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Energy, Fuel Consumption and Greenhouse Gas Emission in Food Processing Industry in Big Cities of Vietnam

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Abstract

Identifying energy consumption trends is difficult as the food processing industry is very fragmented, products are processed to varying degrees, and production is not always continuous. This study has collated data better to understand energy consumption across different food processing sectors. Based on energy consumption data, Greenhouse Gas (GHG) emissions are calculated for direct emissions from fuel usage and indirect emissions from the use of grid-supplied electricity. Energy figures show that electricity, Liquefied Petroleum Gas (LPG), and coal are the main energy sources used in the food industry in the big cities of Ho Chi Minh City (HCMC), Hanoi, and Hai Phong. Patterns of energy sources are different from city to city depending on the composition of subsectors and the availability of local energy resources. GHG emissions from the food industry in HCM are estimated to be 22,014,696 tons of CO_2-eq, with 98% of these emissions coming from indirect sources. The figures for Hanoi and Hai Phong are 493,000 and 36,016 tons of CO_2-eq, respectively, with 29% and 49% indirect emissions. The most GHG emission-intensive food industry sub-sector in HCMC includes processing and preservation of meat products and processing and preservation of frozen seafood; in Hanoi, it is processing milk and dairy products, and in Hai Phong, it is seafood products processing and preservation and production of beer and malt. The study proposed three energy-saving solutions in food processing plants that can be considered: Optimizing the use of existing equipment in production, innovating and upgrading equipment, and investing in low-carbon energy sources.

Keywords: Electricity and fuel consumption, food industry, GHG emission.

1. Introduction

The global food sector consumes around 200 exajoules (EJ) of energy annually, with 45% of this consumption linked to processing and distribution activities [1, 2]. This high level of energy use is directly connected to substantial greenhouse gas (GHG) emissions and the depletion of natural resources [1]. Research indicates that food production is responsible for about 30% of global energy consumption and emissions from the food and beverage sector account for approximately 26% of global emissions, a number that could nearly double by 2050 if current practices persist [3, 4]. The main sources of GHG emissions in this sector include food production and processing, transportation, storage, food waste disposal, the application of chemical fertilizers and pesticides, and the energy required for processing and transporting food products.

Vietnam ranks among the top 10 countries globally in food processing and production and is the third fastest-growing country in Asia regarding food and beverage expenditure, contributing 15.8% to the national gross domestic product (GDP) in 2021. The food processing industry is a cornerstone of Vietnam's economic development, generating over 20% of the annual net revenue from the processing and manufacturing industries [5]. The Vietnamese food industry holds significant potential for growth, driven by the country’s large population, rising average incomes, and rapidly increasing consumption trends. Vietnamese food products, particularly seafood, are exported to major markets, including the European Union, Japan, the United States, South Korea, and Russia. However, the rapid expansion of this industry has led to various environmental challenges, including high energy and fuel consumption and increased GHG emissions.

According to the Nationally Determined Contribution Report, by 2030, Vietnam must reduce GHG emissions by 43.5% compared to the business-as-usual scenario, and by 2050 achieve net zero emissions [6]. To achieve this goal, the Vietnamese government, through Decree 06/2022/ND-CP, has set out requirements for GHG inventory and reporting and GHG reduction for businesses, including those in the food industry. This proactive approach from the government reassures us

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of Vietnam's commitment to environmental sustainability and the reduction of GHG emissions.

Ho Chi Minh City (HCMC), Hanoi, and Hai Phong are significant cities with dense populations and hubs for various industrial activities, including food production and processing industries. The Ho Chi Minh City Investment and Trade Promotion Center identifies the food processing industry as one of the four key industries prioritized for development in HCMC. The production capacity of enterprises in this industry in HCMC satisfies local and domestic market demands and supports exports to numerous international markets [7].

Given this context, studies on the current status of energy and fuel use and GHG emission estimates in the food industry are crucial. These studies can help promote the economical and efficient use of energy and fuel while reducing GHG emissions in Vietnam's food processing industry, ultimately contributing to the country's net-zero emissions target. This study aims to analyze the structure of electricity and fuel consumption and estimate GHG emissions from electricity use and fuel combustion in the food industry in main cities in Vietnam, including HCMC, Hanoi, and Hai Phong.

