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Greenhouse Gas Emissions and Energy Consumption in the Garments, Textile, and Dyeing Sectors in Savar, Dhaka (2019-2021)

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Authors' contributions

This work was carried out in collaboration among all authors. Author MMH designed the study, performed the statistical analysis, wrote the protocol, and prepared the first draft of the manuscript. Authors FBN, NAK, and NIT collected the data. Author MWI managed the literature searches. Authors MAA and SA provided critical revisions. All authors read and approved the final manuscript.

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ABSTRACT

Greenhouse gas (GHG) emissions, a key driver of global climate change, continue to rise due to industrial activities and fossil fuel reliance. This study evaluates energy consumption patterns and greenhouse gas (GHG) emissions from the garments, textile, and dyeing industries in Savar Upazila, Dhaka, from 2019 to 2021. Natural gas has been identified as the dominant energy source, contributing to a steady increase in GHG emissions from 64,920 tons in 2019 to 69,531 tons in 2021. Diesel and electricity consumption also contributed to emissions, with notable growth in the textile and dyeing sectors. Although minimal, solar energy adoption showed a positive upward trend, rising from 0.058 to 0.113 TJ during the study period, indicating a shift toward renewable energy sources. Despite this, the total GHG emissions rose from 129,015 tons in 2019 to 137,880 tons in 2021, emphasizing the need for cleaner technologies and more sustainable practices. The findings underscore the significance of enhancing energy efficiency and implementing renewable energy sources to mitigate the environmental impact of these industries.

Keywords: Greenhouse gas; energy consumption; garments; textile; dyeing.

1. INTRODUCTION

Global warming, driven by greenhouse gas (GHG) emissions, has evolved from a scientific concern into a complex global issue impacting political, economic, social, and ecological dimensions. The Paris Agreement and international climate conferences like COP 26 emphasize the urgent need for reducing global emissions to keep temperature rise within 1.5°C [1]. Multiple international treaties, such as the Kyoto Protocol and the Copenhagen Agreement, reflect global efforts to mitigate climate change [2]. Despite these initiatives, global GHG emissions continue to rise due to human activities, primarily carbon dioxide (CO_2), which accounts for 77% of total global emissions. Methane (CH_4) and nitrous oxide (N_2O) contribute 14% and 8%, respectively [3].

The industrial sector is a major contributor to global GHG emissions, especially in rapidly developing countries like Bangladesh. Energy use in Bangladesh's industrial sector has surged due to economic growth and globalization, leading to significant increases in GHG emissions [4]. Between 1991 and 2012, Bangladesh's energy consumption tripled, rising from 12.55 million tons of oil equivalent (mtoe) to 33.17 mtoe [5]. The country's reliance on natural gas, which constitutes 75% of total fuel consumption [6], is central to its industrial energy mix. The electricity sector alone accounted for 47.72% of total CO_2 emissions, with manufacturing and construction contributing 20.87% [5].

Bangladesh's garments and textile industries, centered around Dhaka city, are key drivers of energy consumption and GHG emissions. The textile and garments industry has an average monthly electricity consumption of 28,175 kWh [7]. This level of energy consumption reflects the energy-intensive nature of textile production processes, including spinning, weaving, dyeing, and finishing. The textile and garments industry accounting for 19.5% of the country's total industrial energy use [7]. These industries depend heavily on natural gas, electricity, and diesel for production processes, further escalating CO_2 emissions. The garment industry, the largest industrial sector in Bangladesh, is a significant contributor to this energy demand and environmental impact. Bangladesh generates just 0.56 percent of global greenhouse gas emissions, yet it is the sixth most susceptible nation to the effects of climate change [8].

