Strategies for Achieving Net Zero Emissions in the Beverage Industry: A Case Study from Thailand's Carbon Footprint Analysis

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ABSTRACT

Parties to the United Nations Framework Convention on Climate Change (UNFCCC) are required to provide detailed accounting of their country's greenhouse gas emissions from various activities for reporting to the UNFCCC secretariat. The latest assessment of Thailand's greenhouse gas emissions shows that the energy sector is the largest emitter, followed by the agricultural sector, the industrial processes and product use sector, and the waste sector. The global beverage industry is a significant contributor to greenhouse gas emissions and climate change, with the majority of emissions stemming from raw material procurement, production processes, and transportation activities. The production process, in particular, relies heavily on resources and energy from fossil fuels. In the case of alcoholic beverages, fermentation by-products generate a substantial amount of carbon dioxide emissions during production. Various methods and strategies have been proposed to mitigation greenhouse gas emissions in the beverage manufacturing industry, including the use of bioenergy as a substitute for fossil fuels. Installing solar cell to reduce electricity consumption aligns with energy efficiency and energy saving policies. Waste management based on circular economy principles, along with expanding forest areas for carbon sequestration in line with carbon capture and storage guidelines are key strategies. These methods support the goals of carbon neutrality and achieving net zero emissions in the future.

Keyword: Carbon Neutrality/ Greenhouse Gases/ Bioenergy/ Carbon Capture Storage/ Net-Zero Emissions

1. INTRODUCTION

The global beverage industry significantly contributes to greenhouse gas emissions and climate change, with the majority of emissions arising from raw material sourcing, production processes, and transportation activities. The production process, in particular, depends heavily on resources and energy derived from fossil fuels, which are burned to power machinery. In the case of alcoholic beverages, fermentation by-products further contribute to carbon dioxide emissions during production.

Alcohol production and consumption in Sweden contribute to climate change, yet this is rarely discussed. The environmental impact of alcohol, from its production processes to the resources consumed and waste generated, plays a role in the ongoing climate crisis, but its effects often go unnoticed. A report titled Climate Impacts of Consumption in Sweden, produced by the state research institute RISE in collaboration with the Karolinska Institute, examined the dietary habits (including food, beverages, and alcohol) of 50,000 Swedes. The findings reveal that alcohol is a significant contributor to Sweden's overall climate impact. Alcohol accounts for 3% of the average per capita greenhouse gas emissions from food and drink consumption, with wine being the largest emitter of greenhouse gases among all alcoholic beverages [1].

According to the BBC's climate change food calculator, alcohol-particularly beer-contributes to climate change [2]. When calculating the emissions from consuming one pint (568 ml) of beer, or drinking 3 to 5 times per week, the impact becomes evident. This level of consumption aligns with the low-risk drinking guidelines set by the National Health Service. It was found that this level of alcohol consumption still results in greenhouse gas emissions of up to 139 kilograms per year. Additionally, a significant portion of emissions from the beverage category comes from tea, coffee, and alcoholic beverages. When combined with cake, biscuits, and confectionery, it was revealed that 24% of all food-related greenhouse gas emissions come from mostly non-essential foods and drinks. Therefore, avoiding

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alcoholic beverages not only promotes health and safety but also plays a key role in addressing climate change. Reducing alcohol consumption helps lower greenhouse gas emissions associated with the production, packaging, and transportation of alcoholic beverages.

Thailand has conducted a significant study to assess the carbon footprint of alcoholic beverages, titled an assessment of the carbon footprint of beer products [3]. The study assessed the carbon footprint of beer products and proposed strategies to reduce greenhouse gas emissions from the brewing process. Using life cycle assessment based on cradle-to-grave (business-to-consumer: B2C) principles, the evaluation covered bottled beer (620 ml), canned beer (320 ml), and keg beer (30 liters). The study found that the carbon footprint of bottled beer, canned beer, and keg beer is 0.3602, 0.1184, and 5.9021 kilograms of carbon dioxide equivalent per unit, respectively. The raw material acquisition process contributes the most to greenhouse gas emissions, accounting for 47%, followed by the production process at 36%. To reduce these emissions, the study recommends focusing on increasing the reuse of old bottles, minimizing damage during bottle washing, and increasing the use of natural gas for steam production instead of fuel oil.

