improved production and the health of livestock through training in areas such as animal health services, disease risk analysis, and emergency preparedness, while enabling policies for better supply, health, safety, and trade in livestock products, with a focus on integrating smallholders and promoting women's roles in livestock production. The project was initially implemented in Myanmar⁵ and Cambodia with financial assistance through loans and grants from the Asian Development Bank. In Cambodia it is expected that at least 40,000 households will benefit from improved infrastructure, technical capacities, and policy frameworks (Ramachandran 2018; Asian Development Bank 2020).

Trade Facilitation: In addition to the GMS 2030, another key approach is the Agricultural Trade Facilitation in the Greater Mekong Subregion, which is a program designed to

⁵ This is likely no longer the case, as the Asian Development Bank has suspended all projects in Myanmar as of February 2021 (Asian Development Bank n.d.).

streamline agri-food product movement, aiming to reduce trade barriers and costs, enhance supply chain efficiency, and alleviate poverty. The program advocates for a cluster approach, urging the GMS to become a nexus for agri-food trade. Initiatives include policy analyses to guide decision-making and systematic improvements to the trade flow of agri-food goods. The Asian Development Bank supports this program, aiming to bolster GMS economies by transforming agricultural trade practices. The impact of these initiatives is likely to be substantial, although specific outcomes will depend on the successful and sustained implementation of the recommended policies and practices (Asian Development Bank 2012, 6-24).

The agricultural structural policies in the GMS tackle climate change in many ways already, e.g., by focusing on climate-resilient and inclusive value chains, as well as harmonizing safety and quality systems for crops and livestock across the region. However, there are two interdependent key areas where GMS agricultural structural policies are lacking, namely ecological fallout from agricultural modernization and the potential threat of water scarcity.

Mitigating Climate Change Through Structural Policy

The imperative to mitigate environmental degradation resulting from the intensification of agriculture, alongside the looming menace of water scarcity, necessitates the implementation of strategic agricultural policies. However, it is not feasible to simply mandate the GMS countries to address the root of these challenges—namely, the modernization of agriculture and the increasingly market-driven nature of the GMS agricultural sectors—as these elements are pivotal to the region's ongoing economic expansion. Instead, GMS countries must endeavor to harness policy innovation to reconcile their structural strategies with the identified climatic vulnerabilities, focusing on adaptation and mitigation strategies. This approach should not regress to an antiquated agricultural framework, but rather progress towards a resilient, modernized agricultural infrastructure that is sustainable and climate adaptive. Some best practices for agricultural structural policy to foster policy alignment are:

Best Management Practices (BMPs): The implementation of BMPs, such as buffer strips, fertilization reduction, and alternative crops, can significantly reduce nitrate pollution and improve water quality in agricultural catchments (Haas, Guse and Fohrer 2017). However, BMPs must be balanced with economic development, this can be achieved through (I) Economic incentives (subsidies, tax breaks, or payments for ecosystem services) for sustainable practices. This approach can make sustainable practices more attractive and economically viable, as seen in policy initiatives like the EU's CAP policy (Bartolini and Viaggi 2013). (II) Integrating environmental and economic policies, e.g., through crafting agricultural policies that consider both the profitability of farms and the health of ecosystems (Boone et al. 2000), and finally (III) Implementing an adaptive management approach, to balance BMPs with economic development by continuously monitoring outcomes and adjusting practices as needed (Lü et al. 2012). These practices need to

balance environmental protection with economic development, highlighting the importance of government policies such as the Water Framework Directive and the Renewable Energy Sources Act in guiding sustainable development (Haas, Guse and Fohrer 2017).

Ecological Modernization (EM) in Policy: EM perspectives applied to agricultural policies, such as those in the 2014 Farm Bill⁶, emphasize the incorporation of environmental protection technologies into agricultural production. This approach fosters a shift towards sustainable intensification, leveraging technology and decentralized governance to reconcile productivity with environmental stewardship (Reimer 2015). The goal is to balance the modernization of agricultural practices with environmental sustainability. Key characteristics of EM are: (I) The adoption of advanced technologies (e.g., precision agriculture) that lead to more efficient and environmentally friendly farming practices, (II) Transitioning away from traditional production subsidies towards incentivizing environmentally beneficial practices, (III) Productive conservation through the integration of conservation practices into active agricultural lands, (IV) Collaborative efforts between different levels of government and local stakeholders to address environmental challenges that transcend local boundaries, (V) Shifting towards decentralized governance, giving local actors, including farmers, more influence in creating and implementing agricultural and environmental policies (Hristov et al. 2020; Reimer 2015).

Conclusion

In conclusion, this study highlights the connections between agricultural practices, climate change, and the effectiveness of structural policies in the GMS. Agriculture in this region is heavily impacted by climate change, with alterations in precipitation patterns and temperature fluctuations posing threats to food security and the livelihoods of millions. The agricultural sector's modernization, while beneficial to contemporary productivity, has also contributed to ecological degradation, thereby increasing its vulnerability to climate change. Policies, therefore, must be designed to support sustainable practices and resilience to climatic shifts.

Based on research, the following policies can help policymakers, stakeholders, and local communities to weather the effects of climate change: (1) Integrating climate adaptation into agricultural policy frameworks, encouraging sustainable farming practices and the use of drought-resistant crop varieties. (2) Enhancing water resource management, considering the high dependence on rain-fed agriculture and the challenges of water scarcity. (3) Foster regional cooperation to address transboundary issues such as water

⁶ The 2014 Farm Bill, as an instance of Ecological Modernization in policy, represents a holistic approach to U.S. agricultural and food policy by integrating major changes in commodity programs, conservation efforts, crop insurance, and nutrition assistance, aiming to streamline these elements in a sustainable manner while still supporting economic growth and innovation in the agricultural sector (United States Department of Agriculture n.d.).

sharing and disease control in livestock. (4) Support smallholder farmers through access to technology, financial services, and markets to build resilience in local agri-food systems.

Looking forward, a progressive path for the GMS should involve aligning economic development with environmental sustainability, employing strategies of ecological modernization to mitigate the adverse effects of agricultural intensification.

Considering these findings and recommendations, it's clear that by focusing on creating robust structural policies, the region can hope to maintain its vital role in global agriculture and secure a resilient and prosperous future for its inhabitants. Further inquiry and targeted research efforts are essential to refine these strategies and implement effective solutions for the region's unique needs.

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EQUILIBRIUM: PATHWAYS FOREARD TO FLOURISHING GREATER MEKONG SUBREGION THROUGH SUSTAINABLE URBANIZATION

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Overview

The [Greater Mekong Subregion](#) (GMS) is a dynamic and nuanced region in Southeast Asia that holds utmost potential for its member states. As the transboundary border, the GMS has been the major factor in bringing together the six countries such as Cambodia, Thailand, Laos PDR, Vietnam, Myanmar, and China (specifically Yunnan Province and Guangxi Zhuang) (About the Greater Mekong Subregion). The undergoing dynamic transformation has remarkably been notorious in various factors with its rich-and-vibrant tapestry. However, amidst the bustling development, how can the GMS achieve and embrace equilibrium in terms of sustainable urbanization?

Looking ahead to other intersections, the nexus of hydrological and socio-economic spheres are intertwined to the communities in border areas and beyond, in which it provides harmonious impact and major considerations to concretely take into account. Similarly, the rapid growth of population, infrastructure deficiencies, environmental degradation, and social inequalities highlight the pressing challenges and difficulties of urbanization in the region (**Table 1**). At the tipping point, sustainable urbanization plays a huge role contributing to the GMS and offering the key to unlock a flourishing future for its people and environment. By drawing these complexities in the Greater Mekong Subregion, it has been marked to be the roadmap to strive for balancing economic aspirations with social equity and environmental stewardships. Consequently, each member of the basin adopts the auspicious mindset by visualizing such a phenomenon along the Mekong River, humming with life and prosperity, while deciphering in harmony with the environment.

Population Growth (2000-2020)	<ul style="list-style-type: none"> - Cambodia: steady population growth in years, with approximately 1.6% rate per year. - Laos PDR: dramatic population growth (slower pace compared to some GMS countries), with 1.6% rate per year. - Myanmar: high population growth with 1.3% rate per year. - Thailand: slow population growth with an estimated 0.4% rate per year. - Vietnam: depreciated population growth with approximately 1.0% per year. - China: slow population growth with an estimated 0.5% rate per year. <p><i>This has exhibited varying levels of population growth on average in the Greater Mekong Subregion, in which it indicates a slower pace compared to the Global Average.</i></p>
Environmental Degradation	<ul style="list-style-type: none"> - Deforestation: the expansion of agricultural sectors has severely impacted the forest and the animals. - Loss of Biodiversity: the exploitation and overhunting have disrupted ecological balances and threatened some protected-species. - Illegal Wildlife Trade: the loss and fragmentation of inhabitants due to overexploitation and hunting, along the Illegal/Black Market. - Water Pollution: has been variably affected by industrial activities, agricultural runoff, untreated sewage and wastewater, etc.
Social Inequalities	<ul style="list-style-type: none"> - Rural Poverty: with the strong concentration, the Mekong is characterized by high levels of poverty in rural areas, especially in remote and marginalized communities due to the limited access to products, resources, and market opportunities. - Economic Disparity: in comparison to capital cities and major economic centers, urban-rural divide establishes different gaps, income disparities, employment, and social service, etc. - Ethnic and Cultural Diversity: the GMS consists of extensive ethnic groups, languages, identities, distinct cultures and traditions. These minorities often encounter socio-economic disadvantages and discrimination.
Infrastructure Deficiency	<ul style="list-style-type: none"> - Transport Infrastructure: <ul style="list-style-type: none"> + Pre-2010: Improper roads, railways, corridors, and inland waterways which limited adequate transportation

Infrastructure Deficiency	<ul style="list-style-type: none"> - Transport Infrastructure: <ul style="list-style-type: none"> + Pre-2010: <p>Improper roads, railways, corridors, and inland waterways which limited adequate transportation</p> <p>Underinvestment and fragmented policies</p> + 2010-2020: <p>Efficient transport networks across the region, and further on-going expansion of adequate transportation</p> <p>Public-Private partnership and active-engagement from other actors/shareholders</p> <p>New reformed regulation and regional cooperation</p> - Energy Infrastructure: <ul style="list-style-type: none"> + Pre-2010: <p>Dominance of fossil fuels</p> <p>Limited energy trade and infrastructure development</p> <p>Inefficiencies of energy distribution</p> + 2010-2020: <p>Energy security and the price prompted diversification efforts</p> <p>Cross-Border energy trade and infrastructure development, establishing a more cooperative master-plan which has led to significant investment in renewable energy.</p> <p>Energy efficiency improvement</p> - Digital Infrastructure: <ul style="list-style-type: none"> + Pre-2010 Vulnerable Phase: <p>Limited Connectivity</p> <p>Inadequate Infrastructure</p> <p>Low Barrier in Policy and Regulation</p> + 2010-2020 Mega-Trend imposed: <p>Rapid Growth in Technological Advancement with huge investment from private sectors, along the government's initiatives.</p> <p>Major Cooperation in the GMS, in particular to the Greater Mekong Subregion Information Highway (GMS-IH) in fostering regional connectivity.</p> <p>Cybersecurity: along the ongoing trend, the Mekong have yet resolved such concerns</p>
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Table 1: Major Consideration to the Growth of Urbanization in the GMS

Population Growth: the number is acquired based on the World Bank Open Data, which the Author has later re-developed by analyzing them individually to each country (from 2000-2020) to avoid generalization. Accordingly, the information above has exhibited varying levels of population growth on average in the Mekong Subregion, which outlines a slower pace compared to the Global Average.

Environmental Degradation: encompassing a wide-reaching of components and varied gaps across different countries. Hence, the Author tempts to briefly give basic understanding within the context.

Social Inequality: in such a context, the Author aims to provide a brief complexity by outlining the gaps in the Mekong Subregion.

Infrastructure Deficiency: the above trends, and each individual country within the Mekong Basins experienced varying degrees and progress, in which the Author gives a brief background within the focused areas.

Transport Infrastructure: the content is based upon “[The Need to Improve the Quality of Transport Infrastructure and Connectivity for Regional Trade Integration and Competitiveness](#)” of the Asian Development Bank, retrieved on 15 February, 2024.

Energy Infrastructure: a brief context and the Author’s analysis based on “[Accelerating the Energy Transition in the Greater Mekong Subregion](#)” of the Asian Development Bank, retrieved on 17 February, 2024.

Social Infrastructure: consisting of a variety of other elements, and majorly the Author illustrated three main components concerning the mega-trend in the GMS.

Sustainable Urbanization

By identifying various concerns above, the Mekong has been witnessing significant urbanization for the last several years, which leads to increased demand for resources, infrastructure, and services. Presumably, it is crucial to develop a practical approach and thrive for concrete implementation, particularly to sustainable urbanization. ***Hence, what is sustainable urbanization referred to?***

A clearly defined terminology from the [World Bank](#), sustainable urbanization refers to the structural architecture of cities development that outlines the requirements without jeopardizing the future generation.⁷ It additionally entails a broad-range of principles and practices, aiming to achieve equilibrium in socio-economic growth and environmental stability within urban areas (Urban Sustainable Framework, 2018). Upon the practice of sustainable cities in the Mekong Subregion, it has yet aligned to the Basin’s vision in perceiving for balance with economically prosperous, socially just, and environmentally

⁷ “Global Platform for Sustainable Cities.” 2021. GPSC. Accessed 15 February, 2024.
<https://www.thegpsc.org/blogs/global-platform-sustainable-cities>.

friendly and sound.⁸ Consequently, the [Mekong River Commision](#) (MRC) aims to complete their mission to seize sustainable management, water development and its related resources⁹, in which it is likewise aligned to the mission.

SWOT Analysis

Under the same umbrella, all GMS members share common challenges and opportunities through the navigation to this rapid growth of urbanization. As pointed out, a better urban future depends heavily on the current works. Thus, the Mekong Basin is among over 90 countries that have been majorly-cooperatively striving for equitable social development and environmental-friendly sustainable for human well-being along with [UN-Habitat](#) with their new focus (**Table 2**).¹⁰

UN-Habitat’s focus	Reducing inequality and poverty gaps across urban-rural areas in the region (Lee and Kind 2021).
	Prosperously enhancing the economy locally and regionally.
	Calling for collaborative work on climate actions and Urban Environment .
	Strengthening urban crises prevention and response effectively.

Table 2: [New Focus for UN-Habitat](#), retrieved 28 February, 2024

Encountering issues, therefore, is undoubtedly inevitable, yet we may claim advantages urbanizations offer, in which the Mekong can thrive for a transformative, prosperous and resilient future. With a strong dedication to improve living conditions and advance sustainability, it is certain for the Basin to unpacking. SWOT (Strengths, Weaknesses, Opportunities, Threats) as identified below, along with the Table and its description.

⁸ “Vision and Mission.” *Mekong River Commission*. Accessed February 17, 2024. <https://www.mrcmekong.org/about/mrc/vision-and-mission/>.

⁹ *Ibid*

¹⁰ “Towards sustainable urbanization.” *UN-Habitat*. Accessed February 28, 2024. <https://unhabitat.org/About%20Us>.

<i>Strengths</i>	<i>Weaknesses</i>
<p>Environmental Conservation:</p> <ul style="list-style-type: none"> - Conserving natural resources - Strengthening energy efficiency - Effective waste management - Initiating healthy transportation systems. <p>Fostering Socio-economic Growth:</p> <ul style="list-style-type: none"> - Promoting basic needs (adequate housing, education and healthcare services) - Jobs/Employment opportunities - Human resources development - Attracting investment. <p>Regional Cooperation & Sustainable Development:</p> <ul style="list-style-type: none"> - Knowledge and information dissemination - Resources sharing - Collaborative practices - Up-scaling sustainable practices. 	<p>Improper Urbanization Maintenance:</p> <ul style="list-style-type: none"> - Intensities of urban-rural enlargement - Inappropriate management - Insufficiency living standard - Strained-public services. <p>Environmental risks:</p> <ul style="list-style-type: none"> - Competing demands - Overfishing - Hydropower dam construction - Improper management to human actions <p>Regional Engagement and Governance:</p> <ul style="list-style-type: none"> - A growing regional framework and lack of comprehensive management - Limited capacity - Lack of active engagement (public-private participation).
<i>Opportunities</i>	<i>Threats Dilemmas</i>
<p>Transitioning to Clean-Renewable Energy</p> <ul style="list-style-type: none"> - Hydroelectric power plants - Wind power plants - <i>Wind Turbines</i> - Rooftop solar arrays <p>Regional Economic Dynamics and Innovation</p> <ul style="list-style-type: none"> - Implication of resources efficiency and <i>Circular Economy</i> and <i>Green Economy</i> - Eco-friendly footprint - sustainable agriculture, eco-tourism, and green spaces - Water consumption - Water saving and drip irrigation in agriculture <p>Social Equity and Cultural Preservation</p> <ul style="list-style-type: none"> - Risk deduction and self-preparedness - Public space and participatory platform - Cultural-Traditional vitality - Revitalized and designation to the promotion of cultural-tourism, and community-based initiative 	<p>Demands Competition</p> <ul style="list-style-type: none"> - Different needs and aims between members and stakeholders - Socio-political tension (internal and external force) <p>Lack of Transparency and Accountability</p> <ul style="list-style-type: none"> - Non-cooperative work and a growing regulatory mechanisms - Inadequate development and ineffective management - Posing threats to neighboring countries and/or members <p>Inequality and Stocking Polarization</p> <ul style="list-style-type: none"> - Socio-economic disparities - Huge gaps in an unjust society or community - Environmental degradation and exploitation

Table 3: Unpacking SWOT, retrieved 19 March, 2024.

The compilation for this **Table** is all based on the elaboration below in the context of **Sustainable Urban-Development** during and post-initiation. Thus, it has been analyzed and developed in-hands by the Author.

Further, in accordance with the [Mekong River Commission for Sustainable Development](#), the Author has also inserted and linked the Basin-wide needs, challenges and opportunities, as it consists of a broad-range of fields to where the Mekong River Basin has to concretely consider in terms of proceeding into a more comprehensive development strategy and thriving for a safety-net to practical implementation.

More on: <https://www.mrcmekong.org/about/mrc/basin-wide-needs-challenges-and-opportunities/>

Strengths

There is a huge proportion of development and well-being in the Mekong Subregion that have been majorly impacted through sustainable urbanization, illustrating the potential to balance socio-economic growth and environmental progress.

For the environmental front, it emphasizes a strong commitment to conservation. As we may observe practically, ecosystems in the GMS consist diversely of farmlands, wetlands, forests, mangroves and so forth which accounted for between 20%-55% of the Basin's wealth (Environment in the Greater Mekong Subregion). To which, sustainable urbanization practices could preserve and restore these resources through measurement such as establishing green spaces, strengthening energy efficiency, effective waste management, and initiating healthy transportation systems.

Hence, delving into the socioeconomic dimension, it potentially serves as a catalyst for employment opportunities and [livable communities](#). Structural development of sustainable urbanization specifically fosters economic growth by initiating jobs and employment opportunities in wide-reaching sectors including construction, manufacturing, infrastructure, transportation and service. Along with the growing integration, the Basin is considered as one of the world's fastest-growing regions ("Labor Mobility") escorted by a huge investment majorly in innovation which prosperously improves living standards for the residents. Sustainable urban planning additionally prioritizes the provision of adequate housing and basic needs to healthcare services and education, ensuring the accessibility for inhabitants within the region.

Among the Mekong members on the other hand, sustainable development brings forth the six members together, while strengthening regional cooperation along relevant stakeholders. With close collaboration to share knowledge, information, best practices, and resources, it is believed to be significantly instrumental for the Basin to up-scaling to another level. Through an empirical platform like [The Greater Mekong Subregion](#)

[Economic Cooperation Program](#), partners across regional subdivisions can utilize such a collective approach into implementation of sustainable urbanization strategically and contribute to all actors within the region (Cortes 2021).¹¹

Weaknesses

With a large expansion on sustainable urbanization in the region, the GMS is considered to be on its fast-growing pace of development, imbalancing regional growth that noticeably poses consequential weaknesses of which socio-economic front, political-security and environmental sphere are no exception.

From the very beginning, the paper described a rapid-pace of population growth and urban development in the GMS. In accordance, intense pressure has been put on all members and collaborators, thoroughly considering infrastructure, goods-services, and resources. Facing such a vulnerable phase, it is crucial to reach a good urbanization maintenance. However, the dynamics has indicated about land use in urban-rural areas and its expansion to sustainable urbanization with intensities since 1990 (Cao et al. 2019). As such, this emerging-development and inappropriate management unquestionably lead to improper settlements, inadequate infrastructure, and strained public services. Besides, insufficient infrastructure and lack-of-basic services hinder regional economies, lower living standards, and impose inequality.