The International Energy Outlook (2016) predicted that global industrial energy consumption would increase by 1.2% per year from 2012 to 2040, driven primarily by non-OECD countries [9]. Bangladesh exemplifies this trend, with CO_2 emissions rising from 15.94 mtoe in 1991 to 57.07 mtoe in 2011, a 140.67% increase [5]. Bangladesh has committed to reducing its GHG emissions by 5% by 2030, yet the fast expansion of the garment industry, which is expected to double in size by 2020, poses significant challenges to achieving this goal [10]. The objectives of this study were to evaluate the sector-specific energy consumption in the garments, textile, and dyeing industries in Dhaka, to estimate the greenhouse gas emissions resulting from these industries, and to assess the trends in energy consumption over time.

2. MATERIALS AND METHODS

This study focused on estimating greenhouse gas (GHG) emissions from the garment, textile, and dyeing industries in Savar Upazila, Dhaka, based on energy consumption patterns over three consecutive years (2019-2021). Nine industries were randomly selected for data collection.

Both primary and secondary data collection methods were utilized. Primary data, gathered from selected industries, included metered electricity consumption and utility bills for determining activity data in MWh or kWh units. Additionally, data on diesel and natural gas consumption were collected in liters and cubic meters, respectively, from industry records. Secondary data were sourced from technical reports, journals, and energy-related websites. The GHG emissions were calculated using the Tier 1 and Tier 2 methods as per the 2006 IPCC guidelines [11].

The Tier 1 method estimated direct emissions by multiplying the amount of fuel combusted with the default emission factors provided by the IPCC. For instance, the default emission factor for diesel was 69,683.32 kg CO_2/TJ. The Tier 2 method calculated indirect emissions using country-specific emission factors, where the grid emission factor for Bangladesh was 0.6078138 kg CO2/kWh. Energy consumption data were converted into joules for standardization using the International Energy Agency (IEA) unit converter.

Global Warming Potential (GWP) values were applied to express methane (CH_4) and nitrous oxide (N2O) in terms of CO_2-equivalent (CO2e), where the GWP for CH_4 and N_2O were 28 and 265, respectively, as per the IPCC Fifth Assessment Report. Emissions were summed across all fuels to estimate total GHG emissions for each industry.

Table 1. Global warming potential values

Species	Chemical Formula	GWP 100
Caron dioxide	CO_2	1
Methane	CH_4	28
Nitrous oxide	N_2O	265

Source: (IPCC fifth assessment report, 2014)

3. RESULTS AND DISCUSSION

3.1 Energy Consumption

Between 2019 and 2021, the energy consumption patterns across selected garments, textile, and dyeing industries in Bangladesh exhibited notable variations, highlighting both trends in fossil fuel reliance and the slow adoption of renewable energy sources.

Solar energy consumption remained minimal across all sectors, though it experienced a modest increase. In the garments industry, solar energy usage grew from 0.028 TJ in 2019 to 0.082 TJ by 2021, while the textile sector saw a slight rise from 0.0076 TJ to 0.008 TJ. Similarly, the dyeing industry's solar usage increased marginally from 0.022 TJ to 0.023 TJ over the same period. Overall, total solar energy consumption rose from 0.058 TJ to 0.113 TJ, yet it continued to represent only a small fraction of the total energy use. The limited adoption of solar energy could be attributed to high installation costs, lack of infrastructure, or insufficient policy incentives promoting renewable energy, reflecting an ongoing dependency on conventional energy sources [12].

Natural gas emerged as the dominant energy source across all industries. In the garments sector, consumption increased from 169.18 TJ in 2019 to 176.13 TJ in 2021, while the textile industry saw a rise from 543.74 TJ to 555.93 TJ. The dyeing sector, being the most energy-intensive, experienced a significant increase from 576.56 TJ to 649.02 TJ. Overall, natural gas consumption across these industries increased by nearly 92 TJ, rising from 1,289.48 TJ in 2019 to 1,381.08 TJ in 2021. This highlights the heavy reliance on natural gas for heating, drying, and steam production in textile processing. While natural gas is a relatively cleaner fossil fuel compared to others, its increasing use raises concerns about long-term environmental sustainability and the industry's growing carbon footprint [13].

