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Six seasons, four summers: How to solve fashion's high heat problem

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INTRODUCTION

Our 2023 *Higher Ground?* reports with Schroders estimated the economic damage that extreme heat and intense flooding will soon inflict on apparel producers, their workers, governments, buyers and investors. By 2030, an apparel industry that fails to adapt to extreme heat, in particular, will forgo millions of new jobs and billions in export earnings. By 2050, the gap in export earnings between apparel industries that invest in climate adaptation and those that ignore the problem could balloon to 65 percent.[1]

In two more analyses, *Hot Air* and *Warming to the Idea*, we tracked the acceleration since 2005 in extreme heat days and the impacts of high heat stress for workers' productivity, their livelihoods and health. Average days per year with outdoor temperatures above 35 °C (95 °F) between 2020 and 2024 topped 116 days in Delhi, 113 in Karachi, 112 in Phnom Penh—more than doubling earlier totals—79 days in Cairo and 74 in Ho Chi Minh City.[2]

In each round of research we looked at how governments, apparel brands, unions and international bodies from the International Labor Organization to the International Accord should be dealing with the damage done by extreme heat. And in all three analyses, our findings pointed to three recommendations. Two of these three are guiding principles: redistribute climate costs and risks away from apparel workers, and treat heat and flood events as health hazards in regulation, both public and private.

The third is specific and concrete: to drive action, calculate the costs of climate adaptation measures in factories and workers' homes, estimate factory-level returns on investment (ROI) and pinpoint financing options that share costs between apparel producers and buyers. The old adage—you manage what you measure—holds true. High heat and its effects on workers have, until recently, been treated by most buyers as a supplier-level problem and by many suppliers as a needless expense.

In this report, we follow our 2023 recommendations to the end in one of the industry's major production cities and deliver our analyses of heat stress levels in eight Dhaka-area factories and from 37 workers' homes. The unique data sets built in 2025 for this project make this first-of-its-kind analysis possible. In Section 1 we examine the year-long impacts of high heat in the factories as a group and, in Section 2, individually to see how it varies factory-by-factory. In Section 3, we look up-close at our data from Bangladesh's 'heat stress season' to see how it shows up by week, by day. We measure both qualitatively and quantitatively the costs of heat stress for workers and employers in Section 4.

> **"I understand that [Bangladesh] was a six-season country before, but now it is not. Now for two seasons it stays cold and the rest is summer. In this hot weather, it becomes difficult for us to live."** ***Dhaka apparel worker, Higher Ground? film interview (2023)***

We lay out remedies in Section 5 using engineering studies conducted in our factories. With a focus on passive and active cooling systems, we calculate costs, returns on investment and payback periods for each of our factories. We outline industry-level remediation costs and the financing options to achieve a climate-adaptive apparel industry in Bangladesh. Finally, we present a comparable analysis—heat stress levels, impacts, remediation costs and benefits—for workers in their homes in Section 6.

We find, first, that workers are bearing the costs of a seven-month long heat stress season that begins in early April and ends in late October. Second, we find that cooling costs—in our small sample—are manageable with an average payback

1 See GLI and Schroders' *Higher Ground?* analysis of (future) economic costs for four key apparel producers: Bangladesh, Cambodia, Pakistan and Vietnam.
2 See GLI's *Hot Air* for (historical) five-year average temperatures.

period of one to four years, depending on future costs and heat stress levels. Third, worker heat adaptation needs to be paid for. This holds whether your approach to the problem relies on a rights or a business case. Our data and analysis make explicit what is tacit knowledge for tens of millions of apparel workers in Bangladesh and beyond.

The ‘Six Seasons, Four Summers’ analysis is designed to help the industry—employers, brands, workers, governments—move to the testing of solutions and cooling on a large scale. For those in positions to act, there are three constraints to keep in mind. First, the problem is urgent. The science is well-known. The technology is often simple and its costs (and financing) and average payback periods one to four years in all scenarios for most manufacturers in our study group. But from long observation of the apparel industry, we know that calculations of efficiency gains and payback periods or the sending of other market signals will not go far. A handful of manufacturers may respond. And the typical apparel buyer—whether a global brand or an individual shopper—is a bargain hunter. None of them are instruments of economic fairness or climate justice.

Second, costs to cool workers should be shared by apparel brands, their manufacturers and government. This is doubly true for the thousands of small, low-margin producers who make up the majority of Bangladesh’s apparel industry.

Third, the future is uncertain. Heat levels will increase but not uniformly. Energy prices will rise or fall or both, and the costs and benefits of cooling will vary by factory, by year. We address these variables in the analysis by calculating scenarios that capture a range of possibilities—for cooling, for their finance, for macro-economic conditions. And we propose solutions that are layered and modular so that early actions to cool workers complement what follows.

So in our concluding sections, we focus on the obstacles both financial and political to large-scale relief and outline next steps for the industry’s actors in Bangladesh and beyond. We address governance issues—the use of power from legislation and enforcement to purchase orders to binding brand agreements. We explain how the right rules, relationships and enforcement can accelerate climate adaptation to protect tens of millions of workers and the tens of thousands of employers in some of the world’s most climate-vulnerable economies.

Section 1. How hot is it inside?

We begin with what seems like too-basic a question: How hot is it inside apparel factories? Accurate hourly data on heat-stress levels for workers inside apparel factories is fundamental for analyses of heat stress and calculation of the costs of solutions. But employers in apparel and footwear production, most of their governments and global buyers and are not yet tracking heat stress levels in a systematic way.

For this research, Cornell GLI and BRAC University in Dhaka placed electronic temperature and humidity sensors in eight tier one apparel factories in the Dhaka region.[3] To equip the apparel industry’s constituent parts—employers and workers, buyers, regulators, campaigners, engineers and epidemiologists—for a discussion of heat stress and to design and cost solutions, we collected half-hourly readings over a six-month period from the various buildings, floors and sections: sewing, cutting, ironing and finishing, in particular.[4]

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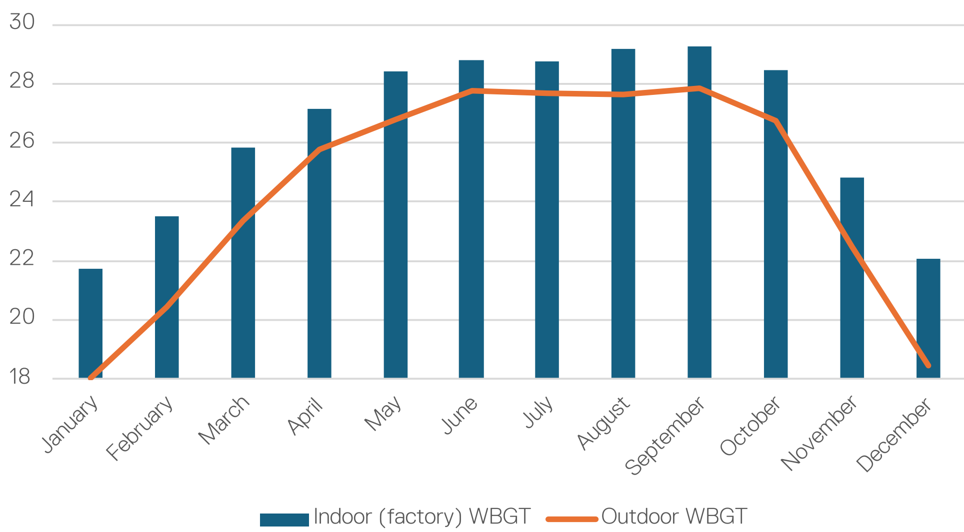
3 Our 70+ digital hygrometers were attached by BRAC University CED and BCWS researchers to pillars or walls (1.5 – 2.5 meters high) in the eight factories–oversampling the sections in the factories in which processes such as ironing or washing produce radiant heat and high humidity–and in (corresponding) workers’ homes. These low-cost sensors captured air surface temperatures and relative humidity data every 30 minutes in the study period. Our Dhaka-based engineering research partners, YGEN Engineering, tested the accuracy of our hygrometers on-site using professional sensors and found them to be highly accurate.

4 Our WBGT data are not direct WBGT measures but estimates. (See, for example, Chowdhury et. al. 2017). Our WBGT estimates are designed to assess heat stress risk broadly. Estimates using this and similar methodologies (including ISO 7243 for indoor thermal risk screening) may in some factory conditions modestly understate (and in others, overstate) heat stress levels. We use them here for screening, not for compliance, purposes. January–May 2025 WBGT estimates (and periodic data gaps) were imputed (with help from Mingwei Liu at Rutgers University and Zhengxiong Yang at Nanjing University of Finance and Economics) from our ‘observed’ WBGT using a hybrid random forest framework—a method employing machine learning to estimate hourly WBGT by sensor for the entire year based on our six-month observed data set. See our methodological note for more details.

To provide a cross-section of Bangladesh's exporting apparel factories, the factories we studied vary by location (urban, suburban and exurban), product (textiles and apparel), age and construction type (single and multi-floor), cooling systems, size, buyers and market position (value, mid-market, premium).[5] As high heat is a general problem for workers and employers in Bangladesh and, in order to win access to factories and sensitive data, we anonymize the factories in our analysis. (See Table 6 below).

In our analysis, we use the now standard measure for heat stress that combines air temperature and humidity—the wet bulb globe temperature (WBGT). Regulators, researchers, militaries, sports federations and, increasingly, employers use this index to track heat stress levels.[6] We calculated heat stress levels around each sensor for 2025. In Figure 1, we compare indoor (aggregate) heat stress levels with outdoor levels across Bangladesh's six seasons.

Figure 1. Outdoor and indoor (eight factories) average workday heat stress levels (WBGT) by month, Dhaka, 2025



Source: Cornell GLI and Liu/Liu/Yang from GLI, BRAC and Iowa Environmental Mesonet data.

Two phenomena that are important for our analysis appear here. First, while air temperatures were highest in a seven- or eight-week period in April and May and humidity is highest in June, we see that Dhaka's heat stress season in 2025 ran for a seven-month period that peaked in September and ended in October. Taken together, our factories saw their highest WBGT readings in September which corresponds to the late monsoon period – famous for damp, humid heat. Factories may partially close windows and shutters to protect materials against September's persistent rain. It also coincides with the race to deliver orders for holiday shopping seasons in the U.S., Europe and elsewhere. Second, factory heat stress levels in the April – October 2025 period ran an average of 1.4 °C WGBT above the comparable outdoor levels. We expect this. Apparel production draws together large numbers of people and enormous amounts of material, adds machines and systems that generate heat, and wraps them all in walls and roofs that collect and trap heat and humidity. We observed similar indoor-outdoor differences in our 2023 analysis of ILO Better Work air temperatures collected in Cambodian apparel factories over the last decade (Judd et al, 2023).[7]

5 The factory group is made up of factory types and processes that will be familiar to industry actors, it is a diverse and purposive sample, rather than representative one. For access to detailed and sensitive data, GLI agreed to protect the identify of factories, managers and workers. Identifying details such as the size of workforces and production area are presented as ranges.

6 See the figure in Annex 1 for broad guidance on the air temperature-humidity combinations that produce the estimated wet-bulb globe temperatures we refer to in this paper.

7 Nearly two-thirds (64 percent) of the ILO's factory assessments in Cambodia showed indoor air temperatures above the Better Work program's 32 C heat standard. And more than two-thirds (69 percent) of those factories in violation of the heat standard had temperatures inside the factory higher than the concurrent outdoor temperatures. "This measure shows improvement over the period [2015 – 2022], but a stubbornly high one-third of factories in 2022—the best year to date—were in violation of the standard and hotter inside than out." Higher Ground Report 1, Also Chea, V. 2026 study.

What is heat stress? What is wet-bulb globe temperature?

Heat stress is the impact of high temperatures, humidity and other factors including the intensity of work effort, on a person. High heat stress can produce exhaustion, fainting, kidney injury, heat stroke and worse in single episodes. Its cumulative effect can be debilitating. Work in hot environments can lead to chronic kidney disease (Hansson, 2025) and female apparel workers report menstrual disruptions, urinary infections and pain that work in high heat environments can cause (HeatWatch, 2026).

Heat stress is now commonly measured with a combined index of surface air temperature, relative humidity, air speed and radiant heat called the wet bulb globe temperature (WBGT). This differs from 'dry-bulb' temperature which is taken with traditional thermometers and is how heat is ordinarily represented.[8] Wet-bulb values integrate relative humidity and the resulting index is compressed; that is, WBGT are lower on the Celsius scale than dry-bulb temperatures but they generally represent higher heat stress. A wet-bulb value of 25 °C at 65 percent humidity, for example, corresponds to a dry-bulb reading of 31 °C in low humidity (Somanathan, 2021).

A 30 °C WBGT reading—common in our sample factories in May and June 2025 may sound manageable for an acclimatized worker in an ironing section but it represents an air temperature of 35 °C (or 95 °F) at 57 percent relative humidity and a high level of heat stress for these workers. That high humidity drives heat stress levels significantly higher is intuitive for those living in humid, tropical climates. But we note it here to emphasize that air temperature alone is not a reliable measure of heat stress. See, for example, Bernard (1999) and see, also, the figure in Annex 1 for the air temperature-humidity combinations that produce the wet-bulb globe temperatures we refer to in this paper.

How hot (and humid) is too hot?

Dhaka's long heat stress season and the persistent gap between indoor and outdoor WBGT raise our first big question: How hot (and humid) is too hot? Studies in workplaces and in laboratories show that heat stress begins to reduce workers' physical capacity at relatively low WGBT and the fall-off in both physical capacity and observed levels of productivity is more pronounced at 25 °C WBGT and higher.[9] Governments in key apparel-producing countries have set limits for heat (and cold) in the workplace and protocols including hourly rest in extreme heat to deal with it. A handful of global apparel brands have followed suit.[10]

Bangladesh, however, lacks a meaningful workplace heat standard so we measure heat stress levels in this analysis against the workplace heat standards set by the government in Vietnam—a similarly hot and humid tropical climate and the world's second-largest apparel producer behind China (Vietnam Ministry of Health, 2016). We also refer to

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8 Indoor WBGT values like those we calculate in this analysis using air temperature and humidity typically assign standard values to air speed and radiant heat. This means that calculated WBGT in factories with, for example, significant airflow or significant radiant heat from washing machines, could slightly over- or under-estimate, respectively, the heat stress levels in some areas. Calculated WBGT are suitable for screening and categorization purposes—our goal in this analysis—and direct measurement sensors should be used for safety compliance purposes. For an example of the discussion and experimentation in the academic literature, see https://www.sciencedirect.com/science/article/pii/S0378778819310965.

9 The thresholds and rates of decline for physical work capacity are contested in the academic literature but there is agreement that for work in all climate types, the decline is significant from 25 – 35 C WBGT. (See, for example, Foster et al. 2021 and Kjellstrom et al, 2009 and 2018): "[I]t is well established that 25°C WBGT already far exceeds optimal ambient conditions for human physical performance.

10 Nike, VF, Levi's and PVH are some of the global apparel brands who have set up specific heat thresholds and protocols. See Section 7 below for more information.

the recommended limits (or risk screening levels) that are points of reference for employers and governments around the world: International Organization for Standardization (ISO) 7243 and the American Conference of Governmental Industrial Hygienists' (ACGIH) 'threshold limit value' for heat exposure.[11]

Heat's impacts are not evenly distributed in apparel production in Bangladesh. Managers often work in air-conditioned offices. Production workers, with very few exceptions, do not. And among production workers, intensity of effort and radiant heat from powerful machines mean that different tasks and processes present different heat stress risks and require different thresholds. In all three regulations above, the threshold for continuous 'light' work which includes many sewing tasks is 30 - 31 °C WBGT. The thresholds for continuous 'moderate' work—including ironing, finishing and (manual or semi-automated) cutting—are 28 °C WBGT in the ISO and ACGIH recommendations (and 26.7 °C WBGT in the Vietnamese regulation).

All are well above the WBGT noted above (25 °C WBGT) at which the fall-off in workers' physical capacity accelerates. This is an important reminder that the heat stress thresholds do not tell us when workers begin to feel the effects of heat stress but the point at which the increase in risk to workers' health is non-linear—that is, it shifts into a higher gear. At the higher WBGT thresholds in the guidance and regulations, workers need to mix more rest with less work to avoid the effects of high heat stress: exhaustion, fainting, heat stroke and worse.

Based on the heat stress thresholds identified in the academic literature and the standards above, we define three heat stress 'zones' for the analysis in this paper of risks, types of responses and, finally, costs: 25 - 28 °C WBGT, 28 – 30 °C WBGT and >30 °C WBGT. The risks for workers correspond to the intensity of their work: sewing work (light intensity and often seated) at 25 – 28 °C WBGT is in the 'Moderate' zone, 28 – 30 is 'Caution' and levels above 30 are 'High', moving quickly towards 'Severe.' For iron/finishing work, the effort required and the risks are higher at the same wet-bulb globe temperatures: 25 – 28 °C WBGT is the 'Caution' zone, 28 – 30 °C is 'High' and levels above 30 °C are 'Severe' and—at higher levels—hazardous.

Table 1. Heat stress zones by apparel industry work type/intensity

Section/intensity	25 – 28 °C WBGT	28 – 30 °C WBGT	>30 °C WBGT
Sewing	Moderate	Caution	High
Cutting	Caution	High	Severe
Ironing/Finishing	Caution	High	Severe

That average monthly gap of 1.4 °C WBGT between indoor and outdoor heat stress levels may looks modest but on the relatively compressed WBGT scale, a one- or two-degree difference can be significant. And following our heat stress zones in Table 1 above, 1.4 °C WBGT can be the difference between workers in a sewing section working continuously at 28.5 °C WBGT in the Caution zone and needing to rest each hour at 30 °C WBGT—the High zone in our classification—to allow them to recover.

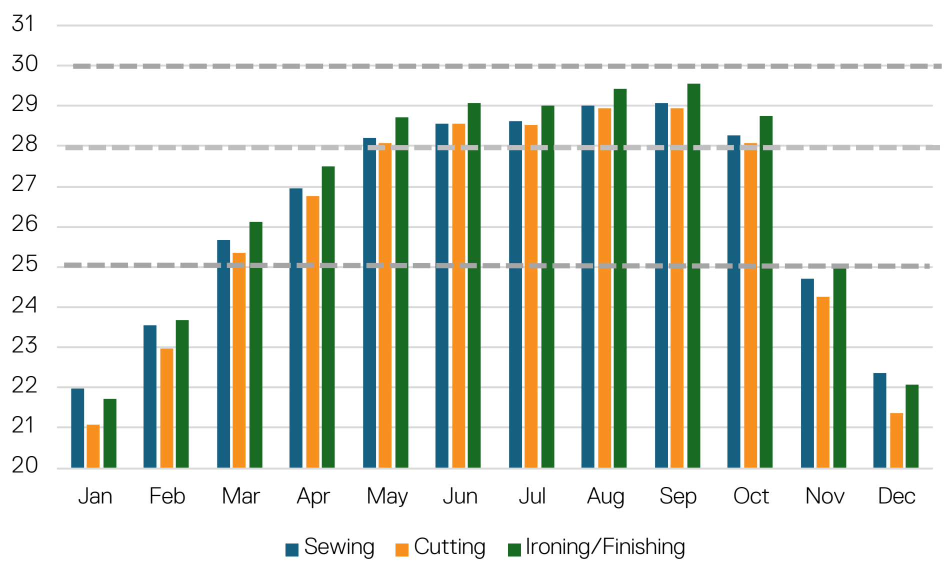
11 See, for example, https://www.osha.gov/otm/section-3-health-hazards/chapter-4. Vietnam's legal thresholds for continuous work are the same as those found in the American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit values guidance—a global reference—for heat stress at work. *Circular on National Technical Regulation on Microclimate- Permissible Value of Microclimate in the Workplace, Vietnam Ministry of Health, ISO 7243, ACGIH TLV (2021)*, and Department of the Navy Manual of Naval Preventive Medicine (2023), Chapter 3. The ISO and ACGIH thresholds and guidance—and work/rest ratios for work in high heat stress, in particular—are being challenged based on new data and studies including, Multi-country Assessment of Existing Occupational Heat Stress Guidelines in Hot Climates (forthcoming, submitted to Occupational & Environmental Medicine). Glaser J., Martin L., Mantzios K., Ioannou L. et al.