2. Material and Method

2.1. Energy and Fuel Data Collection and Source

Energy and fuel data for the food processing industry in HCMC, Hanoi, and Hai Phong were sourced from the General Statistics Office's 2020 energy and fuel database. The data were filtered according to the city code and the industrial sector codes related to food processing activities.

2.2. GHG Emission Estimation

In this study, food processing plants are classified as a point source of emissions. Direct emissions of GHG from the fuel burning and the energy-related indirect emissions from the use of grid-supplied electricity in the plants were calculated according to guideline of The Intergovernmental Panel on Climate Change (IPCC, 2006). The simple method (Tier 2 approach) was adopted from IPCC (2006) [8], considering the activity data and emission factors. The emission factors for CH_4 and N_2O from fuel combustion are significantly lower than those for CO_2 by 600 to 98,000 times for CH_4 and 25,000 to 630,000 times for N_2O. As a result, only CO_2 emissions are considered, with CH_4 and N_2O emissions from fuel combustion being disregarded.

The direct emission of CO_2 from fuel burning in the food processing plants was calculated according to the following equation:

$$E_i = \sum(A_i \times \rho_i \times NCV_i) \times EF_i \tag{1}$$

where E_i is the estimated emissions of CO_2 (in Gg), with fuel type *(i)*; A_i is the activity rate, i.e., burnt fuel by the individual plant in the CO_2 emission base year related to fuel type *(i)*; NCV_i is the net calorific value of fuels *(i)* burnt by the plant (Table 1); ρ_i is the density of the fuel type *(i)* in Gg/m^3; EF_i is the CO_2 emission factors (in Gg/TJ) of fuel type *(i)* obtained from national emission factor (MONRE 2022) [9] (Table 1).

CO_2 emissions associated with electricity consumption was calculated by the following equation:

$$E = A \times EF \tag{2}$$

where E is the estimated emissions of CO_2 (in Gg) from electricity consumption in the emission base year; A is the activity rate relating to electricity consumption (in GWh) from the individual plant; EF is the emission factors (in ton/MWh) of CO_2 from grid-supplied electricity obtained from Department of Climate Change (DCC) – MONRE 2024 [10].

Table 1. CO_2 Emision Factor (EF) and net calorific value (NCV) of fuels

Energy/Fuel	EF		NCV (TJ/Gg)
	Unit	Value	
Electricity	ton/MWh	0.6766	
Anthracite	Gg/TJ	0.0983	26.7
Other coal	Gg/TJ	0.1120	29.5
Diesel	Gg/TJ	0.0741	43
Other oil	Gg/TJ	0.0774	40.2
LPG	Gg/TJ	0.0631	47.3
Natural gas	Gg/TJ	0.0561	48
Biomass	Gg/TJ	0.1000	11.6

3. Results and Discussion

3.1. Electricity and Fuel Usage Structure in Food Industry in Investigated Area

The electricity and fuel usage structure in food processing and/or production in Hanoi, Hai Phong, and HCMC are shown in Table 2 and Fig. 1. In the three main cities of Hanoi, HCMC, and Hai Phong, where food and beverage production and processing make up a significant portion of Vietnam's activities, the primary energy sources used are electricity, Liquefied Petroleum Gas (LPG), and coal. According to 2016 fuel consumption data for the national food industry, coal consumption in this sector of Hanoi, HCMC, and Hai Phong in 2020 represents only 4% of the national food industry's coal usage in 2016, while LPG usage has increased to 150% of the 2016 levels [11]. Based on the 2020 energy balance table for Vietnam, coal used for food industry within these cities represents only 0.1% of industrial coal consumption, whereas LPG accounts for 49.6% [12]. This suggests a shift in the food industry in big cities from the high GHG-emitting energy source of coal to the lower GHG-emission potential of LPG. In term of energy consumption in each locality, HCMC stands out with a remarkably high usage, reaching 120,777 TJ in 2020. In contrast, Hanoi's consumption was 6,357 TJ, which is only about 1/20th of HCMC's figure, while Hai Phong's consumption was 288 TJ, significantly lower than HCMC and Hanoi.