Considering the interests and cumulative impacts of urbanization, the activities in the region have led to environmental matters due to competing demands. And with the requirement of water and natural resources, it is often under-increasing, majorly because of population and economic growth (“Mekong Vision 3.0”). Talking of which, [Cumulative Impacts of Development](#) place the Basin at risk. Overfishing and hydropower dam construction particularly, and the above mentioned consequences have prolonged detrimental impacts on habitants around the Mekong river. The demonstration also claims the decline in [Fishing Engagement](#) across the region, dropping down from 50% in 2014 to approximately 37% in 2018 caused by the drawback of fish stocks. Conversely, human activities mark not only the needs of demands, but also the habitat degradation and reduction of fish stocks (Tilly 2021).

Focusing on regional engagement and governance, it is precisely ethical and substance to raise and re-consider vitally into the context of capacity building and comprehensive management. The GMS has brought upon over thirteen regional cooperation frameworks¹² for its solid basis, the riparian states however, have not consistently and properly adhere to the current coordination principles and coordination bodies. As follows, it has imposed multiple challenges in harmonizing the divergent interests and

¹¹ Based upon *The Greater Mekong Subregion Economic Cooperation Program Strategic Framework 2030*, it demonstrates a number of categories varying sectors, which plays the key-driver in socioeconomic development. Accessed March 1, 2024.

¹² “Mekong Cooperation Framework.” Ministry of Foreign Affairs and International Cooperation. Accessed March 7, 2024. <https://www.mfaic.gov.kh/Page/2021-02-08-Mekong-Cooperation-Framework>.

activities (“Mekong Vision 3.0 Program” 2021). The enforcement in regulations and sustainable urban planning on the other side, the Basin has not effectively performed well to thrive for sustainability efforts due to the limited capacity and proactive engagement (The Sustainable Development Goals Report 2023: Special Edition, 2023). Intrinsically, weak governance often issues public-private participations which makes a complex and difficult scenario to find common ground and reach compromises in relevance to sustainable development.

Opportunities

Inspecting the new inception, sustainable urban planning and management in the Mekong region has not only brought upon considered concerns and challenges, yet it has also instituted a variety of opportunities. Breaking down a more comprehensive means, the undergoing rapid-growth of urbanization highlights a multitude of opportunities to establish a more prosperous economy, equitable society, and sound environment.

Focusing specifically on the environmental dimension, the Mekong has started making use of its resources for green development and climate resilience. Concerning the transition of renewable energy, all of the GMS members have harnessed and boasted the abundant hydropower resources potentially. Moreover, the Basin has not only stayed on track on hydro-power source production, but they have also planted solar panels on rooftops on a large scale to significantly contribute to clean energy generation (HOANG 2023). Consistently, the onshore and offshore farms have been utilized in the GMS that uses wind resource constructions, which can further diversify the energy mix and promote energy production in a clean-and-sustainable way.¹³ Delving specifically to hydroelectric power plants in Vietnam for instance, the Hoa Binh Hydroelectric Power Construction is one successful project based on the decision of the People’s Committee of Hoa Binh Province, which was recognized as a local tourist attraction since 2014.¹⁴ Notwithstandingly, the huge industry has a number of remarkable features to grab lots of attention from tourists as such: the engine tunnels, operation center, the monument, the museum of hydro-power station, and the greeny-dams.¹⁵ Following this, the Mekong managed regional trade and power in the subregion from 2004-2022 through the [Regional Power Trade Coordination Committee \(RPTCC\)](#). The committee has later on formally transitioned to the [GMS Energy Transition Taskforce \(ETTF\)](#) in July 2022. The introduction of such a task-force aims to foster and usher a close cooperation in energy with ASEAN and other relevant collaborators with the implication of the initiatives such as the ASEAN Power Grid (“ASEAN Power Grid - Enhancing Electricity Interconnectedness”).¹⁶

¹³ “Renewable Energy Developments and Potential in the Greater Mekong Subregion.” 2015. Asian Development Bank. Accessed 15 March, 2024. <https://www.adb.org/sites/default/files/publication/161898/renewable-energy-developments-gms.pdf>. Potentially unpacking renewable energy development through navigation and evaluation based upon each individual country of the Mekong, consisting of Cambodia, Laos PDR, Myanmar, Thailand, and Vietnam. Further, as there are a variety of key-factors, the Author has therefore focused particularly on Wind and Solar Arrays Installment.

¹⁴ “Explore Hoa Binh Hydroelectric Power Plant.” 2022. Hoa Binh Tourism. Accessed 10 March, 2024. https://hoabinhtourism.vn/en/detailnews/?t=explore-hoa-binh-hydroelectric-power-plant&id=news_802.

¹⁵ Ibid

¹⁶ Learn more on: Memorandum of Understanding on the ASEAN Power Grid.

Nonetheless, this has sparked regional economic dynamics and innovation into new inaugurations while up-scaling the Basin's growth in a more viable-clean manner. In a similar elaboration, the Mekong also adheres vitally to the implication of resources efficiency and circular economy. Along with the advancement of digital technology, the Mekong River conservation and management has been practicing greatly to water consumption in the region through water saving and drip irrigation in agriculture (The water-food-energy nexus in the Mekong region, 2013). Thus, with a good waste management and green infrastructure into a circular economy, the Mekong Subregion has further promoted the use of sustainable building materials as bamboo, and retrofitting to mark eco-friendly footprint in the construction in small-medium scale (Towards a more resource-efficient and circular economy, 2021). As the environmental risks have been minimized, the Basin has opened another beginning for green infrastructure¹⁷ and green finance¹⁸ to further enhance green spaces, facilitate air quality, provide a market for green technologies, goods and services (Mir 2013).^{19,20} Referring to the tourism sector, it has been amplified significantly and earned its momentum by distributing tourists with authentic traveling-experience. Based upon the sustainable tourism development and proactive engagement from various actors in the GMS, there are a number of activities to attract millions of tourists such as: community-based tourism, ecotourism, and local products which is certainly an indication of a successful initiative ("Tourism").

Equally importantly, this has taken its role as the cornerstone of achieving social equity and cultural preservation, to which the whole region is familiar with work-handling in health issues and risk deduction, along with self-aware preparedness to environmental and health concerns. With a fast-pace of sustainable urban-rural development, it is believed that the Basin has been well-prepared, providing the local and tourists enough public-space, cultural and traditional vitality. It is correspondingly implied to community consultation, participatory budgeting, and affordable housing options in which it produces social-safety nets for vulnerable individuals, groups and/or populations (Barrington, Dobbs, and Loden 2012, 43-46). Specifying to a more comprehensive to cultural front, the GMS consists of a rich cultural heritage, with a diverse ethnicities and invaluable traditions, that is needed to revitalize and design to promote cultural-tourism and reflect its diversity in sustainable means (Urban Development Working Group Events) (Cities Culture Creativity, 2021). Factually, Cambodia, in particular to Phnom Penh and Siem Reap have focused on a community-based development initiative to incorporate traditional Khmer architecture into new construction. The eye-catching and heart-grabbing sight to such buildings has been renovating historic-adaptive revenue as shops, hostels and cafeterias and initiating green-grassy patch (Chamna 2023). And most

17 "Sustainable Mekong | Archive - U.S. Agency for International Development." Archive - U.S. Agency for International Development. Accessed March 11, 2024. <https://2017-2020.usaid.gov/asia-regional/sustainable-mekong>.

18 "Mobilizing Financing for Climate Smart Investments in the Mekong Delta: An Options Note." World Bank Group. Accessed March 11, 2024. <https://documents1.worldbank.org/curated/en/554451593619833314/pdf/Mobilizing-Financing-for-Climate-Smart-Investments-in-the-Mekong-Delta-An-Options-Note.pdf>.

19 "Green Development Key to Growth in Mekong Region." February 2012. Asian Development Bank. Accessed March 11, 2024. <https://reliefweb.int/report/cambodia/green-development-key-growth-mekong-region>.

20 "Greater Mekong Subregion Climate Change and Environmental Sustainability Program." December 2019. Asian Development Bank. Accessed March 11, 2024. <https://www.adb.org/projects/53390-001/main>.

recently, Cambodia had conducted a workshop in Battambang Province once, aiming to further disseminate understanding to the shared cultural heritage with a shared effort to UNESCO in distribution of its impact in the Mekong River Basin (SASAKI 2023).

Threats

Acquiring opportunities is definitely a good option to make a start, beginning with structuring sustainable urban-initiative and taking such inception into account for implementation. The Greater Mekong Subregion, therefore, can inexorably be facing countless threats due to the up-coming unveiled phenomenon such as climate change, potential dilemma, and beyond during and post-construction of sustainable urbanization. Redirecting to demands competition, on the other hand, it lays upon the needs of each individual state to natural resources, commonly in between the upper and lower basin of the Mekong. As can be observed, such fast-paced urban-development most often drives members with different needs and interests, dividing the upstream and downstream to assert on water flow and sediment levels for example. Further, each state claims to obtain the resources which outlines a complex dilemma for irrigation, transportation, and the rich ecosystems. And as a transboundary water, it considerably can be due to a socio-political tension, fundamentally shaped by a complete-diverse interests ("WATER DIPLOMACY IN THE MEKONG" 2020). In alternative, it is based on the decisions to benefit one sector or group, while negatively impacting others, which it is either retrieved from the internal or external force. Focusing a strong interpretation to the [Competition](#) itself with the external force, for a concrete instance, it is clear between China and member states about dams, waterways, movements for agrifood-goods-services, and security (Chantra and Middleton 2021). Yet, the US takes Beijing's influence seriously and actively opposes their power and authority in the area.²¹ To such a restriction from the opposition-side, it is regular on the international arena that the Mekong River Basin turns to be another stage for US-China competition.²²

Nevertheless, as some states have their own stance, forming alliances or joining blocs with others to affirm and secure the needs, it is unavoidable for the occurrence of the lack of transparency and accountability. In aiming for sustainable urban development, it is indispensable for the joint-efforts. However, with tension and other major components, the governance institution may encounter ineffective management that leads to the lack of transparency and accountability ("Strengthening Urban Management and Service Delivery through Performance-Based Fiscal Transfers" 2022). The non-cooperative work and a growing framework to the Mekong region, on the other side, can also hinder sustainable urbanization and inflict a conducive environment to corruption and inadequate urban development ("Global Corruption Barometer - Asia Transparency.org" 2020). Its cause and effect can be seen through public participation with a limited space in the decision-making process ("The Participatory Slum Upgrading Programme" 2020).

²¹ Chantra, Thanikun, and Carl Middleton. 2021. "Cohabitation, Cooperation and Competition in the Mekong River Basin | Heinrich Böll Foundation | Southeast Asia Regional Office." Heinrich Böll Stiftung Southeast Asia. Accessed 18 March, 2024. <https://th.boell.org/en/2021/07/19/mekong-cooperation>.

²² Ibid

Furthermore, the indication is clearly illustrated with not only the engagement to the public-participation, but it also highlights ineffective regulatory mechanisms and weak enforcement in the region.²³ Typical occasions in the Mekong to the joint-efforts can be hardly drawn, and it could somehow threaten one another. An empirical fact, China has planned on funding canal-construction with USD1.7 billion in the southern part of Cambodia. Such a project, it is undeniably enraging Vietnam, even though the Beijing-built canal aims to divert Mekong trade (BROOK 2024).²⁴

To another angle of sustainable urbanization, an immense issue about exacerbating inequality and stocking polarization may arise. With a brief overview inserted in **Table 1**, the Basin has experienced major socio-economic disparities between urban-rural areas. Along with the varying levels of development and inequality to each member, it has led to widening-gaps and further intensifying an unjust society, while deliberately obstructing sustainable development efforts. Due to the fact of having a collectively diverse ethnics and cultures, on the contrary, discrimination and exclusion of certain individuals or groups would lead to social-divide in inclusiveness and cohesion for a sustainable and integrated development. In addition, polarization between affected society and potential stakeholders would also result in displacement of local communities and certain groups in the area, issued by large-scale infrastructure construction, projecting land concessions, and resources extraction. It is essential to dive deeper into the conflicting interests as the cause is argumentative due to a number of natural resources such land, forests, minerals, and water. The occurrence of such overlapped views is competitive as local communities, minorities or indigenous groups, government agencies, investors, and potential collaborators claim to derive. As such economic gains to sustainable urban development, moreover, it tends to concentrate on the unequal distribution, imposing social tensions and stocking polarization within the area. Through navigation to sustainable development within the GMS, it is undoubtedly concerned over environmental degradation and exploitation including: deforestation, habitat destruction, and pollution. These disproportionate impacts would result substantially in the loss of ecosystems and biodiversity (Krawanchid and Middleton 2014, 72-90, 97-111). It could consistently generate issues to environmental justice, to where a certain group may need to handle the burden vulnerably with or less benefit (Meynell, Metzger, and Stuart 2021).²⁵

²³ With wide-reaching sources acquired from the website - secondary source, the Author has entailed and inserted based upon four sources with the below description. Accessed 18 March, 2024.

World Bank - to the insights into governance challenges in urban development,

Transparency International - insights to corruption perceptions in Asia which the GMS is included,

Asian Development Bank - overview of urban-development concerns within the region to the role of regulations and enforcement within the context of sustainable urbanization, and

Participatory Slum Upgrading Programme (PSUP) - overview and case studies of community participation in urban-development for best practices.

²⁴ Blake, David. 2024. "Cambodia's canal project would link its coast with the Mekong River." Radio Free Asia, January 23, 2024. <https://www.rfa.org/english/news/cambodia/mekong-canal-01232024123124.html>. Accessed 19 March, 2024.

²⁵ Within the context of unveiled threats up-coming to occur in the GMS, threats can be arisen in a variety of manners during and post construction of Sustainable Urban Development. Hence, the Author has then focused on retrieving relevant information and insights based on the description below. Accessed 19 March, 2024.

The Greater Mekong Subregion - Environment: overview of the environmental issues which threaten the whole region and indicate the costs of neglecting major concerns.

Pathways Forward: Cross-Cutting Initiatives for Greater Impact

Under the narrative of sustainable urbanization through unpacking SWOT, the paper has conceptualized and outlined the importance of the Mekong River that holds undeniable value to all actors. Carrying out a number of benefits from water-based resources to geopolitical leverage, it is crucial for thriving the balancing acts among members and shareholders. The Basin, thereafter, should also look forward to what lays ahead to anticipating negative circumstances and positive outcomes accordingly. And in alignment to a practical world, it is even essential to address the concerns, as well as to have a good implementation with a multi-pronged approach.

In resolving the dilemmas as mentioned above, the practice of sustainable urban-development is an essential tool. Yet, focusing specifically on the mixed methodology would be a flexible step to move forward.

In recognition of the concerns (**Table 1**), accommodating well-planned and compact cities are strongly considerate which contributes to the population with high-density that can be raised up to double or triple. In this way, it can reduce reliance on personal and/or private vehicles and land consumption, while a part of this method supports the environment. To its consistency and the Basin's practice, it is concretely suggested to adapt-and-adopt the efficient resources management in terms of ensuring the demands which includes but not limited to: water, energy, or land - as to preserve and sustain its dynamic resources in a larger scale and a broader scope. During and after the process, moreover, [Spatial Planning](#) can be illuminated to such methodology as an essential potentiality in thriving sustainable urbanization in the GMS as to identify intensively to strategic allocation and the use of resources within a specific geographical arena. In alignment to that, it also contributes to regional and cross-border planning due to its transboundary characteristics.

The GMS needs to concretely pay close concentration on resources management and embrace the [Circular Economy](#). This methodology implies [Integrated Water-Resources Management](#) (IWRM) and smart irrigation in the ever changing world of internet-based, it tracks the path to [Green Economy](#). For instance, Phnom Penh Water Supply Authority (PPWSA) has implemented smart management systems in Phnom Penh that use advanced technologies, consisting of remote sensors, data-monitoring, and detection algorithms.²⁶ Further, agriculture is considered as a key component to bolster regional economic growth, accounting for over 60% of 340 million inhabitants involved in small-scale

Urbanization and Sustainable Development in the Mekong Region, Academia.edu: demonstration of the correlation of rapid urban-development and environmental degradation and exploitation. Hence, this article majorly discusses infrastructure development and resource consumption associated with the expansion of urban areas that is now threatening livelihoods and ecosystems.

Valuing Ecosystem Services in the Mekong Region, Academia.edu, the article vitally emphasizes the transition of sustainable urbanization.

²⁶ JAPAN INTERNATIONAL COOPERATION AGENCY and YANGON CITY DEVELOPMENT COMMITTEE (YCDC). "Report on Institutional Improvement Plan Based on the Third Country Research Study in PPWSA, Cambodia." Accessed March 7, 2024. https://openjicareport.jica.go.jp/pdf/12362349_04.pdf.

agriculture, supporting the livelihoods directly of millions of individuals (Garcia). To such, the focused project of ADB-supported in the Lower Mekong Subregion, considered as a key component to bolster regional economic growth, international trade and investment - as of promoting inclusive and sustainable development through economic corridors (MRC 2022, 42-126). Following that, Vietnam has utilized the use of nature-based solutions like rooftop solar and wind turbines, lowers operational costs for farmers and supports renewable energy production (Phu 2022). With the emerging of advanced technologies, the implication is supportively considerate to M&E, while directing to renewable energy production while assisting to Regulatory Mechanism and Practices, as well as [Policy Reforms](#).

The inauguration, on the other hand, has sparked a new journey of [Green Finance](#), a key element affiliated to the green economy. And in pursuit of sustainable resources management, it incentivizes investment in eco-friendly projects while minimizing risk and environmental impact. To be precise and concise, this approach prioritizes building climate resilience, vital for the region's long-term health. Therefore, it also fosters social well-being by establishing safety nets and promoting equitable livelihoods, ensuring a just transition. Notably, incorporating nature-based solutions like rainwater harvesting and floodplains into urban planning and infrastructure development can achieve this two-pronged approach. Implementing these solutions not only mitigates climate risks but also generates cost-savings, making the adoption both sustainable and financially advantageous. Besides, holding its impact-driven nature of the characters, participatory and inclusive planning is crucial for the Mekong Basin's urbanization. Yet, incorporating diverse voices and perspectives, the process ensures social needs and cultural considerations are met, leading to a more equitable and inclusive urban development. This requires unwavering cooperation and dialogue among Mekong members, facilitated through public consultations, discussions, and roundtables. However, long-term engagement is essential. Moving beyond one-time consultations, the focus should be on fostering inclusive ideas and building consensus through sustained participation. This collaborative decision-making process will ultimately highlight shared priorities and lead to more comprehensive and innovative solutions for the region's urbanization challenges.

Primary Considerations

As the GMS consists of over 15 regulatory mechanisms and cooperation initiatives as emphasizes of and not limited to: bilaterally, tri-laterally and multilaterally. As such, it majorly factors the Mekong Basin to state's practices. Comprehensively, there seems be redundancy of sustainable practice where it can lead to:

- *Insufficient Use of Resources*
- *Limited Impact of Uncoordinated Efforts*
- *Difficulty in the Tracking Process*
- *Varying Level of Commitment.*

To the empirics of **Waste Management** in the Mekong subregion, each individual country may have varying policies on waste management, waste treatment, renovating process, and so on. Further, specifying on Urban **Infrastructure Development**, there is a vital inconsistency and contradiction on regional connectivity and environmental sustainability.

The Author's Point of View to Practical and Applicable Solutions:

- (1) Strengthening Coordination: streamlining initiatives and ensuring regional cooperation through the promotion of communication and a thorough collaborative effort.
- (2) Policy Reforms and Harmonization: securing and ensuring the alignment of national policies-and-practices and regional development.
- (3) Monitoring and Evaluation (M&E): tracking progress and identifying specific areas to encompass further improvement for transparency and accountability.

Differentiate its significance to bilateral, trilateral, multilateral and incremental initiatives:

- **Bilateral and Trilateral Cooperation:** easy to state specific to the focus areas between two and three dialogue partners - to which this promotes resource sharing, information exchange, and the development of cooperative initiatives for sustainable urban development, entailing developing shared environmental standards, collaborating on infrastructure projects, and exchanging expertise on green technology.
- **Multilateral Cooperation:** contains cross-national organizations and various stakeholders with different interests and aims, to where that can be somehow hard to accomplish the set-target. The complexity pops up when some clauses and sub-clauses are overlapped, misstated, non-informative, and/or non-specific.

Suggestion Based on the Author's Point of View:

- **Incremental Cooperation:** *a methodology of achieving progress through a series of achievable steps gradually and steadily by selecting or scoping well-chosen, smaller*

initiatives acting as stepping stones. Pilot projects testing innovative green building codes could pave the way for widespread adoption. Strategically targeted investments in renewable energy sources could illuminate cities with a cleaner future. Similarly, phased improvements to public transportation systems could evolve into seamlessly connected urban networks. Each of these steps serves a dual purpose: they provide tangible evidence of progress while functioning as valuable testing grounds. This iterative approach allows for course correction and adaptation as needed, mitigating risks and fostering long-term success. Ultimately, the Greater Mekong Subregion can build not just sustainable cities, but adaptable and thriving ones through this emphasis on achievable, incremental progress - where can be implied both: bilateral and trilateral, or multilateral initiatives.