We apply this heat stress zone classification throughout this analysis and two notes on the upper limits of the heat stress scale are necessary here. First, our categorization is necessarily simple with a focus on intensity of effort but workers' individual experience of heat stress varies by other important factors including their levels of acclimatization, hydration, physiologies, clothing and more (See ILO, 2019, and Department of Energy, 2019). Second, the upper limit of the heat stress scale and the required rest-work ratios at, for example, 32 C WBGT for moderate work is not agreed among occupational epidemiologists. While some workers may be able to function at these extremes, their average time-loss leaps and their productivity collapses by 30 percent at 33 C WBGT and nearly 40 percent at 35 C WBGT. The risk of injury and heat-related illness—short-term and chronic—climbs significantly at these levels.[12]

How do the sections compare?

With data from 28 sensors inside our eight garment factories, we evaluated workers' heat-stress exposure during working hours (8 a.m. to 7 p.m.) in sewing, cutting, ironing/finishing sections. We can locate workers in the heat stress rubric in Table 1 above.[13] The lines draw in Figure 2 below—at 25, 28 and 30 C WBGT mark the thresholds for our zones and indicate the share of 2025 production hours that sewing, cutting and ironing workers spent in their respective heat stress zones.

Figure 2. Monthly average WBGT in eight factories, Dhaka, 2025



Source: Cornell GLI and Liu/Liu/Yang from GLI, BRAC and Iowa Environmental Mesonet data.

In the aggregate, workers in ironing/finishing sections saw consistently higher heat stress levels between April and October than those in cutting and sewing.

12 Discussions of high heat's impacts on worker--efficiency and health--are voluminous in the academic and policy literature. Recent examples include Kjellstrom et al (2019), Adhvaryu et al (2020), Foster et al (2021), Flouris et al (2024), Ioannou et al (2025), and Chan et al (2025).

13 Factory 8 has only ironing/finishing-type areas; Factory 2 has no ironing/finishing sensor, so factory-level weighting imputes its ironing/finishing value using the monthly average of the corresponding areas in the other seven factories.

Sewing

Heat stress levels in the sewing sections of our factories rose markedly from mid-April 2025, reaching their peaks in August and September. Taken together, average WBGT across our factories approached 29 °C in those months and sewing workers spent more than 80 percent of the day in the Caution zone (28 – 30 °C WBGT). In September, they spent more than an hour each day—10 percent of their time—in the High heat stress zone (>30 C WBGT).

Table 2. Sewing monthly average time in heat stress zones, Dhaka, 2025

Month	Avg. WBGT (°C)	Avg. daily Caution hrs	Avg. daily High hrs	Avg. daily Severe hrs	Avg. daily Caution %	Avg. daily High %	Avg. daily Severe %
Jan	22.0	0.0	0.0	0.0	0.0%	0.0%	0.0%
Feb	23.5	0.0	0.0	0.0	0.0%	0.0%	0.0%
Mar	25.7	0.5	0.0	0.0	4.2%	0.0%	0.0%
Apr	27.0	0.9	0.0	0.0	8.3%	0.0%	0.0%
May	28.2	6.4	0.3	0.0	58.5%	2.3%	0.0%
Jun	28.6	7.6	0.6	0.0	68.6%	5.7%	0.0%
Jul	28.6	8.7	0.1	0.0	79.2%	1.2%	0.0%
Aug	29.0	10.5	0.2	0.0	95.2%	2.1%	0.0%
Sep	29.1	9.0	1.1	0.0	81.4%	10.0%	0.0%
Oct	28.3	6.9	0.2	0.0	62.5%	1.7%	0.0%
Nov	24.7	0.5	0.0	0.0	4.2%	0.1%	0.0%
Dec	22.4	0.0	0.0	0.0	0.0%	0.0%	0.0%

Source: Cornell GLI and Liu/Liu/Yang from GLI, BRAC and Iowa Environmental Mesonet data. Note on color-coding: Caution > 50% is in yellow; High > 30%, orange and Severe > 5 percent, red.

Cutting and Ironing/finishing

These sections demand generally bigger efforts than sewing so the Caution, High and Severe zones start at lower WBGT levels. The annual average heat stress level in cutting sections across our factories (26.1° C WBGT) is lower than ironing/finishing as well as sewing. But by April nearly all working time in cutting is already in the Caution zone (10.5 hours per day, 95 percent). From May to October, these sections move quickly into the High zone, reaching 10.2 hours per day in August (93 percent).

Table 3. Cutting monthly average time in heat stress zones, Dhaka, 2025

Month	Avg. WBGT (°C)	Avg. daily Caution hrs	Avg. daily High hrs	Avg. daily Severe hrs	Caution share (%)	High share (%)	Severe share (%)
Jan	21.1	0.0	0.0	0.00	0.0%	0.0%	0.0%
Feb	23.0	1.1	0.0	0.00	10.3%	0.0%	0.0%
Mar	25.4	5.6	0.4	0.00	50.4%	3.4%	0.0%
Apr	26.8	10.5	0.3	0.00	95.4%	2.3%	0.0%
May	28.1	4.8	5.9	0.24	43.8%	53.6%	2.2%
Jun	28.6	2.9	7.3	0.82	26.5%	66.0%	7.5%
Jul	28.5	2.3	8.6	0.12	20.5%	78.4%	1.1%
Aug	29.0	0.5	10.2	0.32	4.1%	93.0%	2.9%
Sep	29.0	1.2	9.1	0.73	11.0%	82.3%	6.6%
Oct	28.1	4.6	6.3	0.09	42.1%	56.9%	0.8%
Nov	24.3	2.9	0.4	0.01	26.3%	3.8%	0.1%
Dec	21.4	0.0	0.0	0.00	0.0%	0.0%	0.0%

Source: Cornell GLI and Liu/Liu/Yang from GLI, BRAC and Iowa Environmental Mesonet data. Note on color-coding: Caution > 50% is in yellow; High > 30%, orange and Severe > 5 percent, red.

It is in the ironing/finishing sections that we saw the highest annual average WBGT (26.7° C). Work here requires machines and processes that can add significant heat and humidity. More than 50 percent of the workday between May and October is in the High heat stress zone and, in September, these workers spent 3.7 hours per day—a third of the working day—in Severe heat stress.

Table 4. Ironing/finishing monthly average time in heat stress zones, Dhaka, 2025

Month	Avg. WBGT (°C)	Avg. daily Caution hrs	Avg. daily High hrs	Avg. daily Severe hrs	Caution share (%)	High share (%)	Severe share (%)
Jan	21.7	0.1	0.0	0.0	0.4%	0.0%	0.0%
Feb	23.7	2.7	0.0	0.0	24.3%	0.1%	0.0%
Mar	26.1	7.0	1.5	0.1	63.5%	13.6%	0.5%
Apr	27.5	7.1	3.6	0.1	64.2%	32.7%	0.9%
May	28.7	2.9	6.4	1.7	26.4%	58.6%	15.0%
Jun	29.1	1.7	7.1	2.2	15.9%	64.3%	19.8%
Jul	29.0	1.8	7.4	1.8	16.2%	67.4%	16.3%
Aug	29.4	0.5	7.9	2.6	4.6%	71.3%	24.0%
Sep	29.5	1.0	6.3	3.7	9.3%	57.3%	33.4%
Oct	28.8	3.0	6.2	1.8	27.3%	56.6%	16.1%
Nov	25.1	4.1	1.2	0.1	37.4%	10.8%	0.6%
Dec	22.1	0.7	0.0	0.0	6.2%	0.0%	0.0%

Source: Cornell GLI and Liu/Liu/Yang from GLI, BRAC and Iowa Environmental Mesonet data. Note on color-coding: Caution > 50% is in yellow; High > 30%, orange and Severe > 5 percent, red.

Finally, we can push together the monthly figures by section for a look at shares by zone in the April to October heat stress season.

Table 5. Heat stress season average time in heat stress zones, April – October 2025

Section type	Avg. WBGT (°C)	Avg. daily Caution hrs.	Avg. daily High hrs.	Avg. daily Severe hrs.	Caution share (%)	High share (%)	Severe share (%)
Sewing	28.4	7.2	0.4	0.7	65.0%	3.0%	0.0%
Cutting	28.3	3.8	6.8	0.3	34.6%	62.0%	3.0%
Ironing/ Finishing	28.9	2.6	6.4	2.0	23.3%	58.4%	17.9%

Source: Cornell GLI and Liu/Liu/Yang from GLI, BRAC and Iowa Environmental Mesonet data. Note on color-coding: Caution > 50% is in yellow; High > 30%, orange and Severe > 5 percent, red.

Sewing workers spent more than two-thirds of their working hours in the April – October heat stress season in the Caution and High zones. Compared with the annual averages (4.3 hours and 0.21 hours), the heat stress season exposure is about 1.7 times the annual average for the Caution zone.

The WBGT averages in the three sections are quite close (28.3 - 28.9 *°C* WBGT) over the seven-month period, but the risk for workers differs significantly because of the intensity of work: sewing is dominated by the Caution zone but in both cutting and ironing/finishing sections, the combined time spent in High and Severe zones exceeded 60 percent of the workday. On a typical workday, cutting workers spent more than two-thirds of their time in the High (and Severe) zones. Ironing/finishing workers spent 58 percent of this period in High heat stress and 18 percent in the Severe zone. Together, that is an average of more than 8 hours per day.

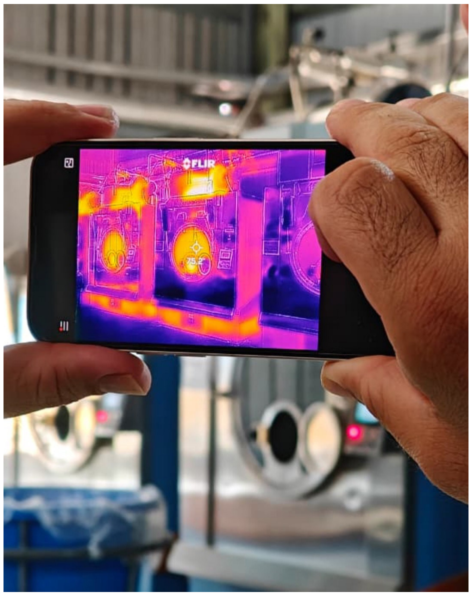
Seeing like an industry

Summing up, what might our findings indicate for the entire industry in Bangladesh? The results indicate a serious problem. Ironing/finishing sections have the highest heat-stress risk. These workers faced the most pronounced Severe zone exposure: moderate intensity work above 30 C WBGT—often with or around high radiant heat from machines—for nearly two hours per day in the heat stress season.

Workers in cutting sections face the lowest average WBGT (26.1 °C WBGT) but the lower heat stress threshold of 25 °C means that a large amount of their time falls in the Caution or High zones and—because of the effects of fans on fabrics on the cutting table—they face limits in terms of remedy.

Sewing sections, with the largest numbers of workers, have the lowest overall heat stress exposure. Aggregate High zone exposure was close to zero in most months in 2025. There was a notable exception: workers in the sewing sections in Factory 6 faced 90 High zone exceedance days (two hours or more per day in the High zone) in 2025.

Is it an outlier? Among sewing sections in our group of eight factories, yes. But this factory is arguably closest to the vast middle of Bangladesh's apparel industry: about 1,200 workers in a shed-style facility with faulty fans, an uninsulated roof and a major buyer at the value end of the market. We will learn more about this totemic factory—and the seven others and how they differ—with a factory-by-factory, section-by-section, hour-by-hour analysis of heat stress below and their costs and benefits of cooling in the sections that follow.



Section 2. How do the factories compare?

We turn now to the heat stress findings by factory. How do heat stress levels for workers vary?

Our eight-factory sample—detailed in Table 6 below—is not representative of the industry.[14] These factories are larger and, on the whole, more highly capitalized and better connected than the smaller producers that make up the majority of the Bangladesh's apparel industry. Their average workforce is 3,350 in an industry in which 73 percent of factories have fewer than 1,000 workers and 19 percent between 1,000 and 2,500 workers.[15] As a result, our factory group's heat stress problems likely understate the conditions that prevail in the thousands of smaller factories with smaller profit margins and simpler systems, less brand scrutiny and fewer controls. Factory 6 in the table below most closely resembles the average producer based on its building design and construction, workforce size and buyers.

We see, nonetheless, some diversity in our group. They are urban/suburban and exurban. Two are quite large with more than 5,000 workers each and two are close to the Bangladeshi industry average of 900. Most are 'simple' cut-make-trim manufacturers and several include significant washing operations. Most of the factories work at the 'value' end of the global apparel trade—typical of Bangladesh's industry—and several produce for middle-market and premium brands. One is chiefly a textile producer.

Table 6. *Profiles of manufacturers participating in the research, Dhaka region*

Factory	Location	Product	Market position	Construc-tion year	Construc-tion	Produc-tion area (sq. m.)	Workforce	Gross revenue (m. USD)[16]
1	NaraLiu/ Yanganj (suburban)	CMT	Value	2001 – 2010	Multi-story	>50,000	> 10,000	$150 – 175
2	Ashulia (suburban)	CMT	Premium	<2001	Multi-story	20,000-30,000	2,000-3,000	$30 – 40
3	Gazipur (suburban)	CMT and denim (wet)	Value	2011-2020	Multi-story	20,000-30,000	3,000-5,000	$50 – 75
4	Ashulia (suburban)	CMT	Mid-market	2001-2010	Multi-story	30,000-40,000	5,000-7,500	$75 – 100

14 Participating factories were chosen by the Cornell GLI and BRAC University CED researchers from a larger group of 20 manufacturers proposed by a group of five major apparel brands/retailers organized in by Cornell GLI. Researchers did not request and did not accept any support from manufacturers or brands/buyers beyond access for the research team to factories and to data relevant for the analysis. As noted above, data was collected under non-disclosure agreements between the Cornell GLI team and manufacturers, and was not available to brands/buyers. Workers were identified independently and away from the factory by our research partners, Bangladesh Center for Worker Solidarity and BRAC University. Uncertainty would be reduced, of course, by disclosure of gross revenues and by more complete information on the industry's exporter/sub-contractor relationships and workforce.

15 Mapped in Bangladesh (MiB) total from April 2026: 3,320 tier one apparel factories in Bangladesh.

16 2025 revenue is estimated as most manufacturers are unwilling to disclose actual figures. We use 2025 apparel industry export revenues (USD) and total estimated apparel industry workforce figures (MiB) for estimates of factory-level gross revenue.

Factory	Location	Product	Market position	Construction year	Construction	Production area (sq. m.)	Workforce	Gross revenue (m. USD)[16]
5	Ashulia (suburban)	CMT and denim (wet)	Value	2001-2010	Multi-story and shed	<10,000	1,000-2,000	$20 – 30
6	Ashulia (exurban)	CMT and denim (wet)	Value	2011-2020	Shed	<10,000	1,000-2,000	$20 – 30
7	Savar, Dhaka (exurban)	CMT and denim (wet)	Value	2001-2010	Multi-story	20,000-30,000	2,000-3,000	$20 – 30
8	Tongi, Dhaka (suburban)	Fabric mill / CMT (wash, dye)	Premium	2001-2010	Multi-story	20,000-30,000	4,000-5,000	$50 – 75

Source: Participating factories, Cornell GLI, YGEN, Mapped in Bangladesh, International Accord for Health and Safety in the Textile & Garment Industry.

Unlike our Section 1 overview of the factories as a group, here we weight our factory heat stress data according to each section's rough share of the workforce. This weighting allows us more accurately to aggregate factory-wide heat stress risk: sewing (70 percent of workers), cutting (10 percent) and ironing/finishing (20 percent).[17]

Sewing

From our aggregate analysis above, sewing workers spent less time on average than other workers in High and Severe heat stress zones across 2025. Their machines generate less heat (and humidity) and—as their tasks are physically demanding—their High heat stress zone starts at 28 °C WBGT and Severe at 30 °C WBGT.

But High-zone exposure for sewing workers in Factory 6 stands out: it reaches an average 1.3 hours per day (about 12 percent), far above other factories and eight times the average of the other six in Table 7 below. Factory 5 and Factory 2 have relatively high Caution-zone exposure.

17 Again, Factory 8 has only ironing/finishing-type areas and Factory 2 has no ironing/finishing sensor so our factory-level weighting imputes their ironing/finishing values using the monthly average of the corresponding areas in the other seven factories.

Table 7. Sewing annual average time in heat stress zones by factory, 2025

Factory	Avg. WBGT (°C)	Avg. daily Caution hrs	Avg. daily High hrs	Avg. daily Severe hrs	Avg. daily Caution share	Avg. daily High share	Avg. daily Severe share
1	26.2	3.8	0.1	0.0	34.7%	0.4%	0.0%
2	26.8	4.8	0.2	0.0	43.4%	2.2%	0.0%
3	26.0	4.1	0.0	0.0	37.2%	0.0%	0.0%
4	26.3	3.9	0.0	0.0	35.2%	0.1%	0.0%
5	26.9	5.0	0.3	0.0	45.3%	2.7%	0.0%
6	26.2	2.9	1.3	0.0	26.4%	11.9%	0.0%
7	26.7	4.9	0.2	0.0	44.4%	1.7%	0.0%

Source: Cornell GLI and Liu/Yang from GLI, BRAC and Iowa Environmental Mesonet data.

Cutting and Ironing/finishing

Differences across factories in cutting sections are relatively even. Average daily High zone exposure was generally 3.6 - 4.9 hours (33 – 44 percent) across 2025. Again, workers in Factory 6 had significant Severe zone exposure (0.9 hours or 7.8 percent), far exceeding the other factories and pulling up the all-factories average among cutting sections.

In ironing/finishing—the sections with the most Severe zone exposure—Factory 8 reaches an average 2.0 Severe hours per day (18.4 percent) and Factory 6 tops 1.9 hours (17.5 percent). At the other end of the scale, Factory 7 has the lowest Severe zone exposure (0.04 hours, 0.4 percent).

Table 8. Ironing/finishing annual average time in heat stress zones by factory, 2025

Factory	Avg. WBGT (°C)	Avg. daily Caution hrs.	Avg. daily High hrs.	Avg. daily Severe hrs.	Caution %	High %	Severe %
1	26.5	2.7	4.0	1.0	24.3%	36.7%	8.9%
3	27.1	2.4	5.0	0.7	21.4%	45.4%	6.0%
4	27.1	3.0	4.0	1.2	27.1%	36.2%	11.3%
5	27.2	2.5	5.3	0.3	22.6%	48.1%	3.1%
6	26.6	2.6	3.0	1.9	23.9%	27.4%	17.5%
7	26.0	3.7	3.8	0.0	33.4%	34.1%	0.4%
8	27.2	2.0	4.1	2.0	18.3%	37.1%	18.4%

Source: Cornell GLI and Liu/Yang from GLI, BRAC and Iowa Environmental Mesonet data. Note on color-coding: Caution > 50% is in yellow; High > 30%, orange and Severe > 5 percent, red.

How do our factories rank?