The energy source structure of the three investigated cities reveals significant differences. In HCMC, electricity consumption is the dominant force, accounting for a staggering 95.5% of energy consumption, with other fuels making up a mere 4.5%. LPG represents 3.2%, and other fuels represent less than 0.5%. This underscores the overwhelming reliance on electricity in HCMC's food production industry. In contrast, traditional fuels such as coal and diesel oil have relatively low usage rates, while clean fuels like LPG are used in larger proportions. Biomass fuel has also started to be used with a contribution of 0.3%. In Hanoi, LPG is the primary energy source for the food industry, contributing up to 82% of the total energy consumption. Electricity is the second largest energy source, accounting for 12%. Additionally, Diesel Oil (DO) contributes 3%, while other fuel sources are nearly negligible.

In Hai Phong, various types of coal are the largest energy sources, accounting for 58% of the total energy consumption. Coke coal contributes 16%, and other types of coal, excluding anthracite, make up 42%. This is likely due to Hai Phong's proximity to significant coal supply sources in Quang Ninh. Electricity is the second-largest energy source, contributing 32%. Diesel and LPG contribute 5% and 4.3%, respectively.

The differences in energy source structures across investigated cities can be attributed to the composition of subsectors and the availability of local energy resources. Survey results on the distribution of key food industry subsectors in HCMC, Hanoi, and Hai Phong show that in HCMC, the processing and preservation of meat products, processing and preservation of frozen seafood, the processing and preservation of meat products, processing and preservation of frozen seafood, and production of other food products not classified elsewhere are among the most energy-intensive sub-sector, accounting for 44.5%, 22.6%, and 18.8% of the total energy used, respectively. The processing and preservation of meat products and the processing and preservation of frozen seafood are two essential sub-sectors in the food industry that supply the daily consumption needs of the population. The thermal, refrigerating, and freezing processes involved in their manufacturing consumed large proportions of the total processing energy. Energy and water use have increased due to increased hygienic standards and cleaning requirements in the meat and seafood processing sub-sectors. Additionally, meat and seafood products are processed - and sometimes over-processed - to a higher degree for consumer convenience, increasing the associated energy usage for manufacturing.

In Hanoi, the processing of milk and dairy products is the main sub-sector, accounting for 76.4% of the energy consumption of the food industry. For the remaining subsectors, the energy consumption of each is below 5% of the total. Dairy processing is recognized as one of the most energy-intensive sectors within the food industry [13]. The production of many dairy products involves concentrating raw milk and separating its solids to different extents. Electricity is commonly used to power pumps, refrigeration systems, control mechanisms, and separation processes, whereas thermal energy is primarily utilized for cleaning, evaporation, and pasteurization activities [14]. In Hanoi, 92% of the LPG used is for the sub-sector of processing of milk and dairy products, and the total energy consumption for this sub-sector is 76%.

In Hai Phong, the subsectors of seafood products processing and preservation and beer and malt production have the highest energy consumption rates, accounting for 32% and 30% of the total energy consumption in the food industry, respectively.

While the food industry in major cities like HCMC and Hanoi is making strides in transitioning from traditional, high-polluting fuels like coal and oil to cleaner alternatives like LPG, there's still untapped potential. Biomass fuel, which is abundant in HCMC and its neighbouring areas, presents a significant opportunity for future energy solutions that should be further explored.