The global food and beverage system does not operate in isolation; rather, like many other systems, it is interconnected and integrated with other sociotechnical systems [4]. Agriculture and food production are closely linked sociotechnical systems; however, in this context, we consider them a subset of the global food and beverage system. Interconnections with other significant sociotechnical systems are illustrated in Fig. 1. The energy sociotechnical system-including coal mines, power plants, transmission grids, heat networks, gas pipelines, and electricity distribution networks- supplies a significant portion of the electricity, heat, steam, and raw fuels (such as natural gas and oil) essential for food and beverage production, with the food sociotechnical system as a whole accounting for approximately 30% of global energy consumption. The transportation system encompasses automobiles, delivery trucks, as well as roads, marine transport, and ports.

The United Kingdom the food industry sits as a moderately energy intensive industry compared to others, and also an industry with moderately high energy costs. That is, the food and beverage industry is more energy intensive than printing, and spends more on energy costs as a percentage than motor vehicle manufacturing, printing, or textiles [5]. The energy intensive aspects of the industry cut across food supply and agriculture to preparing, transporting, packaging and serving food or beverages.

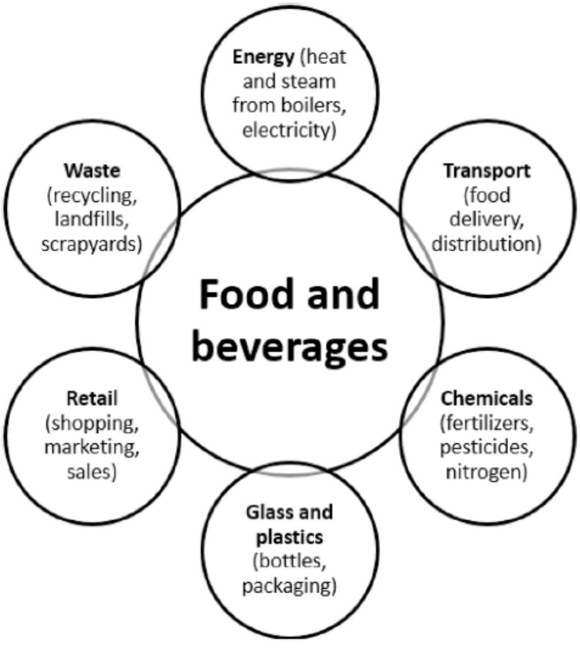

Figure 1. Intriguing connections between food and beverages and other technological systems [6].

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Table 1 Multi-scale solutions to sustainability challenges across three food and beverage products.

Part of system	Beer	Soft drinks
Raw materials	Barley agriculture: Improved irrigation practices and fertilizer management	Sugarcane agriculture: Effective land management and judicious fertilizer use
Food processing	Beer brewing:: Enhanced water recovery and energy-efficient mashing and malting	Sugarcane processing: Wastewater treatment and management of slurry and sludge
Packaging and retail	Glass bottling: Eco-friendly packaging and refrigeration optimization	Plastic bottles: Incorporating recycled materials and steering clear of polyethylene terephthalate
Consumer use	Households: Enhancing the efficiency of domestic refrigerators	Opting for low- to no-sugar alternatives (e.g., diet soda)
End-of-use and waste	Recovery: Recycling of bottles	Recycling initiative: Bottle recovery

Source: Authors modification of [6]

Thailand has driven the policies and strategies of nation. To continuously reduce the impact of global warming by creating a master plan to support climate change 2015-2050 and a road map for reducing greenhouse gases for the country 2021-2030. Which is a policy mechanism for operations in order for the country to achieve its greenhouse gas reduction goals as set forth [15]. Net zero greenhouse gas emissions but there is still a part that is a technology road map. Utilization and carbon storage to analyse the development status of Carbon Capture Utilization and Storage: CCUS technology, technology trends. Marketing information Including the needs of the energy and industrial sectors. and analyse the connection between carbon capture and storage (CCS) technology and carbon capture and utilization (CCU) technology in the world and Thailand. As well as presenting important policy issues, goals, directions, guidelines for research and development of CCUS technology, and a time frame for solving challenging issues appropriate to the Thai context, and support the goal of net zero carbon emissions appropriate to the Thai context [7].