The data points—despite some significant variation—in the same direction. How can we sum it up? And what accounts for the differences? Using composite indicators to produce an index that allows to compare our factories' overall heat stress risk, we weight and stack average daily hours in Caution zone (x 1), hours in the High zone (x 1.5) and the Severe zone (x 2).[18]

Table 9. Factory composite heat stress ranking (descending by hour-based composite index)

Composite rank	Factory	Avg. WBGT (°C)	Composite index (h)
1	8	27.1	12.2
2	5	26.9	7.0
3	6	26.2	6.8
4	2	26.7	6.6
5	7	26.5	6.4
6	3	26.2	6.1
7	4	26.4	6.0
8	1	26.2	5.7

Source: Cornell GLI and Liu/Yang from GLI, BRAC and Iowa Environmental Mesonet data.

Despite high Severe exposure time for workers and occasional spikes above 33 C WBGT in the ironing sections of Factory 6, it is Factory 8 that ranks first (12.2) and by a wide margin. This is a function of inadequate cooling systems, its (wet) processes and their scale—Factory 8 has more than 30,000 sq. m. dedicated chiefly to textile production which produces high heat and high humidity. Factory 6 ranks (only) third, saved from a higher ranking as it had significant daily swings in working-hour heat stress levels—some of the highest highs paired with some of the lowest lows—as we show below in Section 3.

Factories 4 and 1 rank lowest. The bunching of remaining factories in our composite index (5.7 – 7.0) indicates that the heat stress problem is general and calls us back to the data presented in Figure 2 at the top of this paper: taken together, the workers in these factories are spending all of Dhaka's heat stress season between 25 and 30 C WBGT.

18 As in 2023's *Higher Ground?*, we used 'exceedance days' to capture the frequency and duration of sustained heat stress exposure by factory and section in a way that the monthly averages in the analyses do not. We count here the number of days on which exposure in the High and Severe zones exceeds two hours and the number of times those high heat stress conditions lasted for four days or more. Most factories had relatively few High zone exceedance days in sewing sections (average 3.3 percent) in 2025. Factory 6 is again a clear outlier: 90 exceedance days in the year in sewing sections, or 24.7 percent. That is more than six times the second-highest factory, Factory 5 (3.8 percent). Ironing/finishing sections show the most severe exceedance patterns. All factories have High zone exceedance rates above 40 percent, with Factory 8 the highest (213 days, 58.5 percent). And Severe zone exceedance is very high at Factory 8 (112 days, 30.7 percent) and Factory 6 (105 days, 28.8 percent). These workers spent more than two hours in the Severe zone on nearly one-third of production days in 2025.

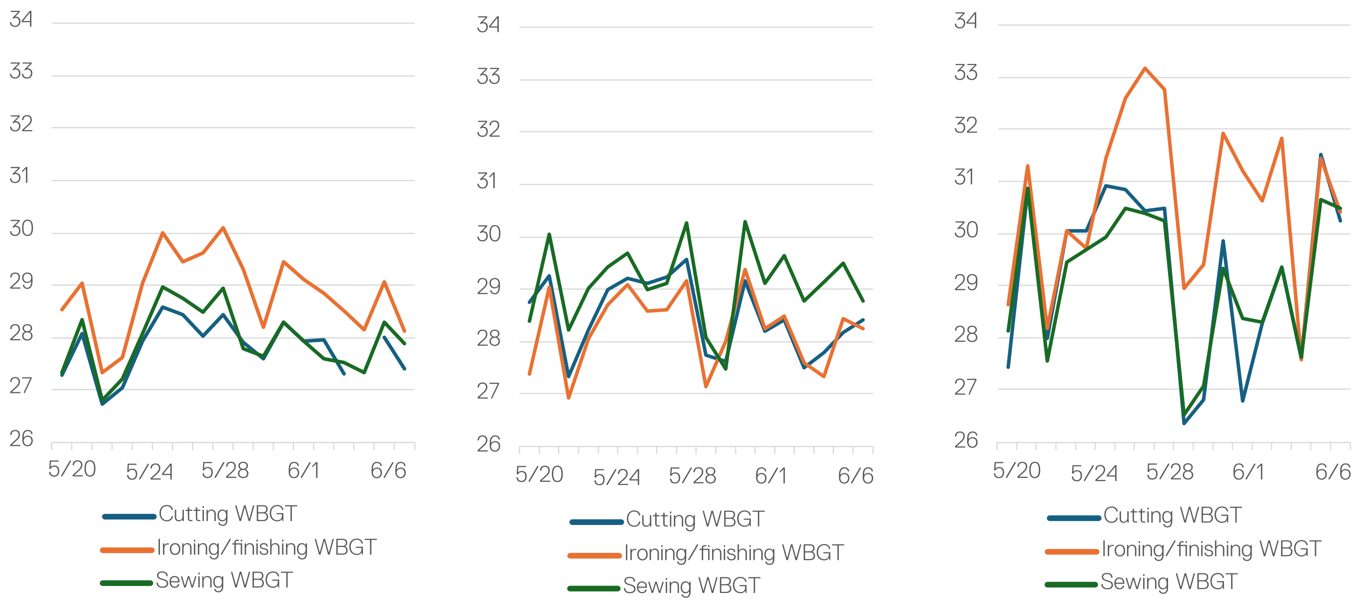
Section 3. Getting close to the heat

Before turning to solutions, costs and benefits, we want to see up close the daily and hourly variations in heat stress levels. They illuminate, in ways that monthly averages cannot, some of the interactions between factory buildings, their processes, workers and the weather.

We approach it first quantitatively, stretching out our heat stress data from a typical three-week period in late May and early June 2025.

Figure 3 below shows not daily averages but *hourly* WBGT from sensors in three of our Dhaka-area factories over a typically hot period in May - June 2025. We can compare here graphically how heat stress levels change over the course of the day and how they vary by factory and by section in a relatively cool factory (Factory 3), in our median factory (Factory 7), and one of the hottest (Factory 6).

Figure 3. Daily high WBGT by section in Factories 3, 7 and 6, 20 May - 5 June 2025



Source: Cornell GLI analysis of GLI/BRAC data.

We note two intensity and persistence phenomena here. The first is familiar but bears repeating. Workers in all three factories and in all three sections are spending every working hour during these typical 'summer' weeks in Caution, High or Severe heat stress zones. Among ironing/finishing workers, only in our median factory do they (mostly) manage to stay out of the Severe zone.

Second, we note that factories hold their heat (and humidity) after the outdoor high has passed, and some for longer than others. Dhaka's *outdoor* afternoon heat stress levels peaked on these days between 2.30 and 3 p.m.: from 26.4 °C to 27.4 °C WBGT. We know (from the underlying data) that the indoor average heat stress level in Factory 6 as the workday ended at 7 p.m. on 2 June was 29.6 °C WGBT, still fully five degrees above the outdoor level (24.6 °C WBGT) at 7 p.m. Factory 6 is an outlier here but the average heat stress level across the factories at 7 p.m. was 28.5 °C WBGT.

These figures confirm what we learned in the previous sections and tell us something new. A failure to adequately cool workers during the day and pull down indoor temperatures overnight compound an already serious problem.

Feeling the heat

The second approach is qualitative. How do workers and their managers perceive and respond to high heat stress? In face-to-face surveys in 2023 for *Higher Ground?*, apparel workers in Dhaka told us that their:

> factories either did not have exhaust fans or ran them infrequently. They noted that increased effort and perspiration in the hottest months required more breaks for water and rest which were often not provided. Workers also described struggling to meet daily production targets which were not adjusted to allow for the high heat.

One senior manager acknowledged in our survey that high heat meant that workdays were typically longer in the hottest quarter of the year—in May, June and July. But managers "generally downplayed the extent to which temperature affected workers. All of the managers of Dhaka-area factories interviewed reported taking measures to cool factories … [and] both that productivity was unaffected by high heat and humidity inside the factory, and that overtime hours to make up for lost output was a benefit; that is, worker income was higher in the hottest months."[19]

Who was right? Both, in a sense.

The high heat stress of April to October in Dhaka corresponds to the industry's busiest season. Factories are running at their top speeds to make deliveries to buyers in the U.S., Europe and elsewhere for the autumn and winter seasons. To meet urgent production targets and get paid—and, in some cases, to avoid abuse from supervisors—workers push themselves to increase their output even when heat stress is high.

This effort can disguise, for a time, the impacts of heat stress on workers' performance and health. This effect is well documented in the academic literature. (See, for example, Somanathan, 2021). And it shows up clearly in the experience of both managers—who see output buoyed—and workers who accumulate heat-related exhaustion, illnesses and debts over the hottest weeks and months. In 2023, workers reported spending BDT 3,500 (USD 31) for medicine and BDT 2,000 (USD 18) for electricity at home in the hottest months when fans have to run constantly to allow them to sleep.[20]

For this paper, we again engaged managers and workers from our study factories with a focus on heat stress and data that might allow us to see its impacts. The context was different this time. First, we were now inside factories and homes over many months to measure heat stress and design possible solutions. Second, the discussion of climate breakdown and heat stress in Bangladesh's apparel industry has advanced. Employers, workers and brands have turned their attention to the problem. Had their experience of and their thinking about heat stress changed in the time between our two studies?

Management

In our 2025 conversations, the production managers in our eight factories were, on the whole, more conversant with heat stress issues than those with whom we spoke in 2023, and readier with data that might allow us to gauge the impacts of high heat on workers and production. This is a broad qualitative measure of change but important. Seven of the eight managers acknowledged heat stress as a problem for their operations and workers and pointed to the measures they take to reduce it—for example, greater use of fans, more breaks in the workday, and more sugar,

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19 See *Higher Ground?* (Judd, Bauer et al, 2023)

20 *Ibid.*

saline and water for workers. But the factory group was split evenly between those which had made or were planning operational and structural changes to combat heat stress and those who responded as they might in a social audit: ‘We have the problem under control’.

Most managers said that high heat drives up workers’ use of leave (sanctioned and unsanctioned) by 3 – 4 percent in the hottest months and requires employers to recruit more workers for short terms. In factory-level data we collected across our study factories, medicine costs for factory clinics climbed 12 – 15 percent in the high heat of April, May, June and July 2025 above each factory’s year-long average medicine costs.

And while management teams in seven of eight factories acknowledged that their workers slowed down in high heat and several have made significant investments, none had analyzed changes in physical work capacity or worker effort levels at high heat stress levels. All noted that output nonetheless held up during the hottest months and a few said the quiet part out loud: delivering on time for buyers means pushing through the effects of high heat stress. ‘Workers need to meet the targets, whatever the weather.’

Workers

How do workers in these same factories react to high heat stress at work? We conducted individual (structured) surveys and small group conversations—along lines similar to those we had with managers—with five workers from each of the participating factories.[21] Through these conversations, often had in homes and always away from the workplace, we were able to gauge workers’ responses to heat stress at work.

Two-thirds of workers surveyed (65 percent) told us they always or almost always report for work even when they feel it’s too hot to work. Of the other workers, 18 percent said they missed up to 10 days in the last year due to the effects of high heat and another 18 percent missed 11 or more. (And of that number, one male and two female workers reported having to take leave for more than 20 days due to extreme heat).

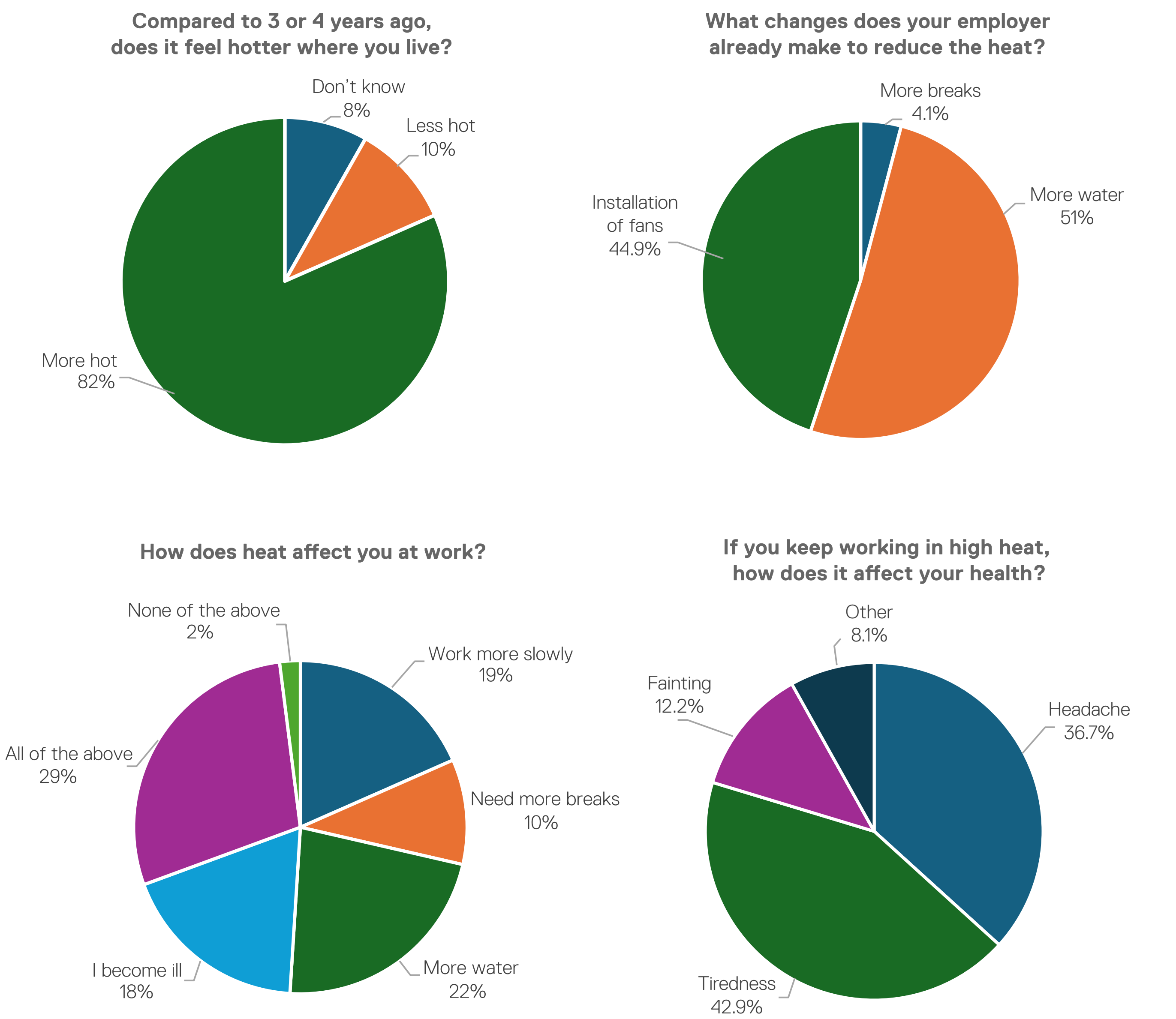
While at work in high heat, roughly one-fifth singled out needing more water, working more slowly or becoming ill. And a further 28 percent reported experiencing all of these impacts. How do the most common physical symptoms of work under these conditions rank among the workers surveyed? Tiredness (43 percent) and headaches (38 percent) top the list. Fainting is third at 12 percent overall and 17 percent among women.

Asked how management responds to the impacts of heat stress for workers, 88 percent of workers surveyed told us that there is always sufficient water to drink. But some workers noted that they must bring their own saline because none is supplied by the management. Eighty percent reported that managers gave them no breaks or insufficient breaks in the hottest months.

Only four of 49 workers said that managers allowed more breaks in high heat. Managers instead provide more water (51 percent) and use of fans (45 percent)—chiefly exhaust fans and ceiling fans and, in one case, an overhead industrial fan. What do workers think management should be doing first to combat high heat? Cooling systems rank first (28 percent), followed closely by more breaks and more fans.

21 BRAC University CED and BCWS conducted surveys in Bangla with 49 workers: 30 women, 18 men, 1 non-binary. Our rough 60 – 40 percent split among participants’ gender is not intended as a probabilistic sample but mirrors the gender split among Bangladesh’s apparel workers. Responses from ten workers from two factories that were excluded from the study (one for lack of co-operation and the other over technical disclosure/identifiability issues) are included in the totals here.

Figure 4. Worker survey responses on impacts of heat stress and factory efforts to reduce it (n=49)



Source: BRAC CED and BCWS worker surveys, Dhaka, July – August 2025

Heat stress is intensified by managerial practice. Workers we surveyed reported that rest, leave or slower output can lead to intimidation and scolding by supervisors, deductions in pay and reputational harm. One worker surveyed reported repeated fainting incidents on high heat days, saying there are effectively no breaks and no medical leave when the heat is excessive. A second explained that workers are resigned to the idea that they must keep working at any temperature as workers asking for rest risk humiliation by supervisors. A third recalled feeling dizzy after working long hours in high heat and being told that taking a break would undermine production targets. A fourth described a colleague who was visibly too weak to continue but was denied permission to leave because there was no substitute available. She fainted, was taken for saline and a brief rest, then brought back to work late into the evening to make up lost time. This is anecdotal (and graphic) evidence but it fits a pattern from previous surveys of apparel workers: heat stress can manifest as a problem of control, targets and punishment.[22]

22 See, for example, Climate Rights International, 2025.

What do their responses share?

Despite the mis-match in their responses, there is broadly speaking a fit here between how managers and workers talk about the effects of heat stress. Managers confirmed increased use of leave by workers, a fall in productivity and higher medical costs. And both noted that management's standard responses to high heat are more water (and saline) and increased use of fans. Managers in three of our factories said that they had changed lunch hours to reduce heat stress and added ducting—that is, some active, mechanical cooling in their factories.

More interesting—and a subtle change since our 2023 *Higher Ground?* survey—is that more managers now concur with workers that their actions are insufficient and report that they are in the hunt for more effective responses. Anecdotally, this appears to follow from managers own experience of higher heat and, for some, requests for information on workplace heat from buyers.

Finally, we can pull apart our survey results by factory and look at two things. First, do manager and worker accounts of heat impacts and responses in the same factory sound similar? Yes, and we can see this more easily seen at the extremes. In Factory 4, workers and managers concur that the ventilation and fans in their factory are relatively effective in combating heat stress. At the other end of our spectrum, both workers and managers in several of our factories agree that the heat levels are sometimes excessive, driven by building design and lack of maintenance of cooling systems.

Second, is our indoor heat stress data a match for the perceptions of workers and managers? Yes, though this convergence is only clear in the least-hot factories. Factory 4 mentioned above has the second-lowest heat stress levels in our Section 2 analysis (see Table 9). Factory 3 is located in a rural area near Dhaka and the impacts of the lower outdoor temperatures, shade trees and open outdoor spaces noted by workers and managers alike fit with the analysis above. (Both factories have LEED certified buildings and managers pointed to this as a contributor to lower heat stress. We evaluate this correlation below in 'What's LEED got to do with it?').

Management responses in the remaining factories in our study—more water and fans—are failing both objectively and in the judgement of workers and most managers we surveyed to address the problem.

What works? In Section 4, we measure losses from extreme heat and gains from effective responses to it.

"Maintenance work is in progress"

Section 4. Measuring the costs, benefits and returns of combating heat stress

In our 2023 *Higher Ground?* reports with Schroders, we calculated these future costs from the literal and figurative outside, using global climate models to forecast outdoor wet-bulb globe temperatures and the losses likely for an apparel industry if it fails to adapt to extreme heat. In this analysis, we build our analysis from the ground up and the inside out. We use our unique data-sets here to calculate the real-time costs of high heat stress and to estimate the return on investments designed to reduce it.

