FROM CONVENTIONAL TO GREEN BUILDING: A FRAMEWORK FOR GREEN FACTORY TRANSFORMATION IN BANGLADESH

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ABSTRACT

Bangladesh has a lot of industrial facilities, yet only a few percent of the factories get the "green factory" classification. While green factories initially prioritize the environment, there is a significant opportunity to transition traditional industries into eco-conscious enterprises. The objective of this study is to establish a solid framework for reshaping the industrial landscape of Bangladesh toward green practices. The work begins with the selection of a well-established green factory in Bangladesh. Detailed surveys, in-depth interviews with management, and a thorough literature analysis are used to discover the distinguishing features of a green factory. After that, a comprehensive examination of a traditional, non-green factory is conducted, using on-site visits, questionnaires, and interviews to identify areas that need adaptation and development. The result of these endeavors is a wealth of information that informs actionable procedures for converting existing factories into environmentally friendly establishments. This study has the potential to set a global standard by demonstrating how conventional industries can be converted into environmentally friendly facilities, lowering carbon emissions and supporting global sustainability. The research developed a framework for transforming conventional non-green factories in Bangladesh, emphasizing green certification through reduced energy usage and increased reliance on renewable sources. The findings offer globally applicable, cost-effective alternatives for any non-green factory seeking environmental sustainability.The insights from this study could inspire factories worldwide to adopt more environmentally friendly practices, contributing to combatting climate change and minimizing ecological footprints.

Keywords: *Green factory, Bangladesh, sustainability, green building, construction industry*

1. INTRODUCTION

Green building involves planning, designing, constructing, operating, and maintaining structures in a manner that minimizes resource consumption, emphasizes renewable resources, and takes responsibility for reducing adverse environmental impacts (Ragheb et al., 2016). According to the U.S. Green Building Council (USGBC), an increasingly popular goal for, green Building is achieving net zero energy. Commercial and Residential buildings consume almost 40% of the primary energy in the United States or Europe, nearly 30% in China and approximately 32% in Bangladesh (Jamal et al.). Green building promotes sustainability in home construction by involving architects, engineers, and clients at every stage. It emphasizes collaborative, environmentally conscious practices for a sustainable environment. Green buildings are an indicator of sustainable development, with their spread indicating a growing economy and reduced greenhouse gas (GHG) emissions (Marotta et al., 2023). It improves operational savings and reduced operative prices by 40-50% in energy savings, 30-50%, CO_2 emissions by 35%, waste generation by 70%, and water usage by 40%, all of which contribute to enhancing the environmental condition (Kamal & Gani, 2016).

Environmental concerns, such as pollution, greenhouse gas emissions, sustainability, global warming and climate change, are the biggest influences to the development of green factories and to research on it. A green factory is a combination of the design for an ecosystem for a sustainable site; integrated infrastructure supports; instrumentation and machinery productive; building health; energy and water efficiency; material optimization; pollution prevention; product ecology and building improvement (Abed et al., 2023). There is a large number of researchers worldwide who have conducted research on the Green Building. To make the business sustainable and eco-friendly the entrepreneurs are running an effluent treatment plant (ETP), using energy-efficient technology and installing renewable energy technology (Çiner & Doğan-Sağlamtimur, 2019). This study result shows Green Factory has a significant relationship with environment performance ($r=0.404$, $P<0.05$) and business performance ($r=0.38$, $P<0.05$) (Çiner & Doğan-Sağlamtimur, 2019). Overall, the survey result shows Green Factory practices are well implemented in Malaysian manufacturing companies (Ahmad et al., 2018). The United States General Services Administration, USGSA (2011) found out that, green buildings have 19% lower aggregate operational costs, 25% of less energy, and 36% of fewer CO2 emissions. Nevertheless, green buildings should effectively use natural resources within economic means while supporting the health and well-being of the occupants (Monarange et al., 2016). In addition, green building materials have lower emissions than conventional analogues (Cheng et al., 2015). A study conducted in Malaysia revealed that green building saves around 71.1% of energy compared to the industry baseline—providing evidence for the economic benefits and energy consumption of green building (Dwaikat & Ali, 2018). The reduction in carbon emissions from buildings and constructions is aimed at the overall goal of mitigating the worldwide effects of climate change.

