HIGHER GROUND?

Report 1: Fashion's Climate Breakdown and its Effect for Workers

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Introduction

Fashion focuses its climate change efforts on goals such as increasing use of recycled fabrics, reducing water usage, and cutting down its very high greenhouse gas emissions—fashion ranks third behind global food production and construction.[1]

Regulators and investors in the United States and Europe—still by far the world's largest markets for imported apparel—also focus on similar climate mitigation measures. The European Union's 2022 sustainable textiles strategy defines the problem with reference to fashion's billowing global production ("doubled between 2000 and 2015"), waste ("one full truckload of textiles goes to landfill or incineration every second"), pollution (35 percent of all the microplastics come from textile products) and its 'top five' global carbon footprint (European Commission, 2022a).

Deep reductions in these impacts are necessary to hold global heating below the limits set at the Paris climate agreement (a 1.5 ºC increase), but the fashion industry's mitigation efforts raise two fundamental problems. First, they fail to reconcile plainly contradictory goals: continued rapid growth of apparel production (sales) and a radically smaller carbon footprint. This mitigation problem is taken up in the academic literature and reporting on the unsustainability of fashion's dominant business models.[2]

We take up the second problem here. Fashion's mitigation efforts ignore the impact of climate change on the workers, communities and industries who produce the world's garments. In these reports, we focus on only two of these climate impacts: exposure to extreme heat and flooding. They affect workers and suppliers—directly and dramatically—in apparel production centers in some of the world's most climate-vulnerable countries. This is the problem of adaptation.

Adaptation has a meaningful prize attached to it. Without adaptation, the projections of losses to gross domestic product (GDP) from high heat and humidity are steepest in the tropical and subtropical zones that are home to apparel production: Bangladesh (-4.9 percent of projected 2030 GDP), Cambodia (-6.5 percent), Pakistan (-5.1 percent), and Vietnam (-4.9 percent) (ILO, 2019). Pell-mell growth in fashion's favorite production centers over three decades has created 'urban heat islands' with dangerously high heat stress for workers.[3]

More building in flood plains and the accompanying blankets of concrete mean more dramatic flooding.[4] Sea-level rise and storm surges, rainfall and riverine flooding threaten to interrupt apparel production and transport, strand industry assets, and jeopardize workers' health and livelihoods.

The combined effects of rising heat and intense flooding will cost hundreds of billions of dollars in would-be earnings and millions of forgone jobs for the fashion industry in our projections for 2030 and 2050. The possible losses calculated in these reports represent material impacts for brands and their investors, as well as apparel workers and their employers. But adaptation to climate breakdown is not part of the global fashion industry's plan.

Building on the Global Labor Institute (GLI) 2021 paper that addressed the apparel industry's mitigation-adaptation gap, this new research from Cornell GLI and Schroders—in the form of two reports—are the first to quantify how fashion brands, manufacturers and workers are likely to experience the effects of extreme heat and greater flooding. We examine un- or under-measured risks for fashion brands, their manufacturers and workers, and the governments and investors who rely on them.

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1 Debate over fashion's share of global greenhouse gas emissions, of which carbon dioxide emissions are by far the largest, continues and the likeliest figure is between two and five percent according to Sadowski et al., 2021, and the World Economic Forum, 2021.

2 See, for example, coal emissions growth estimates at Action Speaks Louder, 2022, and apparel sales projections at Ringstrom, 2022, and Kent, 2023.

3 See, for example, Dell et al., 2012, [https://www.aeaweb.org/articles?id=10.1257/mac.4.3.66] and Myers et al., 2021, [https://www.nytimes.com/2021/07/26/world/asia/china-climate-change.html]

4 See, for example, Feng et al., 2021 [https://link.springer.com/article/10.1007/s11069-020-04480-0]

Our analyses put questions about climate breakdown and working conditions into terms that fashion brands, investors, regulators and workers can act on.

- What are the possible impacts on export earnings?
- What is the likely damage in terms of jobs, incomes, and worker health?
- How are leading brands and their investors likely to be affected?
- What should labor regulation—both public and private—know and do about extreme heat and flooding?

And lastly, what do relief and remedy look like? For this final question, we have the examples of 'just transition' strategies for a global shift to low-carbon economies. These strategies focus on the mechanics and costs of climate mitigation—energy efficiency and emissions in particular. But what do the mechanics and costs of climate adaptation look like? Who will define fashion's adaptation (or 'just resilience') strategies, and who will pay for them?[5]

To answer these questions, this first report tracks climate change impacts for apparel production at the global, national and factory levels. Part One maps fashion's climate vulnerability across 32 centers of production. Part Two estimates economic damage to earnings and jobs in Bangladesh, Cambodia, Pakistan and Vietnam from extreme heat and flooding. Part Three examines what climate breakdown mean for workers. Governance of climate impacts on apparel workers is taken up in Part Four. The final section outlines adaptive strategies for national governments, brands and retailers, manufacturers, workers and their organizations.

Our second report examines company-level climate risk, costs and financing for adaptation and just resilience. We also analyze how shareholder and regulatory pressures could affect brand responses to material physical risks in apparel's manufacturing base.

Our goals in these two reports are, first, to understand the industry's exposure to climate risks and the costs of climate adaptation for workers, manufacturers, buyers and investors, and governments. Our second goal is to inspire industry actors to formulate adaptation strategies that are large-scale and fit for purpose. We want to see these new measures and costs written into the business plans of the fashion industry, into collective agreements, and into the calculus of regulators. We then want to see them enacted.

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5 See, for example, The European Climate Adaptation Platform, 2021 https://climate-adapt.eea.europa.eu/en/eu-adaptation-policy/strategy/index_html, and climate transition plans of the Vietnamese and Bangladesh governments cited in Appendix B.

Dhaka, Bangladesh 2004. Photo credit: Dougsme on Flickr.com

WHAT ARE CLIMATE SCENARIOS?

Throughout our analysis, we use climate scenarios known as Representative Concentration Pathways (RCP) and Shared Socioeconomic Pathways (SSP) along with climate change models that are part of the Coupled Model Intercomparison Project 6 (CMIP6) from the Intergovernmental Panel on Climate Change (IPCC). The pathways allow us to calculate how future climate scenarios—and the level of 'radiative forcing' or atmospheric warming that each one represents—may affect apparel production in 2030 and 2050 (Riahi et al., 2017).