This is because forests play an important role in the world's carbon balance. It is both a storage and a source of carbon release, causing it to affect changes in the amount of carbon dioxide in the atmosphere. The forest ecosystem accumulates carbon in both the trees and the soil through the process of plant photosynthesis. The breathing of living things and the decomposition of microorganisms in the form of carbon dioxide. Carbon stored in trees and soil has been defined as natural carbon stores divided into five sources, including above-ground carbon storage sources, underground carbon deposits, carbon stores in dead trees, carbon stores of plant remains, and carbon storage in the soil [14].

2. METHODOLOGY

2.1 Assessing the carbon footprint of the organization

The process of evaluating an organization's carbon footprint involves preparing an inventory of greenhouse gas emissions to determine the overall carbon footprint. This assessment consists of 5 main steps: [8]

1. Defining Organizational Boundaries: This step establishes the limits within which the organization evaluates and collects data on greenhouse gas emissions and absorption. This includes emissions from beverage production facilities, such as those producing beer, soda, and drinking water.

2. Defining Operational Boundaries: This step involves establishing the operational boundaries that reflect greenhouse gas emissions associated with each activity within the organization's limits. emissions are scope into three types:

Scope 1: Direct emissions and absorption of greenhouse gases generated by the organization. This includes emissions arising directly from various activities, such as stationary combustion, combustion during transport, emissions from the production process, leakage of substances, and other related activities.

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Scope 2: Indirect emissions and absorption of greenhouse gases associated with energy use, which includes emissions from the generation of electricity, heat, or steam imported for use within the organization.

Scope 3: Other indirect emissions and absorption of greenhouse gases that occur from activities not included in Scope 1 and Scope 2. Organizations can measure or evaluate these emissions for additional reporting, though it is not mandatory. Examples include emissions from general solid waste, paper usage, raw material transportation, product distribution, employee commuting, off-site corporate business activities, and packaging materials.

3. Identification of Greenhouse Gas Emission Sources: This step involves identifying the sources of greenhouse gas emissions and evaluating the organization's carbon footprint. It includes assessing emissions sources, collecting data, and utilizing GHG emission factors to calculate greenhouse gas emissions (as shown in Equation 1).

$$\text{GHG (kg } CO_2\text{e)} = \text{Activity data} \times \text{EF (kg } CO_2\text{e)} \qquad (1)$$

Where; GHG represents the total amount of greenhouse gases emitted. Activity data refers to information about activities that generate greenhouse gas emissions. EF (GHG Emission Factor) denotes the factor used to quantify greenhouse gas emissions.

4. Preparation of Greenhouse Gas Inventory: This step involves gathering data to calculate the total amount of greenhouse gases from all three activities. It includes categorizing and summarizing the types of greenhouse gas emissions.

5. Assessing and Managing Uncertainty: This critical step evaluates the quality of the collected data on greenhouse gas emissions and absorption. It addresses uncertainties that arise from calculations using greenhouse gas emission factors sourced from various references.

2.2 Mitigation strategies to reduce greenhouse gas emissions for achieving carbon neutrality

Proposing a plan to reduce greenhouse gas emissions to achieve carbon neutrality in the drinking water industry, by assessing the company's structural readiness, physical characteristics, and the availability of green spaces at each plant. To implement projects aligned with the company's chosen policy for reducing emissions and enhancing carbon storage, initiatives may include the bioenergy project, the expansion of solar panel installations, energy efficiency and conservation projects, circular economy and waste management initiatives, and carbon capture and storage efforts.

3. RESULTS AND DISCUSSION

3.1 Sources of greenhouse gas emissions in the beverage industry

The results of a study on emission sources and greenhouse gas assessments in the beverage industry, conducted across 8 plants- including beer, soft drink, and drinking water factories- identified greenhouse gas emissions categorized by scope as follows: Fig. 2 The greenhouse gas emissions assessment revealed that Plants A, B, and C, which are all alcoholic beverage production facilities, have high emissions. In Scope 1, these emissions primarily result from the burning of fossil fuels to power machinery, coupled with significant carbon dioxide generation from the alcohol fermentation process. Scope 2 greenhouse gas emissions were found to be relatively high, primarily due to the significant use of electricity, which is a critical utility in the production process. In Scope 3 for all plants, greenhouse gas emissions were exceptionally high. This is largely due to the resource- intensive nature of the beverage production industry, which involves activities such as raw material acquisition, transportation of raw materials, waste generation, and product distribution logistics.