Diesel consumption, though more modest compared to natural gas, saw some fluctuations. In the garments industry, diesel usage remained relatively stable, increasing slightly from 0.18 TJ in 2019 to 0.19 TJ in 2021. The textile sector experienced greater variation, rising from 0.85 TJ to 1.22 TJ. Meanwhile, the dyeing industry, which consumed a larger share of diesel, saw its usage

Table 2. Annual energy resource consumption in selected garments, textile, and dyeing industries (2019-2021)

Energy Sources	Garments industries energy resource Consumption (TJ)			Textile industries energy resource Consumption (TJ)			Dyeing industries energy resource Consumption (TJ)			For all Industries energy resource Consumption (TJ)		
	2019	2020	2021	2019	2020	2021	2019	2020	2021	2019	2020	2021
Solar	0.028	0.017	0.082	0.0076	0.0055	0.008	0.022	0.0219	0.023	0.058	0.06	0.113
Natural Gas	169.18	163.02	176.13	543.74	517.12	555.93	576.56	521.75	649.02	1289.48	1201.89	1381.08
Diesel	0.18	0.15	0.19	0.85	0.62	1.22	13.07	11.72	14.46	14.104	12.49	15.87
Electricity	21.16	19.98	21.21	198.88	168.19	210.44	119.16	107.66	129.75	339.2	295.83	361.4
Sum	190.548	183.167	197.612	743.4776	685.9355	767.598	708.812	641.1519	793.253	1642.842	1510.27	1758.463

Table 3. Greenhouse gas emissions from different energy sources in selected garments, textile, and dyeing industries (2019-2021)

Energy Sources	Greenhouse gas emission in garments industries tons (CO_2 eq.)			Greenhouse gas emission in textile industries tons (CO_2 eq.)			Greenhouse gas emission in dyeing industries tons (CO_2 eq.)			For all Industries greenhouse gas emission in tons (CO_2 eq.)		
	2019	2020	2021	2019	2020	2021	2019	2020	2021	2019	2020	2021
Natural Gas	8517.54	8207.4	8867.5	27375	26034.6	27988.4	29027	26267.9	32675.3	64920.19	60509.99	69531.35
Diesel	12.88	10.73	13.59	61.10	44.36	87.29	935.11	838.52	1034.56	1009.09	893.61	1135.44
Electricity	3930.83	3709.69	3938.06	36991.68	31283.34	39141.84	22163.76	20027.76	24133.5	63086.27	55020.79	67213.4
Total	12461.25	11927.82	12819.15	64427.78	57362.3	67217.53	52125.87	47134.18	57843.36	129015.6	116424.4	137880.2
Sum	24922.5	23855.64	25638.3	128855.56	114724.6	134435.06	104251.74	94268.36	115686.72	258031.15	232848.79	275760.39