SSP 1 Sustainability

Taking the green road (Low challenges to mitigation and adaptation)

SSP 2 Middle of the road

(Medium challenges to mitigation and adaptation)

SSP 3 Regional rivalry

A rocky road (High challenges to mitigation and adaptation)

SSP 4 Inequality

A road divided (Low challenges to mitigation, high challenges to adaptation)

SSP 5 Fossil-fueled development

Taking the highway (High challenges to mitigation, low challenges to adaptation)

For projections in our two reports, we use the 'middle-of-the-road' scenario SSP 2 or SSP 2-4.5—where 4.5 represents the level of radiative forcing in this scenario and the corresponding RCP 4.5: "The world follows a path in which social, economic, and technological trends do not shift markedly from historical patterns. Development and income growth proceeds unevenly, with some countries making relatively good progress while others fall short of expectations. Global and national institutions work toward but make slow progress in achieving sustainable development goals" (IPCC, 2007; Riahi et al., 2017). This pathway allows us to avoid both understating risk using the most optimistic SSP 1 or catastrophizing with the fossil-fuel intensive SSP 5 scenario. And stopping our analysis at 2050 means we largely avoid the greater uncertainty that accompanies longer-term projections.[6]

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6 For more details and methodology, see IPCC, 2007, https://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf and O'Neill et al., 2014 https://link.springer.com/article/10.1007/s10584-013-0905-2.

PART 1.
MAPPING FASHION'S CLIMATE VULNERABILITY

We introduce here our measures of climate vulnerability for apparel production—heat and humidity, and riverine and coastal flooding—then apply them to examine the relative vulnerability of 32 apparel production centers. We chose these centers for their importance to the global apparel trade and, in a few cases, to highlight the diversity of an industry that is dominated by production in Asia.

High heat and humidity combine to tax humans—even those acclimatized to difficult working conditions. The resulting 'heat stress' can cut deeply into workers' health and productivity, producing headaches, rashes, nausea, de-hydration, heat exhaustion, fainting and heat stroke (Malaysia Ministry of Human Resources, 2016).

Heat and relative humidity are frequently combined in a measure called the 'wet bulb globe temperature' (WBGT) which is an effective measure of heat stress for manual workers. The combined effects escalate from 'discomfort' for apparel factory workers at 28 degrees Celsius (°C) in a wet-bulb reading, to 30.5 °C (WBGT)—'moderate' heat stress—which

Photo credit: Pok Rei, Canva, Pexel.

requires roughly as much rest as work in an hour in order to maintain safe core body temperatures.[7] That is, 30 minutes of work require 30 minutes of rest. A wet-bulb reading of 32 °C signals 'high heat stress' even for acclimatized apparel workers, and work can become difficult. At 35 °C (WBGT) and more—even at low effort levels—most workers will suffer severe effects including heat stroke and even death (Schwingshackl et al., 2021; Somanathan, 2021).[8]

In Qatar, for example, the government requires work to stop at wet-bulb index readings above 32.1 °C (State of Qatar Ministry of Labour, 2023).[9] Changes to rules there for work in extreme heat followed the deaths of thousands of construction workers—many of them migrant workers from south and southeast Asia—in the run-up to the men's football World Cup there in 2022.[10]

Apparel workers in Bangladesh surveyed in 2023 for this report noted that workplace heat is considerably higher in recent years. In a 2022 survey of 67 Dhaka apparel workers accustomed to high heat, more than three-quarters (78 percent) wished for cooler working conditions in that city's hottest and most humid months (Bach et al., 2022; Chowdhury et al., 2017).

Flooding also interrupts work and life, sometimes dramatically. A minor inundation of 0.25 meters from rainfall, riverine or coastal flooding in factories may cost hours or even days. But major flooding of one meter or more can halt or slow production and transport for weeks. Apparel workers can find themselves stuck in their homes or risking illness by pushing through flood waters to get to their factories and maintain their incomes.

Table 1 below illustrates changes in exposure to three key physical risk measures in our 32 apparel and footwear production centers in 2030 and 2050. We represent relative heat stress levels using the number of days per year—'exceedance days'—for which the wet-bulb readings climb above 30.5 °C WBGT, the threshold noted above at which an hour of light-to-moderate work should be equal parts effort and rest. High heat levels in cities with lower relative humidity such as Cairo, Amman and Monastir can also pose danger to workers.

Our flooding projections include both coastal or tidal and 'storm surge' flooding (hereafter, 'coastal' flooding), and a combination of 'fluvial', or river flooding, with 'pluvial' or rainfall flooding (hereafter, 'riverine'). The indicators of flood vulnerability are the percentages of each center's populations that will be inundated—most of them at less than 0.5 meter—in a 10-year flood, called a 'return period', or RP10.

7 Wet-bulb values are lower than dry-bulb values: for example, a 30 C WBGT has a greater heat stress effect on workers than a 30 C reading on a dry-bulb gauge. In Somanathan (2021): a WBT of 25 C at 65% relative humidity is roughly equivalent to a temperature of 31 C in dry conditions".

8 Wet-bulb globe thresholds and heat stress categories vary by source but generally agree; see, for example, Schwingshackl et al., 2021. State of Qatar Ministry of Labor, 2023. And with reference to acclimatization and heat stress levels, see ILO, 2019: "Physiological heat acclimatization may offer some protection, but only up to a point; moreover, it can only be developed after a certain transition period (typically one to two weeks of heat exposure). During peak heat periods in some hot countries, the [heat] acclimatization threshold of workers is exceeded far too often."

9 Wet bulb globe temperature readings are noted with WBGT, or 'wet-bulb' (a short-hand term that does not indicate the wet bulb temperature measure). Other temperatures are dry-bulb measures unless noted. For a non-technical explanation of temperature measures, see https://www.popsci.com/environment/wet-bulb-globe-temperature/.

10 Estimates of the total number of deaths (and causes) vary widely. The Qatari government acknowledged 400 – 500 worker deaths related to World Cup construction. The Guardian (UK) estimates approximately 6,500 deaths. See https://www.lemonde.fr/en/les-decodeurs/article/2022/11/15/world-cup-2022-the-difficulty-with-estimating-the-number-of-deaths-on-qatar-construction-sites_6004375_8.html and https://www.theguardian.com/global-development/2021/feb/23/revealed-migrant-worker-deaths-qatar-fifa-world-cup-2022.

Table 1: Heat and flood projections by apparel and footwear production center, 2030 – 2050.