Conclusion: A Flourishing Future for the GMS

In conclusion, the Greater Mekong Subregion (GMS) boasts immense potential due to its abundant resources. However, unlocking this potential hinge on the **Strategic Implementation of Sustainable Urbanization Practices**. This necessitates a multi-pronged approach that prioritizes resilient infrastructure development, promotes environmentally conscious urban planning, and fosters inclusive economic growth throughout the region. Collaboration between GMS members and relevant stakeholders is crucial for creating a comprehensive roadmap and ensuring effective implementation. By prioritizing these actions, the GMS can transform into a flourishing region, where sustainable practices ensure a prosperous future for generations to come.

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AMIDST CLIMATE CHANGE, ASSESSING HYDROPOWER DEVELOPMENT EFFECT ON AGRICULTURE SECTOR IN LOWER MEKONG BASIN: CASE STUDY OF CAMBODIA

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Introduction

The world is getting hotter and hotter day by day, resulting in rising sea levels from year to year. Climate change has posed significant impacts on ecosystems, biodiversity, food security, water resources, and human health, disproportionately affecting vulnerable communities, particularly in Mekong regions in the form of rising Earth's temperature, melting down the ice caps, altering weather patterns, etc. The Mekong River has been divided into two basins: the Upper Mekong Basin, consisting of China and Myanmar, and the Lower Mekong Basin, containing Northeastern Thailand, Lao PDR, Cambodia, and Southern Vietnam (MRC, n.d.). Regarding the climate risk profile of countries in LMB, they share some similarities due to their geographical proximity and reliance on the Mekong River system; however, their climate vulnerabilities and impacts seem to be varied.

Cambodia

A small country in Southeast Asia, bordered by Laos, Thailand, and Vietnam, has two great water resources, which are the Tonle Sap Lake and the Mekong River. The climate of Cambodia is tropical, with high temperatures and two distinct seasons: a dry season (November–April) with lower temperatures, especially between November and January, and a rainy season (May–October) driven by the monsoon and bringing clouds and moisture that contribute to 80%–90% of the nation's annual precipitation. Because of its high levels of exposure and susceptibility, Cambodia is particularly vulnerable to natural disasters like drought and flooding. The temperature in the early dry season could reach 32 degrees Celsius and remain between 25 and 27 degrees Celsius during the rainy season, while the average rainfall in the rainy season is typically between 1,400 and 2,000 millimeters. The El Niño Southern Oscillation also has an impact on Cambodia's climate pattern; during this period, Southeast Asia typically experiences warmer and drier winter temperatures, while La Niña episodes bring lower-than-normal temperatures (Bronkhorst and Bhandari 2021, 5-7).

Laos

As a landlocked country in Southeast Asia, Laos seems to share a similar climate pattern with other countries in the LMB. Due to the southeast monsoon, Lao PDR experiences a tropical climate with high humidity and 70% annual rainfall. Rainfall can reach 3,000 millimeters (mm) in an average year. The plateaus and hilly regions in the north and east had mean yearly temperatures of 20°C, while the lowlands had higher temperatures of 25–27°C (Bronkhorst and Bhandari 2021, 5). The Mekong River plays a very important role in the livelihood of Laos' people and the socio-economic factors in this country. This country is rich in natural resources; however, Lao PDR has a low capacity to adapt to climate change because of its poor socioeconomic development, which results in frequent floods and droughts. According to Lao PDR's Second National Communication to the UNFCCC (Lao PDR, 2013), climate change will have a significant influence on the nation's agriculture, energy, health, and water and forestry resources

Thailand

Thailand, which lies in the middle of Southeast Asia, experiences seasonal monsoon winds that affect its climate. Thailand has a varied topography, with coastal plains in the south and mountainous areas in the north, all of which influence the country's climate risk profile. The weather is not different from its neighboring countries. April and May are the warmest months in Thailand, while December and January are the coldest. With a seasonal temperature fluctuation of 5.7°C (between lows of 23.2°C and highs of 28.9°C), the mean yearly temperature is 26.3°C. Meanwhile, the average rainfall in Thailand is 1,542 mm, with the most rainfall happening from May to October (Bronkhorst and Bhandari 2021, 5). According to the INFORM Risk Profile (European Commission, 2019), Thailand also faced several natural disasters, such as flash floods and coastal flooding, tropical cyclones, droughts, and heatwaves, that affected the livelihood of Thai people, socio-economics, the tourism sector, and the agriculture sector of the country.

Vietnam

The Mekong River flows from China to the last Southeast Asian nation, which is Vietnam. Vietnam experiences both tropical and temperate climates, with the yearly monsoon having an impact on the whole nation. Monsoon circulations, which bring intense rainfall to the north and south from May to October and the central areas from September to January, are associated with rainy seasons. The precipitation does not change much in Vietnam; meanwhile, climate change has affected the temperature in Vietnam. There has been a noticeable increase in the frequency of "hot" days and nights in all seasons, while there has been a large drop in the yearly frequency of "cold" days and nights (Bronkhorst and Bhandari 2021, 4). Vietnam is subject to the El Niño Southern Oscillation (ENSO), which influences sea level, the frequency of droughts, and the incidence of diseases, just like other nations in LMB. Besides its positive impacts, the landscape of the Mekong River's flow also has negative impacts on Vietnam's agriculture. Vietnam has been ranked among the five countries likely to be most affected by climate change.

Agriculture Landscape in LMB

a. Cambodia

Cambodia is a market economy country whose sources of income are 37.67% of industry, 33.74% of agriculture, and 21.87% of the service sector (Aaron 2023). Even if its percentage of the gross domestic product (GDP) has decreased due to climate change and global crises, the agriculture sector is still one of the key forces behind Cambodia's economic growth that possibly could contribute to the country's goal of becoming an upper middle-income economy by 2030 and a high-income nation by 2050, said Hun Manet, Prime Minister of Cambodia (Vanyuth 2023). 49% of the workforce in Cambodia is employed in agriculture and fishing, which account for 25% of the nation's GDP. The current agriculture practice in Cambodia is family-based traditional methods, and the government has been working on promoting modern agriculture methods. Based on government data, the export of agricultural goods brought in \$3.9 billion in total income to Cambodia in the first 11 months of 2023. Because of the abundant rainfall that occurs throughout the monsoon season (May to October), Cambodia has a favorable climate, which is ideal for cultivating rice, cassava, rubber, cashew nuts, peppers, corn, and many tropical fruits such as mango, banana, etc., and these kinds of crops have been exported to foreign markets (Invest in Cambodia 2020).

Looking into the agricultural practices of Cambodia, rice is the main commodity, and due to a lack of substantial irrigation infrastructure, Cambodia has historically only produced one rice harvest annually. Conventional agricultural practices call for planting in July or August and harvesting in November through January. In places with fewer irrigation systems, rainfall determines crop size and quality. Livestock and fisheries are also important in the domestic economy (Chandler and Overton, 2024). Tonle Sap Lake and Mekong River have gained plenty of benefits to the agriculture sector and the livelihood of Cambodian people living along the landscape.

b. Laos

Lao PDR is a hilly nation with only 10.6% agricultural land. With its topography, agricultural land is dispersed, such as upland agriculture (Northern mountains), areas along the Mekong River, Vientiane Plain, and southern plains (ADB 2018). Agriculture will contribute 14.87 percent to Laos' gross domestic product (GDP) in 2022 (Aaron 2024). Like Cambodia, rice is the major crop in Laos, which accounts for 50 percent of the national agricultural output. Other important crops that are farmed for both commercial and subsistence use are coffee, bananas, maize, and cassava, as well as livestock productions that contribute significantly to household and national income, with the majority of agricultural households keeping some animals for usage in savings accounts or commercial sales. The agriculture system in Laos is divided into 5 main types: lowland rainfed farming, lowland irrigated farming, upland farming, plateau farming, and highland farming. Laos is transitioning from a subsistence to a market-oriented agricultural economy (Sacklokham 2014, 144-145).

Laos also faced several challenges in its agriculture sector, such as limited access to cultivated land, vulnerability to climate change impacts, and an inadequate irrigation system, which caused agriculturally reliant communities to face crop failures (World Vision 2023). The Mekong River plays a very important role in Laos' agriculture sector. The majority of the provinces that produce the most rice is situated near the Mekong River, and a protracted drought has resulted in dramatically lower water levels and a delay in the seasonal monsoon rains in the Mekong River basin (RFA 2019).

c. Thailand

Thailand's agriculture is not quite different from that of other countries in the region. Agriculture accounts for only six percent of Thailand's GDP, but the sector employs around one-third of the country's labor force (ITA 2024). Roughly 52% of the 127 million acres of land are suitable for agriculture. Rice has long been the breath of Thai agricultural society and has played a significant part in the nation's traditions, despite the diversity of crops there. After Vietnam in 2021, Thailand is among the top 10 producers of rice globally. In addition to rice, the nation's agricultural plantations also include rubber, sugarcane, cassava, and other important crops, including onions, garlic, potatoes, and shallots. Sugarcane production in Thailand has also been the greatest crop in recent years, accounting for 105.9 million metric tons. In addition to raising crops, raising cattle, fisheries, and aquaculture have been vital to Thailand's food security and have a substantial GDP contribution (Statista 2023).

There are five types of agricultural practices in Thailand, which are integrated farming, organic farming, natural farming, agroforestry, and new theory farming (Bronti 2018). Thai's government also introduced a Good Agricultural Practice (GAP) standard that covers provisions of good agricultural practices (GAP) for food crops such as vegetables, fruits, field crops, spices, and herbs at every step of farm and postharvest handling where produce is packed and/or collected for sale to obtain safe produce of proper quality for consumption by taking into account the environment, worker's health, safety, and welfare (Ministry of Agriculture and Cooperatives 2013). However, the agriculture sector in Thailand still faces several challenges, such as climate change, labor shortages, a lack of irrigation systems, high agricultural input costs, and a lack of production planning and management. Climate change impacts are projected to increase the frequency and severity of floods, droughts, extreme weather events, sea level rise, and high temperatures, which destroy rice and other crops unable to cope with floods and increase water stress for farmers in drought-prone areas.

d. Vietnam

Located at the end of the Mekong River flow, Vietnam also shares the same agricultural pattern as other countries in the Indochina region. Most of the cultivation practices happened in the Red River Delta, the Mekong River Delta, and the Southern Terrace region. Similar to other countries, rice is the main crop grown in Vietnam. Sweet potatoes, coffee, sugarcane, cassava, corn, and nuts are the next most popular crops (Duiker et al.,

2024). Agriculture also plays a crucial role in Vietnam's economy. In 2023, the GDP of Vietnam was mostly derived from the agricultural, forestry, and fishery sectors, accounting for around 11.96 percent of the total GDP of the nation (Statista 2024). In 2022, Vietnam's agriculture industry will have grown at its fastest rate in recent years, at 3.36 percent. A total of 2.88 percent rise in farming, 4.43 percent in fishing, and 6.13 percent in forestry were included in this statistic (Uyen 2023). Vietnam has shifted from its traditional extensive agricultural production to intensive agricultural crop cultivation.

However, climate change has been a hindrance to its agricultural sector. Vietnam is very vulnerable to the increasing consequences of climate change and often faces several disasters, including droughts, floods, unstable river flow, and saltwater intrusion (Uyen 2023). Under UNDP support, the Vietnamese government has also been modernizing the country's agricultural sector to increase climate resilience (Phan 2024). This project has integrated and encouraged those in the agriculture sector to promote clean energy, like using solar energy, green innovation that uses eco-friendly lighting, integrates digital transformation, and promotes carbon footprint tracking systems.

Rice has been an important crop for all countries in the Lower Mekong basin, and it demands a well-structured irrigation system to support it. Meanwhile, the water flow of the Mekong River from the upper stream to the lower stream also plays a very essential role in their agriculture sector. However, climate change has also been one of the challenges affecting the sector. Not to mention, coping with the climate change issue, the hydropower dam development along the Mekong River could also hinder growth in the agriculture sector.

Current Status of Hydropower Development on the Mekong River

The Mekong River has been filled with many hydropower dams, approximately more than 160 dams, from the upper stream to the lower stream, mostly located in China and Laos (Carolyn, November 2023). 13 dams are on the river's mainstream, and hundreds more are planned or under construction. On the upper Mekong basin, known as Lancang in China, six dams have been built, two of which are the biggest storage dams, Xiaowan and Nuozhadu, that provide impacts to the lower stream such as changes in water flow, impacts on fisheries, sediments, and downstream community livelihoods (MRC, n.d.). Meanwhile, in the lower Mekong basin, hydropower development has expanded, and 11 projects are planned for the mainstream. As of 2019, 89 hydropower projects in Cambodia, Laos, Thailand, and Vietnam generate 12,285 MW of total installed capacity (MRC, n.d.).

Looking into the current trend of hydropower dam development in the Lower Mekong Basin, each nation shares different perspectives. Cambodia currently has 7 hydropower dams, two of which are located on the mainstream of the Mekong River: Sambor Dam and Lower Sesan 2 Dam. All of these hydropower dams have generated 60 percent of the country's energy mix, and the government aims to push it up to 70 percent by the end of the decade. Understanding the consequences of hydropower dam construction on the

Mekong River, Cambodia's Prime Minister, Hun Manet, said that constructing dams on the mainstream of the Mekong River would have a huge impact on the river's ecology (Sebastian 2023). While presiding over the groundbreaking ceremony for the construction of the Stung Tatai Leu Hydropower Dam of 150 megawatts in the Thmar Baing district of Koh Kong province, he also underlined that the 7th-mandate Royal Government will not build dams on the Mekong River, no matter what the benefits are (Sok 2023).

To become the "battery of Southeast Asia," Laos has 9 dams planned on the mainstream of the Mekong River, 2 of which are in operation: Xayaburi Dam and Don Sahong Dam; Luang Prabang Dam is under construction; and 6 more dams are planned (Andrew 2022). Additionally, Laos is also moving forward with a contentious 86 MW project that would be located on the Sekong River, which is a significant Mekong tributary and one of the few surviving fish migratory routes in the river basin (Carolyn, March 2023). The other planned dams are still in their initial stages, while the Luang Prabang Dam has reached the advanced stage of its development. The World Heritage Committee put the ongoing construction of the Luang Prabang Dam on hold until an evaluation of the project's potential effects on the World Heritage Sites was completed (Roseanne 2021). By 2025, Laos wants to have 30 percent of its energy come from renewable sources.

Thailand has one dam, the Pak Mun Dam, that flows from a tributary of the Mekong to the Mun River in northeastern Thailand. The dam on the Mun River is not only negatively impacting the entire region of northeastern Thailand but also downstream countries such as Laos, Cambodia, and Vietnam. It was developed to supplement the national power grid of the nation. However, the dam also harms the lower stream by blocking the fish flow in the entire basin (Akarath, Ian, and Zeb, 2021). Thailand doesn't have a hydropower dam on the mainstream of the Mekong River; nevertheless, Thailand also imports electricity from Laos as well. However, Thailand's counterpart also warned Laos that they would stop purchasing electricity from Laos if Laos kept developing hydropower dams. Thailand also suggests Laos seek other alternative renewable energy sources rather than depending on hydropower dams.

Located at the end downstream of the Mekong River basin, Vietnam only has hydropower dams on the Mekong's tributaries, such as Son La Dam, Lai Chau Dam, Dong Nai Dam, Huoi Quang Dam, and Chian Dam. Vietnam's government recently approved the National Electricity Development Plan for 2021–2030 with a vision to 2050, known as Power Development Plan 8, which highlights the plan for Vietnam's electricity generation and Vietnam's strategy for achieving renewable energy development such as wind, solar, hydropower, biomass energy, etc. (Mark 2023). Diverse viewpoints exist on the future of hydropower development in Vietnam. Even though Vietnam understands the impact of the hydropower dam on its country, hydropower development still plays an important role in the electricity sector in the country, and Vietnam will have completed the hydropower development plan by 2030 (Gemma 2019).

Impact of Hydropower Development and Climate Change on Agriculture in LMB: A Case Study of Cambodia

Hydropower development in the Lower Mekong Basin brings both positive and negative consequences. The growth of hydropower benefits other water-related industries, such as extending irrigation, which is essential for food security; supplying electricity, which is important for reducing poverty; facilitating navigation, which improves regional trade; and managing floods and droughts, which is crucial for climate change adaptation. However, the potential costs also come along with the benefits. Hydropower development provides negative impacts such as the decline of fisheries, loss of forests, wetlands, and mangroves, reduction of sediment due to dams and sand mining, and reduction of rice growth that bring uneven results between these countries (MRC, n.d.). The construction and maintenance of the hydropower dams would probably have a detrimental effect on the Lower Mekong Basin's cropping schedule, land usage, and agricultural output. In the worst scenario, the effects of climate change and hydropower development will reduce up to 90% of delta sedimentation and 95% of the sediment that reaches the sea, which is thought to have severely reduced fisheries and agricultural output. The building of the dam is expected to have an impact on the wetlands and floodplains that are periodically flooded near Tonle Sap Lake and the Mekong Delta.

The hydropower dam's construction upstream and in Laos reduces the water flow, causes sedimentation, causes displacement, and disrupts fish migration toward not only Cambodia but also the Mekong Delta, and Vietnam. Synchronized with hydropower dams that affect water availability, climate change also introduces significant uncertainties in rice cultivation and production in Cambodia, which is an essential crop for the nation. Rice is a rainfed crop. The significance of rainfed rice is vital and accounts for over 90% of rice production in Cambodia. Cambodia produces rice for two seasons: the rainy season and the dry season. In the rainy season, rice depends on the rainfall, while in the dry season, it depends on the water availability from the river or water reservoirs. Due to hydropower development, rice production in Cambodia decreased by 3.7%, and most rice farmers in the Mekong Delta were prepared to decrease their rice yield and substitute it with alternative ecosystem services to mitigate the impact of dam building and climate change (Yuichiro et al. 2020). However, climate change delays the rainy season, and hydropower dam development restricts the water availability that is needed to support crop production. Another scenario is during the wet season. When the dam releases water from upstream, it causes flash floods in lower regions like Cambodia and Vietnam. This abnormal flood could damage or destroy rice crops. Not only do hydropower dams slow down the water flow, but they also cause significant sediment loss in Cambodia. The sediment delivered upstream to the deltas in Cambodia provides rich nutrients and helps to maintain habitats. Sediment loss first affects the productivity of crops in deltas, and it also puts the fisheries in the area at risk (Yuichiro et al. 2020).

Take the example of the hydropower dam on the Sekong River that flows from Laos to Cambodia. It restricted the amount of water flow, blocked vital sediment, and cut off

migration routes for a range of fish species. Moreover, a surprising flood occurred when the upstream dam released water. Sisuwath, the head of the fishing committee of Kang Speu village in Siem Pang district, Steung Treng Province, stated that the dam would likely have a devastating effect on his community's livelihoods. "During the closed season for fishing [June 1–Sept. 30], fish migrate up from the Tonle Sap Lake, traveling up the Mekong and then through the Sekong River into Laos, then they come back the same way in the open season," Sisuwath says, adding that fish used to migrate up the Sesan and Srepok rivers but now can't navigate these rivers due to hydropower dams (Gerald and Nehru 2022). Hydropower development would be directly harmful to habitat, populations, and communities; foraging and breeding behaviors; species interactions and ecosystem functioning; and the migration of fish (Yuichiro et al. 2020). The community seemed to struggle to catch fish, and the number of fish was declining. "We can't even catch enough to make prahok," he complains, referring to the Cambodian delicacy of fermented fish that typically only requires small fish. "Usually around June, we see fish coming up from the Mekong through the Sekong, but this year, I've been out every day and I've caught nothing." He also added, "There are no fish in the water these days; we have relied on the river, but now we must go to the market for food." Even then, reports of diminishing catches, smaller fish, and a drop in the percentage of large predatory species—especially in the Tonle Sap fishery—have surfaced.

Conclusion

The Mekong River is Cambodia's primary source of water for home supplies, agriculture, and water-related commercial activities. Fish protein and flood irrigation from the Mekong and its tributary Tonle Sap, a vital flow buffer and fertile ecosystem, are essential to many lives. Rice cultivation and production in provinces around Tonle Sap Lake and along the Mekong River heavily rely on these two water resources. Despite climate change, the increase of hydropower dams on the mainstream of the Mekong River presents a complex and multifaceted challenge with significant implications for food security, livelihoods, and environmental sustainability. Both tributary and mainstream hydropower opportunities will support energy demands but may have profound consequences for fisheries, sediments, and hydrological regimes.

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CIRCULAR ECONOMY DEVELOPMENT IN THE MEKONG SUBREGION

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Introduction

Recognizing the importance of transitioning to a circular economy, ASEAN aims to enhance the resilience and sustainability of the ASEAN Economic Community. On 18 October 2021, ASEAN adopted the Framework for a Circular Economy during the ASEAN Council Meeting. Circular Economy Development is perceived to have enormous economic growth potential. The Economic Research Institute for ASEAN and East Asia estimates that circular economic development could lead to economic growth of \$324 billion and create 1.5 million jobs, particularly in cities and in the agriculture, manufacturing and forestry sectors across Asia (cited in ADB 2023).