The best-studied impact of the costs of high heat stress is 'work-time loss'. The 2025 Ioannou et al. (Workplace Environmental Labor Loss or 'WELL') study and Adhvaryu et al. (2020) study of heat impacts in Indian apparel manufacturing set the standard for measurement of heat-induced work-time losses and are the best available matches in the academic literature for our study.[23] We use the WELL function to calculate heat-induced impacts on productivity or efficiency in each of our eight factories as comparable and reliable productivity data across our factory group was unavailable.[24]

Table 10 shows the (non-linear) decline in worker productivity for each one degree increase in the wet-bulb globe temperature. (This analysis is an advance on the (linear) 'damage function'—1.5 percent decline in productivity per 1 °C WBGT—that we applied in *Higher Ground?* And it fits with measures of heat-induced changes in worker efficiency (Adhvaryu et al, 2020) in Bangalore, India, apparel factories, which "indicate[s] that wet bulb globe temperatures above 19 C, a 1 C increase in temperature leads to a reduction of more than 2.1 percentage points in actual efficiency.") At 28 °C WBGT, for example, productivity of ironing workers has already fallen nearly 15 percent and, for sewing workers, nearly 10 percent.[25] As heat stress levels rise, the rate of decline accelerates for both.

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23 To get to apparel-specific figures for heat-induced losses (observed in the workplace as opposed to physical work capacity losses in lab simulations), we need a WELL-scale analysis of heat-induced impacts on worker output and health. "[The] WELL functions were developed using data from multiple countries and ethnicities to better describe the impacts of workplace temperature on different geographical regions and modern worksites, where people with diverse backgrounds and habits work on the same tasks… [T]he models provided in this study are based on real-world scenarios that account for current work practices and should, therefore, be considered representative of the present state" (Ioannou, 2025).

24 Our use of the WELL loss rates—based on outdoor work where ambient heat stress levels can run lower—likely *understates* time-loss and productivity declines for indoor apparel production workers. In contrast to outdoor workers, apparel workers are typically in a relatively fixed position—most are seated—which reduces the cooling effects of freer movement and they work in crowded, high-density spaces. Outdoor workers (without shade) can suffer from solar radiative heat but apparel workers indoors contend with walls, windows, roofs and machines that can add significant and highly concentrated radiant heat and humidity to their enclosed work-areas. In addition, the outdoor work studied in Ioannou et al is done predominantly by men. Apparel production in Bangladesh and elsewhere is done predominantly by women and their physiological responses to heat at work indicates relatively lower productivity at high heat stress levels (see Venugopal, 2024 and Gagnon, 2012). Finally, the work shifts measured in Ioannou average eight hours but ten-plus in our data. Longer days would produce greater fatigue and an acceleration in the loss rates for the apparel workers in our analysis.

25 Light/sewing loss rates are estimated from moderate rates in Ioannou (2025) using the average ratio (0.65) of light to moderate metabolic rates in two standard sources: ISO 8996 (Determination of Metabolic Rates) and Compendium of Physical Activities (2024).

Table 10. Heat stress-induced work-time loss (percent of work-time) per 1 °C WBGT

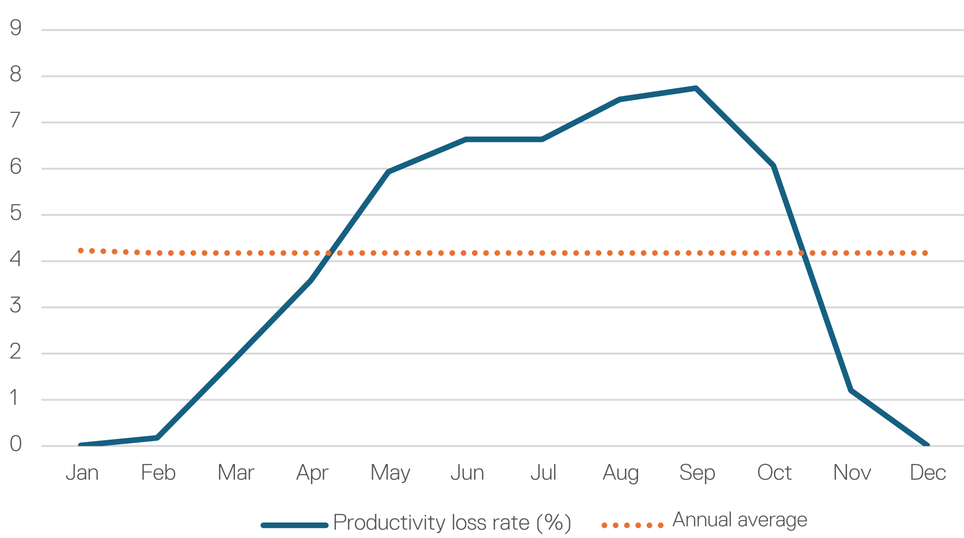
Work intensity	25	26	27	28	29	30	31	32	33
Light (sewing) cumulative loss	5.6	6.8	8.3	9.8	11.5	13.4	15.4	17.5	19.8
Rate of change		1.3	1.4	1.6	1.7	1.9	2.0	2.1	2.3
Moderate (ironing, cutting) cumulative loss	8.4	10.4	12.5	14.9	17.5	20.3	23.3	26.6	30.0
Rate of change		1.9	2.2	2.4	2.6	2.8	3.0	3.3	3.5

Sources: Ioannou (2025), B. Alahmad and Cornell GLI

We apply the above rates of change above 25 C WBGT to our hourly heat stress data from our eight factories and calculate the labor-related losses for each working hour in 2025 in each section of each factory.[26] These losses we weight according to each section's rough share of the factory's workforce—70 percent for sewing and so on—and treat the time (or capacity) losses as losses to revenue. Each day's weighted losses are stacked for an estimate in each factory of heat stress-induced losses (based on the labor share of factory revenue) in 2025.[27]

Across our factories, heat-induced loss rates in sewing averaged about 3.2 percent, cutting about 4.5 percent and ironing/finishing is 5.6 percent, or about 1.8 times the losses in sewing. And the revenue-weighted average loss rate per year across the sections in all eight factories is 4.1 percent.[28] In the peak heat stress season from April to October 2025, the loss rates were about twice the annual average and the peak is 7.7 percent in September. In the December – February winter months, the losses (above 25 C WGBT) were effectively zero.

Figure 5. Revenue-weighted work-time loss rate, by month, 2025



Source: Liu/Yang using GLI data

26 Working time loss and productivity loss are not the same thing but in apparel production where workers rather than machines largely determine the pace and where outputs are often group-based and subject to slow-downs or bottlenecks, time loss reflects lost capacity and orders take more days to complete or require (additional) overtime hours to deliver. Both accommodations to heat stress levels above 25 C WBGT have costs that are broadly captured by the revenue losses calculated here. That is, cooler workers and factories have higher capacity and, for a given level of orders, can generate more revenue. We apply the rate of 20 percent of labor costs (as a share of COGS) calculated in *Higher Ground?* (Report 2, 2023). We express the labor-share losses in terms of revenue (USD) lost, or foregone.

27 See our 20 percent calculation of labor costs as a share of COGS in our *Higher Ground?* (Report 2, 2023).

28 See Table 13 below for the per factory heat-loss rates.

How do our factories' loss rates vary in this calculation? In revenue terms or time-loss terms, the losses vary from 3.5 percent for the factories bunched together in our Section 2 loss by factory, 2025 analysis, up to 4.1 percent in Factory 6 and 6.6 percent in Factory 8.

Table 11. Estimated heat stress-induced losses to annual revenue

Factory	Avg. WBGT (°C)	Labor loss rate (%)	Labor share of gross revenue (USD)	Heat-induced loss (USD)
1	26.2	3.5	$33,060,000	$1,163,712
2	26.7	3.9	$6,500,000	$255,450
3	26.2	3.6	$13,180,000	$467,890
4	26.5	3.6	$15,880,000	$568,504
5	26.8	4.1	$5,220,000	$211,932
6	26.3	4.1	$5,200,000	$212,680
7	26.2	3.6	$5,800,000	$207,640
8	27.2	6.6	$10,540,000	$696,694

Source: Liu/Yang using GLI data

This average annual loss figure of 4.1 percent is a bottom line—or, if you prefer, a top line—in our analysis of this unique data set of 2025 heat stress levels. These are significant losses in an industry with relatively narrow margins and volatility in costs, relationships and orders. We make use of the heat-induced loss rates and figures in Table 11 in the following section where we calculate benefits and returns on investments of cooling, by factory.

A high-level comparison of this heat-induced labor loss rate with our 2030 heat-and-flood losses estimate of 4.5 percent in *Higher Ground?*—in which heat losses were calculated at a generic 1.5 percent per 1 °C WBGT above 25 °C WBGT—and a 5 percent loss rate in the ILO's *Work on a warmer planet* analysis (2019) help confirm the robustness of the new analysis.

Having defined the damage function and knowing the scale of the heat-induced economic losses to each of the factories in our study, we turn to the remedies. What are the expected costs of cooling workers in each of these eight factories? What is the expected benefit? And, finally, what is the return on those investments? What is the payback period?

What changes are required to cool workers?

Our cooling remedy is defined as reducing (or holding down) heat stress levels to 26 °C WBGT for ironing/finishing and cutting and to 28 °C WBGT for work in sewing sections. These levels are at or near the Moderate/Caution zone thresholds (see Table 1) for each work-intensity level. What will it require? Both goals put workers of both types--light and moderate intensity--at or near their Moderate/Caution zone thresholds.

Our technical partner in this analysis is YGEN Engineering, a Dhaka-based firm with long experience in design, costing and installing cooling systems in Bangladesh's apparel and other industries. In visits to each factory between July and October 2025, the project engineering team evaluated their existing passive and active cooling systems, their operation and administrative controls. YGEN combined their assessments with our section-by-section, hour-by-hour heat stress data to design heat stress remedies for each facility and its processes.

To estimate costs, the YGEN team used 2025 prices for Dhaka-region materials and installation (one-time capital expenditures or capex) and on-going operations and maintenance costs (O&M or opex). Energy costs estimates for 2026 and beyond—a sensitive issue for a county and an industry with an active energy crisis—are based on each factory's actual usage and its primary source: grid or on-site generation.

Engineering solutions include both passive cooling solutions such as insulation, partitioning of areas of concentrated heat, and reflective paint on roofs—especially effective in single-story factories—and active cooling ranging from improving ventilation and airflow to highly automated closed-loop air cooling systems. These engineering interventions are organized into three categories:

Convection cooling systems using controlled fresh-air intake, exhaust ventilation, and spot cooling provided, generally, by ceiling fans and industrial fans (high-volume low-speed or HVLS).

Water-evaporative cooling systems (modular) based on water evaporation and high air circulation, (also known as waterwalls).

Closed-loop air cooling systems integrated with cooling towers, chillers, and automated controls.

Based on their heat stress profiles (see Tables 7 and 8), all eight factories require baseline improvements to their ventilation and airflow systems—convection cooling. (As a universal requirement in cooling, it is analogous to good blood-flow for the human body. More sophisticated, supplementary treatments rely on the proper functioning of the rudimentary systems). Six of eight require a reflective coating on the roof to reduce solar radiant heat and two of those require more: insulation on the underside of the roof to slow the transfer of high heat from roof to production areas. And nearly all require that ironing and finishing sections be partitioned with transparent panes and provided with targeted closed-loop cooling systems.

Factory 6 and Factory 8 require extensive interventions to bring air temperatures, in particular, down to safe levels. Factory 6, with the second-highest heat-induced losses among the eight, requires the full suite of interventions: reflective coating and roof insulation, significant ventilation and airflow correction and closed-loop air cooling for both cutting and ironing/finishing sections. And Factory 8 which is not primarily a sewing-cutting-finishing facility but an industrial process-heat facility. Workers there are exposed to heat from burners, pre-treatment rollers, singeing machines, strengthening machines, pad steam machines, hot water circulation, high shed volume and accumulated hot air inside large profile-sheet sheds. The proposed solutions for this factory are intensive and the combination of its processes and scale push up the overall averages for the group of factories.

Factory 3 is one of our group that requires relatively modest interventions. What is it doing right, and what's needed? In YGEN's analaysis, it exhibited "relatively good baseline ventilation, balanced production-floor layouts, limited internal heat accumulation and fewer localized hot spots. The building envelope and surrounding open environment allow effective natural air exchange, and the factory uses its site-specific environmental profile well"--good outdoor airflow, natural shading from a significant number of large trees. Its existing exhaust and ceiling fan arrangements already provide reasonable air movement. As a result, the team's recommendation focus primarily on optimizing indoor airflow, improving fresh-air distribution, reducing heat gain via the roof, and providing targeted cooling in the ironing section where the process generates localized heat. This is the kind of thermal 'performance' that hotter factories in our group can mimic with phased nad layered improvements to their building 'envelopes', and their ventilation and airflow systems before the larger investments in mechanical cooling shown below are made.

Table 12 summarizes YGEN's proposed solutions—in all cases, a combination of interventions. They are based on each factory's heat stress data and the peculiarities of each factory's design and processes. (For reference, Annex 3 includes a detailed engineering report including costs from Factory 5, typical of our group of eight). Both capex and opex are calculated based on the number of 'intervention hours' for the improved cooling systems and attendant energy cost increases required to bring each section back to or below its Caution threshold.

Table 12. Cooling solutions and estimated capital and operating costs (overall and per sq. m.)

Factory	Production area (sq. m.)	Recommended solutions	Capex (USD)	Opex (annual, USD)	Capex per sq. m.	Opex (annual) per sq. m.
1	>50,000	■ Roof coating + finishing roof insulation ■ Ventilation and airflow correction + cutting-floor fresh-air ducting ■ Local extraction + partitioned targeted closed-loop cooling for ironing/finishing	$205,453	$8,331	$4.07	$0.17
2	20,000-30,000	■ Roof coating ■ Ventilation and airflow correction ■ Partitioned targeted closed-loop cooling for ironing/finishing	$147,005	$8,665	$6.33	$0.37

Factory	Production area (sq. m.)	Recommended solutions	Capex (USD)	Opex (annual, USD)	Capex per sq. m.	Opex (annual) per sq. m.
3	20,000-30,000	■ Ventilation and airflow correction ■ Fresh-air ducting + local extraction for cutting ■ Partitioned targeted closed-loop cooling for ironing/finishing	$60,646	$6,077	$2.97	$0.30
4	30,000-40,000	■ Roof coating ■ Ventilation and airflow correction ■ Partitioned targeted closed-loop cooling in ironing/finishing	$264,697	$34,554	$8.23	$1.07
5	<10,000	■ Roof coating ■ Ventilation and airflow correction ■ Targeted closed-loop cooling for finishing/ironing	$78,736	$5,411	$10.59	$0.73
6	<10,000	■ Roof coating + roof insulation ■ Ventilation and airflow correction ■ Targeted closed-loop cooling for ironing/finishing + partial-load chilled-air support for cutting	$78,687	$4,769	$18.97	$1.15
7	20,000-30,000	■ Ventilation, humidity removal and airflow correction ■ Transparent partitioning with fire-safety allowance ■ Targeted closed-loop cooling for ironing/finishing	$183,76	$10,227	$8.50	$0.47
8	20,000-30,000	■ Roof coating + partial roof insulation ■ Extensive active ventilation improvements: high-flow fresh-air inlet systems, ducted distribution, axial/Z-fans and additional induced-draft exhaust fans ■ Strengthen heat-source capture and duct insulation around high-heat process areas[29]	$303,828	$1,041	$10.41	$1.34
Averages			$138,730	$13,266	$9.85	$0.63

Source: YGEN Engineering

29 Partial-load chilled-air support for Factory 8 is retained as an alternative option. Its very high ceilings and open-sided design mean that mechanical cooling may be ineffective or prohibitively expensive. It may be considered for selected worker-zone or machine-zone comfort areas if the base package does not sufficiently reduce WBGT.

As the data above makes clear, intervention costs will vary widely—from USD 3 to 19 on capex and USD 0.17 to 1.34 on opex per square meter—but average square meter costs of USD 9.85 for installation and USD 0.63 for operations and maintenance can be read as encouraging. Each factory's capex and opex costs follow from each's processes, the targeting and scale of the cooling interventions required and the energy required to power them. They are considerably lower than the costs for refrigerant air conditioning systems three to four times higher and can be both elaborated to increase cooling and incorporated into—that is, built on for—refrigerant cooling systems if heat and humidity levels become unmanageable.

This modular, layered design means that cooling investments made now will not be stranded assets if more powerful cooling systems are required in the future. (There is an exception for the heat pump technologies discussed below).

The layered design also allows employers to phase their cooling investments and observe the impacts--on worker health, productivity, costs and more. We break out here the estimates of cooling effect and share of overall costs of the three elements of the solutions.

Passive heat reductions can be expected to reduce heat stress by 0.5 – 1.0 °C WBGT and account for an average 20 percent of overall capex costs in our group of factories. The second phase—airflow and convection improvements—can achieve reductions of 0.5 – 1.5 °C WBGT (and higher in buildings with concentrated heat accumulation) at an average 30 percent of capex. The third—active mechanical cooling—is designed to achieve 2 – 4 °C WBGT reductions and accounts for 50 percent of estimated capex. The cost shares by phase differ by factory type. Process-heavy factories allocate more to mechanical cooling and better-ventilated 'simple' cut-sew factories lean towards the first two phases.

The range of our estimated WBGT effects runs from 3 – 6.5 °C WBGT because the three elements (or phases) are not independent—that is, the cooling effect compounds (modestly) as each phase increases the effectiveness of the preceding one.

Return on investments and payback periods

With factory-by-factory losses to annual revenue and tailored cooling costs, we now calculate expected economic benefits of cooling workers and then the return on each factory's investment (and ongoing operations costs). Finally, we calculate each investment's payback period: How many months or years will it take for higher productivity and earnings to pay off the investment in cooling workers? We run these numbers using 2026 costs and conditions and again assuming higher costs, higher heat stress and lower overall demand in the global apparel trade—headwinds that the apparel industry in Bangladesh and competing countries can expect to run into in the near future.

Employers with effective cooling systems have two choices, broadly speaking. First, use cooling systems proactively to keep WBGT in the Moderate or Caution zones all day. A refrigerant air-conditioning system is designed to work this way. Second, wait and watch as heat stress rises and then intervene when—at 27 or 28 °C WBGT in an ironing section, for example—workers' productivity losses become non-linear. For a conversative estimate of the benefit to cooling, we assume that most factories wait and watch and that the productivity levels to which workers return as they cool down and the workday wears on is slightly lower than the productivity lost as they heated up.[30] We estimate that workers who return to Caution zones from High and Severe zones regain four-fifths (80 percent) of their earlier productivity. This assumption lowers modestly the return on the investment and slows the payback period but accounts for an important phenomenon—work in high heat takes a significant toll and, as we will see below in the discussion of overnight heat stress levels in workers' homes, we should not assume that recovery is complete.

30 The occupational physiology and related literature in sports science supports this assumption but does not provide a per-C WBGT 'recovery rate' to complement the time loss rates, for example, in the WELL study (Ioannou, 2025). An average resting recovery rate for athletes (measured in changes in core body temperature over time) is difficult to adapt for use in apparel production where workers generally continue to work as cooling systems begin to reduce heat stress.

We also do not assume that the conditions we observed and the assumptions required for our analysis--about heat stress levels, productivity losses and gains, material costs and annual revenues--will stay where they are. They move all the time and we have accounted for these changes, within bounds, in alternative scenarios. The most likely of these--our principal scenario--and a more pessimistic one are shown in Tables 13 and 14 where we draw together the parts of our analysis: capital and operating costs of cooling solutions heat stress data and estimated benefits of cooling for each factory. With these data we are able to calculate returns on cooling investments by factory: net benefit (annual productivity gains minus annual opex) divided by the initial investment (capex). We also estimate payback periods: capex divided by net benefit).