Major production centers		Annual exceedance days at 30.5 C WBGT		Riverine flood population % inundated		Coastal flood population % inundated	
City	Country	2030*	2050	2030	2050	2030	2050
Karachi	Pakistan	189.95	202.71	13.02	13.02	0.27	0.29
Colombo	Sri Lanka	144.52	157.76	24.07	24.29	0.15	0.15
Managua	Nicaragua	133.29	151.9	0.01	0.02	-	-
Port Louis	Mauritius	104.29	104.43	-	-	0.64	0.64
Dhaka	Bangladesh	64.81	104.48	36.86	37.09	14.64	17.86
Yangon	Myanmar	58.9	91.62	11.32	11.53	2.97	3.27
Delhi	India	55.14	75	28.55	28.95	-	-
Ho Chi Minh	Vietnam	55.14	97.76	25.78	25.73	3.74	6.23
Chattogram	Bangladesh	50.1	84.86	40.08	41.21	16.95	18.07
San Salvador	El Salvador	42.33	57.29	0.1	0.1	-	-
Bangkok	Thailand	42.19	74.48	41.53	42.44	3.37	3.66
Phnom Penh	Cambodia	41.38	75.05	41.7	42.28	-	-
Hanoi	Vietnam	37.29	55.86	40.49	40.69	0.59	0.82
Guangdong	China	33.29	48.81	42.00	42.13	8.96	11.44
Dongguan	China	33.29	48.81	41.22	41.91	17.74	20.06
Shenzhen	China	33.29	48.81	3.96	4.12	12.63	12.98
Kuala Lumpur	Malaysia	22.86	57.1	7.82	7.72	-	-
Izmir	Turkey	17.9	18.71	18.77	18.77	1.81	1.82
Tiruppur	India	15.38	29.14	0.94	0.94	-	-
Manila	Philippines	10.43	27.24	10.55	10.75	2.51	2.59
Jakarta	Indonesia	9.81	38.29	29.12	29.05	2.99	3.71
Ningbo	China	8.52	17.52	57.13	55.83	26.97	32.18
Monastir	Tunisia	6.67	11.24	2.71	2.71	0.12	0.37
Tangier	Morocco	2.05	2.48	10.69	10.67	0.63	0.63
Cairo	Egypt	1.52	4.24	9.56	9.81	-	-
Istanbul	Turkey	0.86	1.29	0.13	0.13	0.08	0.76
Mexico City, D.F.	Mexico	0.57	2.14	7.02	7.04	-	-
Taipei	Taiwan	0.48	1.9	16.25	16.26	0.74	0.74
Amman	Jordan	0.33	0.62	-	-	-	-
Prato	Italy	0.24	0.24	41.63	41.36	-	-
San Pedro Sula	Honduras	0.19	1.48	25.26	25.13	-	-
Blumenau-Florianopolis	Brazil	0.1	0.33	35.26	35.39	-	-

* Annual exceedance days are based on 10-year projection cycles.

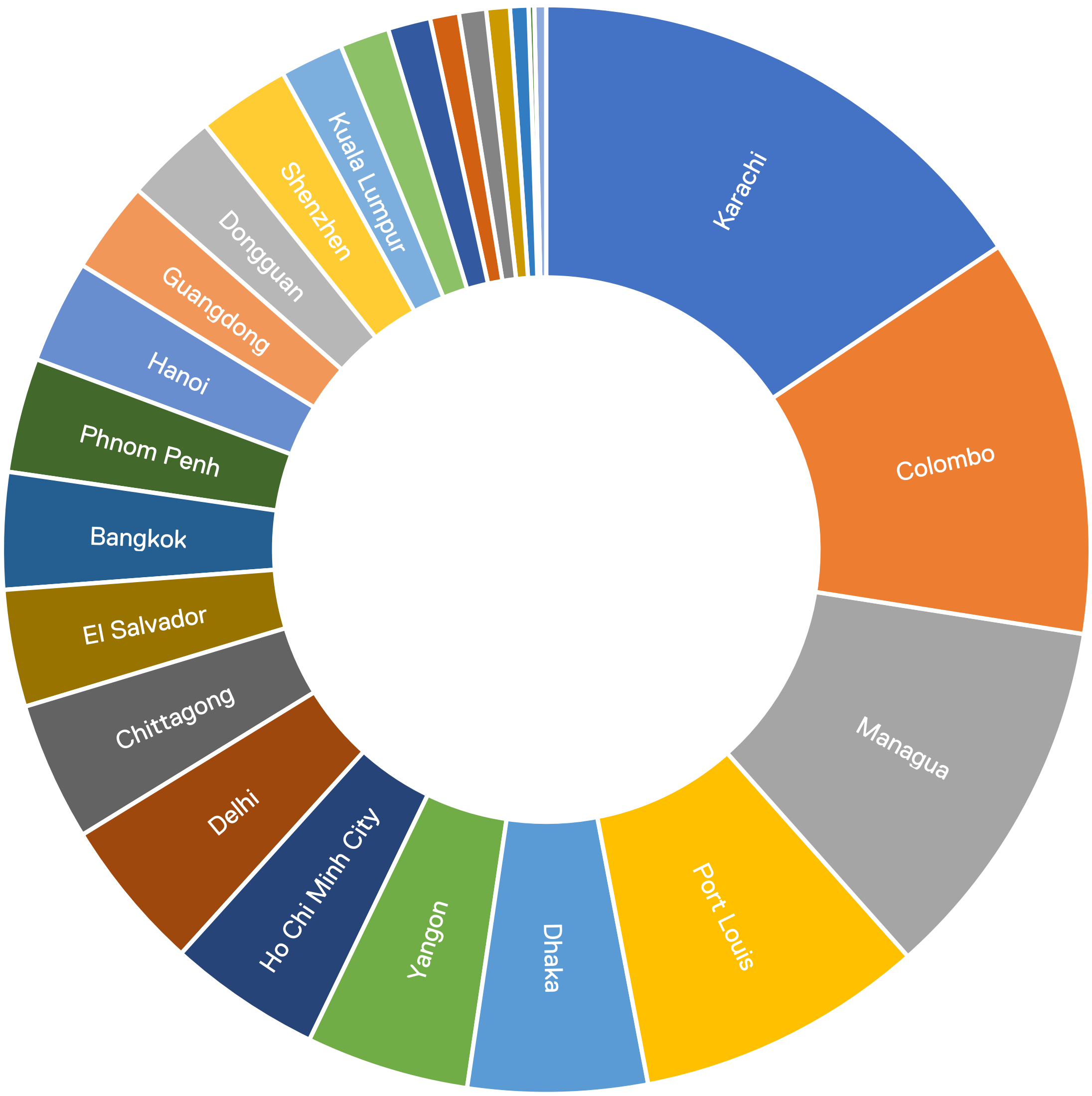
Sources: Schroders, WorldPop, World Resources Institute, Copernicus EU. Flooding based on RP-10 Event, RCP4.5. Heat levels are based on Wet Bulb Globe Temperature, SSP 2-4.5. Analysis undertaken July 2023.