Table 2. Electricity and fuel usage structure in food industry in HCMC, Hanoi and Hai Phong in 2020

Energy/Fuel	**Quantity**				**Energy (TJ)**		
	Unit	**HCMC**	**Hanoi**	**Hai Phong**	**HCMC**	**Hanoi**	**Hai Phong**
Electricity	MWh	32,013,534	240,451	25,847	115,157	749	93
Anthracite	ton	69	12	-	19	0.3	-
Coke	ton	-	3,068	1,603	-	29	45
Other Coal	ton	19,823	7,941	4,113	484	179	121
Fuel oil (FO)	1000 liter	4,174	17	-	146	0.2	-
Diesel oil (DO)	1000 liter	8,798	4,591	394	312	162	14
Kerosene	1000 liter	485	3	-	17	0.1	-
Other oil	1000 liter	548	-	-	19	-	-
LPG	ton	81,175	110,629	261	3,839	5,233	12
Natural Gas	$1000m^3$	13,146	-	-	418	-	-
Biomass	ton	31,469	460	152	365	5	2
Sum	**-**	**-**	**-**	**-**	**120,777**	**6,357**	**288**

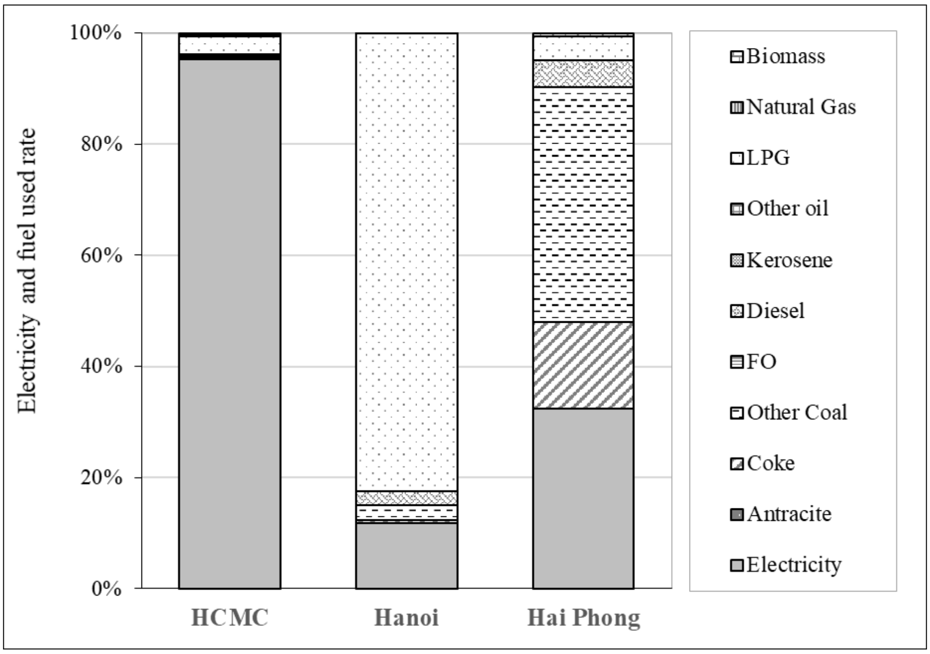

Fig. 1. Contribution of electricity and fuels in energy consumption in food industry in big cities

3.2. GHG Emission from Food Processing/ Production Facilities in Investigated Area

Estimated direct emissions from fuel combustion in food production and indirect GHG emissions from electricity use in the food industry in HCMC, Hanoi, and Hai Phong in 2020 are presented in Table 3. GHG emissions in the food industry in 2020 in HCMC, Hanoi, and Hai Phong are 21,976, 503, and 35 Gg CO_2-eq, respectively. The contributions of direct emissions from fuel combustion and indirect emissions from electricity use to GHG emissions vary significantly across different cities. In HCMC, over 90% of GHG emissions are indirect emissions from electricity use, while in Hanoi, direct emissions account for a large proportion at 71%. In Hai Phong, there is a more balanced contribution, with direct and indirect emissions accounting for 51% and 49%, respectively. In Hai Phong, coal emissions account for 89% of the total direct GHG emissions.

Regarding direct emissions from fuel use in food production plants (Fig. 2), LPG contributes the most in HCMC and Hanoi, accounting for 64.4% and 93.7% of total direct emissions, respectively. In Hai Phong, coal is the primary contributor to direct emissions, accounting for up to 89%, and LPG accounts for 4.2% of the total direct emissions. It can be observed that the contribution to GHG emissions from different types of fuels is relatively closely related to the structure of fuel use: fuels that are used more extensively contribute more to GHG emissions. However, a detailed comparison of fuel consumption and GHG emissions reveals that LPG accounts for 79.5% of total fuel energy, while coal accounts for 7.7%. This indicates that LPG has a lower GHG emission rate, whereas coal has a higher GHG emission rate.