Table 13. Estimated return on investment and payback period, initial scenario

Factory	Annual revenue	Solutions capex (USD)	Solutions opex (annual, USD)	Heat loss rate	Heat-induced loss (USD)	Cooling benefit (USD)	ROI (Year 1, %)	Payback period (years)
1	$165,300,000	$205,453	$8,331	3.5%	$1,163,712	$930,970	349.1	0.2
2	$32,500,000	$147,005	$8,665	3.9%	$255,450	$204,360	33.1	0.8
3	$65,900,000	$60,646	$6,077	3.6%	$467,890	$374,312	507.2	0.2
4	$79,400,000	$264,697	$34,554	3.6%	$568,504	$454,803	58.8	0.6
5	$26,100,000	$78,736	$5,411	4.1%	$211,932	$169,546	108.5	0.5
6	$26,000,000	$78,687	$4,769	4.1%	$212,680	$170,144	110.2	0.5
7	$29,000,000	$183,760	$10,227	3.6%	$207,640	$166,112	-15.2	1.2
8	$52,700,000	$303,828	$39,201	6.6%	$696,694	$557,355	70.5	0.6
Averages	$59,612,500	$127,470	$14,654	4.1%	$473,063	$378,450	152.8	0.6

Source: Cornell GLI and YGEN Engineering with data from participating factories

The estimated payback periods in our analysis range from a few months in the case of Factory 1—very high revenue and relatively low heat stress—to 14 months initial in Factory 7 which is among the smallest in our group and has a significant heat stress problem and a relatively high solution capex. The average payback period for all eight factories is approximately seven months and the returns on investment in the first-year average 153 percent.[31]

Table 14 shows outcomes from a pessimistic (or 'headwinds') scenario that assumes annual factory revenue down by 25 percent, capex and opex up 100 percent, our heat-induced loss rates up 25 percent and productivity regain rates (and hence, cooling benefits) down by 50 percent. Each of these changes has a basis in possible near-future scenarios (see footnote 29) but we increase the force of each headwind to make a point: the economic logic of these cooling solutions

31 See Adhvaryu et al, 2020: "Thus, if only electricity expenditure were taken into account, it would take about three and a half years to break even. However, when the productivity benefits are included, the firm breaks even within twelve months of LED installation. After the initial payback period, the firm benefits from an ongoing combined increase in profitability from energy savings and efficiency gains. These results are of course generalizable only to settings where air-conditioning is not available in the workplace. However, since air-conditioning remains quite rare in factories in developing countries, our results indicate that energyefficient lighting can have substantial co-benefits for worker productivity for a large section of the workforce."

holds in hard times.[32] Payback periods in this headwinds scenario range from 9 months (Factory 3) to 6.4 years (Factory 7)and the average is 2.9 years.

Table 14. Estimated return on investment and payback period, pessimistic scenario

Factory	Annual revenue	Solutions capex (USD)	Solutions opex (annual, USD)	Heat loss rate	Heat-induced loss (USD)	Cooling benefit (USD)	ROI (Year 1, %)	Payback period (years)
1	$123,975,000	$410,906	$16,662	4.4%	$1,090,980	$436,392	104.3	1.0
2	$24,375,000	$294,010	$17,330	4.9%	$239,484	$95,794	-46.6	3.7
3	$49,425,000	$121,292	$12,154	4.4%	$438,647	$175,459	169.3	0.7
4	$59,550,000	$529,394	$69,108	4.5%	$532,973	$213,189	-45.6	3.7
5	$19,575,000	$157,472	$10,822	5.1%	$198,686	$79,475	-12.8	2.3
6	$19,500,000	$157,374	$9,538	5.1%	$199,388	$79,755	-10.8	2.2
7	$21,750,000	$367,520	$20,454	4.5%	$194,663	$77,865	-68.8	6.4
8	$39,525,000	$607,656	$78,402	8.3%	$653,151	$261,260	-39.8	3.3
Averages	$44,709,375	$254,941	$29,309	5.1%	$443,496	$177,399	6.2	2.9

Source: Source: Cornell GLI and Liu/Yang from GLI, BRAC and Iowa Environmental Mesonet data. Note on color-coding: Caution > 50 percent is in yellow.

Only in two of our nine scenarios do some factories face payback periods of four years or more. In the 'worst case' scenarios in which labor productivity gains are reduced by 75 percent (from 3.2 percent to 0.8 percent) do the proposed cooling investments look uneconomic for four of our factories (2, 4, 7 and 8). Even in this most pessimistic scenario--with revenue down, capex and opex up, heat levels higher and labor productivity gains at very low levels--the average payback period is 4.4 years.

Taken together, average payback periods in variations of our initial, 'headwind' and 'worst case' scenarios range from 0.6 - 4.4 years. The rule of thumb amongst apparel industry manufacturers, buyers and creditor alike in Bangladesh is that a three- or four-year payback period is tolerable, if not encouraging.

How do these proposed investments compare with those made by factories as part of Accord-mandated remediation between 2013 and 2016? World Bank analysis of these costs, averaged and adjusted to 2025 U.S. dollars, were USD 393,290 per factory. Average heat remediation capex in our eight-factory analysis is USD 127,470, or one-third of Accord building and fire safety remediation costs and two-thirds with the significant headwinds defined above (World Bank, 2016).

32 Bangladesh apparel export revenue down slightly year-to-date in 2026 (Export Promotion Bureau data, July 2026). BBS YTD consumer price data show less than ten percent change (construction material inflation data unavailable). Higher opex costs (driven by higher volumes and cost of diesel fuel) may exceed 100 percent in 2026 but ease in 2027. (CPD, July 2026). The ILO's 'Warmer Planet' study (Kjellstrom et al, 2019) projects a 4.96 percent heat-induced labor loss rate in Bangladeshi manufacturing in 2030--almost exactly 25 percent higher than our 2026 estimate here of 4.1 percent. Finally, a halving of our estimated 3.2 percent labor productivity gain to 1.6 percent is significantly lower than the key workplace study on heat impacts in Indian apparel factories (Adhvaryu et al, 2019): "Point estimates indicate that at [outdoor] wet bulb globe temperatures above 19 C, a 1 C increase in temperature leads to a reduction of more than 2.1 percentage points in actual efficiency...[With] the introduction of LED [lights to reduce indoor heat] having no significant impact on the slope of the efficiency temperature gradient below 19°C, but a significant attenuating impact on the negative slope of the gradient above 19°C. That is, the introduction of LED offsets the negative impacts of temperature on efficiency by about 85%, attenuating the magnitude of the negative slope above 19°C from about –2 to about–0.3. about -0.3. These gains from LED-substitution only produced significant gains in worker productivity and, in any case, above our 'headwind' gain rate of 1.6 percent (and well above our 'worst case' rate of 0.8 percent).

But will it solve the problem?

Our answer depends on several technical considerations. (We will take up the political challenges in Section 6 below). First, do these cooling solutions solve the problem? Do they create new ones? Will they work as outdoor heat stress levels rise?

YGEN addressed numerous technical challenges to design cooling solutions that will meet the WBGT thresholds set above. Looking here at the most common challenges gives us a look inside the mechanics of cooling and the pressures and counter-pressures on apparel producers.

Does it increase fire risk? How will increased airflow from improved ventilation and mechanical cooling affect fire risk and fire safety? In short, no. The spread of fire in factories (and all industrial plants) depends on heat, fuel and oxygen. In apparel factories air (and oxygen) is moved by exhaust fans, ceiling fans, pedestal fans, open doors, windows and structural gaps. Even without mechanical cooling of the kind in the water-evaporative cooling and closed-loop cooling systems, these systems contribute to natural air exchange. Airflow from mechanical systems do not inherently increase fire risk when proper operational and emergency protocols—of the kind required of Accord/RSC-compliant factories—are in place. And the addition of electrically-powered fans, pumps, blowers, VFDs or cooling units can increase electrical fire risk only if they are installed on undersized, overloaded, or poorly protected circuits.[33]

33 Good factories always have extra load and electrical capacity installed, but that is not the basis of the solutions proposed here. YGEN: "Each intervention requires a load schedule, verification of available panel capacity, correct cable sizing, MCB/MCCB and overload protection, earthing, short-circuit and earth-fault protection, panel ventilation, proper termination, and integration with the factory's fire alarm and emergency shutdown protocol. Where existing distribution boards or feeders are insufficient, panel upgrades or dedicated circuits are required before installation. In this sense, the recommended cooling systems do not rely on informal plug loads or ad hoc extensions; they must be installed as engineered electrical loads. VFDs can also reduce motor in-rush current compared with direct-on-line starting, while efficient motors and controlled operation can reduce unnecessary electrical loading."

In a fire emergency, all systems should be designed to shut down immediately—'main power isolation'. This stops all electrically operated systems and eliminates the supply of forced air. It is standard fire safety protocol in apparel factories. Fans of all types stop. Evaporative cooling units, pumps, blowers, and chillers all stop and, as a result, no forced airflow supply oxygen to the fire.

What about heat and fuel? Convection cooling includes no heat-generating components, no combustible refrigerants and it is widely used in fire-safety compliant factories. The water-evaporative system requires no compressors or high-temperature components and, because it operates using water evaporation, the slight increase in air moisture actually reduces fire risk and spread. The closed-loop cooling system operates using industry-standard mechanical systems for large factories that can be integrated with fire alarm and emergency shutdown systems, part of building automation systems that use Programmable Logic Controllers (PLC) to run other factory systems such as lighting and water.

Does it increase humidity? We know that factories are operating at high humidity levels of 60 – 80 percent between April and October. Will cooling solutions change humidity levels and affect apparel product quality? Managers made clear that sewing operations perform well at 55 – 70 percent humidity and that ironing, washing and finishing sections can operate at higher humidity without a loss of quality but generally require a mixture of cooling methods—like those in Table 12 above—to reach safe heat stress levels.

Convection primarily reduces temperatures by removing hot and humid air from production areas using exhaust fans, for example. It does not increase or otherwise control humidity levels but improves air turnover and reduces moisture stagnation for a net reduction in humidity. In very high humidity conditions outside the factory—Dhaka's humidity routinely topped 80 percent in May and June 2025—this solution is likely insufficient to bring heat stress levels inside factories below 28 °C WBGT, let alone 26 °C WBGT.

Water-evaporative cooling systems can deliver strong reductions in air temperature. They are relatively energy-efficient and inexpensive. But they can increase humidity so this solution includes additional exhaust fans to reduce it and heat stress levels. Its high airflow prevents moisture accumulation on fabrics and machinery and we find it in wide use in apparel production across South and Southeast Asia.

Closed-loop cooling's controlled airflow and system modulation does not introduce moisture into production areas. Its cooling power is achieved through heat exchange, allowing manufacturers to manage both temperature and humidity and, therefore, heat stress. Its humidity effect is neutral so in very hot and high humidity conditions, it has the necessary power to reduce air temperature by up to 10 °C and therefore pull most WBGT down to safe levels.

Does it increase energy use and greenhouse gas emissions? Cooling interventions will add some electricity demand. But these increases—shown for each factory in Table 12—should be assessed alongside the energy-efficiency potential in apparel factories. For a measure of possible savings in cost and greenhouse gas emissions in one of our hotter factories, YGEN Engineering conducted a detailed assessment of energy systems and usage in Factory 5. Their assessment found annual (2025) electricity consumption of 989,258.71 kWh and annual electricity cost of BDT 11.29 million, (~91,700 USD). Its major energy-consuming systems are sewing machine motors, ventilation fans, air compressors and water pumps:

> The assessment identified technically practical efficiency measures like servo motor conversion, VFD installation on fixed-speed compressors and pumps, BLDC fan modernization and compressed-air leakage reduction that could reduce annual electricity use by an estimated 375,528 kWh, or roughly 20 – 25 percent of the factory's baseline consumption. The largest single opportunity was replacing 381 clutch motors with servo motors, while VFD application to Compressor-1 and water pumps offered relatively quick payback opportunities of about 12 – 13 months.[34]

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The package of changes is estimated to cost approximately USD 67,000 (BDT 8.18 million) in capex for the five principal measures, save about BDT 4.49 million (~36,400 USD) per year and reduce emissions by approximately 251.6 tons of CO_2 per year. (The full YGEN report is published as an annex to this paper). These energy efficiency measures have been standard practice (or standard recommended practice) among producers for major brands for years, but is not universal.

This means that actions to reduce heat-stress—a form of climate adaptation—and improve energy efficiency and reduce carbon emissions—climate mitigation—should not be treated as competing priorities. Our proposed cooling investments can be paired with targeted energy-efficiency upgrades, or done in sequence. Gains from improved energy efficiency and use of renewable energy can pay for themselves and partially or fully offset the additional electricity and carbon emission impacts of the required cooling measures.

Finally, the increases in energy usage and costs connected with the proposed solutions should also be assessed against factories' totals. A senior apparel climate-energy expert estimates that less than 10 percent of an apparel factory's operating costs is energy--but considerably higher in textile mills--of which an estimated 30 percent (of electricity usage) is for air conditioning of management offices.

Will installation disrupt production? The installation of engineering solutions—from insulating roofs to mechanical cooling systems—can be organized to minimize disruptions to production: installation is conducted in phases, floor by floor or zone by zone, and most work is completed outside production hours and weekly holidays. Electrical and mechanical 'tie-ins' can be conducted in short, scheduled shutdown windows and full production stoppage by floor or zone, or factory-wide, are not required.

For each solution, we are able to estimate the number of days per operation per floor or zone. (By way of example, the footnote below spells out for a typical factory from our study group the estimated days per floor for each aspect of installation).[35] Convection cooling and water-evaporative cooling systems require, on average, four-to-five days per floor or zone for installation with no or minimal disruption to processes and production. Off-hour installation work means that, in all eight factories, convection cooling and water-evaporative colling systems can be completed for a typical 5,000 square meter factory in approximately six weeks. A closed-loop cooling system is more involved and involves minor disruptions—some of them to be completed during off-shift hours and weekly holidays—in the course of a zone-by-zone installation over 10 – 12 weeks.

Will it be effective and for how long?

Will the engineering solutions proposed here—both active and passive—solve a problem that we expect to grow? Outdoor heat stress levels in Dhaka, while high in 2025, are predicted to be higher in 2027 and future years.

Will these proposed solutions be able to cope with very high temperatures and humidity levels in ironing sections, for example, that combine for readings of 32, 33 or even 34 °C WBGT? In other words, would we encourage manufacturers to 'throw good money after bad?' if more powerful and more expensive systems—including refrigerant air conditioning—will soon be required? And, if non-engineering measures such as reductions in working hours, overnight or early-hours work, longer rest periods, rotations of working roles and so on, will be required to keep workers safe?

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35 YGEN estimates of installation times: convection cooling installation time estimates: wall inlet cutting and installation, 1 – 2 days per floor; exhaust and fresh-air fan installation, 1 day per floor; spot cooling installation, 1 day per floor; electrical connection and testing, a few hours per floor for a total of 4 – 6 working days per floor and one-to-two months overall. "Production never need stop across any floors though temporary relocation of a small number of sewing lines may be required near wall openings." Water-evaporative: unit placement and mounting, 1 day per module; duct installation, 1 – 2 days per floor; water and electrical connection, 1 day per floor; testing and commissioning, 1 day per floor for a total of 4 – 5 working days per floor and one-to-two months overall. Installation can be carried out while production continues as cooling modules are placed outside of production zones. Short-term relocation may be required directly below the duct installation areas and completed during off-shift hours. Closed-loop: cooling tower construction, 10–14 days; chiller and pump installation, 3 – 5 days; ductwork installation, 2 – 3 weeks; electrical and automation works, 5–7 days; testing and commissioning, 3 – 5 days. This installation requires higher skills and 2.5 – 3 months in total.

The interventions proposed here are not alternatives to future refrigeration-based cooling systems. Tareq Ahmed Robin, Managing Director at YGEN, argues that future climate conditions may require refrigerant-based cooling and effective operational changes to make work safe. Sustained outdoor temperatures above 40°C and persistently high humidity mean that ventilation and passive cooling may no longer be sufficient to hold WBGT down to the safe zones in all production areas. These steps "can be treated as first stages of a progressive heat-management strategy: passive heat reduction, airflow correction, improved fresh-air distribution, local heat extraction and targeted cooling to reduce the building's overall cooling load regardless of the future cooling technology adopted."[36]

The measures proposed here will continue to "improve system efficiency by reducing heat gain, minimizing localized hot spots and lower the total refrigeration capacity required which reduce both capital and long-term operating costs by lowering the underlying cooling demand. These investments will remain valuable, not become stranded assets."

What's LEED got to do with it?

Manufacturers and their industry groups in Bangladesh tout LEED certified factories as the answer to the industry's heat stress problem (and more). Are they right? We invited Billie Faircloth, Associate Professor in Cornell's College of Architecture, Art and Planning and a practicing architect with long experience in design and LEED certification to analyze the connection between LEED and cooling in the context of apparel production in Bangladesh.

Workers in some apparel factories in Bangladesh are encountering buildings designed to meet the U.S. Green Building Council's Leadership in Energy and Environmental Design (USGBC LEED) green building rating system. Factory owners have been pursuing LEED certification since 2012—including Factories 3 and 4 in our study group—and news outlets continue to track and report this trend.[37,38] What does LEED certification and LEED Platinum mean for Bangladesh's factory workers who are vulnerable to indoor heat stress?

There are approximately 3,320 apparel factories indexed in the Mapped in Bangladesh database, and 160 of these (~4.8 percent) have achieved USGBC LEED certification.[39] By cross-referencing this list with the USGBC LEED Project Directory, we identified 75 (~2.3 percent) that have been awarded LEED Platinum—the highest certification level.[40] These percentages support our presumption that green building rating systems offer some producers in Bangladesh's apparel industry sustainable design guidance, performance baselines and benchmarks, but they do not drive industry-wide factory design.

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36 Note: an interim measure that builds on the solutions proposed here is "expansion of the targeted closed-loop cooling beyond ironing/finishing areas. These can be scaled from a localized system to a floor-level or factory-level hybrid chilled-air system—designed as an engineered air-conditioning or chilled-air distribution system. In such a scenario, chilled air could be supplied through overhead air-distribution systems such as ducted diffusers, perforated ducts, fabric ducts or high-induction jet nozzles, while the existing convection measures would support air movement, de-stratification and distribution. Fresh-air control, exhaust balancing and local extraction would still remain necessary, because chilled air alone will not remove steam, humidity or process heat efficiently unless the airflow path is properly managed."

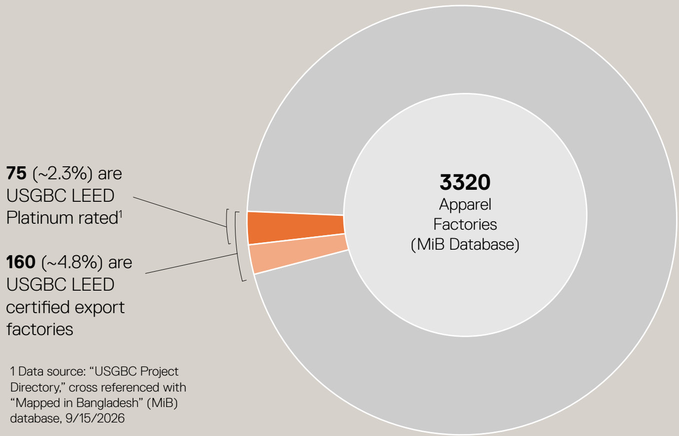
37 The year 2012 is logged by the "USGBC LEED Project Directory" as the first year for a LEED Platinum rated factory. https://www.usgbc.org/projects

38 Four more RMG factories earn LEED Certification. (2026, Jul 14). BSS News (Dhaka, Bangladesh). Available https://www.bssnews.net/business/405451

39 Mapped in Bangladesh (MiB), Centre for Entrepreneurship Development (CED), BRAC University, https://mappedinbangladesh.org/ (data accessed September 15, 2026). This database includes apparel factories that export garments only and does not represent all LEED Platinum Certified facilities related to the garment industry.