Several production centers stand out in 2030 and beyond for their vulnerability to high heat and humidity and flooding: Colombo, Dhaka and Chattogram (Chittagong), Yangon, Delhi, Bangkok, Phnom Penh and the massive Dongguan-Guangdong-Shenzhen region.

Of the rest, most centers have to contend with high heat or flooding, or both but at *relatively* lower levels. Only a small group—Izmir and Istanbul, Tangier and Taipei—appear likely to escape the worst of the projected increases in heat, humidity and flooding. (Manila, perhaps surprisingly, keeps a low profile in the table above but our analysis does not isolate impacts of tropical cyclones/typhoons).

We look now at the individual measures, beginning with heat and humidity. Figure 1 illustrates the scale of the challenge for many major production centers, but Karachi, Colombo and Managua stand largely alone. In Karachi, over half of all days (52 percent) in 2030 are projected to have wet-bulb globe temperature readings above 30.5 °C, and 56 percent by 2050.

Figure 1. **Annual exceedance days at 30.5 C WBGT in 2030, by center**



Sources: Schroders, Copernicus EU. Heat levels are based on Wet Bulb Globe Temperature, SSP 2-4.5. Analysis undertaken July 2023.

But many of these centers are tropical and sub-tropical hotspots. Are these projected exposures to extreme heat and humidity much higher than recent levels? We compared 2004 – 2014 wet-bulb globe temperatures using the same climate models to our 2030 exceedance days estimates. Among cities in our focus countries—Karachi, Dhaka, Ho Chi Minh City and Phnom Penh—the average number of 30.5 WBGT exceedance days climbs 50.9 percent from 39 days in 2014 to 59 by 2030. Starting from relatively low levels, exceedance days more than double by 2030 in Ho Chi Minh City (and Hanoi) and Phnom Penh. Starting from relatively higher levels, Dhaka's exceedance days will be 63 percent higher and Karachi's 20 percent.[11]

A few centers figure prominently in both wet- and dry-bulb rankings: Delhi, Dhaka, Yangon, Bangkok and Hanoi. (Wet-bulb and dry-bulb projections overlap on some days. For example, a day with a 40 °C dry-bulb reading will also appear in a 30.5 °C wet-bulb count when humidity is high. So, wet- and dry-bulb exceedance days cannot simply be stacked, or added together).

A few centers with lower humidity have relatively high dry-bulb 'exceedance' days: Delhi, Cairo, Tiruppur and Amman, for example.

We isolate flood measures in the tables below and rank ten centers based on the share of city-wide populations at risk of riverine and coastal inundation in 2030 and 2050.[12] We also present inundation percentages above 0.5 meter to signal more disruptive flooding. This is roughly analogous to the 30.5 wet-bulb threshold used above to indicate high heat and humidity.

Table 2. Riverine flooding percentage of population by city, 2030 and 2050

City	Country	Riverine flooding of population (percent)		Riverine flooding of population (percent) >50 cm inundation	
		2030	2050	2030	2050
Ningbo	China	57.13	55.83	0	0
Guangdong	China	42.00	42.13	7.43	7.19
Phnom Penh	Cambodia	41.70	42.28	11.22	12.69
Prato	Italy	41.63	41.36	0	0
Bangkok	Thailand	41.53	42.44	0	0.12
Dongguan	China	41.22	41.91	12.46	16.97
Hanoi	Vietnam	40.49	40.69	5.79	4.36
Chattogram	Bangladesh	40.08	41.21	14.54	19.49
Dhaka	Bangladesh	36.86	37.09	12.04	11.71
Florianopolis-Blumenau	Brazil	35.26	35.39	4.64	7.27

Sources: Schroders, WorldPop, World Resources Institute. Flooding based on RP-10 Event, RCP4.5. Analysis undertaken July 2023.

11 To maintain consistency in our analyses, we have taken the mean average of the back-casts of CMIP6 models for our historical values.

12 We note here three important caveats about flood modeling. First, inundation levels represent the maximum flood level for a single event per return period, so lower-level flooding events are not captured in the analysis. Second, our analysis focuses on the likeliest flood events; for example, return period of 100 and 250 in fossil fuel intensive pathways such as SSP 5-8.5 are not included here. And as a result, we consider our projections to be conservative.

Table 3. Coastal flooding percentage of population by city, 2030 and 2050

City	Country	Coastal flooding of population (percent)		Coastal flooding of population (percent) >50 cm inundation	
		2030	2050	2030	2050
Ningbo	China	26.97	32.18	15.22	20.75
Dongguan	China	17.74	20.06	9.84	10.79
Chattogram	Bangladesh	16.95	18.07	6.56	7.72
Dhaka	Bangladesh	14.64	17.86	7.11	9.67
Shenzhen	China	12.63	12.98	8.03	8.32
Guangdong	China	8.96	11.44	3.48	4.38
Ho Chi Minh	Vietnam	3.74	6.23	0.8	2.25
Bangkok	Thailand	3.37	3.66	1.12	1.27
Jakarta	Indonesia	2.99	3.71	0.96	1.43
Yangon	Myanmar	2.97	3.27	1.44	1.5

Sources: Schroders, WorldPop, World Resources Institute. Flooding based on RP-10 Event, RCP4.5. Analysis undertaken July 2023.