Table 3. Direct and indirect GHG emission from food industry in HCMC, Hanoi, and Hai Phong in 2020

Cities	Direct emission (Gg CO_2-eq)	Indirect emission (Gg CO_2-eq)	Total (Gg CO_2-eq)
HCMC	338	21,638	21,976
Hanoi	362	141	503
Hai Phong	18	17	36

Compared to the 2016 GHG inventory results for the food industry, it is evident that by 2020, while the energy from fuels used in the food sector of HCMC, Hanoi, and Hai Phong accounted for 16% of the total fuel energy consumed by the nationwide food industry in 2016, the corresponding GHG emissions represented as much as 47%. This discrepancy is mainly due to the contribution of biomass in the fuel usage structure. In 2016, biomass provided 76% of the total energy from fuels in the food industry, while in 2020, biomass consumption in the three investigated cities accounted for only 3.3% of the fuels used. According to the Intergovernmental Panel on Climate Change (IPCC) guidelines, CO_2 emissions from biomass combustion are excluded from GHG calculations for energy recovery. As a result, GHG emissions in HCMC, Hanoi, and Hai Phong appear significantly higher when comparing energy use.

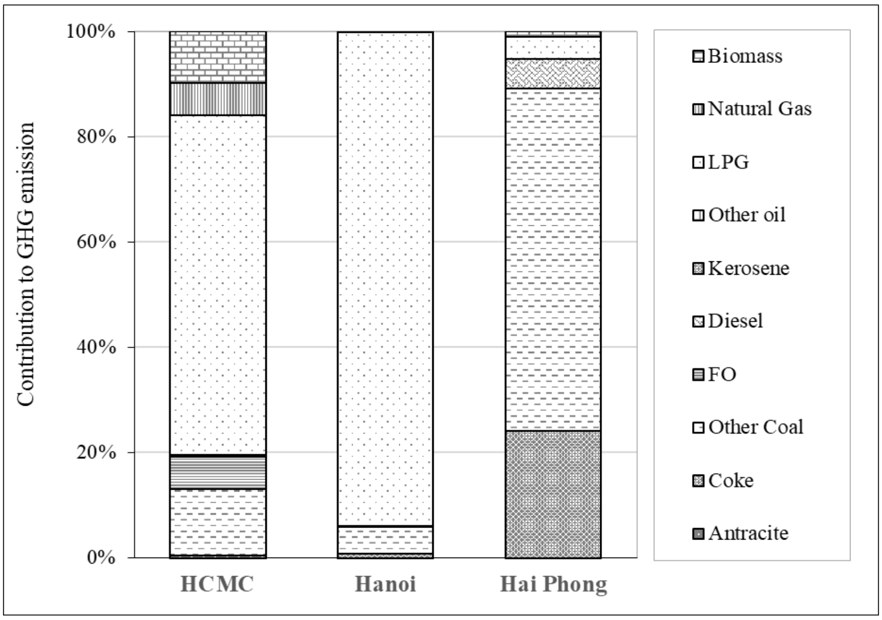

Fig. 2. Contribution of GHG emission from different fuel consumption

In HCMC, most subsectors that use electricity in their operations have a significant portion of their GHG emissions from indirect emissions associated with electricity use. Subsectors of the slaughter of livestock and poultry, meat processing and preservation, processing and preserving meat products, frozen seafood processing, and preservation, milling, production of raw flour, and production of starch and starch products have nearly 100% of their GHG emissions originating from indirect emissions associated with electricity use. Production of vegetable oils and margarine, flour cakes, sugar production, cocoa, chocolate, and confectionery are sub-sectors where indirect GHG emissions from electricity use account for less than 50% of their total GHG emissions. Among these, the subsector of cocoa, chocolate, and confectionery production is particularly notable for having indirect GHG emissions from electricity use that account for less than 10%. This sector's primary sources of GHG emissions are direct emissions from LPG (82%) and coal (8%).