40 LEED Project Directory, United States Green Building Council, www.usgbc.org/projects (data accessed September 15, 2026). Filters applied: "Country or Region: Bangladesh," "Certification Level: Platinum."

Number of USGBC LEED certified apparel factories, Bangladesh, 2026



Green Building Certification

Green building rating systems, such as USGBC's LEED, align an owner's environmental and social sustainability goals with a building's design and planning. LEED awards one of four certification levels: Certified, Bronze, Gold, or Platinum using a points-based system. Building owners earn points after a project's completion by documenting the sustainable measures used. LEED measures apply to new and existing factory buildings, and to all systems of a building including its site, walls and roofs, cooling and ventilation, and indoor workspaces for apparel workers.[41]

The LEED Thermal Comfort Credit

A LEED design measure relevant to the readers of this report is the Thermal Comfort Credit. Although the credit does not provide guidance on managing extreme indoor heat events, it does address designing for people's contentment indoors and whether indoor temperatures make it difficult for people to work.[42] Project teams who use LEED to plan and design Bangladesh's factories will consider if a project can meet the following criteria:[43]

- Comply with "ASHRAE Standard 55: Thermal Environmental Conditions for Human Occupancy" or with equivalent standards "ISO 7730" or "EN 15251/EN 16798." This design standard aims to make at least 80% of people in a building comfortable.[44] It takes into consideration what people are doing, what they are wearing, and the temperature, relative humidity, heat-radiating surfaces, and air speeds surrounding them.[45] These standards inform performance targets for a factory's cooling and ventilation system, its walls, floors, and roof assembly.
- Provide building users with the means to control how they feel in a space. In coordination with facility managers, a building can be designed and planned to let users decide when and how to make themselves comfortable. Building systems are planned to permit at least 50% of building users to adjust the thermostat temperature, turn on a fan, close a blind, or open a window. This requirement prioritizes the apparel workers' agency to manage their own comfort.

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41 USGBC, "LEED rating System-How LEED works," accessed August 10, 2026, www.usgbc.org/leed

42 USGBC, "Thermal Comfort," *LEED BD+C New Construction, v4,* accessed August 11, 2026.

43 The Thermal Comfort Credit in LEED 2009 treats each of these requirements as separate credits, while LEED v4 and v4.1 requires meeting and complying with comfort and control standards. Bangladesh's LEED-rated factories use all three rating systems. LEED 2009 launched in 2009, LEED v.4 launched in 2013, and LEED v4.1 launched in 2018.

44 ASHRAE. "ANSI/ASHRAE Standard 55-2023, Thermal Environmental Conditions for Human Occupancy." (2023). "Or equivalent," emphasis which standard applies best accounting for regional specificity, codes and engineering practice.

45 ASHRAE. "ANSI/ASHRAE Standard 55, Thermal Environmental Conditions for Human Occupancy." accessed 09/09/2026,https://www.ashrae.org/technical-resources/bookstore/standard-55-thermal-environmental-conditions-for-human-occupancy. As of this summary, Standard 55-23 is the most current, with 55-2004, 55-2013, and 55- 2018 used by LEED 2009, LEED v.4, and LEED v4.1 respectively.

- Conduct a survey of building users. Once a project is implemented, owners are required to survey users to determine whether the comfort goal is being met and, if not, to propose improvements. The LEED rating system, as a design standard, has historically been limited in scope and jurisdiction, requiring a single point-in-time survey over a predefined period.

We reviewed 43 scorecards for Bangladesh's Platinum rated apparel factories, including exporting and secondary production facilities, certified between 2012 and 2026 using the LEED BD+C: New Construction rating system to understand if and how they incorporated the Thermal Comfort Credit.[46,47] Aggregating scorecards across all LEED versions reveals that 17 of 43 factories met one or more requirements of the Thermal Comfort Credit. Of these, six met all three requirements.[48] Thermal comfort design appears underutilized as a sustainable design measure, irrespective of the urgency of the heat stress crisis facing Bangladesh's apparel workers. Nevertheless, LEED's thermal comfort measure could provide an important foundation for apparel factory design guidance.

Design for Extreme Heat

In contrast to building design and planning, building owners and facility managers, not green building rating systems, manage a factory's day-to-day performance. In Bangladesh, climate vulnerability mixes with a range of building system factors contributing to the on-the-ground reality that heat stress abatement is not a guaranteed outcome for people working inside LEED-certified buildings.[49,50] In Bangladesh's apparel factories, including LEED-rated ones, workers are at risk of succumbing to unsafe temperatures if any of the following are true:

- people are not acclimatized;
- people are unable to reduce effort, rest, or stop work;
- people are near sources of heat or operate equipment radiating heat (and steam) for extended periods of time;
- a building's cooling and/or ventilation system is turned off;
- a building's cooling system is undersized, undermaintained, and unable to meet daily or even peak cooling demand—a factor exacerbated by the increasing frequency of extreme heat events in Bangladesh;
- a building's power supply for cooling has no backup power source, is disrupted for several days, and no designated indoor space maintains inhabitable temperatures, especially during extreme heat events.

We should not conflate LEED certification–at any level–with a factory owner's capacity or commitment to keep heat stress at safe levels and protect workers. Instead, we should address heat abatement challenges directly. Factory owners can protect workers through heat-illness prevention planning, programming, and education; upgrading underperforming building systems; and integrating WBGT monitoring to help manage indoor heat stress. They can also change factory design and factory management standards to keep apparel workers both comfortable and safe.

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46 LEED Project Directory, United States Green Building Council (USGBC), www.usgbc.org/projects (data accessed September 15, 2026). Filters applied: "Country or Region: Bangladesh," "Rating System: LEED BD+C: New Construction," "Certification Level: Platinum."

47 In the LEED BD+C: New Construction rating system "BD+C" stands for "Building Design + Construction," and refers to newly constructed factories. In the O+M: Existing Buildings, "O+M" stands for Operations + Maintenance, and refers to upgrades of existing factories. The level of documentation on O+M LEED scorecards was unavailable to perform the same analysis.

48 Bangladesh's factories are certified using three different LEED versions. See Footnote 43.

49 Emanuele Leonardi and Deborah Lucchetti. (2025) Green Industry, Grey Realities, Between LEED's factories and Just Transition: pathways for the RMG sector in Bangladesh. FAIR. Page 8.

50 In "Six Seasons, Four Summers," two of the eight factories studied (Numbers 3 and 4) are LEED-certified buildings experiencing heat stress values measured in average WBGT figures. See table 9, Page 15.

Section 5. High heat stress in workers' homes

Reducing heat stress at work is a partial solution to the apparel industry's problem. Despite its impact on worker health, productivity and factory earnings, high heat at home is largely left out of the equation when manufacturers, researchers and industry observers quantify the costs of heat stress and design solutions for it.

How much damage is done to productivity and workers' health away from work? What are the roles of housing and medical costs, social protection and wages in coping with heat stress? From temperature and humidity data captured by sensors in 37 workers' homes, we are able to assess the role that heat stress plays in much of the rest of workers' lives.[51]

As with our eight factories, we can use the unique data set built with their workers at home to estimate the time spent in heat stress zones. We also present both workers' and our engineering team's responses to heat at home. Finally, we analyze the possible costs by type of home and take up the critical question: who will pay and how?

How hot (and humid) is it?

We again use indoor WBGT data to measure night-time heat stress exposure from 8 p.m. – 7 a.m. (and, as with our factory data, imputed a full year-long WBGT series using the hybrid random forest approach). Work at home—including sleep—is treated as 'light' work and the heat stress zones match those used to evaluate sewing work.

Most of the night is spent in the Moderate and Caution zones and a year-long average of 4.8 percent is spent in the High heat stress zone. But from lows around 20 C WBGT in January and February, Caution zone exposure rises ticks up in April and May and between June and September, workers spent 6 – 7 hours per night in the Caution zone and 1 – 2 hours in the High zone. September is the peak month, with the average night-time WBGT reaching 29.0 °C—higher than many workers experience in the factories.

Table 15. Time in monthly night-time heat stress zones, Dhaka, 2025

Month	WBGT avg. (°C)	Moderate hrs./day	Caution hrs./day	High hrs./ day	Moderate share	Caution share	High share
Jan	19.1	0.2	0.1	0.0	2.0%	0.7%	0.0%
Feb	21.5	0.3	0.1	0.0	2.6%	1.2%	0.0%
Mar	24.9	3.7	1.1	0.0	33.3%	9.7%	0.0%
Apr	26.5	9.8	0.5	0.0	89.0%	4.6%	0.0%
May	27.5	7.4	3.3	0.3	66.9%	29.6%	2.3%
Jun	28.7	3.5	6.1	1.4	31.4%	55.4%	13.0%
Jul	28.6	3.1	6.4	1.3	28.4%	58.4%	12.2%
Aug	28.7	2.4	7.3	1.2	21.7%	66.7%	11.2%
Sep	29.0	1.9	7.3	1.9	17.0%	66.1%	16.8%
Oct	27.8	6.1	4.7	0.1	55.4%	42.6%	1.3%
Nov	23.6	2.8	0.5	0.0	25.1%	4.8%	0.2%
Dec	19.6	0.1	0.1	0.0	1.2%	1.2%	0.2%
Annual av.	25.5	3.4	3.2	0.5	31.3%	28.6%	4.8%

Source: Source: Cornell GLI and Liu/Yang from GLI, BRAC and Iowa Environmental Mesonet data. Note on color-coding: Caution > 50 percent is in yellow.

51 As noted earlier, workers from our subject factories were identified by BCWS and BRAC University CED independently—that is, without involvement of factory management. A single sensor per home was placed by our teams and surveys conducted with the consent of workers.

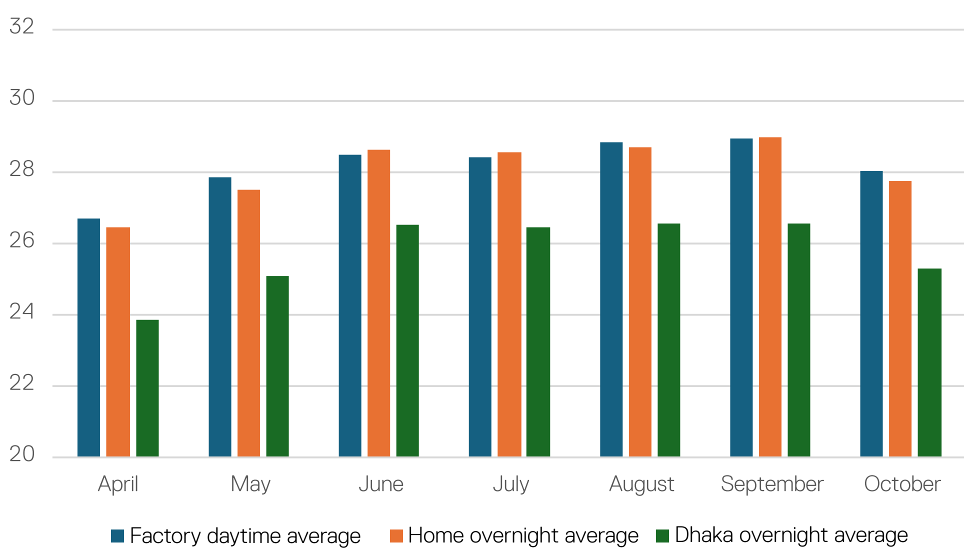
Limiting our data to the April and October 2025 heat stress season, we find average WBGT of 28.1 °C, with more than five hours per night in the Caution zone (46 percent) and nearly one hour in the High zone (8 percent). These values are substantially higher than the annual averages, meaning that workers spend long hours in Moderate-to-High zones on almost every night during the heat stress season. In September, workers spent nearly all night (83 percent) in Caution and High heat stress zones.

How does home heat stress compare?

The annual average overnight WBGT in homes (25.5 °C) is slightly lower than the daytime averages in factory sections (26.1 – 26.7 °C). During the heat stress season, overnight average WBGT in homes (28.1 °C) is in fact close to daytime heat stress season levels in sewing at 28.4 °C and cutting at 28.3 °C, meaning that workers experience sustained heat-stress environments both at work and at home with little time to recover.

But are high heat stress levels overnight a serious problem? Overnight hours are physically less demanding than factory tasks but there is work at home and the tasks—cleaning, cooking and caring for family members—are unevenly distributed and come at the end of long workdays. For women, who perform most of them, they compound the exhaustion that they reported feeling during the heat stress season. In our sample, workers and their families spent 44 percent of the overnight hours in the April-to-October period in the Caution zone between 28 and 30 °C WBGT and seven (7) percent of their hours above 30 °C WBGT.[52]

Figure 6. Worker homes monthly average overnight heat stress vs outdoor and factory average daytime heat stress (WBGT), April – October 2025, Dhaka



Source: Cornell GLI and Liu/Yang from GLI, BRAC and Iowa Environmental Mesonet data.

In our 37-home sample, nearly one-quarter of workers and their families (9 homes) saw midnight readings top 32 °C WBGT—very high heat stress levels with a profound impact on sleep, recovery and long-term health. Sleep itself is,

52 Grouping workers by the factory in which they work, we found little difference in heat stress levels in their homes—all groups fell within 0.3 C WGBT of the overall average home heat stress levels between March and October. Workers in one of the least-hot factories (Factory 3) were in the homes with the highest overnight heat stress levels.

metabolically-speaking, very light work. But how do high heat and humidity affect it? The scientific literature on this question is deep and uniform in its core findings: high heat stress levels reduce the quantity and quality—the recovery value—of sleep. The effects are cumulative and lead to chronic fatigue, especially in tropical and sub-tropical countries where overnight temperatures are generally higher.[53]

Getting close to the heat, again

How do workers react to the high heat at home? In our survey of 49 workers, most respondents feel that their homes have become hotter in recent years. A large majority (74 percent) say their homes become very hot and cannot be properly cooled. Workers describe their homes—rented rooms—as part of the problem: low-ceilinged and poorly ventilated with too-few fans and unreliable electricity.

Workers feel that their rooms are sometimes hotter than their factories but many report that their landlords do not allow an additional fan because of electricity costs. In interviews for this report, they reported constant worries about poor fans, old housing and weak ventilation that combine to keep them (and their families) from recovering at night. Thirty-three (33) percent reported that they have trouble sleeping, and 39 percent report that high heat causes them to feel unwell and to seek medical care for their health issues.

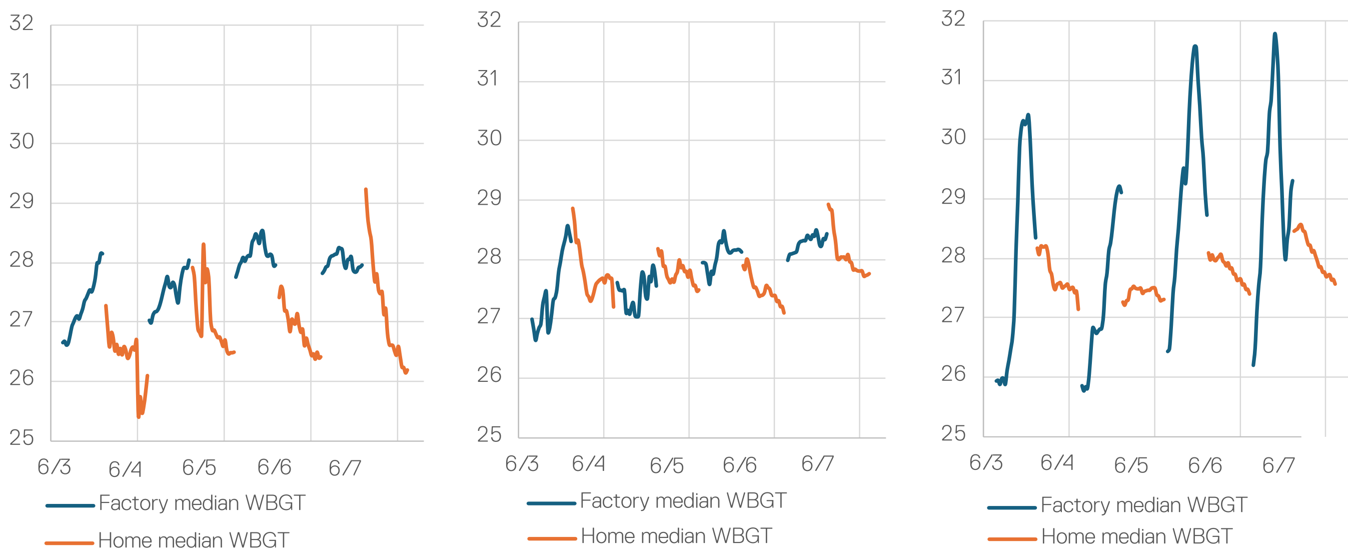
Living conditions determine whether the body arrives at work restored or in near-constant deficit. In this way, the struggle against high heat at home has become part of the labor process.

A second finding—drawn both from workers' testimony and our sensor data—is that apparel workers are not choosing between a cool factory and a hot home or even a cool home and a hot factory. Most workers we surveyed are moving from one high heat stress environment to another with little chance for recovery in the heat stress season.

Figure 7 traces the day-and-night heat stress levels over a typical summer week in early June 2025 for workers in three of our factories—one of our group's lower heat factories (Factory 3), our median (Factory 7) and one of our hottest (Factory 6). We see their heat stress exposure at work (in blue) and at home (orange). In all three, these workers spent 100 percent of these few days and nights above 25 °C WBGT, and 31 percent of the total hours above 28 °C WBGT, including 17 percent of their overnight hours. For some of these workers, heat stress levels at home in the late evening are higher than at work and their homes cool very little overnight.

53 Minor, K. et. al., 2022, and Raja, M. et. al., 2026.

Figure 7. Workday and overnight heat stress levels (average) in factories and homes in low, median and high heat factories, early June 2025.



Source: GLI analysis of BRAC and BCWS data.

This near-constant exposure helps explain why dizziness, headaches, weakness and exhaustion appear across their stories. Heat stress does not end with symptoms but continues in the form of household spending. Most respondents told us they are spending more on medicine for health problems in the summer months and spending more year-on-year on their heat- and flood-related medical costs.[54] Workers reported that the thin income margins they are managing—after rent, utilities, food costs, schooling, transportation—mean that they pay for heat-related medical costs by borrowing, selling land, reducing food intake, cutting household spending or trying to work more.

Engineering solutions for heat stress at home

In their analysis of workers' homes in Ashulia and Savar—both industrial suburbs of Dhaka—YGEN described the standard: a single 10 – 12 square meter room with several adults and, often, children living under a metal roof. Typical rooms have low ceilings, a single window blocked by shelving or a wardrobe, a low-efficiency ceiling or standing fan, no exhaust fans with little or no cross-ventilation and, importantly, cooking inside the room that increases both air temperature and humidity.

For this 'tin shed' house, workers we surveyed pay an average of BDT 2,850 monthly and, in some cases, more for electricity. Workers in 'semi-*pucca'* (i.e. semi-permanent) and '*pucca'* houses pay BDT 4,250 and 7,000 per month respectively. Overnight heat stress levels in all three types are similar, driven by five factors: indoor cooking, uninsulated and heat-retaining roofs, poor cross-ventilation, electricity outages (load-shedding) and lack of living space. How can heat stress levels in workers' home be reduced, made safe? How much will it cost? Table 15 details YGEN's analysis, including three suites of changes based on need and cost.