Ningbo is susceptible to storm surge from typhoons and ranks highest in the coastal and riverine flood tables. It is expected to see coastal flooding above 50 centimeters for 15 percent of its population in 2030 and more than 20 percent in 2050. And while 57 percent of its population may see riverine flooding in 2030 during a 10-year flood event (RP10), there is little or none above 50 centimeters.[13]

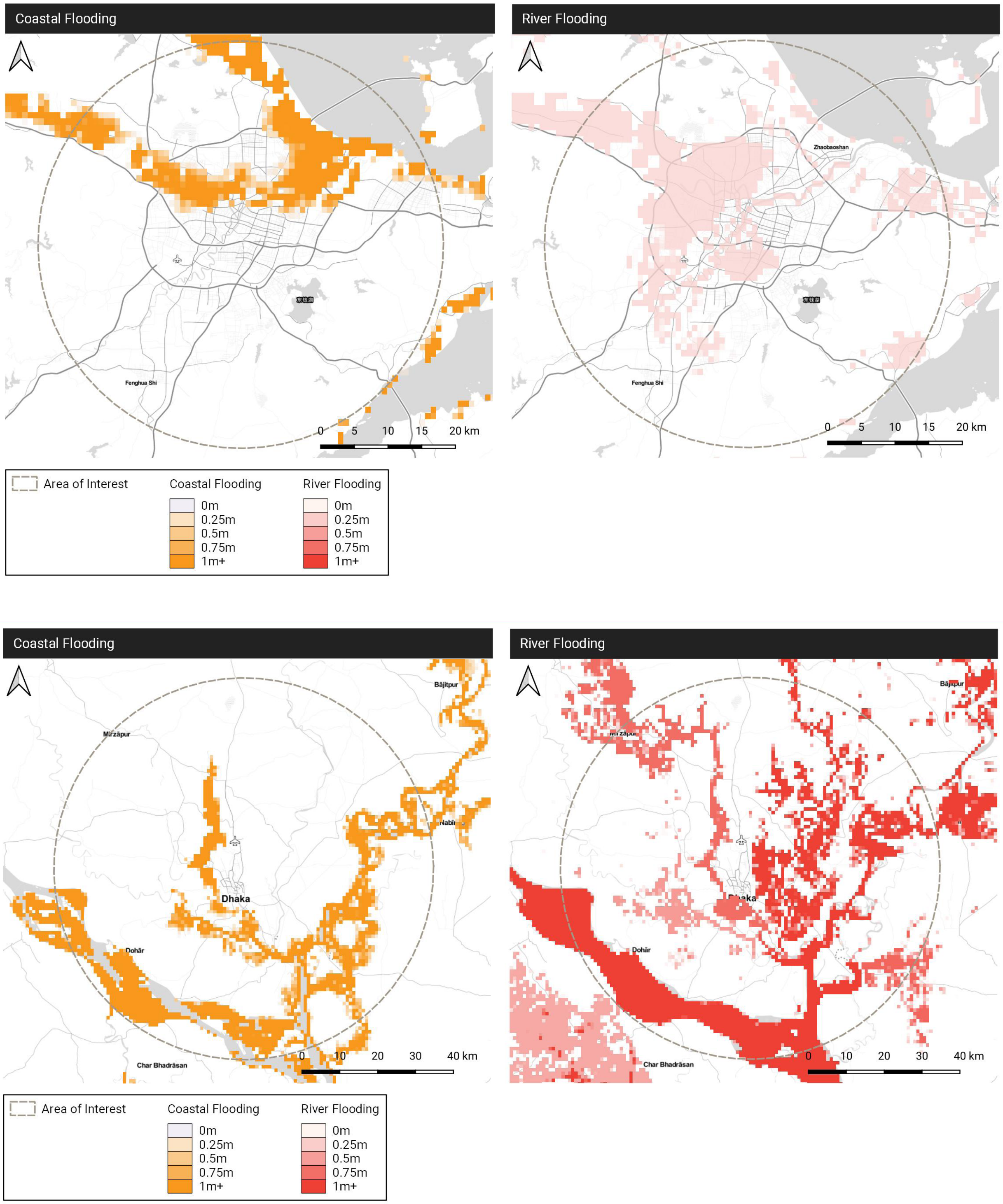
Coastal and riverine flooding often occur at different times of the year, so by combining the percentages of populations at risk of both types of flooding we see that Ningbo, the Guangzhou-Dongguan-Shenzhen region, and Chattogram and Dhaka face the greatest risks.

To compare the relative impacts of flooding we can also illustrate flooding in, for example, Ningbo and Dhaka by mapping our 2030 flood projections. In the figures below, flooding of both types is widespread in Ningbo but riverine inundation levels (in red) are low. In Dhaka, it is the combination of significant coastal flooding (yellow) and riverine flooding—along with its larger area, greater population density, and relative lack of climate-readiness—which mark intense flooding as a greater threat for Dhaka.[14]

13 Despite significant levels of flooding and heat in Ningbo and the Guangzhou region, China is not a focus country in this report because of a lack of access in China to workers and employers makes pairing our geospatial analysis of climate impacts with on-the-ground experiences of it difficult.

14 For rankings by country of climate vulnerability and readiness, see the University of Notre Dame-GAIN index [https://gain.nd.edu/our-work/country-index/rankings/]. In the 2021 survey, China is better positioned on both vulnerability (74) and readiness (36). Bangladesh is at 156 and 167 respectively.

Figure 2. Coastal and riverine inundation levels in Ningbo, China and Dhaka, Bangladesh, 2030



Sources: Schroders, WorldPop, World Resources Institute. Flooding based on RP-10 Event, RCP4.5. Analysis undertaken July 2023.

This comparison illustrates a larger point. The production centers singled out above for their vulnerability to both high heat stress and riverine and rainfall flooding—Colombo, Dhaka and Chattogram, Yangon, Delhi, Bangkok, Phnom Penh and Dongguan-Guangdong-Shenzhen—differ in important ways. Our high-level measures of climate vulnerability are not calibrated for each center's share of global apparel exports, worker or national income levels, flood defenses or the prevalence of air-conditioning in workplaces, responsiveness of political systems and general climate resilience.

These characteristics will determine how centers with roughly similar heat or flood projections—Ningbo, Dhaka and Ho Chi Minh City, for example—will experience and respond to climate threats. Closer estimates and comparison of the impacts of climate breakdown require an examination of apparel production in a subset of climate-vulnerable countries. We take this up in the following section.

Phnom Penh, Cambodia. Photo credit: Cornell GLI

PART 2.
CLIMATE BREAKDOWN AND APPAREL PRODUCTION IN BANGLADESH, CAMBODIA, PAKISTAN AND VIETNAM

In this section, we calculate and compare possible climate-driven loss and damage in the apparel industries of Bangladesh, Cambodia, Pakistan and Vietnam.