This study examines how ASEAN defines a circular economy and analyzes the policy frameworks and strategies adopted at both the regional level and by ASEAN member states in the Mekong subregion. It investigates whether these adopted policy frameworks and strategies have successfully initiated the development of a circular economy and explores the current state of the transition from linear to circular economies in the Mekong subregion. Data were gathered from ASEAN and member states documents and secondary sources examining the current state and anticipated policy outcomes of circular economic development in the Mekong subregion.

Data were gathered from ASEAN and member states documents and secondary sources examining the current state and anticipated policy outcomes of circular economic development in the Mekong subregion. The exploratory study concludes that ASEAN member states in the Mekong subregion are in the early stages of circular economic development, though it can be expected that circular economy development will continue to grow.

Conceptualizing Circular Economy Development

This study relies on a concept of circular economy that has been developed by a group of scholars in their journal article “Conceptualizing Circular Economy (Revisited): An Analysis of 221 Definitions” (Kirchherr et al., 2023). They define the circular economy as

a system comprising enablers, core principles, aims, and beneficiaries. The core principles focus on reducing, recycling, and recovering materials in production, aiming to enhance environmental quality economic development, and social equity for current and future

generations. In contrast to a linear economic model characterized as an open-ended system of producing, consuming, and disposing based on the assumption of abundant resources, the circular economy is a closed system that operates under the premise that resources are finite (Kirchherr et al., 2023).

To operationalize this definition, the study references another group of scholars who identify four sources of value produced by a circular economy: renewable resources, reuse and sharing, repair and remanufacturing, and recycling. These values were measured across 25 EU member states to explore correlations between the circular economy and sustainable development. The findings indicate that correlations vary among the measured values. Renewable resources and reuse and sharing are positively correlated with greenhouse gas emission reductions (environmental sustainability) but not with GDP growth (economic sustainability). Additionally, renewable resources are positively correlated with a decline in unemployment (social sustainability). Repair and remanufacturing showed a positive correlation with economic sustainability and a negative correlation with social sustainability, while recycling was only negatively correlated with social sustainability (Knäble et al., 2022).

While these study results cannot be generalized to other contexts, they highlight the need for further comparative studies to examine the relationship between the circular economy and sustainable development. The following section will apply these concepts to investigate the current state of circular economic development in the Mekong Subregion, albeit through a qualitative analysis and a case selection that focuses on ASEAN members in the region.

Commitment for Circular Economy Development in the Mekong Subregion

ASEAN member states in the Mekong subregion recognize the significance of developing a circular economy. In recent years, Thailand, Vietnam, Laos, and Cambodia are demonstrating their commitment to the ASEAN initiative to promote circular economic development by establishing regional and national policy frameworks as well as relevant institutions.

Regional Initiatives

At the regional level, ASEAN's circular economic model aims to create an ecosystem for circular products and services by prioritizing standards harmonization through mutual recognition agreements; promoting openness in trade for circular goods and services; technology utilization through innovations to green supply chains; financing access supporting green projects; and resource efficiency ensuring efficient use of energy and other resources (ASEAN 2021). The Greater Mekong Subregion (GMS) Economic

Cooperation program, set up in 1992 by the six countries of the Mekong Subregion backs the transition towards a circular economy. The GMS Strategic Framework for Accelerating Climate Action and Environmental Sustainability and the Joint Statement on the Prevention of Plastic Pollutions including proposals for implementation worth 1 billion USD was endorsed at the 6th GMS Environments Minister meeting in 2024.

The GMS strategy has four priority areas: enhancing climate and disaster resilience for communities and ecosystems, supporting a just and inclusive low-carbon transition, fostering a circular green economy, and strengthening pollution control measures and deploying nature-based solutions for promoting biodiversity, ecosystem restoration and improved livelihoods (Seangly 2024).

National Commitments

Thailand has integrated the Bio-Circular-Green Economy (BCG) model into its development strategies in 2021. Rooted in the economic sufficiency philosophy of late King Bhumipol Aduljadej, the model emphasizes moderation, prudence and social.

immunity (BCG 2024). It extends beyond circular economy principles by incorporating bioeconomy and green economy concepts across four strategic sectors: agriculture and food; wellness and medicine; energy, materials, and biochemicals; and tourism and the creative economy. The BCG model aims for sustainability, resource efficiency, economic growth, and social inclusion (BCG 2024). Additionally, it aligns with the Sustainable Development Goals (SDGs), particularly in fostering sustainable production and consumption. Already in 2019, Thailand became the first ASEAN member in the Mekong Subregion to join the United Nations Partnership for Action on Green Economy, demonstrating its commitment to a green economic transition (UN PAGE 2024).

Laos prioritizes green growth and circular economy since its 9th Five-Year National Socio-Economic Development Plan (2021-2025). This plan aims to reduce reliance on the natural resource sectors and mitigate environmental degradation by promoting effective waste management, pollution reduction and recycling (Laos PDR 2021). The national green growth strategy defines green growth as achieving economic growth and poverty reduction while ensuring sustainable use of limited resources and minimizing pollution and greenhouse gas emissions (Laos PDR 2018). Additionally, Laos has adopted a Sustainable Production and Consumption Roadmap for 2022-2025, along with Vision 2030, which aims to promote environmentally friendly products and services through clean production mechanisms, energy savings, improved waste recycling, and increased environmental awareness campaigns and education (Laos PDR 2022).

Vietnam has enacted various laws and decrees to foster a circular economy since 2021. Article 142 of the Law on Environment Protection, defines the circular economy as a holistic model focusing on design, production, consumption, and services aimed at reducing raw materials, extending product life, reducing waste generation and minimizing adverse impacts on the environment (Vietnam Circular Economy Hub 2024).

The term “circular economy” appears 57 times in this law, reflecting the government's strong commitment. In 2022, a Prime Ministerial decision underscored the importance of circular economic development for both economic recovery and sustainable development, aligning with the National Strategy for Green Growth (Vietnam Circular Economy Hub 2024).

To support the Sustainable Development Goals (SDGs), Vietnam adopted a National Action Plan on Sustainable Consumption and Production (SCP) for 2021-2030. The plan aims to resource and material use in production by 8%, raise awareness of sustainable consumption and production in 70% of industrial parks, implement 20 to 30 models of sustainable practices, distribute eco-friendly packaging in 85% of supermarkets and commercial centers, and promote eco-friendly production and services (SCP Vietnam 2020).

Cambodia has introduced several circular economy development initiatives since 2013, including the National Strategic Plan on Green Growth 2013-2030, the Circular Economy Strategy and Action Plan (2021), and the Circular Strategy on Environment 2023-2028 that align with the SDG's (Puthearath 2024). Cambodia envisions advancing toward a circular economy that fosters a prosperous economy, an inclusive society, and a healthy environment (NSCD/MoE 2021). Key objectives include enhancing the efficient use of raw materials, promoting sustainable production and consumption, improving waste management and recycling, and building stakeholder engagement and capacity (NSCD/MoE 2021). Cambodia's Roadmap for Sustainable Consumption and Production (2023-2035) aims to implement reform measures that transform the systems of production, distribution, consumption, and investment toward sustainable practices (GDPS/MoE 2022). Additionally, Cambodia joined the UN Partnership for Action on Green Economy (UN PAGE) in 2022.

Governance Structures

Thailand has formed a BCG Committee, which includes an Executive Board chaired by the Prime Minister and a National BCG Driving Committee chaired by the Minister of Higher Education. The committee oversees ten subcommittees who cover various sectors, including law, agriculture, food, capacity building and human development, energy material and chemical biology, circular economy, tourism and creative economy, biodiversity, medical devices, innovation and infrastructure, and medicine and vaccine. These subcommittees facilitate collaboration of ministries, industries and academia (BCG 2024).

Vietnam has established a National Steering Committee for Green Growth led by the Deputy Prime Minister and the Ministry of Planning and Investment. This committee collaborates with various inter-governmental (UNDP f. ex.), and non-governmental organizations and the business sector indicating stakeholder involvement. The Prime Minister directs policy implementation which primarily is the responsibility of the

Ministry of Planning and Investment in coordination with other ministries (Vietnam Circular Economy Hub 2024).

Laos has set up a National Steering Committee for Green Growth, focusing on eight priority sectors, including natural resources and environment, agriculture and forestry, public works and transport, industry and commerce, energy and mines, information, culture and tourism, and science and technology. This committee is guided by various ministries, the National Economic Research Institute and the Ministry of Planning and Investment. The latter plays a pivotal role in the development and implementation of green policies (PDR Laos 2018).

Cambodia has created a National Council for Sustainable Development (NCSD) to ensure systematic development and implementation of policies fostering a circular and green economy. Chaired by the Minister of Environment, the NCSD oversees functional departments divided into five sections: Administration, Planning and Finance; Climate Change; Green Economy; Science and Technology; and Biodiversity. Supported by eight technical working groups, the NCSD addresses key sectors, including climate change, sustainable cities, sustainable energy, sustainable consumption and production; science and technology, and biodiversity (NSCD 2024).

Circular Economy Development Policy Outcomes in the Mekong Subregion

The Mekong subregion is in the early stages of developing a circular economy, with a primary focus on transitioning to renewable energy sources. Various initiatives in sectors such as remanufacturing, repair, resource efficiency, waste reduction, and recycling indicate significant potential for enhancing circular economic growth. While policy frameworks and institutions have been established, the challenge now lies in effectively implementing circular economic models.

Renewable Energy Sources

The most advanced circular economic development in the region centers on the transition from non-renewable to renewable energy sources. All ASEAN member states in the region have committed to the Paris Climate Agreement and submitted their Nationally Determined Contributions (NDCs) to the United Nations Framework Convention on Climate Change (UNFCCC). Each country aims to achieve climate neutrality by 2050 and reduce reliance on non-renewable energy sources (UNFCCC 2024). Solar and wind farms are especially recognized to support this energy transition. The projected utility-scale solar and wind capacity for the Mekong subregion is 95 gigawatts (GW) out of a total of 220 GW projected for Southeast Asia, although currently only 28 GW is generated from these sources (Global Energy Monitor 2024).

Vietnam leads in Southeast Asia and the Mekong subregion with the largest share of operating utility-scale solar and wind capacity, totaling 19 GW, which accounts for 25% of the national energy supply. The prospective capacity for utility-scale solar and wind in

Vietnam is projected at 86 GW. Together with the Philippines, the combined solar and wind energy capacity is expected to reach 185 GW, with 60% coming from offshore wind farms. However, only 3% of this capacity is currently under construction (Global Energy Monitor 2024).

Thailand follows with an operational utility-scale wind and solar capacity of 3 GW, while Laos and Cambodia are also making strides in renewable energy development. Despite having an economy only 2% the size of Thailand's, Laos boasts a prospective wind and solar capacity of 4 GW. Although Laos currently lacks operational utility-scale solar or wind farms, it is set to host ASEAN's largest onshore wind project, the Monsoon Wind Power Project, with an expected capacity of 600 MW. This project is backed by the ASEAN Development Bank (ADB), which has committed \$693 million in addition to commercial

and concessional loans and grants. Cambodia currently has an operational utility-scale solar and wind capacity of 429 MW, with a projected capacity of 2.5 GW. In 2022, with ADB's support, Cambodia launched a 100 MW National Solar Park, of which 60 MW are currently operational (GMS 2024).

The Mekong subregion also witnesses changes in the transportation industry promoting circular economy development. Vietnam and Thailand are leading in this regard. In the automotive industry, the Vietnamese company VinFast is expected to increase its production of electric vehicles (EVs) from 250,000 to 600,000 annually by 2026. Similarly, Vietnam Airlines has made efforts to reduce its environmental impact by introducing fuel-efficient aircraft resulting in a 16% reduction in fuel consumption and a 60% decrease in emissions. By 2021, two marine ports in Vietnam have received the Green Port Award, which recognizes ports that rely on renewable energy and resource efficiency for their operations (Nho Ha 2023). In Thailand, the PTT company announced a substantial investment of \$USD 7 billion in green hydrogen projects, including the construction of a hydrogen power plant that will be the first of its kind in the region (Bain & Company et al., 2023). PTT also builds Thailand's first green port relying on hydrogen for energy production and redesigning marine transport to utilize green methanol. Thailand is recognized as the 17th largest producer of biofuels in the world, which are used for road and air transportation (Intan et al., 2023).

Other Circular Economy Development Initiatives

Vietnam is experimenting with various circular models across agriculture, processing industries, manufacturing, and construction. In agriculture, Vietnam employs several circular economic models, including the Garden-Pond-Livestock model, the Biomass model, and the Garden-Forest- Pond-Livestock model, focusing on small-scale, bio-intensive farming practices. Noteworthy practices include gas recovery from livestock waste, biogas production, dairy cow farming, and agricultural waste collection such as bark and rice husks, alongside bio-aquatic models (Thuy 2023). New circular economic models are also being developed in various industrial parks. For instance, the Vietnam

Chamber of Commerce has launched the “Zero Waste to Nature” initiative, creating ecological industrial parks in three provinces. Additionally, the Packaging Recycling Organization Pro Vietnam, which includes nine companies (Coca-Cola Vietnam, Friesland Campina, La Vie, Nestlé Vietnam, NutiFood, Suntory PepsiCo Vietnam, Tetra Pak Vietnam, TH Group, and URC Vietnam) is committed to implementing circular economic models. Other initiatives include Upp!, which recycles plastic waste into construction materials, and efforts by Heineken and Tiger to recycle iron from beer caps (Thuy 2023). Recycling craft villages also represent an innovative circular model, with approximately 4,000 such villages operating in Vietnam. These villages contribute to waste reduction and economic growth by recycling plastics, metals, paper, and other materials. However, many recycling techniques are of poor quality, leading to environmental degradation. Policy frameworks are needed to reform recycling craft villages by incorporating standards and new recycling methods and technologies to mitigate negative environmental impacts (Herrador et al., 2023).

In Thailand, various stakeholders - including the government, the private sector, and academia - are exploring circular economic models (World Bank Group, 2022). Several companies have integrated circular systems into their operations. The Siam Cement Group (SCG) employs a strategy that focuses on reducing material use, upgrading and replacing materials, and reusing and recycling. The company has developed innovative packaging materials that use less material while maintaining durability. In 2018 alone, SCG generated 313,000 tonnes of alternative fuels and materials from reconditioned waste, which has been repurposed as an alternative to raw fuels and materials. SCG has also introduced a new chemical recycling technology that transforms post-consumer plastics into recycled feedstock for producing virgin plastic resin. Additionally, the company has developed new types of green construction materials and innovative methods for recycling and reusing construction waste (Allan, 2024). Another notable initiative comes from PTT Global Chemical, which aims to sustainably manage waste in its supply chain and supports the "Upcycling Oceans" project, which turns ocean plastic waste into fashion products. Indorama Ventures, the world's largest PET polymer producer, has recycled 38 billion PET bottles between 2011 and 2018 and is committed to using 750,000 tons of post-consumer PET materials as feedstock in its polyester production by 2025. Other initiatives in Thailand include the "Recycle for Life" program by the Thai Beverage Can Company, which collects post-consumption packaging for recycling and repurposing (TIR, 2019).

In Cambodia, circular economy development initiatives are primarily driven by a small segment of the private sector. Some businesses have embraced circular business models supported by the government and development agencies. An example is the “Textile Waste Opportunities for Circular Textiles, Garments and Footwears in Cambodia” initiated by German development agencies, which supports a pilot project to recycle textile waste. It is estimated that Cambodia’s textile industry produces between 130,000 and 160,000 tons of textile waste annually (UN Page 2024). Another example is Heineken Cambodia with the “Brew for a Better Cambodia” initiative aiming for the company to become fully circular and decarbonize the whole value chain by 2040. Another innovative

initiative is the Cambodian-Thailand joint venture Chip Mong Insee Cement Corporation, which has created the Chip Mong Ecocycle aiming to reduce construction waste and related environment pollution in construction. The company has developed a sustainable industrial waste management solution via cement co-processing (Sithambalam et al. 2024).

In Laos, a significant number of circular economy development initiatives are reported by the United Nations Development Program (UNDP). In the food value chain, circular economy initiatives focus on community based and organic agriculture. Examples include the Laos Buffalo Diary, Clinsect, which converts organic waste into fertilizers and animal feed, and Dakdae, which produces organic food products. In the construction sector, initiatives include the use of fly ash for cement production, the development of a sustainable wood processing industry, and eco-building designs. Other production industries are substituting plastics with biodegradable alternatives and prioritizing regenerative materials. Examples include Lao Biogas, which provides household biogas appliances, Nham Dong, which produces bamboo eco-plates and containers, and Danlao Rattan, which manufactures furniture from Rattan (UNDP 2021).

Ecolabelling has also gained some traction in the Mekong subregion, with active promotion by businesses and governments. Thailand holds full membership, and Vietnam is an associate member of the Global Ecolabelling Network (GEN, 2022). Both states have established official green label certification programs. Thailand has also adopted a new “Green Leaf” certification program tailored for sustainable tourism aimed at recognizing and promoting environmentally responsible practices in the tourism industry (Bain & Company et al., 2023; Green Leaf Foundation, 2024). In Cambodia, the government has adopted "Guidelines and Certification Standards for Green Buildings in Cambodia" (NCSD, 2021).

Future Potential of Circular Economy Development in the Mekong Subregion

A major concern in the region is the high levels of air, water, and soil pollution. While the transition to renewable energy for electricity production and transportation shows promise in reducing air pollution, waste significantly impacts both the environment and sustainable development. Although there are initiatives in all Mekong countries aimed at promoting sustainable waste management and clean production, circular economy practices have yet to become systemic across all economic sectors, resulting in only limited waste reduction.

The MRC's Riverine Plastic Monitoring Programme (RPM) estimates that Cambodia, Thailand, Vietnam and Laos produce about eight million metric tonnes of plastic waste combined per year of which, some 70% to 90% were plastic bottles, plastic bags and styrofoam. Yet this debris does more than adversely affect the Mekong and its tributaries. It also pollutes the oceans with an estimated 40,000 tons of plastic waste every year (MRC 2022). The pollution is mainly caused by the manufacturing sector, the agriculture sector and the energy and transportation sector. How to mitigate the pollution remains a major

challenge despite various efforts of governments, industries, academia and environmental organizations to reduce pollution.

Among the various initiatives, the agriculture sector holds significant potential for reducing soil pollution by adopting circular economic models, as previously outlined in this study with examples from Vietnam. Key strategies to mitigate air, water, and soil pollution include reducing, remanufacturing, repairing, reusing, recycling, and implementing clean production practices. However, many businesses specializing in remanufacturing, repair, and recycling operate in the informal sector and lack adequate policy frameworks, standards, and certification schemes. This situation hinders the enhancement of circular economic models, making them less environmentally friendly - similar to what was illustrated with the recycling craft villages in Vietnam. Providing incentives such as tax exemptions could encourage the development of these businesses and promote a shift in current practices. To reduce industrial pollution, targeted interventions are needed in specific sectors responsible for significant water, air, and soil pollution. For example, a study by the ADB found that a small number of enterprises in Laos and Cambodia are primarily responsible for pollution, and their negative externalities could be mitigated through government interventions and public-private partnerships. In Cambodia, this primarily involves the textile sector, where initiatives are already underway. In Laos, just 10 cement and lime companies account for 30% of industrial air pollution (ADB 2018).

Conclusion

The Mekong subregion has significant potential to enhance circular economy development. Priority areas are generating renewable energy, improving energy and resource efficiency in production, improving clean production and consumption, developing sustainable national, regional and global supply chains, adopting green technologies and practices, and providing education and training for a green workforce ensuring no one is left behind. However, major challenges remain. The transition to a circular economy may involve trade-offs that could slow economic growth and lead to job losses in certain sectors in the short term - an economic risk that many countries may be reluctant to accept.

Moreover, circular economy development does not automatically result in economic growth, increased employment, or reduced negative environmental impacts. This transition must be incremental, as transforming entire economic systems is a complex and daunting task. The linear economic model has been entrenched for decades, necessitating extraordinary efforts to shift economic techniques and practices toward a circular framework while balancing economic, social, and environmental sustainability. Significant investments will be required to facilitate this circular transition, which may divert public and private financing from other critical sectors such as infrastructure development, education, health, and climate adaptation measures.

Given these challenges, governments in the Mekong subregion must continue to develop sophisticated policy frameworks to support a circular transition. Meanwhile, the private sector is exploring and experimenting with different circular business models, familiarizing themselves with new technologies, methods, and practices, and adjusting their business models to align with circular economy principles in support of this transition. Ultimately, substantial economic growth is a prerequisite for the effective transition toward a circular economy in the region.