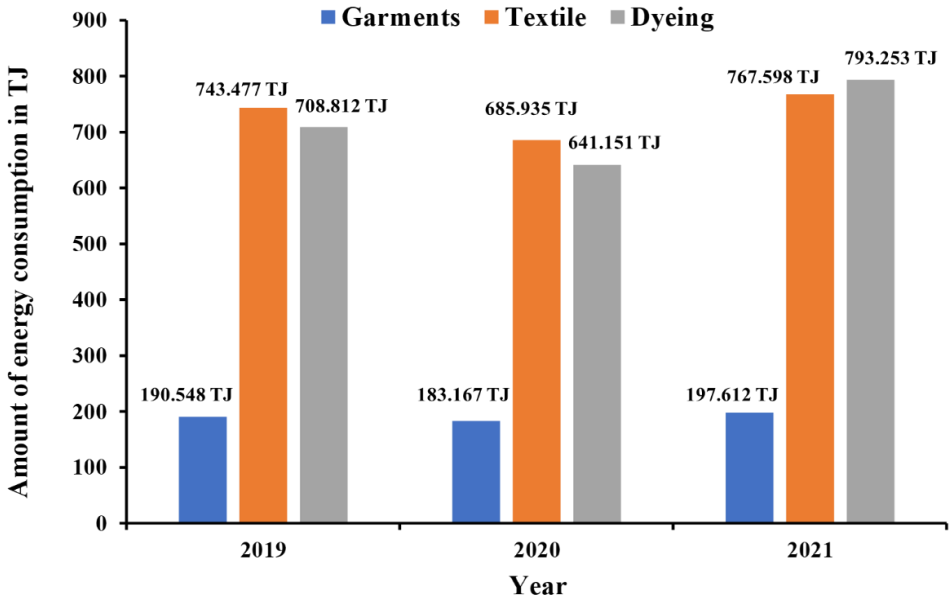

Fig. 1. Energy consumption in the garments, textile, and dyeing industries from 2019 to 2021

increase from 13.07 TJ to 14.46 TJ. The total diesel consumption across all industries rose from 14.104 TJ in 2019 to 15.87 TJ in 2021. While diesel is often used for backup power generation and transportation, its combustion contributes to higher levels of greenhouse gas emissions, making its increasing use a concern for air quality and environmental health [13].

Electricity consumption also showed notable growth, reflecting the increasing mechanization and production demands within the industries. In the garments sector, electricity consumption remained steady, growing from 21.16 TJ in 2019 to 21.21 TJ in 2021. The textile industry exhibited a more substantial rise, with consumption increasing from 198.88 TJ to 210.44 TJ. The dyeing industry followed a similar trend, with its electricity use growing from 119.16 TJ to 129.75 TJ. Overall, electricity consumption across the three sectors rose from 339.2 TJ in 2019 to 361.4 TJ in 2021. This increase is indicative of expanding production and the use of electricity-powered machinery, but it also underscores the need for improved energy efficiency and a shift toward cleaner power sources, as electricity generation in Bangladesh is still heavily dependent on fossil fuels [14].

The energy consumption patterns from 2019 to 2021 in the garments, textile, and dyeing industries of Bangladesh reveal a clear dependence on natural gas and a slow integration of renewable energy sources like solar power. The steady rise in energy use, particularly natural gas and electricity, highlights the need for energy-efficient technologies and stronger policies to promote renewable energy adoption. Without significant changes in energy practices, these industries risk exacerbating environmental challenges, especially in the context of climate change and carbon emissions.

3.2 Greenhouse Gas Emissions

Significant variations in greenhouse gas (GHG) emissions were seen in the apparel, textile, and dyeing sectors between 2019 and 2021. These variations were mostly caused by the industries' use of natural gas, diesel, and electricity. Among these energy sources, natural gas emerged as the dominant contributor to emissions, with its impact steadily rising across all sectors. Specifically, GHG emissions from natural gas increased from 64,920 tons in 2019 to 69,531 tons in 2021, indicating its central role in the industry's energy profile. This increase can be attributed to the growing reliance on natural gas for industrial processes, which is often favored for its cost-effectiveness and availability, despite its environmental consequences [15].