Although a number of researchers worldwide have conducted research on the Green Building; and a few were in the context of Bangladesh. At present, Bangladesh has more than 7000 factories with more than 4.0 million workers (Mia & Akter, 2019). Bangladesh currently boasts 90 LEED-certified green factories accredited by the U.S. Green Building Council (USGBC), with an additional 250 factories in the process of obtaining LEED certification through USGBC registration (Azad et al., 2022). But this number is low compared to the total existing factories. However, there is no specific work on converting a non-green factory into a green factory in the context of Bangladesh. This paper aims to describe the importance and prospect literature review and in-depth interviews with planners, architects and engineers of three LEED-certified green factories in Bangladesh to take actionable procedures for converting an existing non-green factory into green factories while also keep in mind about the low-cost solution. The insights from this study could inspire other factories to adopt more environmentally friendly practices, contributing to combatting climate change and minimizing ecological footprints.

2. METHODOLOGY

This study was conducted in three steps. At first, three of the well-established green factories in Bangladesh were selected. They are: (1) Karupannya Rangpur Ltd., Rangpur, (2) Mithela Textile Industries Limited, Uttara, Dhaka and (3) Bitopi Group, Mirpur, Dhaka. Detailed survey, in-depth interview with the management and literature review were conducted to collect the distinguishing features of green factories in Bangladesh and criteria was selected for analysis. After that, a local non-green factory named Dong Bang Dyeing Ltd., Kaliyakair, Gazipur was selected. Onsite visits, questionnaire surveys and detailed interviews were conducted to find out which key characteristics should be improved. After that, using the data collected from green factories were utilized in the improvement of the non-green factory. Finally, the cost assessment was conducted to know the effectiveness of using that technology in a large scale.

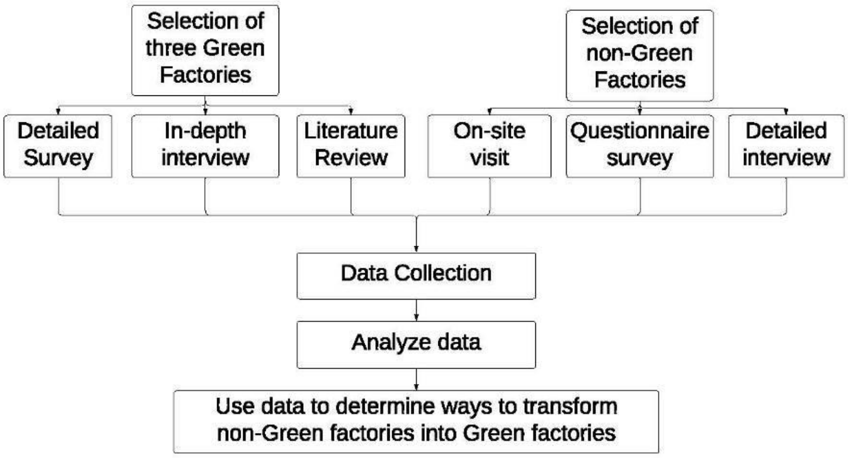

Figure 1: Flow chart of the process

3. RESULTS AND DISCUSSION

3.1 Collected Information From Green Factories

Information collected from the survey and interviews of the selected three factories is summarised in Table 1. In this table, their certification categories, credits achieved and technologies that were used to achieve those credits, are enlisted. Also, the total earned points by these factories are mentioned. Each factory is platinum-certified. Among them, the Mithela Textile Industries Limited earns the certification in the LEED BD+C category which is awarded for the newly constructed buildings. The other two earned in the O+M category and it is awarded for turning existing buildings into green buildings.