We chose these four countries for their prominence in apparel and footwear production and, in the case of Pakistan, textile production. Together, these four represented 18 percent of global apparel exports in 2021. This represents a fraction of China's share of global apparel exports, but these countries represent one direction of travel as brands and retailers accelerate the shift away from China underway since 2011.[15]

These countries' major production centers—Dhaka, Phnom Penh, Karachi and Lahore, Ho Chi Minh and Hanoi—are already confronting extreme heat and humidity. And all of these cities are also likely to experience significant flooding.[16] We also chose these centers because they are at different stages of evolution as apparel and footwear producers. They include local and foreign-owned manufacturers, and they sell to a mix of fashion brands and retailers. How will climate breakdown affect the local and national governments, suppliers, workers, and global brands sourcing from these centers? To answer this question, we analyze future heat and flooding levels for each country and estimate industry-level shortfalls—earnings not realized and jobs not created—for 2030 and 2050.

To assess heat impacts, we use the projections of heat and humidity analyzed for the global analysis above to estimate changes in worker productivity in apparel manufacturing. We then calculate the resulting changes in apparel export earnings and jobs over the next 25 years. We calculate possible flood inundation levels for more than 8,100 apparel factories in these four countries using detailed projections of coastal and riverine flooding. We translate flood levels into factory-level 'disruption days' and, as with extreme heat, calculate the resulting changes in earnings and employment.

We are able to combine heat-related productivity impacts and flood-related interruptions for each country and measure the income and job gaps under two different scenarios—an apparel industry that is investing quickly in climate adaptation, and another that is not adapting.

2.1 Extreme heat's impacts on industry earnings and employment

From the testimony of apparel workers and managers, we know that high heat and humidity do significant damage to worker productivity and health, and to industry output. And we know from the deep academic literature on the interplay of high heat, labor productivity and economic growth, that the damage is highest in hot and relatively low-income countries: a one degree rise in temperature (Celsius) reduces overall economic growth by 1.3 percent (Dell et al., 2012). The economic effect of these year-on-year losses—compounded as in our analysis below—is substantial over the 30 year period we cover in these two reports.

Macro- and factory-level analyses end up in a similar place: high heat has the power to bend growth curves away from the plans of governments, the hopes of industry and the needs of workers.

15 See, for example, https://www.ft.com/content/0e23cf24-ed9c-4a0a-916c-7059d3795b93, and Judd et al., 2021.

16 WRI flood layers used in our analysis did not model Karachi being exposed to heavy riverine flooding, but the city is still vulnerable and was hit by massive pluvial flooding in 2023: https://www.bbc.co.uk/news/av/world-asia-53945049.

How will extreme heat impact apparel production in our four focus countries? We project earnings and employment impacts of extreme heat for each country in 2030 and 2050 under two growth scenarios. The 'climate-adaptive' scenario presents the growth trajectory of apparel industries that move quickly to reduce heat stress for workers. Here, projected export earnings and employment for 2030 and 2050 are based on compound annual growth rates for apparel export earnings (2016 – 2021) and apparel employment.

We adjust these climate-adaptive projections to calculate export earnings and employment impacts for a 'high heat stress' scenario in which the apparel industry does not act to adapt to extreme heat. Here we combine wet-bulb globe temperature projections with observed changes in productivity due to heat stress: apparel workers' output declines by approximately 1.5 percent for each 1 °C increase in the wet-bulb globe temperature. (Hsiang et al, 2010; Somanathan et al, 2021).[17]

We calculate changes in output for days ('exceedance days') above the significant thresholds for heat stress: 28, 30.5, 32 and 35 °C WBGT. These reduced output projections in the high heat stress scenario are then annualized and expressed in terms of export earnings. Finally, we calculate employment growth based on changes in export earnings under the climate-adaptive scenario and adjust those figures for high heat stress jobs figures using the ratio of earnings under the two scenarios.

Export earnings. In our projections, all four industries continue to grow in nominal terms between 2025 and 2050. But in all four cases, the effects of slower year-on-year growth in earnings are dramatic when compounded, even over the initial five year period between 2025 and 2030. Nominal export earnings in 2030 under the high heat stress scenario will be significantly lower—between 18.9 percent in Cambodia and 30.9 percent in Pakistan—than those in the climate-adaptive scenario.

Table 4. **Heat-related changes in export earnings (nominal USD, billions) in climate-adaptive and high heat stress scenarios, by country for 2030 and 2050**

County	Year	Climate-adaptive scenario* (USD)	High heat stress scenario (USD)	Change (percent)
Bangladesh	2021 (actual)	46.55 b.		
	2030	122.01 b.	95.35 b.	-21.85%
	2050	1,038.22 b.	328.11 b.	-68.40%
Cambodia	2021	15.24 b.		
	2030	35.64 b.	28.92 b.	-18.85%
	2050	235.41 b.	79.31 b.	-66.31%
Pakistan	2021	9.07 b.		
	2030	24.54 b.	16.95 b.	-30.92%
	2050	224.35 b.	43.76 b.	-80.50%
Vietnam	2021	56.99 b.		
	2030	116.80 b.	92.17 b.	-21.09%
	2050	575.46 b.	197.85 b.	-65.62%

**USD are nominal, i.e. not inflation-adjusted.*
Sources: Cornell GLI with data from Katalyst Initiative and Atlas of Economic Complexity 'apparel' trade figures based on HS Codes 4204, 4203, 61, 62, 64 and 65. Analysis undertaken July 2023.

17 See Appendix 1 for a description of our methodology. The academic literature includes several long-term studies measuring the effect of heat on labor productivity, including some conducted in apparel production in S. Asia. For a comparison of heat-productivity approaches and studies, see Somanathan et al (2021) at https://www.journals.uchicago.edu/doi/10.1086/713733#1st_rf7R. Our use of Hsiang (2012) and a 1 - 2 C WBGT decline in manufacturing productivity per degree above 25 C WBGT represents a conservative choice among the approaches.

In these four countries, we project that their combined export earnings in the high heat stress scenario will be 21.9 percent (USD 65.6 billion) lower than in a climate-adaptive scenario by 2030, and 68.7 percent lower (USD 1,424 billion) by 2050.

In our projections, all four industries continue to grow in nominal terms between 2025 and 2050. But in all four cases, the effects of slower year-on-year growth in earnings are dramatic when compounded over just five years. Nominal export earnings in 2030 under the high heat stress scenario will be significantly lower—between 18.9 percent in Cambodia and 30.9 percent in Pakistan—than those in the climate-adaptive scenario.