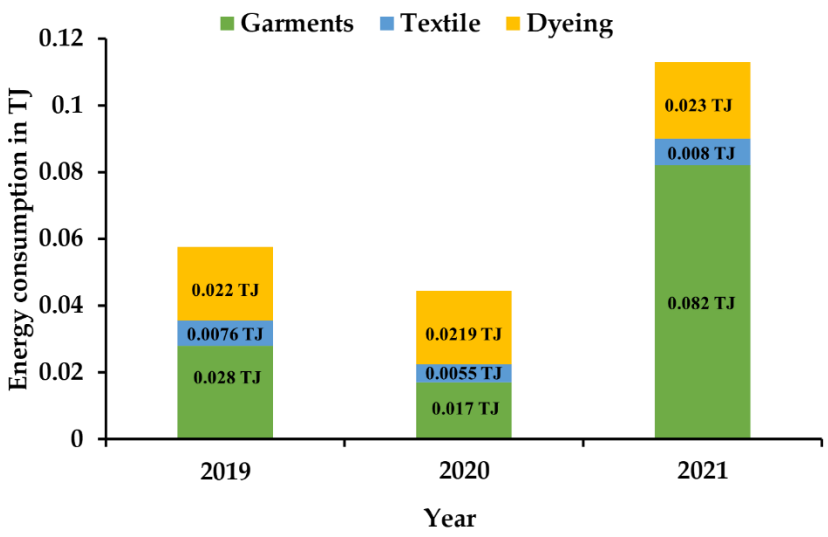

Fig. 2. Utilization of solar energy in all selected industries

Diesel, while contributing relatively minor emissions compared to natural gas, also exhibited a slight upward trend during this period. The emissions from diesel consumption rose from 1,009 tons in 2019 to 1,135 tons in 2021. Although its overall contribution remained small, the increase underscores the continued use of diesel-powered machinery and transport in the industry, which could be targeted for further optimization to reduce emissions [16].

Electricity consumption presented another major source of GHG emissions, with emissions growing from 63,086 tons in 2019 to 67,213 tons in 2021. The increase in electricity-related emissions reflects the industry's rising energy demands, particularly in the textile and dyeing sectors, which saw more pronounced growth compared to the garments sector. This trend highlights the importance of transitioning towards more sustainable energy sources or improving energy efficiency in these energy-intensive industries.

Overall, the total GHG emissions from all energy sources combined rose from 129,015 tons in 2019 to 137,880 tons in 2021. While the garments sector maintained relatively steady emissions, the textile and dyeing industries demonstrated sharper increases, signaling a need for focused efforts to mitigate emissions in these areas. The continuous rise in emissions across the board emphasizes the urgency for implementing cleaner technologies and more sustainable practices to curb the environmental impact of these industries.

3.3 Solar Power Installation

During the study period, the adoption of solar power as a renewable energy source exhibited a promising upward trend in the selected garments, textile, and dyeing industries. Although the overall contribution of solar energy remained relatively small, its steady increase from 0.058 TJ in 2019 to 0.113 TJ in 2021 reflects a growing awareness and implementation of sustainable energy practices within the industry. This positive shift is largely attributed to the utilization of available rooftop spaces for solar panel installations, a practical approach for industries seeking to offset their dependence on conventional energy sources such as natural gas and diesel [17].

The gradual integration of solar energy into the energy mix, though modest in its current scale, represents a critical step toward reducing the industries' reliance on fossil fuels. By generating renewable energy on-site, industries are not only cutting operational costs but also contributing to the reduction of GHG emissions [18]. This transition is particularly relevant considering the rising GHG emissions from natural gas and electricity, as discussed earlier, and underscores the potential for solar energy to mitigate environmental impacts in the long term.

Despite the increasing adoption of solar power, natural gas remains the dominant energy source, continuing to drive the majority of GHG emissions in Bangladesh's garments, textile, and dyeing industries. However, the growing investment in solar energy reflects a broader movement toward cleaner energy alternatives. If this trend continues, solar power could play a more substantial role in reducing emissions and promoting sustainability within the industry. These findings emphasize the importance of encouraging policies and incentives that facilitate the wider adoption of renewable energy technologies, further accelerating the shift toward a more sustainable energy landscape.

4. CONCLUSION

The increasing energy use and greenhouse gas (GHG) emissions in Bangladesh's garment, textile, and dyeing industries between 2019 and 2021 are highlighted in this study. Even though there has been a small rise in the use of solar energy, these industries still heavily depend on natural gas, diesel, and electricity. Natural gas is the main source of energy and has been a major contributor to rising GHG emissions. Overall emissions grew from 129,015 tons in 2019 to 137,880 tons in 2021, showing a clear need for better energy efficiency and a faster shift to renewable energy. While there are some positive signs of adopting renewable energy, these industries need to take more decisive actions to reduce their environmental impact and meet global sustainability targets. Improved policies and new technologies are essential to cut emissions and create a more sustainable energy system for these industries.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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