Table 1: Special features of the selected green factories

Category	**Karupannya Rangpur Ltd.**	**Mithela Textile Industries Limited**	**Bitopi Group**
Certification Category	O+M	BD+C	O+M
Integrative Process	–	–	–
Location and Transportation	–	–	–
Sustainable Sites	• Rainwater collected in four large ponds that are used again	• Use of alternative transport system such as bicycle by	• Increased bicycle transportation by introducing more

	in different works • Whole compound, buildings and roofs are covered in greeneries that reduces heat island effect • Lots of openings and louvers ensures less need for artificial lights	increasing storage room for bicycle • Reduced heat island effect by using non-reflective tiles in roof	bicycle stand • Conducted tree plantation with habitation of birds • Use of non-reflective tiles for reducing heat island effect
Water efficiency	• Water from large ponds are used in case of fire • Water from dyeing section are reused again which reduces ground water usage by 20%	• Reusing waste water by treatment and rain water harvesting	• Efficient additional fitting setup to reduce water wastage
Energy & Atmosphere	• Air circulation through the louvers and waterbodies ensures zero artificial air conditioning	• On-site renewable energy (solar) system • Maximum use of daylight	• On-site and off-site renewable energy (solar) system • Ensured maximum use of energy
Material & resources	• Active waste management and recycling system	• Proper waste management and recycled it	• Ensured proper solid waste management
Indoor Environmental Quality	• Reduces indoor air temperature up to 6 degrees from outside through natural ventilation	• Effective air flow control to keep temperature of the production sector always in between 27-29°C. • Use of maximum daylight	• Maintained maximum indoor environmental quality
Innovation	• Used a fountain to remove Iron particles from dyeing water as well as enhancing the beauty	• Reuse the excess steam from machine to boil water which reduces the use of gas	• Undertook innovative approach to operation
Regional Priority	_	• Optimize energy performance to reduce water use	_
Total earned points	84	91	89

3.2 Problems Identification From The Non-Green Factory

The location of Dong Bang Dyeing Ltd. from google map is shown in Figure 1. After visiting the factory, it was found that the factory premises are dirty. There was no proper waste management system, as presented in Figure 2. There was no waste recycling system either. They have an Effluent Treatment Plant but after treatment, they throw the water directly into the pond. This activity is one of the reasons behind water pollution in that area. After entering the factory, it was found that it had been lacking enough daylight. It had to keep all the artificial lights on during the day, Figure 3. After taking interviews with some workers and the manager, we came to know that the indoor work environment was not suitable for long time working. Because the ventilation system in the factory was not good. The inside of the factory was not clean as well because of the lack of a proper waste management system. Their energy consumption was also very high due to heavy machineries running and artificial lighting all day long. As a dyeing factory, they need a huge supply of water every day. But they solely depended on groundwater for their source of water.

Figure 2: Dong Bang Dyeing Ltd.

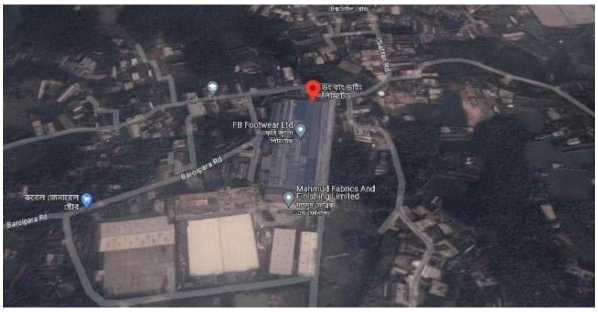

Figure 3: Factory location from google map

Figure 4: Lack of proper waste management system

Figure 5: Use of artificial lights during the day

3.3 Proposed Solutions

As discussed above, Dong Bang Dyeing Ltd. is not qualified to achieve any green certification. However, they have the potential to achieve at least the minimum qualification level (credit score 40) as specified by LEED. Similarly, a lot of non-green factories in Bangladesh also have the scope to achieve at least a minimum credit score. However, transforming a factory into a green factory is expensive. The main thing that is holding these factories back from being a green factory is the cost. As a result, this study tries to find effective yet cost-efficient ways to transform these factories. The findings from a thorough literature review and interview, questionnaire, and on-site survey are discussed below:

a) Inside of Dong Bang Dyeing Ltd., workers have to use artificial lights the whole day. As a result, it costs a lot of money and energy. To reduce the use of artificial lights, natural lights must be allowed as much as possible without the risk of heat getting entrapped. As the roof of the factory looks like a bunch of triangular-shaped teeth of a saw, as in Figure 6, sawtooth lighting can be implemented which is also suggested by Architects (2023), shown in Figure 5 as well as more side lighting on the wall. Also, building and roof must be covered with greeneries so that the heat island can be reduced (Kim et al., 2020). These two alternatives might help the factory to earn credit in the Sustainable Sites category.

Figure 6: Triangular shaped roof of the factory

Figure 7: Proposed sawtooth lighting system on the roof (Architects, 2023)

b) Water from the dyeing section is wasted and thrown directly in the ponds after treatment. However, it is dangerous to throw water directly into natural water bodies even after treatment. As a result, treated after can be reused. This will reduce the usage of ground and also reduce the risk of water pollution. Also, rainwater can be reused by collecting it from the roof. Yew et al. (2021) proposed a sloped structure to collect rainwater and reuse it. As the roof is triangular, rainwater can be gathered in the similar manner in between the spaces of two adjacent slopes. Then the water will be collected, filtered, and used again. By doing this, it will earn credit in the Water Efficiency category.

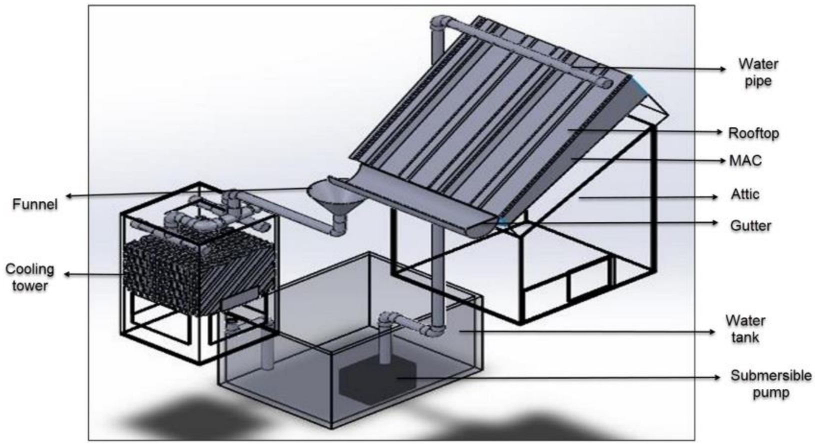

Figure 8: Rainwater harvesting system (Yew et al., 2021)

c) Crossed ventilation should be implemented and more exhaust fans, shown in figure 9, should be installed in order to earn credit in the Energy & Atmosphere category. As there is almost no internal walls in the factory, by maintaining a two-opening configuration and adequate opening size as suggested by Zhang et al. (2022), it would be the most effective mode of natural ventilation.

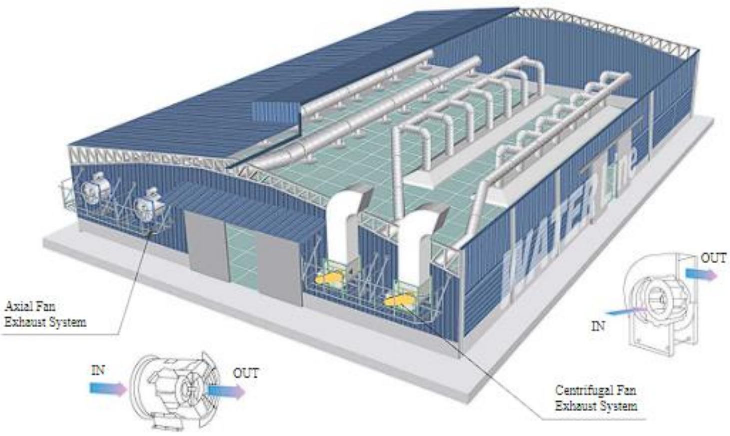

Figure 9: Factory exhaust system (cooling, 2020a, 2020b)

d) While standard treatment technologies are successful in removing organic pollutants from wastewater, they often leave behind inorganic salts. Reusing treated wastewater is essential to reduce disposal fees and lower the costs associated with obtaining fresh water. The treated dye water from the factory can be reused as proposed by Jorge et al. (2023), shown in figure 10.