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RESPONSES OF THAI HOTEL BUSINESSES TO CLIMATE CHANGE: CHALLENGES AND OPPORTUNITIES

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Introduction

Climate change has become a critical global issue, with far-reaching implications for various industries, including tourism and hospitality. Rising temperatures, sea level rise, and increasingly frequent extreme weather events, such as floods and hurricanes, are directly impacting travel destinations and tourism patterns worldwide (The University of Cambridge Institute for Sustainability Leadership (CISL), 2014). The hospitality industry is struggling to adapt because of their elevated energy consumption for heating, hot water, lighting, or cooling aggregates. For the hotel sector, these changes present significant operational challenges, including increased energy and water costs, physical damage to properties, and disrupted supply chains. As a result, sustainability has emerged as a strategic imperative for hotels globally. Many hospitality businesses are integrating eco-friendly practices not only to comply with regulatory requirements but also to meet the growing demand from eco-conscious travelers and enhance their market competitiveness (Mota, Luis & Leite, Eduardo & Ghasemi, Vahid, 2024).

Overview of Thailand's Hotel Industry

Thailand is regarded as one of the world's foremost tourist destinations, and the country's continuing ability to attract foreign arrivals. In 2022, the tourism industry contributed around 1.3 trillion Thai Baht to Thailand's GDP (Statista, 2024). Thailand's hotel industry is a vital component of the country's tourism sector, which is one of the primary contributors to its economy.

The hotel trade (which here covers hotels, resorts and guesthouses) is directly connected to the wider tourism sector. In terms of its contribution to the broader economy, the growth of hotel industry in Thailand raised 104.8 percent from 2021 to 2022 resulted to the easing of the pandemic (Krungsi, 2024).

The country's diverse attractions, from tropical beaches and nature to its rich cultural heritage sites, the hospitality of the people, draw millions of international tourists

annually. However, Thailand is particularly vulnerable to climate change due to its geographic location. Coastal areas, where many luxury resorts are located, are facing increasing risks from sea-level rise and coastal erosion, while inland regions are experiencing changes in seasonal weather patterns, including prolonged droughts and more intense rainfall (ASIAN Development Bank, 2021). These environmental shifts pose substantial risks to the hotel industry, threatening the sustainability of Thailand's tourism model.

This article aims to explore how Thai hotel businesses are responding to the challenges posed by climate change, identifying both the difficulties they face and the opportunities that arise from adopting sustainable practices. The author reviewed related literature from credible sources as well as interviewed hotel business owners or managers to gain insights from the current players in the market. By examining the current strategies employed by the industry and the broader implications for tourism in Thailand, this article seeks to offer insights into how hotels can enhance their resilience to climate impacts while leveraging the growing eco-tourism market.

Impact of Climate Change on Thai Hotel Businesses

Physical and Environmental Challenges

The physical and environmental impacts of climate change are already being felt by the Thai hotel industry. Rising temperatures, more frequent extreme weather events, and sea-level rise pose significant threats to hotel operations and infrastructure. Thailand's coastal regions, which host many of the country's luxury hotels and resorts, are particularly vulnerable. The Department of Marine and Coastal Resources (DMCR), in the Thai Government's Ministry of Natural Resources and Environment, has calculated that each year erosion causes Thailand to lose 30 square kilometers of coastal land. In addition, the Office of Natural Resources and Environmental Policy and Planning of Thailand, predicts that sea level will rise by 1 meter in the next 40 -100 years, impacting at least 3,200 square kilometers of coastal land, through erosion and flooding, at a potential financial cost to Thailand of 3 billion Thai Baht over that time-period (Nakapakorn, 2022). In turn, such phenomenal potentially submerging or damaging properties in popular tourist areas such as Phuket, Koh Samui, and Pattaya. Additionally, extreme weather events like typhoons and floods have increased in frequency, causing disruptions in hotel operations and costly damage to infrastructure.

For example, the 2011 floods in Thailand affected over 13 million people and caused damages amounting to approximately USD 46.5 billion, with the tourism and hospitality sectors heavily impacted (The World Bank, 2022).

Moreover, rising temperatures are leading to increased energy consumption in hotels as they attempt to maintain comfortable indoor climates. This not only raises operational costs but also contributes to a vicious cycle of energy demand that further exacerbates climate change. Hotels in Thailand's tropical regions are seeing more frequent heatwaves.

According to Thailand's National Adaptation Plan by Department of Climate Change and Environment of Thailand, in the worst-case scenario of the projected trend, Thailand could experience a mean temperature increase of 2°C by the end of the century or 2070. This would undeniably affect guest comfort and operational efficiency (Department of Climate Change and Environment, Ministry of Natural Resources and Environment, 2023).

Economic Implications

Thailand has been ranked ninth as the country most affected by the impact of climate change during 2000 to 2019 by the Global Climate Risk Index 2021 (CRI), both in terms of human consequences (fatalities) and direct economic losses. The CRI indicated that Thailand was among the highest-risk countries because it had faced many mega natural disasters. During the past 20 years, the country has experienced 137 natural disasters, the worst of which was the major flood in 2011. This flood accounted for 87 percent of the past total damage; the World Bank estimated that the cost of damage and losses were as high as 1.44 trillion THB (approximately 46.5 billion USD) (Department of Climate Change and Environment, Ministry of Natural Resources and Environment, 2023). In addition, climate change also brings considerable economic implications for Thai hotels. The rising cost of energy, driven by the need for cooling systems and water management, is placing additional financial burdens on hotels. Given the highly interconnected nature of global energy markets, particularly the market for fossil fuels, this volatility impacts energy prices worldwide. In 2022, the Energy Regulatory Commission (ERC) of Thailand increased electricity prices by 4.6 per cent (Economic and Social Commission for Asia and the Pacific (ESCAP), 2022). This upward trend is expected to continue as demand for air conditioning rises with increasing temperatures. In addition to energy costs, hotels are also facing higher insurance premiums as they are classified as high-risk properties due to their exposure to natural disasters, such as floods and storms. The need for frequent repairs and renovations due to weather-related damage further drives up operational expenses (United Nations Development Programme Thailand (UNDP Thailand), 2023). Additionally, climate change is altering tourist behavior and seasonal patterns. Traditionally popular tourist seasons are being disrupted by unpredictable weather, leading to fluctuations in occupancy rates.

Reputational and Market Risks

In an era of increasing environmental awareness, international tourists are placing greater emphasis on sustainability when choosing accommodations. Booking.com's Sustainable Travel Report 2022 revealed that 71 percent of travelers globally expressed a preference for eco-friendly accommodations (Booking.com, 2022). This shift in consumer behavior presents a reputational risk for Thai hotels that fail to adopt sustainable practices. Hotels that are perceived as not implementing green and sustainable practices risk losing business to competitors who are more proactive in addressing climate change.

Challenges Faced by Thai Hotel Businesses in Adapting to Climate Change

Financial Barriers

One of the most significant challenges facing Thai hotel businesses in their efforts to adapt to climate change is the high cost associated with implementing green practices. Energy-efficient technologies, waste management systems, and infrastructure upgrades designed to reduce a hotel's carbon footprint require substantial financial investment. For example, installing solar panels, adopting energy-saving appliances, or upgrading water conservation systems can require upfront capital that many hotels, especially smaller establishments, struggle to secure.

According to Sustainable Hospitality Alliance research, hotels that prioritize sustainability can reduce their operating costs by up to 30 percent. These cost savings come from various factors, such as lowered utility bills, reduced waste disposal costs, and improved employee productivity. Mitigating the effects of climate change must be accompanied by efforts to strengthen the climate resilience of the hospitality industry. However, the initial investment is still a significant hurdle (World Sustainable Hospitality Alliance, 2023).

For smaller hotels, limited access to green financing options exacerbates the financial burden. While larger, multinational hotel chains often have the resources or access to international financing institutions to support sustainable initiatives, smaller, independent hotels face barriers in obtaining loans for green projects. Fortunately, the green movement is gradually getting into action. In Thailand, government incentives or subsidies aimed at supporting eco-friendly hotel infrastructure are now being offered. For instance, UOB Bank in Thailand initiated the Sustainability Innovation Programme (SIP), which offers SMEs transformation low-interest loans to adopt digital technology, invest in green energy, environmental-friendly services, and innovate, all regulated by the Bank of Thailand. In 2023, over 150 entrepreneurs from the tourism sector have participated in the program, receiving sustainability expert guidance, cutting-edge digital tools, and opportunities to network with like-minded businesses. This indicates a good sign for Thai hotel businesses in adapting to climate change with support from the government (Molpasorn Shoowong, 2023).

Regulatory and Policy Issues

Thailand's regulatory landscape presents another challenge for hotel businesses attempting to adapt to climate change. The absence of clear and consistent government policies on climate adaptation in the hospitality sector may lead to uncertainty for hotel operators. Although the Thai government has introduced several national policies to promote sustainability, including the Thailand 4.0 initiative, there appears to be limited specific guidance tailored for the hospitality sector. As a result, many hotel operators find it challenging to fully grasp how to comply with environmental regulations or integrate climate adaptation strategies into their operations (Anonymous interviews with 5 hotel owners in Chiang Mai, Thailand, 2024).

Furthermore, the enforcement of existing environmental regulations can sometimes be less consistent. For instance, in 2024, the Ministry of Natural Resources of Thailand has exempted hotels with 1 to 49 rooms from preparing an environmental impact assessment (IEE), which is an increase from the previous exemption for hotels with 1 to 29 rooms. It is notable that in the past, many small hotels were unable to obtain licenses due to strict environmental regulations imposed by the Ministry of Natural Resources and Environment (Khaosod, 2024). Currently, hotels that implement sustainable practices often do so voluntarily rather than due to regulatory requirements, and there are few incentives for those that go beyond compliance. For example, tax breaks or financial rewards for hotels that adopt green certifications are still rare. The aforementioned green certifications are, for instance, Green Key, a certification awarded to hotels that adhere to strict environmental standards across a range of criteria including energy and water conservation, waste management, and community involvement. Another example of green certification is EarthCheck certification which is known globally. This certificate requires hotels to adhere to sustainable practices in areas such as environmental policy, social and cultural engagement, and economic management (Panneeselman, 2024). Without more robust governmental support or clearer regulatory enforcement, the adoption of climate-friendly practices in the Thai hotel industry tends to progress at a slower pace.

Technological and Infrastructure Challenges

Upgrading outdated infrastructure to meet sustainability standards is another challenge for many Thai hotels. A significant portion of Thailand's hospitality infrastructure was built decades ago, before sustainability became a central concern. These older buildings often lack the modern design features necessary to reduce energy and water consumption. It is important to recognize that retrofitting older properties can be costly, especially for smaller hotels that may face challenges in affording the necessary capital investment. While owners are focused on making hotel upgrades and other changes to meet guest expectations in terms of modernity and sustainability, concern over the high cost and availability of capital is limiting investment in renovations for many hotel owners (Kirk, 2024).

In addition, access to advanced technologies that would enable hotels to reduce their environmental impact is limited. Technologies such as renewable energy systems (solar, wind) and water-saving technologies (e.g., greywater recycling systems which is a treatment of wastewater from appliances such as showers, baths and sinks, to be re-used and fed back into a property for non-potable purposes such as flushing toilets) are available, but adoption remains limited (Edie, 2024).

A survey conducted by the Bangkok Bank Innovation Research Hub revealed that only approximately 14.9% of Thailand's energy is generated from renewable sources, despite the government's target to increase this share to 30% by 2037 (Bangkok Bank Research Hub, 2023). The adoption of renewable energy systems in the hospitality sector remains

limited, primarily due to high costs and a shortage of technical expertise. Furthermore, many hotel operators are unaware of the technological innovations that could enhance the sustainability of their operations, highlighting the need for improved knowledge dissemination and greater access to green technology solutions.

Cultural and Awareness Barriers

Cultural resistance to change presents a significant challenge for Thai hotel businesses in their efforts to adapt to climate change. Many hotel operators, particularly those managing smaller or family-owned establishments, are hesitant to adopt sustainable practices due to perceived risks, lack of knowledge, or deeply ingrained habits. Interviews with five green hotel owners in Chiang Mai, Thailand, revealed that some of their guests express concerns that sustainability initiatives may increase costs without delivering tangible benefits. The hotel owners also acknowledged that limited awareness of climate risks and the long-term advantage of sustainability contributes to guests' reluctance. While large international hotel chains often incorporate sustainability into their corporate values, local hotel operators may perceive these measures as unnecessary or of lower priority (Anonymous interviews with 5 hotel owners in Chiang Mai, Thailand, 2024). Furthermore, many hotels lack formal sustainability training programs for their staff, which hinders the ability to build a culture of environmental awareness within the organization. Efforts to overcome this barrier will require more targeted education and awareness campaigns that clearly articulate the financial, operational, and reputational benefits of sustainability.

Opportunities for Thai Hotel Businesses in Addressing Climate Change

Growing Demand for Sustainable Tourism

The growing global demand for sustainable tourism presents a significant opportunity for Thai hotels to position themselves as leaders in eco-friendly hospitality. Eco-conscious travelers are increasingly seeking accommodations that prioritize sustainability, with a strong preference for hotels that have earned green certifications, such as Green Key or EarthCheck (Booking.com, 2022). According to Operto survey, 85.6% of travelers said that they would pay more for an eco-friendly choice of hotels. Furthermore, most respondents (82%) of the survey said they believe that providing a sustainable experience is the responsibility of both the hotel and the guest (Operto, 2024). This shift provides Thai hotels with an opportunity to differentiate themselves in a competitive market by adopting and promoting sustainable practices.

Thai hotels can market themselves as eco-friendly destinations, appealing not only to international tourists but also to domestic travelers who are becoming more conscious of their environmental footprint. The Tourism Authority of Thailand (TAT) has already begun promoting “low-impact” travel, focusing on eco-friendly destinations and accommodations (TAT, 2023). By obtaining green certifications and adopting transparent sustainability reporting, Thai hotels can enhance their appeal to eco-conscious travelers, contributing to both environmental protection and business growth.

Financial and Operational Benefits of Sustainability

Beyond market positioning, adopting sustainable practices offers long-term financial and operational benefits for Thai hotels. Energy-efficient systems, such as LED lighting, smart ventilation and air-conditioning systems, and renewable energy sources like solar panels, can result in substantial cost savings. Hotels that implement energy-efficient technologies can reduce their energy consumption by 20-35%, translating into significant savings on electricity bills, lower operating cost, and lower carbon footprint (Hotel & Resort Innovation Expo, 2024).

Hotels generate a significant volume of waste, including food waste, packaging materials, and single-use amenities. Inadequate waste management not only increases landfill contributions but also results in the emission of greenhouse gases, such as methane, from decomposing organic materials. Waste reduction programs also contribute to operational efficiency. To minimize waste and promote recycling, hotels can implement comprehensive waste management practices. This includes implementing recycling programs throughout the hotel. By minimizing waste, reducing plastic use, and implementing comprehensive recycling systems, hotels can lower waste management costs. For example, hotels that participate in zero-waste initiatives report reduced waste disposal fees and increased operational efficiency through better resource management (Balaban, 2023). In addition, sustainable water management practices, such as installing low-flow fixtures and water recycling systems, can reduce water consumption by up to 50%, further contributing to cost savings (FS Group, 2024).

The financial returns from these investments are not immediate, but over time, hotels that embrace sustainability will see reduced operating costs and increased profitability. Furthermore, sustainability-focused hotels often experience higher occupancy rates and customer loyalty, as environmentally conscious guests are more likely to return to properties that align with their values.

Partnerships and Collaborations

Partnerships and collaborations represent another critical opportunity for Thai hotels in addressing climate change. By working with international organizations, non-governmental organizations (NGOs), and government programs, hotels can access resources, expertise, and funding to support sustainability initiatives. The United Nations Sustainable Development Goals (SDGs), particularly SDG 13 (Climate Action), provide a framework for the hospitality industry to align with global climate action efforts (UNDP, 2024). Hotels that align with the SDGs can leverage international support and enhance their reputation as responsible businesses.

Moreover, government programs in Thailand, such as the Green Leaf Programs, knowledge and technical assistance to hotels that adopt sustainable practices (Green Leaf Programs, 2024). By collaborating with sustainability-focused organizations, hotels can gain access to grants and investment opportunities for green projects, such as renewable

energy installations or sustainable construction upgrades. These partnerships not only reduce the financial burden of sustainability but also enhance a hotel's credibility in the eyes of eco-conscious consumers.

Technological Advancements

The adoption of advanced technologies offers significant potential for Thai hotels to reduce their environmental impact and improve operational efficiency. Digital tools, artificial intelligence (AI), and smart systems are increasingly being used to monitor energy consumption, manage resources, and optimize operational processes. Smart building management systems, for instance, can automate heating, cooling, and lighting based on occupancy, reducing energy waste and improving guest comfort (Romain Philipon, 2023). In addition, renewable energy sources, such as solar and wind power, can further enhance energy efficiency in hotels. Thailand, with its abundant sunshine, is well-positioned to harness solar energy.

Thailand's Alternative Energy Development Plan (AED) (2024) has set a target to increase the proportion of renewable and alternative energy consumption to 36% by 2037. This provides a reliable and cost-effective energy source for hotels (SustainNation, 2024). Hotels that invest in renewable energy not only reduce their carbon footprint but also protect themselves against future energy price volatility, enhancing their long-term financial stability.

By embracing technological advancements, Thai hotels can reduce their environmental impact, improve operational efficiency, and position themselves as industry leaders in sustainability. These innovations provide a pathway for hotels to align with global sustainability trends while also improving their bottom line.

Case Studies: Positive Responses to Climate Change from Thai Hotels

Highlighting Leading Hotels or Chains

Several leading Thai hotels have made significant strides in addressing climate change by integrating sustainable practices into their operations. One such example is the Banyan Tree Phuket, which has implemented a comprehensive sustainability program. The resort spends its efforts towards global sustainability goals through endorsing responsible tourism, thereby fostering resilience and enriching local communities. For instance, it released 2,186 sea turtles into the Andaman Sea, and with 7.7 million Baht raised to support the Phuket Marine Biological Center (PMBC). In addition, the hotel was awarded the prestigious Gold-level Green Hotel Award by Thailand's Department of Environmental Quality Promotion. This award acknowledges Banyan Tree Phuket's comprehensive sustainability initiatives, including the use of energy-efficient technologies, efficient waste management systems, water conservation efforts, and sustainable procurement practices (Banyan Tree Hotels & Reports, 2024).

Another outstanding example is the Intercontinental Phuket Resort, a luxury resort known for its environmental stewardship. The resort has implemented an advanced water management system by harvested rainwater from all over the resort to reduce the impact of the runoff on marine life. The water is temporarily collected and stored in an underground retention tank before it is treated and used for flushing in urinals and toilets. With the use of low-flow water fixtures the resort is able to save water by 50% annually. Wastewater is also treated and reused and as a result 100% recycled water is used in the gardens and landscaped areas (Intercontinental Phuket Resort, 2024).

The Dusit Thani Hua Hin is another prime example. The hotel has partnered with the Thai government and local organizations to promote green tourism. Dusit Thani Hua Hin's sustainability initiatives are numerous, particular focus on mitigating effects of climate change by reducing our carbon footprint, from water management to the elimination of waste and pivoting to use of alternative energy sources. In addition, the hotel is working towards engaging with the community (Dusit Hotels & Reports, 2024).

Lessons Learned

These case studies demonstrate several key lessons for other Thai hotels seeking to enhance their sustainability practices. First, leadership and commitment to environmental responsibility are critical. The Banyan Tree Phuket's sustainability initiatives are driven by its top executives, who view sustainability as integral to the hotel's long-term success. Similarly, Intercontinental Phuket Resort and Dusit Thani Hua Hin's executives have instilled a company-wide philosophy of environmental stewardship, influencing everything from guest experiences to behind-the-scenes operations.

Second, innovation in energy and waste management can drive significant environmental and financial benefits. By investing in renewable energy sources like solar power and waste-to-energy systems, these hotels not only reduce their ecological impact but also lower their operational costs. Hotels that adopt such innovations are better equipped to adapt to regulatory changes and shifting consumer preferences.

Finally, community involvement and collaboration are essential to achieving sustainability goals. Those aforementioned hotels have engaged local communities in their sustainability efforts, helping to create positive social and environmental impacts beyond the hotel premises. By involving local stakeholders and partnering with government programs, these hotels demonstrate the value of collective action in addressing climate challenges.

Overall, these examples highlight the importance of leadership, innovation, and community involvement in creating climate-resilient hotels. By integrating these elements, Thai hotels can both mitigate their environmental impact and strengthen their market position in an increasingly eco-conscious industry.

Policy Recommendations for the Future

Strengthening Government Regulations

One of the most pressing needs for the hospitality sector in Thailand and the Greater Mekong region is the strengthening of government regulations related to climate adaptation and environmental sustainability. Current policies often lack specificity and enforcement mechanisms. Governments should implement clearer, more comprehensive environmental regulations specific to the hospitality industry, focusing on reducing carbon emissions, water conservation, and waste management. This could include mandatory requirements for hotels to meet green building standards or adopt renewable energy sources. Strengthening regulatory frameworks can also be achieved by enhancing monitoring and enforcement mechanisms to ensure compliance with environmental laws.

Governments should also offer incentives to encourage hotels to adopt sustainable practices. These could include tax breaks, grants, or low-interest loans for hotels investing in green technologies such as solar panels, energy-efficient appliances, and water recycling systems. Such incentives would not only reduce the financial burden of transitioning to sustainable practices but also accelerate the adoption of climate resilience measures.