54 Unknown are the long-term health outcomes for these workers. Detailed studies of workers in agriculture (see, for example Schlader et al, 2025, and La Isla Network analyses) pinpoint prevalence of workplace heat-induced chronic kidney disease and acute kidney injury, and test interventions to reduce them.

Table 16. Cooling solutions for workers' homes with costs (BDT and USD), Dhaka

Item	Basic passive cooling	Minimum heat-reduction	Safe heat-reduction
Goal	Low-cost heat reduction and improved ventilation	Practical minimum for metal-roof homes	Higher performance for highly exposed homes
Main components	a. Reflective roof coating (incl. white lime wash) b. Unblock and reuse existing window c. Install two opposing wall vents or louvered openings; d. Draught-proofing of unnecessary gaps	a. Reflective roof coating b. Low-cost roof insulation below metal sheet (e.g. foil/jute board) c. Exhaust fan (10 in.) at high level + two opposing vents d. Window clearance + storage re-arrangement; e. Low-cost kitchen hood	a. Reflective roof coating b. Durable roof insulation system c. Reflective wall painting on sun-facing wall d. Two opposing wall vents with mosquito mesh/louver e. Energy-efficient (BLDC) fan + exhaust fan[55] f. Kitchen hood
Peak °C reduction[56]	1 – 2 °C WBGT	2 – 4 °C WBGT	4 – 6 °C WBGT
Cost (BDT)	Materials: 7,000 Installation: 5,000 Total: 12,000 (USD 100)	Materials: 17,500 Installation: 8,000 Total: 25,500 (USD 210)	Materials: 46,100 Installation: 15,000 Total: 61,100 (USD 500)
Added elec. load cost (BDT)	Load: 0.0 kWh/month Cost: 0 BDT	Load: 25.5 kWh/month Cost: 184 BDT	Load: 40.5 kWh/month Cost: 292 BDT

Source: YGEN

The lowest-cost remedy—basic passive cooling—is equivalent to the monthly minimum wage in Bangladesh' apparel industry. But its cooling power is insufficient. To bring the overnight 28.1 °C WBGT—the average in worker's homes between April – October 2025—down to 25 °C WBGT requires more effective and expensive remedies. Energy-efficient fans and low-cost kitchen 'hoods' are BDT 7 - 8,000 each. The minimum and standard interventions are double and five times the monthly BDT 12,500 minimum wage and bring increases in monthly electricity costs. These are investments workers we surveyed, including those in households with multiple earners, cannot afford.

Who should pay for this, and how?

Landlords whose rooms will be improved by these changes top the list. Inevitably, workers will be expected to contribute. But housing costs already take up a large portion of the apparel worker's monthly earnings: 23 percent of the minimum wage for a tin-shed home, 34 percent for a semi-pucca home and 56 percent for a pucca home. If the 'minimum' or 'safe heat reduction' solutions above are implemented in these homes, the expected installation and operating costs push those percentages higher.

55 A brushless direct current (BLDC) fan cost in Dhaka costs approximately BDT 7,000 in 2026.

56 Estimating WBGT impacts requires an accounting for changes in relative humidity (RH). Basic passive cooling likely has only a small effect on humidity (a 2 – 3 percent reduction under typical occupied conditions), since it mainly improves passive airflow and roof heat reflection. Minimum heat reduction should have a noticeable impact because of the exhaust fan, kitchen hood, and improved airflow, of 5 – 10 percent RH reduction, especially during cooking periods and evening heat buildup. Safe heat reduction could achieve around 8 – 15 percent RH reduction because it combines insulation, stronger ventilation, reflective treatment and better air movement. However, the actual effect will depend heavily on outdoor humidity, cooking practices, and whether vents remain open.

What about moving to and living in a better and cooler home instead of implementing these fixes? A hypothetical, 'ideal' apartment—on an upper-floor of a multi-story pucca apartment building with a separate kitchen and a washroom—costs BDT 8,750 on average. It would take up an astonishing 70 percent of an apparel worker's monthly minimum wage.

One approach under development at the World Bank in Bangladesh is a funding mechanism for workers and employers to share the costs of one of the proposed improvements for workers' homes. A high-efficiency brushless direct current (BLDC) fan for homes that workers would own: BDT 7,000 in Dhaka in 2026. Although they may have bank accounts, workers' income is too low for banks to be willing to offer credit. Employers can instead purchase fans and deduct, for example, BDT 125 (USD 1) monthly from workers' earnings for five years at zero interest, or BDT 200 (USD 1.6) monthly over three years. Employers can also share in the cost or forgive the cost altogether. (Some apparel manufacturers in Bangladesh already provide this in cases, for example, of sudden illness and hospitalization).

How would this pencil out in one of our factories? In Factory 3 with approximately 5,000 workers and estimated 2025 revenues of USD 50 million, a concessional home fan program would cost less than 0.6 percent of annual gross income. The full cost (capex) of the safe-home heat reduction in Table 15 above for 4,000 homes—assuming some overlap among worker households—would total 4.0 percent of annual revenues at Factory 3.

Climate finance programs including Bangladesh Bank's Green Transformation Fund make capital available for factory-level investments at reduced rates—concessional lending. These programs are meant to speed and scale investments in energy efficiency and carbon mitigation more generally. They are integral to the billions-to-trillions strategy that seeks to use billions of dollars in public money to leverage larger climate mitigation investments by the private sector.

But the 'green' funds are difficult for many factories to access or make work—as indicated in interviews for this paper—and factory- and worker-focused adaptation investments are much smaller. The factory cooling systems proposed in this paper can be installed and run for a few hundred thousand dollars. BLDC fans for workers are USD 60. And the business case and public purpose for bank lending to factory owners at concessional rates and for brand support for investments that reduce factory and home heat stress levels is sound.

So our challenge here is not turning billions of dollars into trillions, but into millions for use by employers. And turning millions into thousands and hundreds for workers and their families for whom the most modest investments have profound effects. We examine this in the following section.

Combating the costs of climate breakdown using adaptation's top technology

The same workers surveyed regarding heat also report flooded neighborhoods, waterlogged housing areas and transportation disrupting during rainy periods. Many (37 percent) report that flooding has forced them to leave home temporarily, with 57 percent saying that flooding stopped them going to work and 63 percent say it has made them arrive late at least a few days over the year.

Workers report arriving at work during flooding wearing wet clothes and with no place to dry off or recover before starting work. Workers also report spending extra money on transport and coming under pressure to work longer to make up for hours lost to flooding and rain. The burden of climate exposure is cumulative. Bangladesh's high heat and humidity weaken the body and flooding disrupts mobility, attendance, and income. Workers report using their incomes, their savings, their sleep and their bodies to absorb climate impacts, at home and at work. The risks and costs of climate breakdown are privatized, individualized.

The heat stress season also brings higher medical and electricity costs. Our *Higher Ground*? reports in 2023 included estimates of those higher costs from worker interviews, with interviewees estimated spending BDT 3,500 for additional medicine and BDT 2,000 for additional electricity costs during the hottest months. 76 percent of workers surveyed for this report reported having to buy medicine to treat health problems from high heat, with the average expenditure being BDT 2,004, and 73 percent of workers who pay for their own electricity say they pay more for electricity during the hottest months.

Most garment workers make more than the minimum wage thanks to overtime and many live in a home with multiple income earners. As noted in our 2025 policy brief, Waiting Game: Minimum wage-setting in Bangladesh's apparel industry, Bangladesh's minimum wage-setting system adjusts apparel wages every two years (down since 2025 from five years) means wages are kept low and inflation-adjusted income can often fall, a phenomenon accelerated by the energy and other price impacts of the 2026 war in Iran. Adjusting this system to provide a higher minimum wage that more accurately reflects the cost of living in Bangladesh—BDT 30,459 per month is the living wage calculation by the Global Living Wage Coalition—would allow for workers and their families to live in homes that keep them safe.

As we wrote in *Higher Ground*? the most effective and flexible technology for climate adaptation is arguably the simplest and oldest:

> The final element of worker protection in the era of climate change is worker income. From the testimony of apparel workers and long research based on Amartya Sen's studies of 'entitlement' in famine, we know that the policy templates of public and private regulation are relatively inflexible (Sen, 1983). The needs of workers that these systems often do not touch—cooler homes and sleep at night, efficient fans and reliable electricity, safe transportation through flooded streets, sufficient drinking water and proper meals—are met by income.

> For apparel workers, this means living wages and social protection systems. Without them, workers who risk their health, pushing through extreme heat and flooding to keep their jobs and hold onto their incomes, are in effect subsidizing the earnings of their employers, fashion brands and even distant customers… The ultimate lesson of the [COVID-19] pandemic for economies of the Global South with weak social protection systems and fashion brands is that the most adaptive, point-of-impact response to a complex crisis is 'entitlement' for the poor, including apparel workers (Sen, 1981). Entitlement in this context means stable, living wages and basic social protections that allow workers to 'command' access to cooler homes, adequate drinking water, medical care and transport to safer areas.

Going beyond survival—Sen was concerned chiefly with famine responses by governments—on the reach and success of efforts by the government of Bangladesh to build and effectively administer large-scale programs to build affordable, safe housing in Dhaka's working class neighborhoods and large-scale investments to improve infrastructure—from gray (or 'hard') such as storm-drainage to green (or 'soft') including tree-shade—around workers' homes. Will government or employer-led programs to install efficient overhead fans in workers' homes reach three million apparel workers? Two million? Half a million?

In this context, living wages, transfers and low-risk concessional borrowing sufficient to combat the worst of heat stress are crucial to combating the worst effects of climate breakdown. Bangladesh's apparel industry has room to run. Our 2025 analysis of Bangladesh's minimum-wage setting practices makes clear that apparel wage levels in Bangladesh are low and that much of the benefits of growth and the extraordinary wealth created by Bangladesh's role in global apparel trade—in contrast to similar growth in Cambodia and Vietnam, for example—have been directed overwhelmingly to owners.

Section 6. What will it take to make these changes at industry scale?

As we argued at the top of this paper, capital-intensive investment that benefits workers and employers in the apparel industry—the Accord in Bangladesh is the obvious analog—has been fueled by a mixture of mandates from apparel buyers and governments with economic incentives which can show up as improved terms of trade including higher volumes and/or prices for producers, blended finance facilities and short payback periods.

What would it take to bring heat stress levels in all of Bangladesh's apparel-exporting factories to safe and sustainable levels? What combination of mandates and incentives is required? What are the whole-industry costs? Who pays and how would changes be financed? And, who would do the work?

Governance. Mandates or maybes?

The threshold issue for a rapid and large-scale effort to make the apparel industry in Bangladesh safe for workers in an era of extreme heat is not a technical (or technological) one. It is political. What are the obstacles to large-scale relief? What are the uses of power—from capital investment to legislation and enforcement to purchase orders to binding brand agreements—that can accelerate climate adaptation? Will the institutions and individuals with the ability to act do what they should? At present, the government of Bangladesh requires 'adequate ventilation' and 'comfortable temperatures' for workers but includes no specific temperatures or thresholds. From an interview for this paper with a long-time inside observer of Bangladesh's apparel industry:

> Factories will not be able to ignore the fact that the heat is rising, that temperatures are rising, and that productivity is dropping. It will not be easy for them to get workers to continue work in such horrid conditions. It's difficult now [because of energy prices and softening of orders] but it is unavoidable that factories will have to put forward some investment in cooling.

What will accelerate it? "Unless and until there is a brand requirement, such investment will be difficult [to scale]. If brands are telling them [to cool workers] then—even if [borrowing] is at a commercial rate—they [owners] will find a way for investment. And, if the government of Bangladesh brings on a maximum temperature requirement in a labor ordinance, it will be even more difficult [to downplay] because brands will start asking for that to be implemented."

Are brands requiring that their manufacturing partners cool their workers? The number of major brands and retailers working towards workplace heat stress standards is growing. A handful have heat-specific standards in their codes. Many more do not. Among the 25 leading global apparel brands and retailers in the world, three have detailed requirements with heat threshold levels in their codes, four have some specific heat guidance, and eight have broad or generic heat-safety language. Ten have no requirements, guidance or heat-related language.[57]

Access to shade or cooler environments as well as rest breaks when temperatures are high are required by **Nike**, **Levi's**, and **VF**. Nike, PVH and VF discuss or list specific heat thresholds that should be avoided and call for worker protocols for excessively high temperatures. VF instructs manufacturers to avoid air temperatures below 10 °C or above 35 °C (dry-bulb) with 10 – 15 °C and 30 – 35 °C as 'borderline' and 15 – 30 °C as 'ideal'. PVH tells their suppliers that dry-bulb temperatures should "generally be maintained between 18.3˚ C and 29.5˚ C" and should never exceed 35˚ C. **Nike's** range for sedentary work is 16 to 30 °C, and for physically exertive work, 13 – 27 °C. Nike's guidance also includes standards for, hydration, shade and recovery, protective clothing, medical response and training protocols.

Another handful of brands provide broad guidance on heat: factories must maintain a safe working environment with 'acceptable temperatures' with upper limits in the 35 °C range. Next (U.K.) says that "indoor working environments should be kept within safe, comfortable and legal temperatures… Increased air movement at temperatures below 36 degrees Celsius will help cool workers. Above 36 degrees it will heat workers further: temperatures need to be reduced before increasing air flow." Adidas says that in hot environments, suppliers should "[shield] radiant heat sources (e.g., hot equipment), increase air velocity past workers if air temperature is <35 °C, [encourage] sensible clothing for workers, rest breaks in a cooler environment and/or job rotation in the hot environment, [provide] cooling vests or other water-cooled garments."

Missing here are at least three vital elements: continuous monitoring of heat stress and specific heat stress standards (zones) like those applied in Sections 1 and 2 above, and binding obligations for buyers and manufacturers to act.

The last of these—binding commitments with clear incentives including enforcement—we find in the International Accord which is drafting a heat stress protocol for use in Bangladesh and Pakistan. The Accord, directed in Bangladesh by the Apparel Sustainability Council (RSC), differs fundamentally from voluntary codes of conduct and the multi-stakeholder groups that administer them: inspections will assess heat safety against a uniform standard, define corrective action to remedy unsafe heat stress levels and manufacturers and their buyers are obligated to make them. Financing of improvements, maintenance of orders for a period and no losses for workers from disruptions are built into the system.

Second, brands and retailers based in the European Union (and European Economic Area) or doing significant business in the E.U. are required to comply with rules designed to prevent harms to workers along global supply chains: Corporate

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57 The list of 25 leading brands was created from McKinsey & Company's 2026 State of Fashion report. For the breakdown of codes and language that follows, we added PVH, VF, Levi's, Adidas and Primark. We used corporate reports including supplier codes of conduct or human rights policy documents from these brands to determine their level of heat-specific standards.

Sustainability Reporting Directive (from 2025), Corporate Sustainability Due Diligence Directive (from 2028) and the Forced Labor Regulation, applied from December 2027. 'Omnibus' changes by the European Commission in 2026 to the reporting and due diligence directives reduced the scope and left undecided issues of liability for firms covered by the rules. Even in reduced form, the directives' requirements on worker health and safety are bright enough to throw light on the general lack of heat stress protections for workers. (Abusive working conditions—a possible indicator of forced labor—surely includes dangerously hot work environments). Buyers of Bangladeshi apparel for the E.U. market will be expected to show that they have explored the risks and impacts of extreme heat on workers in their supply chains and acted to protect those workers. Ignorance of extreme heat's impacts for workers and inaction will not be acceptable under the new rules.

Cost. Is industry-wide remediation possible?

As we noted above, our eight-factory sample is 'purposive' and diverse (as opposed to strictly representative) of the industry. These factories are larger and, on the whole, more highly capitalized and better connected than the smaller producers that make up the majority of the Bangladesh's apparel industry. Although our sample's heat stress results—two with relatively low risk, three with medium and three with high risk—imitates the middle of a normal distribution, its bias is for larger factories and, as a result, our findings likely understate the conditions that prevail in the thousands of smaller factories.

A stacking up of estimated heat stress risk and remediation costs on a narrow base is, we acknowledge, not very stable. But lacking accurate heat stress data from across Bangladesh's apparel industry, we have assigned heat stress risk levels to the industry's factories based on our risk-and-cost analyses of of the study factories square meters of production area. The lack of relevant public data on factories makes the building of a simple predictive model very difficult so any estimates of remediation costs for the entire industry are necessarily broad. Grouping factories by size of production area—the most influential (available) factor in determining remediation costs among cut-make-trim factories—we apply the corresponding cooling solution costs from Section 4. For medium-large and very large factories with 10,000 square meters or more of production area, the average capex and opex rates (per square meter) are USD 6.57 and 0.48 respectively based on average costs for Factories 1 – 4, 7 and 8. The two small and medium factories in our study group—Factories 5 and 6—average USD 14.78 and 0.94, or roughly double the rates in the larger factories. In a small sample size, these are necessarily broad indicators of costs for similarly-sized factories. And our two small-medium factories bear a lot of weight given the industry's average factory production area size—8,880 square meters—in the tier one factories in the Mapped in Bangladesh database.

The total estimated capex required to keep the industry's small and medium factories below a weighted 26 °C WBGT (ironing/finishing and cutting) and 28 °C WBGT (sewing) is USD 99.9 million. For the large and very large factories, the estimate is USD 136.9 million. Spread over three years, these combined capital costs represent 0.2 percent per year of Bangladesh's 2025 apparel industry revenue. Strong as that finding is, reports of falling orders, factory closures and layoffs give everyone in the industry pause. As the higher capex costs and longer payback periods in our alternative scenarios above show, 'headwind' estimate do not weaken the basic economic logic of cooling investments. While large, non-essential investments are harder for factories under financial pressure, reducing heat stress is essential: it protects productivity, the safety and health of workers and relationships with buyers.

And phased implementation of the solutions proposed and costed above are a good fit for an uncertain period: roof treatment, airflow correction, local extraction of heat and humidity, and partitioning of and focused cooling in the high-risk zones. These investments can be phased in, financed with support from sustainability-linked funds and integrated in future years with more ambitious cooling systems, including air conditioning. But they cannot be ignored.

Class divide: How do approaches to heat stress differ between major producers and small and medium enterprises?

Pressures and incentives for the largest firms are the inverse of those for smaller producers. In the largest firms, systems for dealing with safety issues (including extreme heat) are generally stronger and their ability to act—including the financing of their responses—is relatively strong. The middle-tier and smaller employers have strong incentives to act on heat stress. In general, their risk appears high and their 'recovery function' is the steepest. That is, they have a lot to lose and a lot to gain in addressing the problem. (Factory 6 in our group of eight factories is a good example). But compared to major producers, they have less freedom to act: their brand relationships are less stable and their margins and access to cash (or borrowing) are relatively low.

How will firms with the ability to make significant capital expenditures respond? And, for these firms, where will the pressures to automate production intersect with the need to contend with (or outpace) cooling and its attendant costs?

We invited **Sarah Krasley**, founder of industrial ed-tech company Shimmy Technologies and author of the GLI brief ***Cooling Before It Got Cool*** (Krasley, 2026) to analyze the how firms approach the need to build heat-safe factories and to describe the heat-automation interaction.

Factories that combat heat stress typically do not adopt a single, comprehensive cooling solution. Instead, they mix methods and often implement measures in a piecemeal way, layering interventions based on budget, feasibility, and near-term operational pressures.

These responses are often short-term reactions to heat stress. Fans are added or moved around. Airflow is adjusted. Work schedules are modified during heat waves. In some cases, basic monitoring systems are introduced. And personal cooling systems can be used as short-term measures for reducing acute heat strain: individual fans, ice and cool water, even vests with pockets for cooling packs that can be inserted and removed to reduce core body and skin temperatures (Gutiérrez-Arroyo et al., 2025).