Figure 10: Reused treated dye water (Jorge et al., 2023)

e) Waste must be thrown in proper places. Industrial waste must be separated from biowaste. Also, active waste management and recycling systems must be introduced. This has to be done to earn credit in the Materials & Resources category. Wan et al. (2019) mentions community composting centres, green waste collection, treatment points, and community gardens as some of the approaches of managing waste which can be adopted in this case.

f) In order to earn credit in the Indoor Environment Quality category, natural ventilation and maximum daylighting must be ensured. Sandanasamy et al. (2013) showed that adopting different daylighting strategies e.g. bouncing of daylight to create indirect lighting, adjusting ceiling height etc. can reduce up to 25%-40% energy consumption.

3.4 Cost Assessment

Cost estimation of the used technologies are given in table 2.

Table 2: Cost estimation of the tentative technology

Components	**Total Number of Components Used**	**Total cost of components (Including Labor cost)**	**Contingency Cost (10% of total material and labor costs)**	**Total Cost**
Sawtooth lighting fixtures	161 Nos	$80,500	$8050	$88550
Roof greening materials	250,000 lbs	$50,000	$5000	$55000
Rainwater Harvesting System	Storage capacity of 100,000 gallons	$50,000	$5000	$55000
Exhaust Fans	20	$3400	$340	$3740
Dye Water treatment plant	4	$4 million	$400000	$4400000
Waste Management and Recycling Systems	20	$40,000	$4000	$44000

Net Cost	$4646290 $5 million (Approximately)

This table shows the net cost of $5 million approximately to set the existing factory as a green factory. Costs of each facilities are compared below in order to find out the economical viability of the proposed solutions:

a) Based on cost study, typical lighting fixtures need an initial expenditure of around $351 to $531 per fixture (Nelson & Bugbee, 2014). According to a case study, a 15% decrease in power usage resulted in savings of 7.4 million pounds of CO2 emissions and $500,000 in savings over a ten-year period (Amoah et al., 2018). Because of the possible energy savings and environmental advantages, sawtooth lighting fixtures are a feasible option for green industries, even if their initial cost may be greater than that of regular lighting fixtures.

b) Energy consumption may be greatly decreased by installing green roofs. A National Research Council of Canada research found that even a six-inch wide green roof may save summer energy needs by over 75% (Shahmohammad et al., 2022). Reducing the need for air conditioning and the impact of the urban heat island can be a fantastic solution. A green roof is a feasible option for green industries, even if the upfront costs may be greater due to the long-term advantages including lower energy usage and better stormwater management (Calheiros & Stefanakis, 2021).

c) Rainwater Harvesting Systems (RHS) are decentralized water solutions that collect rainfall, often from a rooftop or other impermeable surface, and store it for later use (Gee & Sojka, 2022). Harvesting System may save 138.6 (kWh/year-family) on energy and 21.6% on domestic water usage. agreement relates to energy production and has the ability to save up to 50% of energy savings when it comes to mains water use (Rahman, 2017). Furthermore, long-term power cost savings usually offset the initial RHS investment.

d) Exhaust fans are frequently employed in a variety of industrial equipment and processes to provide the airflow required for heat and mass transfer activities. Rouleau and Gosselin (2019) estimated that the cost of a typical exhaust fan may be as high as $1,500, depending on how complicated the process is. Although exhaust fans initially cost more than standard ventilation systems, their potential for energy savings and environmental advantages makes them a competitive option for green enterprises (Piwowarski & Jakowski, 2023).