The widening of the gaps between the scenarios is more extreme by 2050. Export earnings in 2050 dollars will range from 66.3 (Cambodia) to 80.5 (Pakistan) percent lower in the high heat stress scenario.

Apparel industries with relatively low growth rates and lower heat stress levels fare *relatively* well. Those with higher growth rates and higher heat stress will see wider gaps between outcomes in the climate-adaptive and high heat stress scenarios. In Pakistan, the combination of high export growth since 2016 (11.68 percent) and the significant drag of high heat and humidity (annualized productivity declines are -8.62 percent in Karachi and -6.07 percent in Lahore) pull projected earnings dramatically apart. Vietnam fares best in our group: relatively low recent growth (8.28 percent) and relatively low heat-productivity impacts (-6.15 percent in Ho Chi Minh and -3.08 in Hanoi).[18]

This gulf between the outcomes of the climate-adaptive and non-adaptive scenarios has two main causes. First, our analysis cannot account for the ways in which governments, employers and workers adapt to higher heat and 'claw back' some of what extreme heat is taking away in earnings and jobs.[19] (In this way, our approach tracks with the SSPs which are built along similar lines and do not make assumptions about the effects of future changes in policy and adaptation).

The second cause of the wide gaps is the compounding of the effects of lower productivity in long-term projections. The result is that growth paths for non-adaptive industries are effectively redrawn by high heat and lower productivity.[20]

Employment. What about jobs and workers? Total employment in apparel production through 2030 likewise does not go backwards in the high heat stress scenario. But its heat-driven slow-downs in output translate into more than 946,000 jobs that these four industries will fail to create by 2030 if they do not move quickly to adapt. In the context of economies anxious to produce new jobs, this 6.81 percent decline in projected job growth by 2030 is a significant loss.[21] By 2050 the fall-off in the jobs growth rate in the non-adaptive scenario means that these four industries will forego nearly 8.62 million new jobs—a 34.36 percent decline—to be had in a climate-adaptative scenario.

18 See growth rates for export earnings, jobs and exceedance day-output effect calculations in Appendix 1.

19 And a third cause: export earnings figures are reported by governments in nominal, not inflation-adjusted (or 'real') terms. 'Real' earnings figures would be less dramatic in dollar terms but the growing gap between the two scenarios would persist.

20 For a non-technical explanation of the SSP methodology, see Hausfather, 2018. https://www.carbonbrief.org/explainer-how-shared-socioeconomic-pathways-explore-future-climate-change/

21 Historical apparel jobs growth rates lag growth in export earnings. That is, each additional worker creates a multiple in earnings terms.

Table 5. Apparel and footwear employment, climate-adaptive and high heat stress scenarios, 2030 and 2050

Country	Year	Climate-adaptive scenario	High heat stress scenario	Change	Change (percent)
Bangladesh	Baseline	4.22 m.			
	2030	4.83 m.	4.58 m.	-0.25 m.	-5.18
	2050	6.31 m.	5.05 m.	-1.27 m.	-20.05
Cambodia	Baseline	0.70 m.			
	2030	0.94 m.	0.89 m.	-0.05 m.	-5.54
	2050	1.70 m.	1.14 m.	-0.56 m.	-32.66
Pakistan	Baseline	2.75 m.			
	2030	3.43 m.	3.14 m.	-0.30 m.	-8.63
	2050	5.37 m.	3.51 m.	-1.85 m.	-34.53
Vietnam	Baseline	2.97 m.			
	2030	4.70 m.	4.35 m.	-0.35 m.	-7.41
	2050	11.70 m.	6.75 m.	-4.94 m.	-42.26

Sources: Cornell GLI and data from ILOStat, BGMEA, Vietnam National statistical yearbook.
Analysis undertaken July 2023.

As with export earnings, apparel employment climbs in all four countries under both climate-adaptive and high heat stress scenarios, but significantly more slowly in Vietnam. This is a product of a high apparel jobs growth rate in recent years and an export earnings growth rate lower than the other three countries. Bangladesh, with a comparatively lower jobs growth rate since 2016 fares best, but still faces a fall-off of 1.26 million new jobs in apparel production by 2050.

We note, too, the enormous secondary income and jobs effects that follow from export-driven growth. It is possible that governments, investors and industrialists in these countries will have managed by 2050 a transition away from apparel production to other sectors or to low-carbon, capital-intensive apparel production. Or they will shift to some combination of the two.[22] Vietnam is already moving along this path with, for example, more stringent water treatment requirements and planning restrictions for new apparel plant construction. But for economies with apparel production in their plans, our projected declines in apparel industry growth mean lower economic growth and lower government revenue from exports, industry earnings and wages.

22 For evaluation of just transition challenges see, for example, Huq and Khan (2023) at https://www.brookings.edu/wp-content/uploads/2023/02/Chapter-2.-Just-and-green-transition-in-Bangladesh-1.pdf.

'GREEN' FACTORIES AND ADAPTATION EFFECTS

What about industries that are adapting, even on a small scale? An alternative analysis for Bangladesh allows us to estimate the long-run differences that integrated changes in factory design might have on temperatures and productivity and, therefore, on export earnings and jobs projections.

We see in Bangladesh, and in other mature apparel and footwear industries, a move away from the dense urban industrial areas in which they first grew. Investments in new factories often means pushing into rural or ex-urban areas where land is less expensive and 'heat island' effects are smaller. The Arsht-Rockefeller-published 'Hot Cities' (2022) report on Dhaka's intense heat notes that in one of the city's lowest-income districts "containing a high concentration of informal settlements with widespread use of corrugated iron sheet roofing, temperatures are typically 12 °C higher than Dhaka's surroundings."

We offer here a calculation of possible impacts of investments in 'green' factories—with passive cooling design elements and energy-efficient active air-cooling systems—on the industry's future. Bangladesh's industry has made urgent (and heavily-promoted) investment in certification of 'green factories', but we use the term advisedly here. (The Bangladesh industry's investment in LEED certification of factories, with its focus on energy efficiency, tells us little or nothing about their effects on workplace temperatures. LEED-certified factories may, or may not, make improvements in ventilation, roofing materials, workplace crowding, heat from machines, and active cooling systems. It makes 'green'/LEED factories imperfect proxies for cooler factories and more comfortable and productive workers.)