Taken together, these steps form a kind of evolving solution stack rather than a unified system as the number of heat waves increases. This aligns with the Climate Rights International framework outlined in their December 2025 report which emphasizes immediate, lower-cost actions that can help reduce dangerous heat exposure in the near term while more comprehensive factory cooling and infrastructure adaptations are financially out of reach or while heat stress is not tracked by government and buyers, or both. In this framing, the approach is not a substitute for integrated cooling strategies but measures to supplement ventilation improvements, work-rest schedules, hydration strategies and, eventually, the more systemic cooling investments described in this paper.[58]

This approach reflects how owners of small- and medium-sized factories perceive their constraints. Retrofitting a building with sealed climate-controlled 'envelopes' or centralized cooling is often treated as a high-cost, high-disruption undertaking. Yet the broader evidence base across GLI's research—including the YGEN-devised solutions detailed in this paper—suggests a more nuanced reality. Many retrofit measures can be introduced incrementally and stacked, with manageable cost and limited downtime.

58 This is borne out by the findings of a 2025 laboratory-based heat stress study at the University of Sydney Heat and Health Research Centre. The study mimicked 'peak' heat stress in Dhaka-area apparel factories (40 C at 38 percent humidity for an approximate WBGT of 32 C WBGT) and simulated cooling interventions—from individual fans to insulated roofs to air-conditioning—as subjects worked at ironing and sewing tasks. Researchers tracked heart rate, core body temperatures and work performance. How was productivity affected? "Relative to [control conditions], work output was improved by air conditions (13%) and was not negatively impacted by the use of any [lower-cost] cooling interventions [at an average of 4%]".

For example, An Giang Samho, a footwear factory in Vietnam we profiled in our *Cooling Before It Got Cool* case studies, utilized vendor-supplied solar panels and roof insulation on one of their buildings to cut indoor temperatures by an estimated 3 °C (dry-bulb) with no meaningful downtime or investment (Krasley, 2026).[59]

As the renewable energy-cooling example above shows, there are synergies between climate mitigation (decarbonization) and adaption. Some emerging technologies may not be purpose-built for cooling but can contribute in less direct ways. According to apparel energy efficiency experts interviewed for this paper, heat pumps being introduced primarily as decarbonization tools in textile manufacturing may also provide localized cooling benefits while generating steam and hot water. Unlike traditional boilers that burn fuel to create heat, heat pumps work more like kitchen refrigerators, pulling existing heat from surrounding air, water, or industrial machines and concentrating it where it is needed. They can reduce ambient heat from machines—textile production as in Factory 8, drying and washing, for example—and even produce cool air for workers nearby.[60]

With heat pump technology, we are crossing the barrier between the iterative, lower-cost solutions and those requiring significant capital.

Automation and Cooling: How are the machines (and managers) reacting to the extreme heat?

There is a direct correlation between cooling and automation. The more automated the machines, the higher the likelihood that they will be cooled comprehensively.

High heat and humidity do not only affect workers. They also have measurable impacts on the performance and longevity of industrial equipment and may increasingly serve as a quiet driver of cooling and humidity control inside factories.

According to automated machinery vendors, exposure to high temperatures and moisture can contribute to a range of machine-related issues including overheating of electronic components, increased corrosion and rust in metal parts, sensor malfunction, and the contamination or premature breakdown of lubricants. These effects can degrade machine performance over time and increase maintenance requirements.

In many cases, these impacts may be less immediately visible than the effects of heat stress on workers. However, they carry financial implications for factory owners. Machines operating outside recommended environmental conditions may fall out of warranty, experience reduced lifespan, or require more frequent repair.

For example, laser cutting tools require low humidity operating environments because they operate with lenses and mirrors to focus their laser beams. If there is condensation in the air, mirrors and lenses will fog up and the machine will not be able to function properly. This may result in cracked lenses, damage to delicate and costly machine parts, and even harm the machine operator because the laser is not pointed correctly.

Another example would come from humidity entering into the circuit boards of machinery and degrading the electrical connection points. Over time, the circuit boards will need to be replaced. If the machine vendor determines the machine was not used within operating guidelines, the factory would have to replace that component and underwrite an international technician's travel and time to make the repair. The factory would additionally lose significant time and money while the machine sits idle waiting for the repair.

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59 This was seen in Bach, A. et. al., 2023, where four retrofitted variations were tested (simulated) for cooling impacts—extensive green roof, rooftop shading, reflective paint, and underside insulation plus reflective paint. They all had similar effects, reducing indoor air temperatures by around 2 °C (dry-bulb) on average.

60 Epic Group, 2025.

While the effects of heat on machinery are often discussed in technical specifications and maintenance guidelines, they are less frequently framed as part of the broader climate adaptation challenge facing manufacturing.

As PwC announced in February 2026, the share of industrial manufacturers who expect to highly automate key processes by 2030 will more than double, from 18 percent to 50 percent. While this figure represents pan-segment manufacturing purchasing trends, Shimmy's Apparel Automation Pulse, a multi-department factory research initiative that tracked the rate of change in automation across the apparel supply chain, showed that across 20 Bangladeshi apparel factories, 80 percent of factory decision-makers planned to purchase automated machines between 2023 – 2025. As automated machine purchasing in apparel production accelerates, interior temperature and humidity stability becomes increasingly relevant not only for worker safety and health, but for asset protection and production reliability.

In this sense, heat and humidity may begin to shift from being a background condition to a factor in capital planning. Factory owners unwilling to make investments in air conditioning for worker safety or productivity may, like those from WorldOn—a Vietnamese cut-and-sew factory we profiled in our *Cooling Before it Got Cool* case studies—easily achieve their desired ROI for factory-wide air conditioning through the automation it enabled and through the competitive advantage it gave them as the "air conditioned factory" in a highly competitive local labor market.

As factories adopt more technologically integrated production systems, that economic logic of cooling may become even more compelling. Cooling investments increasingly intersect not only with worker safety comfort and retention, but with machinery protection, warranty preservation, sensor reliability, product quality consistency, and the stable operation of advanced automated equipment in extreme environmental conditions.

And as industrial robotics, aided by AI, continue to improve their ability to manipulate flexible materials like fabric—one of the apparel sector's longest-standing barriers to sewing automation—it will be interesting to see how quickly the conditions change. The result may not simply be cooler factories, but fundamentally different ones: more climate-controlled, more machine-dependent, and with fewer workers and lower heat stress on the factory floor.

Finance. How will the costs be shared?

The workers and employers in the vast middle of the industry are represented in our study by Factories 5 and 6. They face significant heat stress risk and, for this group, the economic logic of these investments is clear and becoming more urgent. How will these factories approach the problem?

Some will ignore it as will their buyers, says a Dhaka-based climate finance expert interviewed for this paper. That is, they will allow workers to continue to bear the costs, and they will accept long-term losses from the effects of high heat. For those who decide to address the problem, what are their finance options? Beyond cash reserves and favorable changes in commercial terms from buyers, they will borrow at market or concessional interest rates. In interviews for this paper, senior finance executives, manufacturers and multilateral bank officials confirmed that green finance facilities via Bangladesh Bank (Green Transformation Fund or GTF) can reduce interest rates for manufacturers from 12 – 14 percent to 5 – 6 percent.

But will owners do it? A long-time apparel industry insider argued that owners "would refuse or be unsure about even a small investment—not all but most factories. They often do not want to spend their money on things that are not, in their eyes, directly linked to production." Some factories will go to the commercial banks, and, supported by the Bangladesh Bank GTF, receive concessional financing but these borrowing facilities are "often very cumbersome for factories to access":

> The process is not very standardized and not very simple, plus factories may have troubles if their bookkeeping is not clean enough. But sometimes in business, finding low-cost financing is less important than finding the financing right away. You can wait six to eight months to get financing from GTF or instead pay a few percent higher [in interest] and get it from a commercial bank and [the latter] makes more sense for a lot of businesses.

Another long-time industry climate specialist argues that payback periods on climate mitigation projects are several years longer and nonetheless doable for manufacturers receiving the right mixture of mandates and incentives.

Engineering. What are the mechanics of cooling an industry?

Available funds, willing employers and pressure from the International Accord, brands and government for heat-safe production do not quite complete the equation. Will Bangladesh's engineering and installation industries be prepared to upgrade an estimated 3,000 apparel factories in a three-to-five year timeframe?

Yes, if the work is coordinated, that is, organized as a multi-year project rather than as individually and factory-by-factory. This scale can be managed by experienced *in situ* engineering firms using centralized project management, standardized technical assessment tools and multiple field teams working in parallel. Also required are supply chain coordination for fans, ducts, inlets, exhaust systems, cooling units, electrical panels and sensors.

The timing of a campaign like this by engineering and installation firms depends in large part on the split among cooling solutions. Convection cooling can be scaled easily because it involves components that are available in Dhaka or can be procured quickly, and their installation is easier to divide across multiple teams. (Water-evaporative cooling—not a key component of YGEN's proposed solutions—requires more planning because the cooling units and ducting depend in part on imported equipment and supplier availability.) Closed-loop cooling requires the most careful planning as it involves larger mechanical systems, cooling towers, pumps, chillers, automation, ducting and more specialized installation. But the capacity issues are manageable if demand is known in advance and through phase-planning.

A final capacity issue—energy availability and cost—is the hardest to gauge as the energy issues in Bangladesh, the apparel industry and global production generally are in flux.

Bangladesh has built significant capacity for electricity production over the last ten years and—when the liquified natural gas (LNG) that powers it is widely available in Bangladesh—supply exceeds demand. But the reliability of the grid is a problem and costs are relatively high as Bangladesh has shifted from domestic supply to a roughly 70/30 split in 2025 with gas imported chiefly from Qatar. (IEEF, 2026) This growing dependence on (unstable) imported LNG for electricity means that costs for the Bangladeshi government—via subsidy—or for apparel producers, or both, are climbing.

Investments in refrigerant air-conditioning systems with their attendant capex costs and high energy demand may be within reach for a relatively small number of large manufacturers in the short term. But it may be a need rather than an option for producers if heat stress levels rise significantly.

Section 7. Conclusions and What comes next?

Our findings are clear and consistent. From early April to late October in Dhaka, workers experienced sustained heat stress at work and at home. Using wet-bulb globe temperatures, we defined four heat stress zones (Moderate, Caution, High and Extreme), based on intensity of effort and process. We applied in our analysis—hour-by-hour, section-by-section and factory-by-factory—new heat-productivity damage and recovery functions to estimate the heat stress-induced losses and benefits of cooling. Finally, we used tailored cooling interventions to calculate remedy costs per square meter, returns on investment and payback periods. The average payback period of one to four years makes the business case for cooling clear.

But the goal of our analysis and climate adaptation more generally is not simply ensuring that apparel brands and their partners can hold onto or rebuild profit margins while workers merely hold onto or improve their health.

We are interested in the impacts, costs and benefits that are harder to see and harder to count. Heat stress is a climate phenomenon but also a socio-economic one. For apparel workers in Bangladesh, heat accumulates across the spaces they occupy all day long, from home to commute to factory and back again. Fatigue accumulates across days and months because sleep on hot nights is poor and rest is reduced. Costs accumulate because medicine must be bought again and again. Pressure accumulates because missing work or arriving late threatens income in households that are already working on very narrow margins.

And climate burdens accumulate because rainfall and floods do not replace heat. They arrive alongside it and increase heat stress. Workers are systematically required to absorb climate stress and this is what makes heat stress so dangerous in Bangladesh: it is not just weather but an amplifier of inequality.

Our findings document this and, where we have good data, quantify the costs for workers and their employers. The returns on the physical cooling investments in the factories that we have calculated are strong enough to make room for employers, apparel buyers and governments—all beneficiaries of the upsides of cooling workers in factories—to extend those investments to help cool workers' homes. The encouraging payback period for factory-level cooling also makes room for two of the most highly flexible climate-adaptive strategies: living wages and collective bargaining. These age-old approaches can tailor quick responses to climate breakdown in factories and for workers and their families in ways that even scaled-up industry or government programs cannot.

What are the next steps?

First, manufacturers and buyers should measure heat stress with attention to how it varies by location, process, factory design and even worker. They should engage qualified engineers to evaluate the costs of cooling workers, calculate the likely return on those investments and engage their buyers on the sharing of costs. It is the capturing and comparison of the costs and benefits of these different interventions that can produce the confidence needed to scale and speed these investments.

Manufacturers and industrial engineers in Bangladesh and elsewhere should also test, refine and scale up solutions that reduce heat stress to safe levels. These will differ by climate and economy. Dhaka differs from Chittagong, Delhi from Chennai and Jakarta from Ho Chi Minh and so on. Each center needs an approach and a plan. And while they are at it, they need to integrate the solutions that help employers meet their obligations both to cool workers and to reduce carbon emissions.

Second, the government of Bangladesh should engage employers, workers and apparel brands to draft, enact and enforce a specific heat stress standard to protect workers' health and safeguard Bangladesh's competitiveness in a rapidly warming world. As we argued in *Higher Ground?*, those with power in the industry need to treat extreme heat as a health hazard, and cooling as an urgent investment in safety for workers and stronger margins for management. Brands must do the same in their sustainability, sourcing and pricing strategies for Bangladesh and almost everywhere they buy apparel. Their new EU reporting and due diligence obligations confirm this.

The International Accord with its mandate to protect worker safety and health and its binding obligations for employers and apparel brands—including by sharing costs—can show the way. In fact, the Accord's maintenance-of-volumes and financing provisions may prove useful to manufacturers found to be in need of significant investments to keep workers safe. This will be doubly true if acceleration in heat stress levels in the coming years outpaces the cooling solutions described in this paper. Of equal importance to the engineering solutions are administrative changes—more accurately, 'worker safety protocols'—to make work in high heat stress seasons safe and healthy. These include changes in hours, work-rest balance, worker pay including piece-rates and targets, medical leave policy and more. (Protocols that combine with engineering solutions to protect workers are the topic of an upcoming GLI study). Finally, easier access to (concessional, green) finance for smaller and medium-sized factories ranks high in our list of recommendations, as does forbearance by brands on terms of trade including long-term commitments, prices that reflect new capital and operating costs or finance mechanisms with longer payback periods for suppliers making meaningful investments to cool workers.

At one level, making an industry safe for its workers is a technical exercise. And despite the acceleration in climate breakdown, the science and the solutions remain relatively simple. And the business and rights cases are clear. In other words, the remaining obstacles are largely political—questions of power in the apparel industry and its uses. Our third recommendation is to challenge the catastrophists who argue that "the electrical grid will break" or "emissions will be impossibly high" or "workers hate cool air". These are often political objections posing as technical problems.

Our final recommendation is a corollary to the one above: do not get mired in recommendations. The experience of extreme heat—or climate breakdown—is now general and our knowledge of it is intuitive, tacit. Workers, engineers, managers, ministers and COOs can draw on this when the will is weak. But its impacts are not evenly distributed. They are amplified by poverty and the social investments detailed above rank with the physical investments for their impact on workers.

Annexes

- Annex 1. WBGT reference table
- Annex 2. YGEN factory engineering report
- Annex 3. YGEN energy efficiency/VFD report
- Annex 4. Methodological note, including hybrid random forest and heat stress data imputation and machine learning imputation

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Annex 1 WBGT reference table

Annexes 2, 3 and 4 are available on the Six Seasons, Four Summers webpage.

For broad guidance, we provide a table based on Stull (2011) natural wet-bulb formula and ISO 7243 calculation for estimated wet-bulb global temperatures at different air temperature and relative humidity levels (with fixed values for air velocity and solar load). Color-coding corresponds to the heat stress zones used in this paper for medium-intensity work (e.g. ironing).

°C / RH	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%	75%	80%	85%
20°C	10.2	11.1	11.9	12.6	13.2	13.8	14.3	14.8	15.3	15.8	16.3	16.7	17.2	17.6	18.0	18.5	18.9
21°C	10.8	11.8	12.6	13.3	14.0	14.6	15.2	15.7	16.2	16.7	17.2	17.6	18.1	18.6	19.0	19.4	19.9
22°C	11.5	12.5	13.4	14.1	14.8	15.4	16.0	16.6	17.1	17.6	18.1	18.6	19.0	19.5	20.0	20.4	20.9
23°C	12.2	13.2	14.1	14.9	15.6	16.3	16.9	17.4	18.0	18.5	19.0	19.5	20.0	20.5	20.9	21.4	21.9
24°C	12.8	13.9	14.8	15.7	16.4	17.1	17.7	18.3	18.9	19.4	19.9	20.4	20.9	21.4	21.9	22.4	22.8
25°C	13.5	14.6	15.6	16.5	17.2	17.9	18.6	19.2	19.8	20.3	20.8	21.4	21.9	22.4	22.9	23.3	23.8
26°C	14.1	15.3	16.3	17.2	18.0	18.7	19.4	20.0	20.6	21.2	21.8	22.3	22.8	23.3	23.8	24.3	24.8
27°C	14.8	16.0	17.1	18.0	18.8	19.6	20.3	20.9	21.5	22.1	22.7	23.2	23.7	24.3	24.8	25.3	25.8
28°C	15.4	16.7	17.8	18.8	19.6	20.4	21.1	21.8	22.4	23.0	23.6	24.1	24.7	25.2	25.7	26.3	26.8
29°C	16.1	17.4	18.6	19.6	20.4	21.2	22.0	22.7	23.3	23.9	24.5	25.1	25.6	26.2	26.7	27.2	27.7
30°C	16.7	18.1	19.3	20.3	21.2	22.1	22.8	23.5	24.2	24.8	25.4	26.0	26.6	27.1	27.7	28.2	28.7
31°C	17.4	18.8	20.1	21.1	22.0	22.9	23.7	24.4	25.1	25.7	26.3	26.9	27.5	28.1	28.6	29.2	29.7
32°C	18.1	19.5	20.8	21.9	22.9	23.7	24.5	25.3	26.0	26.6	27.3	27.9	28.5	29.0	29.6	30.1	30.7
33°C	18.7	20.2	21.5	22.7	23.7	24.5	25.4	26.1	26.8	27.5	28.2	28.8	29.4	30.0	30.6	31.1	31.7
34°C	19.4	20.9	22.3	23.4	24.5	25.4	26.2	27.0	27.7	28.4	29.1	29.7	30.3	30.9	31.5	32.1	32.6
35°C	20.0	21.6	23.0	24.2	25.3	26.2	27.1	27.9	28.6	29.3	30.0	30.6	31.3	31.9	32.5	33.1	33.6
36°C	20.7	22.3	23.8	25.0	26.1	27.0	27.9	28.7	29.5	30.2	30.9	31.6	32.2	32.8	33.4	34.0	34.6
37°C	21.3	23.0	24.5	25.8	26.9	27.9	28.8	29.6	30.4	31.1	31.8	32.5	33.2	33.8	34.4	35.0	35.6
38°C	22.0	23.8	25.3	26.5	27.7	28.7	29.6	30.5	31.3	32.0	32.7	33.4	34.1	34.7	35.4	36.0	36.6
39°C	22.6	24.5	26.0	27.3	28.5	29.5	30.5	31.3	32.2	32.9	33.7	34.4	35.0	35.7	36.3	36.9	37.6

<25°C — Moderate

25 – 28°C — Caution

28 – 30°C — High

>30°C — Severe

>32 °C — Hazardous

Stull (2011) natural wet bulb estimate equation:

$$TW = T * \arctan[0.151977 * (\sqrt{rh + 8.313659})] + \arctan(T + rh) - \arctan(rh - 1.676331) + 0.00391838 * (rh)^{1.5} * \arctan(0.023101 * rh) - 4.686035$$

And the ISO 7243 equation for screening indoor heat stress risk:
$WBGT = 0.7t_{nw + 0.3tg}$

YGEN

BCWS

CED centre for entrepreneurship development

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ILR Global Labor Institute

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