3.3. Energy-Saving Solutions in Food Industry

Thermal processes are energy-intensive and account for a large proportion of the energy consumed in food processing. In the UK, it has been estimated that about 68% of the energy is used for process and space heating, 8% is electric heating, and 6% corresponds to refrigeration [15]. Energy reductions can be made through process optimization and technological and manufacturing behavioral changes [16].

Optimizing the Use of Existing Equipment:

Real-Time Monitoring and Standardization: Improving the real-time monitoring of production data and standardizing processes can help entities identify areas prone to energy loss. By addressing these areas promptly, companies can optimize equipment efficiency and reduce electricity waste.

Effective Power Shutdown Processes: The nature of food processing involves continuous operations, meaning that many machines run even when not actively processing products. Frequently switching machines on and off can consume excess energy and lower production line efficiency. The solution lies in setting up automatic modes that minimize energy consumption when the equipment is idle.

Optimizing Temperature and Pressure: Different equipment operates best at different temperature and pressure settings. For example, refrigerators should be kept away from heat-emitting devices like food dryers. Instead of applying uniform settings across the plant, it is more efficient to zone different areas, adjust settings accordingly, and improve insulation to ensure each piece of equipment operates under optimal conditions.

Innovating and Upgrading Equipment

Heat Recovery and Reuse: Implementing technology to recover and reuse waste heat from food processing (e.g., drying, cooking) can significantly reduce the need for new energy inputs while also lowering carbon emissions.

Using Low-Cost Alternatives for Moisture Removal: Many food products require the removal of excess moisture to enhance preservation. Rather than relying solely on thermal processes, which can be wasteful, combining more energy-efficient technologies such as filtration or centrifugation can be more effective. Reusing waste heat for these processes is also a viable option. Modern heat pumps now offer features that support these energy-saving processes.

Exploring Alternative Sterilization Methods: Hygiene is crucial in food processing, traditionally achieved through sterilization, a method that has been in use for over a century. However, modern alternatives like microfiltration, UV treatment, and ultrasonic processing are emerging. These methods consume less energy for heating and cooling and are particularly suited for food products with nutrients sensitive to high or fluctuating temperatures.

Investing in Low-Carbon Energy Sources

Solar Energy: Installing solar panels can generate electricity and preheat water, providing a renewable energy source for the plant.

Biogas: Utilizing biogas produced from organic waste can help manage waste and provide a sustainable energy source for the plant's operations.

By implementing these solutions, food processing plants can significantly reduce energy consumption, resulting lower GHG emission, and contribute to a more sustainable future.

4. Conclusion

Quantifying energy demand in food manufacturing and estimating GHG emissions are essential for identifying energy-intensive activities. This information is valuable to policymakers and industry leaders in reducing emissions and achieving net-zero targets.

Among the 3 investigated cities, the energy used in the food industry in 2020 was 120,777 TJ in HCMC, 6,357 in Hanoi, and 288 TJ in Hai Phong. The differences in energy source structures across investigated cities can be attributed to the composition of subsectors and the availability of local energy resources. Regarding fuel usage, there has been a shift from traditional fuels like coal and oil to cleaner alternatives such as LPG in HCMC and Hanoi.

In 2020, GHG emissions in the food industry 2020 in HCMC, Hanoi, and Hai Phong were 22, 014, 493, and 35 Gg CO_2-eq, respectively. The ratio of direct and indirect emissions, as well as the proportion of emissions from different types of fuels, is closely related to the fuel usage structure.

Three energy-saving solutions for food processing plants to consider include (1) Optimizing the use of existing equipment in production: Enhancing energy efficiency by improving monitoring, standardization, and management of current equipment operations. (2) Innovating and upgrading equipment: Implementing advanced technologies and modern equipment to improve energy efficiency and reduce fuel consumption. (3) Investing in low-carbon energy sources: Deploying renewable energy solutions such as solar panels and biogas to reduce greenhouse gas emissions and save energy.

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