Scope 1: The list of sources includes fuel combustion in steam generators, emergency fire extinguisher fuel combustion, generator fuel combustion, maintenance unit fuel combustion, chemical combustion in the laboratory, fuel combustion from corporate vehicles, carbon dioxide emissions from

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alcohol fermentation processes, methane emissions from septic tanks, hydrofluorocarbons; HFC emissions from refrigerants, and nitrous oxide emissions from fertilizer use activities.

Scope 2: List of electrical energy usage from purchase

Scope 3: This includes emissions from purchased goods and services, tap water consumption, paper usage in the office, chemical use, transportation and distribution, waste generated from operations, business travel, employee commuting, and additional transportation and distribution activities.

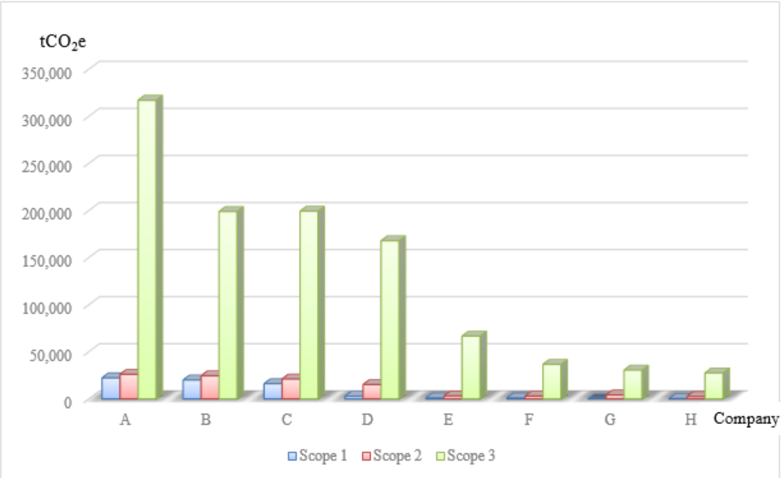

Figure 2. Results of the study on emission sources and greenhouse gas emissions in the beverage Industry

3.2 Reducing greenhouse gas emissions in the beverage industry

3.2.1 Bioenergy

Bioenergy with Carbon Capture and Storage (BECCS) refers to any energy pathway in which CO_2 is captured from biogenic sources and permanently stored. Currently, approximately 2 million tons of biogenic CO_2 are captured annually, primarily in bioethanol applications. Based on projects currently in the early and advanced stages of deployment, CO_2 capture from biogenic sources could reach approximately 60 million tons per year by 2030. However, this falls significantly short of the nearly 185 million tons of CO_2 per year projected to be captured from biogenic sources by 2030 in the Net Zero Emissions by 2050 scenario. To convert recent momentum into operational capacity, targeted support for carbon dioxide removal (CDR), particularly for BECCS, will be essential.

Energy content in solid, liquid, and gaseous products derived from biomass feedstock's and biogas, including solid bioenergy, liquid biofuels, and biogas. The use or production of bioenergy products in a way that prevents CO_2 generated by combustion, oxidation, or fermentation from entering the atmosphere and contributing to climate change. Since the captured carbon is biogenic in origin-having integrated into plant matter relatively recently, often within the last 1-2 years- it can be considered removed from the atmosphere, thus reducing total greenhouse gas levels, if it is permanently sequestered, for instance, through geological CO_2 storage. Bioenergy with carbon capture and storage entails capturing and permanently storing CO_2 from processes that convert biomass into fuels or directly burn it to generate energy. Since plants absorb CO_2 during their growth, this approach effectively removes CO_2 from the atmosphere [9].

Organic by-products and waste can be utilized for biogas production through anaerobic digestion. This methane-rich gas can fuel combined heat and power plants, satisfying both thermal and electrical demands. Furthermore, agricultural residue biomass can serve as an auxiliary biofuel. In the beverage production industry, there is potential to apply bioenergy-related technologies to manage raw materials from the alcohol fermentation process. The waste generated can be utilized to produce biomass energy or serve as the primary raw material for biogas production plants. This approach emphasizes waste

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management by reducing methane emissions, rather than disposing of waste in landfills or through composting.