Encouraging Private Sector Investment in Sustainability

Private sector investment in sustainability is crucial for the long-term success of climate adaptation efforts in the hospitality sector. Governments and financial institutions should create more opportunities for green financing, such as green bonds or sustainability-linked loans, specifically designed to support hotels that invest in energy-efficient infrastructure or renewable energy projects. These financing mechanisms would help lower the upfront costs associated with adopting sustainable technologies, making it more feasible for small and medium-sized hotels to participate. Corporate social responsibility (CSR) should also play a more prominent role in driving sustainability initiatives in the hospitality industry. Major hotel chains in the Greater Mekong region should integrate environmental goals into their CSR strategies, not only to meet regulatory requirements but also to enhance their brand reputation. The involvement of private corporations in climate action, through partnerships with local communities or environmental NGOs, can create synergies that drive both business success and environmental protection.

Educational and Training Programs

Educational initiatives are essential for ensuring that hotels in the Greater Mekong region can successfully implement sustainable practices. Governments and hospitality associations should develop comprehensive training programs aimed at educating hotel staff and management about sustainable operations. These programs should cover areas such as energy efficiency, waste reduction, and the use of renewable energy, emphasizing practical steps that can be taken within hotels to minimize environmental impact.

In addition, awareness campaigns shall be launched to educate hotel owners and guests on the long-term benefits of sustainability and climate action. Such campaigns can highlight the cost savings, brand reputation enhancement, and customer loyalty that come from adopting environmentally responsible practices. By building a culture of sustainability within the industry, these campaigns would encourage a widespread shift toward more sustainable operations in the hospitality sector.

Conclusion

Summary of Challenges and Opportunities

Climate change poses significant challenges for the Thai hospitality industry and the broader Greater Mekong region, particularly in terms of physical impacts, economic strains, and reputational risks. Hotels are facing increased costs from energy consumption, repairs due to extreme weather, and the need for infrastructure upgrades to meet sustainability standards. Despite these challenges, the rise of eco-conscious travelers and the long-term cost savings associated with sustainable practices present major opportunities for Thai hotels and those across the Greater Mekong region. By adopting renewable energy solutions, improving waste management, and engaging in green certifications, these hotels can enhance their competitiveness and appeal to a growing market of environmentally conscious guests.

Call for Action

To secure a sustainable future, Thai hotels, policymakers, and other stakeholders' region must take immediate and long-term action. Governments should strengthen regulatory frameworks, offer incentives for sustainable investment, and prioritize climate resilience in tourism development. Hotels need to invest in sustainability, not just as a response to regulatory requirements but as a strategic business move that aligns with evolving market expectations. Corporate social responsibility should be expanded, with private sector involvement playing a key role in climate action.

The time to act is now. The future of the hospitality industry in Thailand depends on how well the sector adapts to the growing pressures of climate change. By embracing innovation, fostering collaboration, and committing to sustainability, the industry can thrive in an increasingly eco-conscious global market while ensuring the preservation of natural and cultural resources for future generations.

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GREEN INFORMATION: ENHANCING SUSTAINABILITY AWARENESS TO PROMOTE RESOURCE EFFICIENCY

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Introduction

Unsustainable consumption levels have caused serious environmental issues, including climate change. For instance, Thailand is the world's sixth-largest contributor to ocean waste, and plastic accounts for 12% of Thailand's total wastes. Moreover, only 24.55% of the consumption of plastic products are processed to material recycle and energy recovery (Nikkei Asian Review 2018). This situation has urged the shift to sustainable consumption and purchase behavior. Resource efficiency is one of the solutions to decelerate climate change. Accordingly, many organizations have engaged in sustainability by promoting closed-loop supply chain (CLSC) and reverse logistics based on the idea of circular economy. Modern consumers select environmentally friendly product to contribute to global sustainability. Consumers are increasingly paying attention to goods and services that produce less pollution, consume fewer natural resources, and are generally less detrimental to the nature. A global study of 17,000 people found that, 56 % identified themselves as "green," meaning "someone who avoids environmentally hazardous products, minimizes waste, strives to preserve energy, and chooses environmentally friendly products as much as possible (Bureecam, Chaisomphob, and Sungsomboon 2018)." Accordingly, businesses have responded to consumers' green preferences by introducing products that feature components created from environmentally friendly materials. In the closed-loop approaches, end-of-life products are collected and recovered either by refurbishing, recycling or remanufacturing, rather than being disposed of by landfilling or incinerating. Modern consumers have been interested in resource efficiency, but there is still the gap regarding their behavioral intention and actual behaviors. Consumers are willing to pay extra for environmentally friendly items if they are aware that the products are actually environmentally friendly. Therefore, green information plays crucial role in clarifying the green benefits to the consumers.

Green Information

Responding to the conventional marketing that generate wastes and overconsumption, businesses try to encourage the long term benefits by strategically promoting sustainability operations. Socially and ecologically responsible operations can improve customer impressions of the company. An individual tends to take action of pro-environmental consumptions when the social or environmental benefits match his or her self-interests. Presenting information that conveys information about desired behaviors and their effects is one method of convincing consumers to engage in pro-environmental behavior. However, a lack of understanding and a lack of exposure to information can lead to a low adoption of environmentally-friendly actions. Specifically, if an individual is not informed about the problem, potential good acts, and positive consequences, he or she is unlikely to engage in more deliberate types of sustainable behavior. Based on previous meta-analytic assessment, information has a considerable impact on pre-environmental behavior (Delmas, Fischlein, and Asensio 2013).

Information which is one of the cognitive factors is essential for encouragement of sustainability consumer behavior. Consumers' lack of awareness on material recovery such as recycling is one major barrier of reverse logistics and usually result in low intention to participate both by buying recycled products or by returning the end-of-life products for material recovery. Therefore, it is important to promote green information regarding recycling, for instance, end-of-life product collection channels, recycling process as well as the benefits of material recovery in the individual, national and global level. For instance, electronic wastes, including mobile phones have been analyzed in previous research to explore the attitudes and behavior of returning end-of-life products for material recovery (Bai, Wang, and Zeng 2018). It is possible to increase recycling rate; however, most consumers are still not aware of recyclability of their unused mobile phones. Furthermore, in case consumers are concerned about waste problems, the information on waste collection and recycle programs is still unclear. Hence, it is essential to promote impactful education and advertisement that encourage sustainability mindset. Moreover, environmental initiatives, including campaigns, advertisement, and education should be promoted to enhance the people's awareness on recycling. If there is sufficient information, such as clear instruction about end-of-life product collection campaign, the tendency of recycling behavior will increase. In contrast, when the instructions are unclear, the tendency of recycling decreases.

Experimental Study in an ASEAN Country

Do consumers respond differently when sustainability information is presented in slightly different ways? Sustainability is a nebulous notion and research has shown that people's perceptions of what it means to be environmentally sustainable, green, or eco-friendly are very diverse; hence, businesses can use a variety of trends to frame these sustainability statements. An information may be presented in a global or local context. Similar to that, the information might be presented as having both short-term and long-term benefits. The

information content that is pertinent to constructs like time, place, and reference group might affect how the consumer interprets an organization's sustainability information. Previous literature revealed that information that is consistent with one's mindset is easier to process than information that is inconsistent with one's mindset (Line, Hanks, and Zhang 2016). Moreover, one tends to process the information more concretely if he or she is familiar with the content. Specifically, perceptions of sustainability influence how individuals process the information, and in turn, how information processing interacts with other components related to psychological distance. For example, the information showing that using recycled products will help reducing the waste generated "in the local community" would be more effective than "globally" as the local community presents nearer psychological distance than the global aspect.

The author conducted an experimental study in Thailand to find out more about how consumers' opinions about recycled, refurbished, and remanufactured goods are affected by given green information. The study aimed to examining how perceptions of material recovery products are affected by the congruence between customers' construal of green information based on the complementary views of construal level theory (CLT) and self-construal (SC). The result would assist marketers in persuading customers to make long-term decisions and utilize message framing for green products. By employing the scenario manipulation, the study aimed to prove whether enhancing the urgent needs of pro-environmental behaviors significantly leads to actual green behaviors in the short run. The experiments set 'temporal distance' as a main factor to emphasize the importance of 'time' in encouraging green attitudes, green purchase intention, and perceived green image of the company that offers green products. The study attempted to enhance the broader analysis on different construal level of green information in stimulation of (1) recycled (2) refurbished and (3) remanufactured product purchase.

Hypothesis Development

The objective of this study is to investigate how the congruence of the construal of green information influence the consumers' attitude toward green products, the perceived green image of the company as well as the consumer's intention to purchase the products that contain used content made of recovered materials. The green marketing communication used in this study involve with recycled / refurbished / remanufactured products. This study contends that due to their emphasis on a global scope (spatial distance), future timelines (temporal distance), and benefits accruing to unfamiliar groups, sustainability activities are generally perceived as being abstract in nature (social distance). If green information is congruent with psychological distance, such as if the message focuses on the distant future, people would not require any additional processing, but the message will be assessed at the heuristic level. When there is a misalignment between the customer's perception of sustainability activity and the marketing communication, such as when the messaging is present-focused, the misalignment will lead to more thorough, methodical information processing. When there is inconsistency, the consumer will be forced to take other parts of the marketing message into account, including social and

spatial distance. Because the context of the sustainability research is described as "development that fulfills the demands of the present without compromising the ability of future generations to satisfy their own needs" (World Commission on Environment and Development 1987), temporal distance is thought to be the most important aspect characteristic of psychological distance. Sustainability has a stronger association with temporal distance than the other two dimensions due to its heavy emphasis on the future. In other words, when consumers think about sustainability, the present automatically takes precedence over the future (Postmes et al. 2013; Rabinovich et al. 2009).

Temporal distance

While sustainability is by nature future-focused, consumers are typically present-focused. Additionally, it becomes less appealing in the present when consumers anticipate a distant environmental payoff (Van Vugt, Griskevicius, and Schultz 2014). Encouraging customers to think more abstractly and/or to focus on the long-term benefits of sustainable action is one strategy to overcome this misalignment (Reczek, Trudel, and White 2018). Future-oriented people are more inclined to take part in pro-environmental actions. By encouraging people to consider legacy, one can lessen their present-focused biases and encourage them to make more environmentally friendly decisions (Zaval, Markowitz, and Weber 2015).

Spatial distance

Communications that outline the more immediate implications of environmentally friendly measures for a particular city, region, or neighborhood can help make environmental actions and effects seem more relevant and real (Scannell and Gifford 2013). People may adopt more sustainable ideas and behaviors as a result of their connections to a particular place, their personal experiences with the effects of climate change, and current issues like extreme weather crisis (Li, Johnson, and Zaval 2011).

Self-construal

Another way to deal with intangibility is to make sustainability issues more personally relevant and tangible (Reczek, Trudel, and White 2018). Long-term consumer behavior may be well predicted by how a person views their own self-concept. While some people have a more interdependent self-construal, such as the idea that they are connected to others, other groups of people might have a more independent self-construal, such as the idea that they are separate and distinct from others (Markus and Kitayama 1991). Theoretically, individuals who see themselves as interdependent self-constructs are more inclined to take part in sustainable behaviors, particularly when those behaviors benefit their fellow ingroup members (Duclos and Barasch 2014). According to White et al. (2019), the enhancement of the self-concept to be seen as larger than the self (either interdependent or transcendent) will improve sustainable behaviors. However, consumer psychology contends that one would anticipate anything to reflect things more concretely when those things are less distant to them (Liberman, Trope, & Stephan, 2007). Hence, the

current study predicts that green information framed with independent self-construal would result in more favorable attitudes and a greater likelihood of actual sustainable behaviors.

The hypotheses underlying this framework are as follows:

H1. When temporal distance in the green information is high (focused on the distant future):

H1a. there will be no significant difference in attitudes toward green products across condition.

H1b. there will be no significant difference in green purchase intention across condition.

H1c. there will be no significant difference in perceived green image of the company across condition.

H2. When temporal distance in the green information is low (focused on the near future):

H2a. low spatial distance (local referent) will result in a significantly more positive attitudes toward green products when the message features independent self-construal beneficiaries than when the message features interdependent self-construal beneficiaries.

H2b. high spatial distance (global) will not significantly affect attitudes toward green product regardless of whether the message features independent or interdependent self-construal.

H3. When temporal distance in the green information is low (focused on the near future):

H3a. low spatial distance (local referent) will result in a significantly more positive green purchase intention when the message features independent self-construal beneficiaries than when the message features interdependent self-construal beneficiaries.

H3b. high spatial distance (global) will not significantly affect green purchase intention regardless of whether the message features independent or interdependent self-construal.

H4. When temporal distance in the green information is low (focused on the near future):

H4a. low spatial distance (local referent) will result in a significantly more positive perceived green image of the company when the message features independent self-construal beneficiaries than when the message features interdependent self-construal beneficiaries.

H4b. high spatial distance (global) will not significantly affect perceived green image of the company regardless of whether the message features independent or interdependent self-construal.

Research methodology

Organization of scale items: This study applied measurement items created and validated in previous literature. Measured dependent variables include attitudes toward green products green purchase intention, and perceived green image of the company (Jaiswal and Kant 2018; Jeong et al. 2014). All scale items are based on five-point Likert scale ranging from 1 (Strongly disagree) to 5 (Strongly agree).

Sampling: We employ the data collected from university student samples to test the hypotheses. We conducted the data collection at the universities in large cities during 2019 to 2020. Final samples include first to fourth-year undergraduate students. Each of the samples got a ball-point pen as a premium at the time of participation in the experiment with no monetary incentives offered. Finally, a total of 2,028 usable data was included for statistical analysis.

Scenario manipulation: We employ a 2 (temporal: near future vs. distant future) x 2 (spatial: local vs. global) x 2 (self-construal: independent vs. interdependent) between subjects factorial design to examine the influence of temporal and spatial construal as well as self-construal content in green information of attitudes toward green product and purchase intention as well as perceived green image of the company. The experiments are divided into Group a, Group b, and Group c which are based on recycled products, refurbished products, and remanufactured products respectively. Upon agreeing to take part in the experiment, participants were assigned to the classroom where the paper questionnaires are distributed. There are totally twenty-four versions of the paper questionnaires dividing into eight scenarios for Group a, Group b, and Group c, and we randomly assign each participant to one of the eight scenarios. Each participant is directed to a randomly assigned scenario by reading the script.

Results

In the recycled product groups, the results align with the theoretical framework that low level of temporal and spatial distant combining with independent self-construal framing of green information leads to more positive attitudes toward recycled products, recycled product purchase intention, and perceived green image of the company. Specifically, the level of positive attitudes toward green products, green purchase intention as well as the perceived green image of the company is higher when the green information points out the benefits in the near future (vs. distant future), on the local community (vs. global), and for oneself (vs. others). Positive attitudes and purchase intention will eventually lead to Thai consumers' actual purchase of recycled products. In contrast, the results of refurbished and remanufactured products disclose that there is not the statistically significant difference across almost all conditions, expect one condition regarding perceived green image of the company.

As aforementioned that information consistent with an individual's mindset is easier to process than information that is inconsistent with his or her mindset, and one tends to process the information more concretely when being familiar with that content. The inconsistency found among the results of recycled, refurbished, and remanufactured product groups implies that consumers are more familiar with recycle products and recycling process comparing with refurbished or remanufactured cases. Accordingly, the results of hypothesis testing are all statistically significant. However, for refurbished and remanufactured products, there was no significant difference across almost all conditions. This may be caused by the unfamiliarity to the concepts of refurbishing and remanufacturing which are still new to Thai consumers. Interestingly, the significant differences found exhibit only the interaction effect on perceived green image of the company. Hence, it implies that in case of refurbished and remanufactured products, different construal level of green information regarding remanufactured products does not affect the consumers' attitudes toward the products and the intention to purchase. Therefore, we conclude that, when consumers are not familiar with specific green information such as material recovery innovation in this case, the information may not positively impact the attitudes toward the product or the purchase intention directly. Because Thai consumers are already familiar with the concept of recycling and recycled products, low construal level information framing which are relatively close to and more visible for an individual will be processed concretely and more positively. However, for marketers of refurbished and remanufactured products, it is still not necessary to promote the green benefits in various level of information construal, but it is recommended to focus more on giving basic foundation that enhance consumers' awareness or understanding about refurbishing / remanufacturing concepts. These results have implications for green product marketing and environmental communication fields in that they shed light upon the mechanism of message construal impact on consumer perception. By focusing on the importance of congruency and how it positively influences consumers' attitude green information, we can encourage sustainable product purchase and contribute to climate change deceleration.

Promoting Environmental Study to Enhance Sustainability Awareness

For green marketers, it is essential to communicate green information that match the basic understanding and foundation knowledge of the target customers. Media can act as the main channel for promoting the sustainability concepts, consequence of pro-environmental behavior and new innovations regarding green products such as refurbished products and biodegradable materials. For policy makers, in addition to general environmental knowledge, encouraging the knowledge about green product innovation such as material recovery process would be an effective channel to promote green product purchase as the sustainable behaviors. The schools in European countries (i.e. France) have solidly developed sustainability education so that the Europeans are familiar with sustainability concepts such as carbon-emission, carbon-tax, renewable energy, reverse logistics and material recovery (recycling, remanufacturing). What about in ASEAN countries? The schools and universities in Thailand have started including the

contents of sustainability into the curriculums recently, so it is predicted that there will more greater opportunities for refurbished and remanufactured products in Thailand markets in the future. In the Philippines, the creative game for environmental awareness has been developed and it is planned to be launched in school as a part of sustainability education (Escolano et al. 2023). Moreover, ASEAN has supported sustainability engagement via education through various campaigns such as ASEAN Eco-Schools Award Program which was first held in 2012 in Malaysia (ASEAN 2024). It is recommended that the contents of circular economy, closed-loop supply chain, reverse logistics, material recovery innovation (such as recycling, refurbishing, remanufacturing and biodegradable technology) should be introduced in primary and secondary education. Establishing the sustainability awareness in children would encourage sustainable behaviors in the long-run, leading to the contribution to contend against the climate change.

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GREEN LOGISTICS IN ASEAN: A STRATEGIC PATHWAY TO CLIMATE-RESILIENT SUPPLY CHAINS

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Introduction

As global supply chains become increasingly interconnected, the logistics sector is under mounting pressure to adapt to the growing realities of climate change. In the Association of Southeast Asian Nations (ASEAN), these challenges are particularly pronounced, with rising fuel costs, extreme weather events, and resource constraints significantly affecting the region's economic stability. ASEAN, a region comprising ten diverse economies, plays a crucial role in global trade and supply chain networks. However, its geographical vulnerability to climate change, coupled with high dependence on traditional logistics systems, presents both a significant threat and a unique opportunity for innovation.

The logistics sector, responsible for the transportation, warehousing, and distribution of goods, is one of the largest contributors to greenhouse gas (GHG) emissions globally (McKinnon 2018). In ASEAN, this reliance on carbon-intensive practices, coupled with the increasing frequency of extreme weather events, poses a severe risk to supply chain continuity and overall economic resilience (Amran et al. 2016; Yang and Li 2024). Without strategic intervention, climate-induced disruptions such as floods, droughts, and rising sea levels could severely impact trade routes, fuel availability, and infrastructure integrity, thereby threatening the region's economic growth and global competitiveness (Zhou, Endendijk, and Botzen 2023).

Green logistics, which refers to the integration of sustainable environmental practices into logistics and supply chain management, offers a strategic pathway for ASEAN countries to mitigate the environmental impacts of their logistics systems while also enhancing supply chain resilience. By adopting practices such as energy-efficient transportation, alternative fuels, and smart logistics technologies, ASEAN can reduce its carbon footprint, lower operational costs, and improve the flexibility of its supply chains in response to climate-related disruptions (Gonzalez-Feliu, Semet, and Routhier 2014).

Furthermore, the pursuit of green logistics aligns with global trends toward sustainability and presents ASEAN with a competitive advantage in the global market. As consumers and businesses increasingly demand environmentally responsible practices, supply chains that are optimized for both sustainability and resilience will be better positioned to thrive in the long term (Rodrigue 2020). Thus, ASEAN's adoption of green logistics is not just a matter of environmental responsibility but also a strategic move toward economic sustainability and competitiveness in a climate-challenged world.

This paper explores the critical role of green logistics in building climate-resilient supply chains within the ASEAN region, examining both the challenges and opportunities presented by this transition. It argues that the integration of green logistics practices is essential for ASEAN's long-term economic growth, offering a roadmap for how the region can enhance the sustainability and resilience of its supply chains in the face of mounting climate risks.

Key Challenges in ASEAN Supply Chains due to Climate Change Disruptions from Extreme Weather

Southeast Asia is increasingly affected by extreme weather events, including floods, typhoons, and rising temperatures, which disrupt transportation networks, warehouses, and production facilities (Farajzadeh, Ghorbanian, and Tarazkar 2023). These events pose significant challenges to supply chain stability across the region. For instance, the World Meteorological Organization (WMO, 2020) reported that the region experiences frequent extreme weather events, which cause substantial delays and damage to logistics infrastructure. A notable example is the flooding in Thailand, which disrupted key industries such as automotive and electronics, leading to regional and global supply chain breakdowns (Forslid and Sanctuary 2023; Loc et al. 2023).