e) Dye Water Treatment Plants (DWTPs) can save a substantial amount of electricity. One research found that 0.26 kW h/m3 of energy are needed in treated wastewater by people, equipment, chemicals, and electricity (Sharawat et al., 2021). Reducing energy usage not only saves money but also lessens the environmental effect of producing energy.

f) Using waste plastic to create fuel is a workable method that is more efficient and economical than the chemical recycling standards in use today (Nikiema & Asiedu, 2022). At a lower temperature of 220°C, this method can turn 90% of plastic trash into fuel in just one hour (Pandyaswargo & Premakumara, 2014). Organic waste composting offers several benefits. Water is conserved when soil quality is improved since less watering is required.

3.5 Challenges

a) Sawtooth Lighting: Because of structural limitations, implementing sawtooth lighting in an existing facility might be difficult. The roof structure of the existing factory was appropriate to apply Sawtooth lighting. But, in order to maximize natural light and prevent overheating, the Sawtooth's position and shape must be carefully planned (Füchtenhans et al., 2019).

b) Reusing Treated Water and Wastewater: Although it can have advantages, reusing treated water necessitates a thorough treatment procedure to guarantee the water's safety. Inorganic salts and other impurities that might be dangerous if improperly eliminated could still be present in the treated water (Kesari et al., 2021). To maintain water purity, the firm would also need to make investments in a strong treatment system and frequent monitoring.

c) Cross Ventilation: Because of the size and design of the plant, cross ventilation might be difficult to implement. Outside variables like wind speed and direction might affect how well cross ventilation works (Elhadary et al., 2021).

d) Trash Management and Recycling Systems: Because factories create a wide range of trash and require adequate facilities for sorting and processing, it might be difficult to implement efficient waste management and recycling systems. Furthermore, the manufacturer might need to adhere to norms and regulations (Badola & Chauhan, 2022).

e) Natural Ventilation and Maximum Daylighting: Because of a factory's size, layout, and location, it might be difficult to provide natural ventilation and maximum daylighting. It could be necessary to make structural changes to make greater room for natural light and ventilation (Aboulnaga & Maryam, 2022). Furthermore, the efficiency of natural ventilation and daylighting can be impacted by variables like the local temperature and weather (Aboulnaga & Maryam, 2022).

4. CONCLUSION

This study aimed to establish a solid framework for reshaping the conventional factories of Bangladesh into green factories. In order to achieve the result, a non-green factory was selected for which the framework was developed. The findings of this study show that to achieve the minimum criteria for receiving green certification, a factory must focus on the reduction of energy and natural resources, reuse resources, and try to recycle used materials. Also, increased dependency on renewable sources should be the focus of the conventional factories that want to become green. These alternatives and how a non-green factory should implement them were discussed in this study.

Any non-green factory from Bangladesh and even from any part of the world can utilize these techniques to become a green factory. One of the major contributions of this study is to find the most efficient and cost-effective alternatives. So, any factory which is struggling to get green certification but does not have proper resources can benefit from this study. Although the suggested alternatives require an upfront investment, there is great potential for long-term financial sustainability. Sawtooth lights, green roofs, rainwater collection systems, exhaust fans, and decreased expenses from dye water treatment and waste plastic fuel conversion can all help to compensate for the upfront costs of energy conservation over time. Additionally, by enhancing brand awareness and adhering to future regulatory requirements, these tactics support environmental sustainability, which might result in further indirect economic benefits.

The factories that were considered in this study were mainly garments, dyeing and crafting factories. Certainly, there are other types of factories and buildings which also need to become green. But they were not considered in this study. Still, these other types of factories and buildings can also be benefitted by following a similar approach discussed here. Also, there is a scope for enhancing this study by considering different factory types or building types and also considering the global implications. Moreover, the recommended solutions may not be appropriate to many companies, since they are specific to the unique circumstances of Dong Bang Dyeing Ltd. and its economical and geographical characteristics. Additionally, the research is predicated on the current regulatory and technological landscape which might change in the future and affect how feasible and effective the suggested remedies are.

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