3.2.2 Solar cell

The environmental impact of energy-intensive food and beverage manufacturing has come under increased scrutiny, driven by rising regulatory pressures and shifting consumer preferences that compel industries to decarbonize. As one of the primary sources of greenhouse gas emissions in the agri-food value chain, manufacturing operations represent a crucial lever for enabling the sector's transition to net-zero and enhancing climate resilience. In this context, integrating green energy solutions that reduce emissions by harnessing renewable, low-carbon energy sources present a compelling value proposition for food and beverage producers.

Solar photovoltaics can be installed on the roofs of processing plants, warehouses, and administrative buildings to generate emission-free power for local use. Any surplus energy produced can be fed into the grid, providing additional revenue through net metering.

3.2.3 Energy efficiency and energy saving

Many applications in the food and beverage industry, such as fans, pumps, compressors, and conveyor belts, typically operate at partial load. However, they often rely on mechanical control methods like valves, brakes, and throttles to regulate speed. In such systems, the motor performs more work than necessary, leading to energy loss through mechanical speed control.

Reduce electrical energy consumption and CO_2 emissions through energy efficiency solutions and services. Plug-and-play digital solutions securely gather data from applications, offering deeper insights into operational status and providing a true indication of the condition of the installed equipment. By collecting and analyzing information directly from your powertrain, cloud-based technologies help to understand and predict potential downtime, enabling maintenance services to be scheduled at the most convenient times [10]. Switching forklift fuel from fossil fuels to electricity to reduce greenhouse gas emissions within the organization.

3.2.4 Circular economy and waste management

One effective approach is to adopt a circular economy model. This involves shifting away from a linear production and consumption model-where resources are used and then discarded-to a more circular system that emphasizes the reuse and recycling of materials. Embracing a circular economy can yield numerous benefits for the beverage industry, including waste reduction, cost savings, and the creation of new revenue streams. Additionally, it can help mitigate the environmental impact of production by lowering carbon emissions and conserving water resources. In this context, beverage industry companies must adopt a holistic approach to sustainability, examining their entire supply chain-from raw materials to consumer disposal. Implementing circular economy principles can foster a more sustainable and resilient beverage industry that benefits both the environment and financial performance.

As we confront global challenges such as climate change and resource depletion, the beverage industry, along with other sectors, must adopt a proactive approach to sustainability. Embracing circular economy principles can be a powerful strategy in achieving this goal and fostering a more sustainable future for all. The emergence of the circular economy highlights the importance of upcycling materials to achieve zero waste and extending a product's life cycle for as long as possible-countering the prevalent use of disposable plastic packaging in the food and beverage industry. This shift has illuminated the environmental impact of companies' various practices and manufacturing processes [11].

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3.2.5 Carbon capture storage

Carbon capture utilization and storage (CCUS) is a term that refers to a group of technologies that can help achieve a variety of global energy and climate goals. CCUS entails the extraction of CO_2 from large point sources such as power plants or from industrial facilities, which run on fossil fuels and biomass. CO_2 can also be directly extracted from the atmosphere. If the CO_2 is not used on site, then the gas is compressed and transferred using a pipeline or other means to be used in a variety of applications. The CO_2 is stored via injection of the gas deeply into geographic formations such as depleted oil and gas reservoirs or saline formations [12], [13]. Expanding green spaces and planting forests within the factory, or establishing a Memorandum of Understanding (MOU) with relevant agencies and forest landowners, are effective methods for offsetting the organization's carbon emissions.

4. CONCLUSIONS

Environmental sustainability and the fight against climate change share the common goal of reducing greenhouse gas emissions, but they differ in scope and approach. Understanding the distinction between carbon neutrality and net zero emissions is essential for grasping their roles in addressing climate change. Carbon neutrality refers to balancing the amount of carbon dioxide released into the atmosphere with the amount removed through reforestation, renewable energy use, or purchasing carbon credits. It focuses specifically on offsetting carbon emissions.

Net zero emissions, on the other hand, addresses all greenhouse gases that contribute to global warming, not just carbon dioxide. Achieving net zero is crucial because it targets the reduction of all emissions responsible for rising global temperatures. Both concepts are critical but vary in their scope and impact such as, climate mitigation, environmental responsibility, economic opportunities and social equity.

In summary, the beverage industry can play a pivotal role in achieving carbon neutrality and net-zero greenhouse gas emissions. By adopting these key strategies, the industry contributes to combating climate change and supporting the transition to a more sustainable future. This begins with actively participating in the reporting of its greenhouse gas emissions and implementing measures for carbon sequestration.

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