As climate change intensifies, these disruptions are expected to become more frequent and severe. The Intergovernmental Panel on Climate Change (IPCC, 2022) projects an increase in extreme weather events, further threatening logistics reliability. ASEAN countries must invest in resilient infrastructure and adaptive strategies, such as flood-resistant transportation and diversified supply routes, to mitigate these risks and safeguard economic growth (Kashiwase, Magistretti, and Sy; Sundram 2023).

Rising Carbon Emissions

As ASEAN economies continue to grow, so too does the demand for transportation and logistics, leading to a significant rise in carbon emissions. This increase poses a major challenge for the region's sustainability efforts, as emissions from the logistics sector, particularly from freight transport, contribute heavily to greenhouse gas (GHG) emissions. According to Chandran and Tang (2013), ASEAN's transportation sector is projected to account for a significant portion of the region's carbon emissions, driven by growing industrialization, urbanization, and trade activities.

Without the adoption of green logistics practices, such as energy-efficient transportation modes and alternative fuels, carbon emissions in the region are expected to rise even further, exacerbating the global climate crisis. McKinnon (2018) notes that logistics activities, including freight transport and warehousing, are among the highest contributors to global CO₂ emissions. In ASEAN, the shift to low-carbon solutions remains slow, with many countries still heavily reliant on fossil fuel-based transportation and traditional logistics systems.

Reducing carbon emissions in logistics is crucial not only for environmental sustainability but also for the long-term economic stability of ASEAN. Countries in the region must prioritize the adoption of green logistics strategies, such as electric vehicles, optimized routing systems, and energy-efficient warehousing, to mitigate emissions and ensure that logistics growth does not come at the expense of the environment (Rodrigue 2020). Failure to act could undermine the region's broader sustainability goals and increase its vulnerability to climate change impacts.

Fragmented Infrastructure

A key challenge facing the ASEAN region in adopting green logistics practices is its fragmented infrastructure. Many countries in Southeast Asia have transportation networks, warehousing facilities, and logistics hubs that are outdated and unable to support energy-efficient or environmentally friendly operations. The World Bank (2020) highlights that the lack of infrastructure integration between ASEAN countries results in inefficiencies in cross-border trade and transportation, further complicating efforts to streamline logistics and reduce emissions.

This fragmentation creates significant barriers to the region's sustainability efforts. Without the modernization of transport networks, particularly in rural and less-developed areas, the potential for adopting green logistics practices such as electrified transport or optimized routing systems remains limited. For example, inadequate rail networks and outdated road systems prevent the shift from road to more eco-friendly modes of transport, such as rail and waterway freight, which could significantly reduce carbon emissions and energy consumption.

Investments in modern, energy-efficient infrastructure are critical for overcoming these challenges. Establishing eco-friendly logistics hubs, upgrading transportation networks, and implementing smart logistics technologies are essential steps toward achieving sustainable logistics across the region. Without such investments, ASEAN risks falling behind in mitigating the environmental impacts of its growing economic activity, ultimately hindering long-term regional sustainability.

Opportunities for Green Logistics in ASEAN

Adoption of Low-Carbon Transportation

The adoption of low-carbon transportation technologies, such as electric vehicles (EVs), fuel cell electric vehicles (FCEVs), and fuel-efficient logistics systems, presents a significant opportunity for ASEAN to reduce its final energy consumption (Li and Chang 2019) and eventually, carbon footprint while enhancing the sustainability of its supply chains. With transportation being one of the largest contributors to carbon emissions in the region, transitioning to greener alternatives is crucial.

Electric vehicles, in particular, offer a promising solution for reducing transportation-related emissions. Their adoption, coupled with investments in renewable energy infrastructure, could lead to more sustainable logistics operations, especially in urban areas where pollution is a growing concern. Additionally, the use of fuel-efficient systems, such as optimized routing and load consolidation, can further reduce emissions and improve the overall efficiency of logistics networks.

By investing in these greener transportation technologies, ASEAN countries can not only mitigate the environmental impacts of logistics but also build more resilient supply chains. This shift will enable the region to adapt to future climate risks while maintaining economic competitiveness on the global stage.

Eco-Friendly Warehousing

Eco-friendly warehousing presents a key opportunity for ASEAN countries to reduce the environmental footprint of their logistics operations. By integrating energy-efficient technologies and sustainable building practices, such as solar power and optimized energy use, warehouses can significantly lower carbon emissions while enhancing supply chain sustainability. According to Ren et al. (2023), green infrastructure in warehousing, including renewable energy sources and energy-efficient lighting and cooling systems, can drastically reduce energy consumption and operational costs.

Solar-powered warehouses, for example, offer an immediate solution to reducing reliance on fossil fuels, especially in regions with abundant sunlight, such as Southeast Asia. In addition, optimized energy use through smart systems, such as automated lighting and temperature control, can further reduce the carbon footprint of warehouse operations. As ASEAN's logistics demand grows, the adoption of eco-friendly warehousing solutions becomes essential for ensuring long-term environmental and economic sustainability.

Investment in green building certifications, such as LEED (Leadership in Energy and Environmental Design), can further encourage the development of sustainable warehousing infrastructure across the region. These certifications not only help in reducing energy use but also position companies to meet global sustainability standards, making ASEAN logistics more competitive in international markets.

Supply Chain Optimization through Technology

Leveraging advanced technologies such as artificial intelligence (AI), data analytics, and the Internet of Things (IoT) presents a critical opportunity for ASEAN countries to optimize supply chain efficiency and sustainability. By implementing these technologies, logistics operations can be streamlined, reducing waste and lowering carbon emissions. According to Abaku, Edunjobi, and Odimarha (2024), AI and data analytics enable predictive logistics management, allowing companies to optimize routes, forecast demand, and minimize fuel consumption, thereby reducing the environmental impact of supply chains.

The integration of IoT devices further enhances real-time monitoring capabilities, enabling businesses to track goods, monitor conditions, and optimize asset utilization across the supply chain. For instance, IoT sensors can help reduce energy consumption in warehouses by adjusting lighting and temperature based on occupancy and conditions (He et al. 2021). Moreover, these technologies can enhance supply chain resilience by identifying potential disruptions before they occur, enabling companies to respond proactively to climate-induced challenges. In summary, this digital transformation not only enhances operational efficiency but also positions the region's supply chains to thrive in a climate-constrained world.

Collaboration and Regional Integration

Collaboration and regional integration are critical components in advancing green logistics across ASEAN. Unified policies, resource sharing, and cross-border cooperation allow member countries to pool efforts and implement more effective, sustainable logistics solutions. According to the Asian Development Bank, regional cooperation is essential for developing climate-resilient infrastructure and for harmonizing standards that encourage sustainable practices across borders (Caballero-Anthony 2012).

ASEAN countries face shared environmental and economic challenges, making collaboration particularly valuable for addressing issues such as carbon emissions, infrastructure development, and supply chain disruptions caused by climate change. By promoting joint initiatives, such as shared logistics hubs and synchronized transport regulations, ASEAN can optimize resource use and reduce duplication of efforts (Rodrigue 2020). Furthermore, cross-border cooperation facilitates the efficient flow of goods, reduces transportation bottlenecks, and minimizes the environmental impact of logistics operations (McKinnon 2018).

For ASEAN to successfully transition toward greener logistics, it must continue to strengthen regional integration mechanisms, such as the ASEAN Economic Community (AEC), which fosters cooperation in trade and infrastructure development. By aligning logistics policies and investing in shared technological platforms, ASEAN can collectively enhance the resilience and sustainability of its supply chains.

Case Studies

Example 1: Key Green Logistics Practices in Singapore

Energy-Efficient Transportation

Singapore has encouraged the use of electric vehicles (EVs) and alternative fuel vehicles, particularly in its commercial fleet. The government has implemented policies such as the Commercial Vehicle Emissions Scheme (CVES) and Enhanced Early Turnover Scheme (ETS), which incentivize logistics companies to replace polluting vehicles with low-emission alternatives. The long-term goal is for all vehicles in Singapore to be cleaner and more energy-efficient by 2040.

This focus on decarbonizing transportation also includes investments in route optimization software and telematics systems. These technologies allow logistics companies to reduce fuel consumption by minimizing travel distances and ensuring more efficient fleet utilization.

Sustainable Warehousing Practices

Warehouses in Singapore are increasingly adopting energy-efficient systems, such as LED lighting, solar panel installations, and energy management systems. The playbook emphasizes the importance of reducing electricity consumption, particularly in cold storage warehouses where energy demand is high due to air conditioning and refrigeration needs. Some logistics providers, like YCH Group, have implemented solar leasing models, allowing them to achieve significant reductions in energy costs and carbon emissions.

Circular Economy Integration

Leading logistics providers in Singapore, like Bolloré Logistics, have integrated circular economy principles by offering services that focus on recycling and reducing waste from packaging materials. These companies help their clients reduce their environmental footprint by recycling product containers, shrink wraps, and even expired goods.

Collaboration and Innovation

Singapore promotes collaboration among logistics companies and the use of shared resources through initiatives like consolidation hubs and pooling platforms. This maximizes resource utilization, reduces wastage, and lowers costs, aligning with the green logistics goals.

Lessons for ASEAN Countries

Other ASEAN countries can learn from Singapore's strategic approach to green logistics by:

- **Implementing incentive programs:** Governments can introduce similar schemes to encourage the transition to electric and low-carbon vehicles, such as tax incentives, rebates, or grants for companies that adopt greener technologies. For instance, the CVES and ETS in Singapore have proven effective in accelerating the shift towards sustainable transportation options.
- **Adopting energy-efficient warehousing:** ASEAN nations can follow Singapore's lead in promoting the installation of renewable energy solutions like solar panels and energy-efficient lighting systems in warehouses. These steps help reduce operational costs and environmental impacts, especially in energy-intensive sectors like cold storage.
- **Encouraging circular logistics:** Integrating circular economy principles in logistics operations—such as recycling and reuse of packaging—can significantly reduce waste across supply chains. Singapore's focus on circularity through partnerships with third-party logistics providers like Bolloré can serve as a model for ASEAN countries to enhance sustainability in their logistics sectors.
- **Leveraging digital solutions:** ASEAN countries can adopt digital tools like route optimization software, telematics, and demand forecasting systems, similar to Singapore's approach. These tools not only improve logistics efficiency but also help in reducing fuel consumption and greenhouse gas emissions.

Example 2: Green and Sustainable Development in WHA Corporation's Industrial and Logistics Sectors

As climate change intensifies, the logistics and industrial sectors in ASEAN face unprecedented challenges. WHA Corporation, a leader in Thailand's logistics and industrial estate development, has responded by adopting green and sustainable practices to mitigate environmental impacts and enhance supply chain resilience. This case study explores how WHA integrates green logistics, circular economy principles, and resource management to address these issues, offering actionable insights for ASEAN countries.

Key Green and Sustainable Issues in the Industrial and Logistics Sectors

- **Climate change vulnerabilities:** Extreme weather events and rising fuel costs threaten the stability of supply chains. Traditional logistics models heavily reliant on fossil fuels increase exposure to environmental risks.
- **Resource scarcity:** Industrial activities are straining natural resources, particularly water, making efficient management and recycling crucial for sustainability.

- Demand for green solutions: Stakeholders, investors, and regulators are increasingly pressing companies to implement sustainable logistics practices that align with global environmental standards.

WHA's Approach to Tackling Sustainability Issues

- Green logistics and electric vehicles (EVs): WHA has launched a Green Logistics initiative that includes the use of electric vehicles and the development of renewable energy-powered charging infrastructure. This reduces fuel consumption and carbon emissions, aligning logistics operations with sustainability goals.
- Circular economy integration: Committing to a 100% circular economy by 2050, WHA focuses on reducing waste and optimizing resources through over 40 projects. These initiatives include green product development, resource-efficient designs, and operational excellence.
- Solar energy and water management: WHA has expanded its solar energy use by installing solar rooftops in industrial estates, significantly lowering its carbon footprint. Efficient water management practices, including wastewater recycling, reduce reliance on natural resources, fostering sustainable operations.
- Digital transformation: WHA is on track to becoming a tech-driven company by 2024. Its "Mission to the Sun" project integrates digital solutions that enhance logistics efficiency, reduce operational costs, and contribute to sustainable practices.
- Transparent sustainability reporting: WHA adheres to the Global Reporting Initiative (GRI) standards, ensuring its sustainability efforts are transparent and aligned with the UN Sustainable Development Goals (SDGs).

Key Lessons Learned for ASEAN Countries

- Circular economy implementation: WHA's circular economy initiatives offer a roadmap for ASEAN nations to reduce waste, enhance resource efficiency, and create competitive green products that align with global market demands.
- Green logistics adoption: ASEAN countries can replicate WHA's use of electric vehicles and renewable energy infrastructure to minimize the environmental impact of their logistics sectors while reducing fuel costs.
- Efficient water and resource management: WHA's approach to water recycling and efficient resource use serves as a model for ASEAN countries facing natural resource constraints. Effective management practices can reduce dependency on limited natural resources.

- Digital and tech-driven solutions: WHA' s digital transformation demonstrates the potential for ASEAN nations to adopt technology that enhances logistics operations, reduces emissions, and increases supply chain resilience against climate disruptions.
- Stakeholder engagement and governance: WHA' s transparent and inclusive approach to stakeholder engagement underscores the importance of building trust and maintaining strong governance to support long-term sustainability initiatives.

WHA Corporation's green logistics, circular economy, and digital transformation strategies provide a blueprint for ASEAN countries seeking to address the dual challenges of climate resilience and economic growth. By leveraging renewable energy, sustainable practices, and stakeholder engagement, ASEAN nations can strengthen their supply chains and position themselves as leaders in the global fight against climate change.

Example 3: Green and Sustainable Development in ASEAN Manufacturing Supply Chain

The ASEAN region has long been a critical player in global manufacturing, driven primarily by its role as a hub for low-cost labor-intensive industries. However, the manufacturing landscape is rapidly shifting due to global trends such as climate change, economic nationalism, and advances in Industry 4.0 technologies. Boston Consulting Group (BCG) emphasizes that ASEAN now has an opportunity to move up the manufacturing value chain by adopting greener, more sustainable practices. This case study explores the green and sustainable issues in ASEAN's manufacturing sector and BCG's insights into how the region can capitalize on new opportunities for growth and competitiveness.

Key Green and Sustainable Issues in the Industrial and Logistics Sectors

ASEAN's manufacturing and logistics sectors face several critical challenges, including:

- Rising carbon emissions: Southeast Asia has experienced a rapid increase in CO2 emissions, driven by its industrial sectors. As global consumers and regulators place more emphasis on reducing greenhouse gas emissions, manufacturers must find ways to decarbonize their operations.
- Supply chain vulnerabilities: The region' s heavy reliance on specific global markets, particularly China, leaves it vulnerable to supply chain disruptions. Rising trade tensions, natural disasters, and the COVID-19 pandemic have highlighted the risks of overdependence on single-source supply chains.
- Pressure for technological adoption: Global competitors are leveraging Industry 4.0 technologies to enhance productivity and sustainability, while ASEAN still lags in adopting advanced manufacturing systems.

How BCG Suggests Tackling These Issues

BCG outlines several strategies that ASEAN manufacturers can adopt to address these sustainability challenges:

- **Leveraging Industry 4.0:** BCG emphasizes that the adoption of advanced manufacturing technologies such as robotics, IoT, and AI can improve both productivity and environmental sustainability. Countries like Singapore and Vietnam have made strides by integrating smart factories and advanced digital platforms in their manufacturing processes.
- **Decentralizing and localizing supply chains:** To reduce dependence on global supply chains, BCG recommends a "China Plus One" strategy, where companies maintain a manufacturing base in China while developing additional locations in ASEAN. This approach not only diversifies risk but also brings manufacturing closer to end consumers.
- **Greening supply chains:** BCG highlights the importance of reducing carbon emissions by adopting greener manufacturing practices. This includes utilizing renewable energy sources, improving energy efficiency, and optimizing production processes to minimize waste and emissions. BCG also advocates for regional collaboration in establishing carbon trading systems and promoting green innovation.
- **Twinning models:** This involves splitting up different parts of the value chain across multiple ASEAN countries to capitalize on their specific strengths. For example, one country might provide cost-effective labor, while another excels in innovation and logistics.
- **Key Findings and Lessons for ASEAN Countries**
- **Move Up the Value Chain:** By adopting Industry 4.0 technologies and focusing on high-value segments like medical technology and electric vehicles, ASEAN can shift from low-wage assembly work to more advanced, sustainable manufacturing.
- **Strengthen Regional Integration:** The Regional Comprehensive Economic Partnership (RCEP) offers ASEAN countries a chance to deepen integration, allowing manufacturers to take advantage of tariff-free access to key markets across Asia. This opens opportunities for building multinational value chains that leverage each country's strengths.
- **Focus on Green Manufacturing:** The global trend toward greener supply chains offers a strategic advantage for ASEAN countries that prioritize environmental sustainability. ASEAN governments should incentivize renewable energy investments, implement carbon-reduction targets, and help manufacturers align with global green standards.

- **Diversify Supply Chains for Resilience:** The shift towards regional supply chains will reduce vulnerability to global disruptions and enable ASEAN countries to position themselves as attractive alternative manufacturing hubs, complementing China's dominance in the region.

Conclusively, BCG's analysis provides a clear roadmap for ASEAN countries to not only mitigate the environmental impacts of their manufacturing sectors but also to capitalize on the global shift towards sustainable and resilient supply chains.

Policy Recommendations for ASEAN Governments

The policy recommendations for ASEAN governments emphasize the urgent need to adopt green logistics practices in response to the challenges posed by climate change, including extreme weather disruptions, rising carbon emissions, and environmental concerns. Green logistics focuses on reducing environmental impact while improving supply chain efficiency and resilience.

The recommendations advocate for leveraging advanced technologies from Industry 4.0 and Industry 5.0, promoting public-private partnerships, and fostering regional cooperation. These strategies aim to build adaptable, efficient, and sustainable logistics systems that integrate human-centric solutions, advanced technologies, and climate-conscious decisions. By implementing these policies, ASEAN countries can reduce their carbon footprint, enhance operational efficiency, and mitigate climate-related risks. The shift towards green logistics will not only help preserve the environment but also strengthen economic stability and competitiveness in the global market.

1. Incentives for Green Investments

- **Supporting the adoption of low-carbon technologies:** Governments should provide financial incentives (e.g., tax breaks, subsidies) to logistics companies that invest in low-carbon transportation systems, such as electric vehicles and fuel-efficient technologies. This is aligned with Industry 5.0 goals of sustainability and resilience, which are critical for reducing emissions in logistics operations.
- **Encouraging investment in smart logistics and industry 5.0 solutions:** Encourage investments in smart logistics systems, including AI-driven optimization, automated guided vehicles (AGVs), and human-robot collaboration, which reduce carbon footprints and improve energy efficiency.
- **Funding sustainable infrastructure projects:** Expand green financing to logistics firms that invest in renewable energy-powered warehouses and smart energy management systems. This supports ASEAN's transition towards greener infrastructure and aligns with the goal of resource efficiency outlined in Industry 5.0.

2. Cross-Border Green Logistics Framework

- Regional data integration for sustainable supply chains: ASEAN should develop a regional data-sharing platform that leverages blockchain for real-time tracking and transparency across supply chains. This will improve carbon footprint traceability and ensure sustainability throughout logistics networks.
- Implementation of smart transportation networks: ASEAN governments should promote IoT-enabled transportation systems for logistics optimization, which can reduce route inefficiencies and fuel consumption by using real-time data analysis.
- Harmonizing green logistics standards: Develop unified regional policies that standardize low-emission transportation and carbon-neutral warehousing across ASEAN. This consistency will enable smoother cross-border logistics integration.

3. Public-Private Partnerships (PPPs)

- Supporting circular economy in logistics: Governments should foster PPPs that promote reverse logistics and circular economy practices, such as recycling and reusing materials. This will align supply chains with Industry 5.0's sustainability goals.
- Workforce development for smart logistics: Collaborate with the private sector to create training programs aimed at upskilling workers for smart logistics environments. This includes proficiency in AI-based operations, human-robot collaboration, and augmented reality systems.
- Investing in human-centric logistics innovations: Promote private-sector investments in human-centric technologies, such as wearable devices, exoskeletons, and collaborative robotics, to enhance both efficiency and worker well-being.

4. Integration of Climate Change Goals in Supply Chain Policies

- Digitalization for climate resilience: ASEAN governments should encourage the adoption of digital twins and AI-driven supply chain simulations to enhance risk management and prepare for climate change-related disruptions.
- Sustainable product lifecycle management: Promote the use of circular lifecycle management in logistics, ensuring that products are designed for recycling, remanufacturing, and reduced waste. This aligns with Industry 5.0's focus on sustainable value creation.
- Regional alignment with global climate goals: Ensure that supply chain and logistics policies are aligned with global climate agreements like the Paris Agreement. This will help ASEAN countries lead in sustainable logistics practices and meet international climate commitments.

5. Long-Term Agricultural Policy Reform

- Smart agriculture and supply chain integration: ASEAN should encourage AI-powered monitoring and precision agriculture to build resilient agricultural supply chains that are less vulnerable to climate impacts. This will secure food supply chains while reducing environmental degradation.
- Development of green logistics hubs for agriculture: Establish logistics hubs dedicated to supporting sustainable agricultural exports, using energy-efficient cold chains, low-emission transport, and renewable energy for warehousing.
- Scaling circular practices in agricultural supply chains: Promote circular economy principles in agricultural logistics, such as using biodegradable materials and recycling agricultural waste, to ensure that agricultural supply chains are both sustainable and resilient.

Table 1 - Summary of recommended policies for ASEAN

Policy Group Sub-Issues Source (Authors, Year)

Incentives for Green Investments Adoption of low-carbon technologies; Investment in smart logistics & Industry 5.0; Funding sustainable infrastructure projects Ivanov (2023)

Cross-Border Green Logistics Framework Regional data integration; Implementation of smart transportation networks; Harmonizing green logistics standards Ghobakhloo et al. (2022); Ivanov (2023)

Public-Private Partnerships (PPPs) Circular economy; Workforce development; Human-centric innovations Ivanov (2023)

Integration of Climate Change Goals Digitalization for climate resilience; Sustainable product lifecycle; Alignment with global climate goals Villar, Paladini, and Buckley (2023); Ivanov (2023)

Long-Term Agricultural Policy Reform Smart agriculture & supply chain integration; Development of green logistics hubs; Circular practices in agricultural supply chains Ghobakhloo et al. (2022); Villar, Paladini, and Buckley (2023)

Conclusion

In conclusion, the paper emphasizes the critical need for ASEAN to adopt green logistics in response to climate change. By integrating energy-efficient transportation, alternative fuels, and smart technologies, ASEAN can reduce carbon emissions and enhance supply chain resilience. Key challenges include fragmented infrastructure and rising emissions, but opportunities lie in low-carbon technologies and eco-friendly warehousing. Collaboration and regional integration are essential for a unified approach. The research provides a strategic roadmap for ASEAN to align with global sustainability goals, ensuring long-term economic growth and climate resilience through green logistics.

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EMPOWERING WOMEN: EXPLORING THE INTERNATIONAL OF CLIMATE CHANGE, REPRODUCTIVE HEALTH, AND RESILIENCE

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Introduction

According to the National Aeronautics and Space Administration (NASA), climate change refers to the long-term alteration of average weather patterns that define Earth's local, regional and global climates. The observed changes in the Earth's climate since the mid-20th century are primarily driven by human activities, notably the burning of fossil fuels, which elevates the levels of heat-trapping greenhouse gases in the atmosphere and raises the planet's average surface temperature. While natural processes such as internal variability – exemplified by cyclical ocean patterns like El Niño (1), La Niña (2), and the Pacific Decadal Oscillation – can contribute to climate change, these have been largely overshadowed by human actions. Additionally, external factors such as volcanic activity, fluctuations in solar energy output, and variations in Earth's orbit also play a role in climate dynamics.

Every human being is exposed to the risk of climate change, however women and children – especially those living in poverty – are disproportionately affected by climate change, with significant consequences for their health. Climate change acts as a risk multiplier, exacerbating gender-based health disparities. While both men and women face health risks from climate impacts, women have distinct vulnerabilities, such as increased nutritional needs during pregnancy and breastfeeding, which heightens their susceptibility to climate-sensitive diseases. Men, on the other hand, are more likely to experience mental health challenges like stress, severe depression and suicide due to climate-related factors like drought and agricultural losses (3) and may also be at higher risk of drowning during extreme weather events (4).

Cultural and social norms further multiple women's health vulnerabilities, particularly in regions where gender-based discrimination is prevalent. Globally, 1.3 billion people in low- and middle-income countries live in poverty, and 70% of them are women (5). The intersection of poverty, gender inequality, and climate change intensifies health risks for women, but at the same time, women's social roles in the community present opportunities for addressing these challenges. Women can play reduction and in promoting sustainable solutions, disaster risk reduction, and improving health outcomes

in the face of climate threats. Year after year, The world witness record-breaking data for global temperatures, rainfall, wildfires, storms, and the spread of vector-borne diseases. The common thread in these trends is the pervasive impact of climate change, which is further compounding health risks, including worsening air pollution. These effects are projected to exacerbate the COVID-19 pandemic's impact. The Lancet Countdown reports on health and climate change for 2019 and 2020, convening 35 academic institutions and United Nations agencies, highlighted alarming statistics. In 2019 alone, the world saw unprecedented population exposures to wildfires and 475 million additional heatwave events. Global warming is now projected to exceed a 3°C rise in average temperature by the end of the century, a threshold that the United Nation's Intergovernmental Panel on Climate Change has declared a "code red" for the planet.

Literature Review and Methodology

This study undertakes a thorough literature review to explore the complex relationship between climate change and its impacts on women, with particular emphasis on vulnerabilities related to food security, water scarcity, displacement, and health outcomes. By synthesizing insights from prominent reports and studies published by esteemed organizations such as the FAO, UNHCR, and the World Bank, this review aims to uncover critical gaps in the existing body of research, especially in the areas of reproductive health, climate-induced migration, and the mental health challenges faced by women in developing regions.

The methodology employed in this study is a desk review, which systematically analyses both empirical data and theoretical frameworks to illuminate underexplored aspects of reproductive autonomy and the mental health implications arising from climate disruptions. This structured approach facilitates a comprehensive understanding of the nuanced ways in which climate change affects women and their specific vulnerabilities. By integrating findings from a diverse range of researchers, including Azra Ali, Doris Anjula, Amina Baroudi, Xerxes Bhan, Anna Bhatti, Mohamed Elshamy, Amani Shair, and Ambreen Shams, this literature review aims to inform future research trajectories and guide policy interventions that address these urgent and interconnected issues.

The Climate Change and Reproductive Health of Women

These climatic shifts, including more frequent and severe weather events—such as droughts, heavy rains, rising sea levels, extreme heat, and storms—create ideal conditions for the spread of vector-borne diseases. The World Health Organization (WHO) reports that natural disasters have tripled since 1960, resulting in more than 60,000 deaths each year (6). By 2030, WHO forecasts that climate-related factors will contribute to at least 250,000 deaths annually. These impacts threaten not only global health but also critical aspects of the daily lives—such as the air people breathe, the water people drink, the food people eat and the access to shelter (7). The healthcare professionals, particularly in obstetrics and gynecology recognize that these changes directly affect reproductive health

and women's choices, with long-lasting effects that could carry over into future generations. Additionally, death rates from disasters are disproportionately higher in low-income countries.

How do climate change & air pollution affect pregnancy & human development?

Air pollution poses significant risks to reproductive health, influencing both fertility outcomes and pregnancy complications. The following points outline key findings from recent research on the impact of air pollution on pregnancy and human development:

The Impact of Air Pollution

Studies have shown potential associations between proximity to major roadways and reduced fertility outcomes. Recent study by Gaskins et al. (8) found that women living closer to major roads exhibited a lower probability of successful implantation and live birth during in vitro fertilization (IVF) cycles. Similarly, Mendola et al. (9) observed that couples residing near major roadways experienced longer times to pregnancy and faced higher risks of infertility, though these findings were not statistically significant. Additionally, Quraishi et al. (10) reported a significant decrease in live birth rates, especially among women with specific infertility diagnoses, such as diminished ovarian reserve, who lived near heavily trafficked roads.

Particulate Matter and Ovarian Function

Several research have increasingly pointed to the adverse effects of environmental pollutants on fertility. Ogliari et al. (11) demonstrated in animal models that exposure to diesel exhaust particulate matter (PM_{2.5}) during intrauterine development led to a marked reduction in ovarian reserve, potentially impacting reproductive health over the long term. This aligns with findings from Gaskins et al. (12), who reported a link between higher exposure to PM_{2.5} and diminished ovarian reserve in women, as evidenced by lower antral follicle counts (AFC). Together, these studies highlight the serious reproductive risks associated with air pollution, particularly its influence on ovarian function and fertility outcomes.

Air Pollution and IVF Success

Furthermore, recent studies by Legro et al. (13) observed that exposure to nitrogen dioxide (NO₂) and fine particulate matter (PM_{2.5}) had detrimental effects on in vitro fertilization (IVF) outcomes, most notably by reducing live birth rates. Additionally, they found that PM_{2.5} exposure during the embryo culture phase was linked to decreased conception rates. On the other hand, Perin et al. (14) reported that while exposure to larger particulate matter (PM₁₀) during the follicular phase did not significantly influence overall IVF clinical outcomes, it was associated with a higher risk of miscarriage. These findings indicate that air pollution, particularly exposure to different types of particulate matter, can adversely affect IVF success and pregnancy outcomes.

General Fertility and Fecundability

Both scientists Wesselink et al. (15) and Slama et al. (16) both found that increased exposure to nitrogen dioxide (NO₂) and particulate matter (PM_{2.5}) was correlated with reduced fecundability, meaning that the likelihood of conception within a specific period decreased as exposure levels rose. These findings underscore the impact of air pollution on reproductive health, particularly its influence on the time it takes to conceive.

Impact of Air Pollution on Sperm Quality and Male Fertility

Remarkable research by Hammoud et al. (17) reported a significant association between higher levels of PM_{2.5} and reduced sperm motility in men, suggesting a detrimental effect on male fertility. Similarly, Yang et al. (18) demonstrated that chronic exposure to diesel exhaust PM_{2.5} in mice impaired spermatogenesis, leading to a reduction in both sperm count and motility. Chen et al. (19) further linked increased exposure to sulfur dioxide (SO₂) and nitrogen oxides (NO_x) with decreased testicular volume and poorer sperm quality in infertile men, highlighting the broader reproductive consequences of air pollution on male fertility.

Impact of Air Pollution on Preterm Birth and Birth Defects

Many scientists observed that higher levels of PM_{2.5} exposure during pregnancy were linked to an increased risk of preterm birth (20). Similarly, Kwag et al. (21) identified that the combination of heat waves and elevated PM_{2.5} concentrations significantly heightened the risk of preterm birth in Korea. Cheng et al. (22) further found that higher levels of PM₁₀, PM_{2.5}, NO₂, and SO₂ during the first trimester were associated with an elevated risk of birth defects, particularly congenital heart defects. In addition, Padula et al. (23) noted that exposure to airborne polycyclic aromatic hydrocarbons (PAHs) during the last six weeks of pregnancy significantly raised the risk of early preterm birth, with a more nuanced relationship between PAH exposure and preterm birth risk earlier in pregnancy.

Case Study: The intersection of climate change and women's access to healthcare, contraception, and safe childbirth

In Bangladesh's coastal areas, particularly in Khulna and Patuakhali districts, offers critical insights into the intersection of climate change and women's access to healthcare, contraception, and safe childbirth. These regions, heavily affected by climate hazards such as rising sea levels, salinity intrusion, and extreme weather, present numerous challenges for women, especially regarding reproductive health services.

In these areas, women face increased responsibilities in collecting safe drinking water, traveling long distances to fetch it due to contamination of water sources. This added burden leaves less time for them to access healthcare services, including contraception and maternal care. The lack of gender-sensitive medical facilities further exacerbates the situation, particularly in times of crisis when shelters lack adequate provisions for women's privacy and safety. These environmental changes directly affect women's reproductive health, with salinity linked to increased risks during childbirth.

Moreover, with male out-migration, women are left to manage households and seek livelihoods, often in unsafe or informal sectors, without sufficient access to sexual and reproductive health services. Policies in place, such as the Bangladesh Climate Change Strategy and Action Plan (BCCSAP), have identified these gender-specific impacts, yet challenges remain in implementing gender-responsive solutions on the ground (24).

This case highlights the urgent need for targeted interventions that improve women's access to essential healthcare in climate-vulnerable regions like Bangladesh's coast (25).

Socioeconomic Barriers and Gender Inequality

Economic Vulnerability

Climate change poses significant challenges to women's livelihoods, particularly in agriculture-dependent economies, where they often play critical roles. Women make up a significant portion of the agricultural workforce globally, especially in developing regions. However, they face heightened vulnerabilities due to climate-related impacts such as extreme weather events, droughts, and floods, which threaten crop yields and food security. For instance, a report by the Food and Agriculture Organization (FAO) indicates that climate change could reduce agricultural productivity by up to 30% in some regions, disproportionately affecting women who rely on farming for their livelihoods (FAO, 2021) (26).

Furthermore, women's economic activities are often confined to subsistence farming, limiting their ability to invest in climate-resilient practices. In many societies, women's access to land, credit, and resources is restricted, making it difficult for them to adapt to changing climatic conditions. A study published in *Climate and Development* found that women are less likely to receive agricultural training or access climate-smart technologies compared to their male counterparts, exacerbating their vulnerability in the face of climate change (Agarwal, 2010) (27).

Limited Access to Resources

Women face numerous barriers in accessing resources essential for adapting to climate change. Limited access to climate-resilient technologies, Internet of Things (ToT), financing, and education further hinders their capacity to respond effectively to climate-related challenges. For example, women often have less access to extension services that provide information on smart agricultural practices and climate adaptation strategies. A report by the World Bank highlights that women farmers are less likely to receive information about new agricultural technologies, which hampers their productivity and ability to cope with climate stresses (World Bank, 2019) (28).

Financial barriers are also a significant challenge. Women often have less access to credit and financial services, which limits their ability to invest in climate-resilient technologies. Research shows that when women are included in agricultural financing programs, there is a notable increase in productivity and income, emphasizing the importance of addressing these financial gaps (Gonzalez, 2020) (29).

Gender Inequality in Decision-Making

A study by the United Nations Environment Programme (UNEP) found that countries with higher female representation in decision-making positions are more likely to adopt effective climate policies (UNEP, 2019) (30). The exclusion of women from decision-making processes in climate adaptation planning and policy-making perpetuates gender inequality and hinders effective responses to climate change. Women are often underrepresented in leadership roles within environmental governance, which limits their ability to influence policies that affect their lives and livelihoods.

Moreover, the lack of women's voices in climate negotiations and planning processes can lead to policies that do not adequately address their specific needs or challenges. For example, the Global Gender and Climate Alliance emphasizes that integrating gender perspectives into climate action is crucial for achieving equitable and sustainable outcomes (GCCA, 2021) (31).

Climate Migration and Women's Safety

Displacement and Migration

Climate-induced migration presents unique challenges for women, who often face heightened risks during their displacement. As climate change exacerbates natural disasters and environmental degradation, many women are forced to migrate from their homes to escape these impacts. This forced migration can significantly increase their vulnerability to gender-based violence (GBV). According to the United Nations High Commissioner for Refugees (UNHCR), women in refugee camps or informal settlements are at a greater risk of experiencing sexual violence, trafficking (32), and exploitation, as the breakdown of social structures often accompanies climate disasters (33).

Moreover, during migration, women frequently encounter barriers to accessing safe shelter. Displaced women may be compelled to sleep in unsafe conditions or rely on temporary accommodations that lack adequate protection and privacy (34). This vulnerability is compounded by disrupted access to healthcare and hygiene services, as women often struggle to find essential reproductive health care, prenatal services and mental health support during and after their migration (35). The absence of targeted health services can lead to significant risks, including maternal mortality and increased psychological distress.

Adapting to New Environments

Once displaced, women face the challenge of adapting to new environments that may present social, cultural, and economic barriers. Many migrant women find themselves in unfamiliar settings, where they must navigate different cultural norms and practices, which can limit their ability to integrate into local communities (36). For instance, women may experience discrimination or hostility, particularly if they belong to marginalized ethnic or cultural groups (37).

Economically, displaced women often struggle to secure stable employment due to various barriers, such as lack of recognition of their skills, language differences, and limited access to financial resources (38). These challenges hinder their ability to support themselves and their families, making them more susceptible to exploitation and abuse in the labour market. A report from the International Organization for Migration (IOM) highlights that empowering displaced women through skill-building programs and access to financial resources is essential for their successful integration into new environments (39).

Case Study: Migrant Women in the Andean Region

The Andean region offers a poignant case study of how climate change and socio-political factors drive women to migrate. Countries like Bolivia, Peru, and Ecuador are experiencing significant environmental challenges, including droughts, glacial melting, and extreme weather events, which threaten agricultural livelihoods (40). In addition, socio-political instability and economic hardships further exacerbate the need for migration.

Migrant women in this region often face multiple layers of challenges. For example, many women migrating from rural areas to urban centres in search of better opportunities encounter not only environmental hardships but also social barriers such as discrimination and limited access to social services. A study conducted by the United Nations Development Programme (UNDP) illustrates that these women often engage in informal work, which exposes them to job insecurity and inadequate labour protections (41).

Furthermore, their experiences are shaped by cultural expectations and gender roles that can limit their mobility and agency. Women are often tasked with caring for family members, which can hinder their ability to pursue employment or educational opportunities in new environments (42). Addressing these challenges requires a multi-faceted approach that includes policy interventions aimed at protecting the rights of migrant women and providing them with access to resources and support networks (43).

Mental Health Impacts on Women and the family

Climate change significantly contributes to emotional and psychological distress and anxiety, particularly among women, especially in marginalized communities. Research indicates that women are often at the forefront of experiencing climate-related stressors due to their roles in families and communities, as well as their reliance on natural resources for livelihoods. This can lead to heightened levels of climate anxiety (44), characterized by persistent worry about environmental degradation and its implications for the future (45). In areas heavily impacted by climate events—such as hurricanes, droughts, or floods—women often bear the brunt of these changes (46), leading to increased rates of depression and anxiety (47).

For example, a study conducted in low-income communities highlighted that women reported feelings of helplessness and fear regarding their families' safety and well-being amid increasingly frequent natural disasters (48). Furthermore, women in these communities frequently face compounded stressors, including economic instability, loss of home, and disruptions to their social networks, all of which contribute to mental health challenges (49). As mental health issues become more prevalent, access to mental health resources remains limited in many regions, exacerbating the problem (50).

Given the rising mental health impacts of climate change, there is an urgent need for targeted research that explores climate trauma and specific coping strategies among women, particularly in disaster-prone regions like the Pacific Islands. Emerging studies suggest that the unique experiences of women during climate-related disasters—including displacement, loss of livelihoods, and trauma from violence—warrant focused attention (51).

Research could investigate how women in these regions cope with climate anxiety and trauma, identifying culturally relevant support systems and coping mechanisms. For instance, community resilience initiatives that incorporate traditional practices and peer support could offer valuable insights into effective coping strategies (52). Additionally, qualitative studies that explore women's narratives and experiences can shed light on the psychological toll of climate change and highlight the importance of incorporating mental health resources into climate adaptation strategies (53).

Adaptation and Resilience: Empowering Women in Climate Action

Women play a crucial role in climate adaptation, often leading initiatives that promote sustainable practices and resilience-building within their communities (54). For instance, various grassroots organizations empower women to take leadership roles in environmental conservation, disaster risk reduction, and smart agriculture (55). In many developing regions, women are the primary managers of natural resources and have a wealth of knowledge about local ecosystems. Programmes that harness this knowledge, such as women's cooperatives focused on agroecology and permaculture, have proven effective in enhancing food security and adapting to climate impacts (56).

One notable example is the work of the Women's Environmental and Development Organization (WEDO), which promotes gender equity in climate change negotiations and supports women's initiatives globally. In regions like sub-Saharan Africa, women have been instrumental in implementing community-led reforestation projects, which not only combat climate change but also enhance local biodiversity and improve livelihoods (57). Such initiatives demonstrate that when women lead climate adaptation efforts, they contribute significantly to building resilient communities capable of facing environmental challenges (58).

Policy Recommendations

To maximize the impact of women's contributions to climate adaptation, it is imperative to advocate for gender-sensitive climate policies. These policies should prioritize women's access to resources, education, and decision-making roles within climate action frameworks.

Key Recommendations for policymakers include:

- Enhancing women's accessibility to resources: Provide women with access to climate-resilient technologies, financing, and training. For example, microfinance programs can enable women to invest in sustainable agricultural practices and renewable energy solutions.
- Promoting inclusive education and capacity development programme: Invest in educational initiatives that empower women with the knowledge and skills needed for effective climate action. This includes training on sustainable practices, environmental management, and leadership development.
- Ensuring women representation in decision-making: Implement measures that promote women's participation in climate policy-making at all levels, from local to national. Ensuring women have a voice in these discussions is vital for creating comprehensive climate strategies that reflect diverse experiences and insights.

Conclusion

In conclusion, addressing the nexus between climate change and gender is essential for building resilient communities and empowering women to take an active role in climate adaptation. Women, particularly in vulnerable regions, face compounded challenges such as limited access to healthcare, economic resources, and decision-making power, all of which are exacerbated by climate disruptions. By incorporating gender-sensitive policies that enhance women's access to resources, education, and leadership roles, societies can foster more inclusive and effective climate solutions. This approach not only mitigates climate risks but also promotes sustainable development and equity.

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