To the extent that 'green' factories make these investments in indoor cooling technologies and production practices, evidence from studies in India and Bangladesh suggest that investments can reduce heat stress and claw back losses in worker productivity.

The introduction of LED lighting in a group of Indian apparel factories reduced indoor temperatures in the hottest months of the year by an average 2.4 °C (Adhvaryu, 2020). In Bangladesh, this passive cooling investment would correspond to an annualized 1.25 percent increase in productivity compared with factories making no changes. In a second study, a suite of other cooling practices—green or shaded roofs, exhaust and industrial fans, sufficient work breaks and adequate water—are predicted to reduce indoor temperatures by 2 °C in Bangladesh's hottest months and improve apparel worker productivity by an annualized 1.41 percent (Bach et al., 2022).

Combining these two temperature-productivity impacts, we estimate a 2.66 percent annualized productivity effect by 2030.[23] If one-half of apparel manufacturers have invested in 'green' improvements—new factories, retrofits, efficient passive and active cooling systems—the resulting improvements in worker productivity can claw back 28.44 percent of the export earnings by 2030 (USD 7.58 b.) and 73,372 of the jobs foregone in the high heat stress scenario.[24] The effects compound in the longer term and the gap between the climate-adaptive and 'green' factory earnings will narrow. Pushing the share of 'green' factories above 50 percent and assuming higher productivity gains from improved production practices, we would see much larger impacts by 2040 and 2050.

These figures may encourage the optimists and discourage the realists. Achieving the 'green' industry growth rates depends on sustained high levels of investment for energy efficiency gains—a global climate mitigation goal—and signification investments in adaptation goals such as cooler buildings and effective social protection systems. We take up the costs (and financing) of factory- and industry-level adaptations in our second report.

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23 We note the overlap in fan technologies in the two studies. Future research of certified factories could measure changes in worker heat stress in 'green' factories.

24 The 500 larger 'green'/LEED certified factories are estimated to represent an estimated 20 percent of export earnings in 2030 and 50 percent in 2050. Per an interviewee for this report, "Any producer who can't over a few years deal with and offset a 5 percent productivity loss with other changes is not a good one".

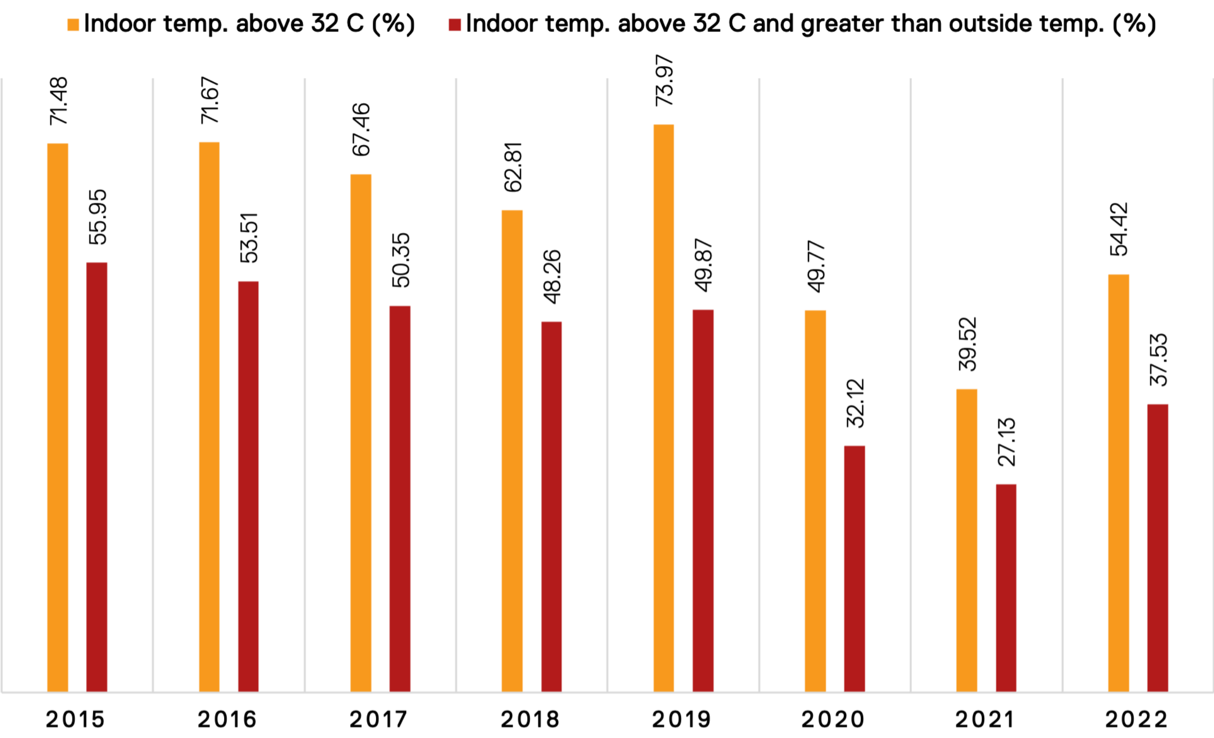
2.2 Cambodia: In-depth factory temperature readings from the ILO's Better Work program

The ILO's Better Factories Cambodia program assesses all exporting apparel and footwear factories and applies its own threshold (32 C°) for acceptable levels of indoor heat. The ILO program uses dry globe temperature sensors to obtain consistent and reliable factory temperature readings from nearly 3,000 ILO assessments in Cambodian factories between 2015 and 2022, but not for the other three countries surveyed here. Our analysis found that:

- Workers in one in five factories during this seven-year period experienced days when the indoor temperature was over 35 °C.
- Nearly two-thirds (64 percent) of the ILO's factory assessments in Cambodia showed indoor temperatures above the Better Factories Cambodia heat threshold.
- More than two-thirds (69 percent) of factories in violation of the heat standard had temperatures ***inside*** the factory that were higher than the concurrent outdoor temperatures.
- Data show improvement over time, from a high of 74.0 percent of factories in violation of the 32 °C threshold in 2019 to 54.4 percent in 2022.

The annual data in Figure 3 below relate to the number of factories in which indoor temperatures exceeded 32 °C, and that ranges from 49 – 71 percent.

Figure 3. **Cambodian apparel factories (percent) with indoor temperatures above 32 °C (dry-bulb) and hotter inside than outside, 2015 – 2022.**

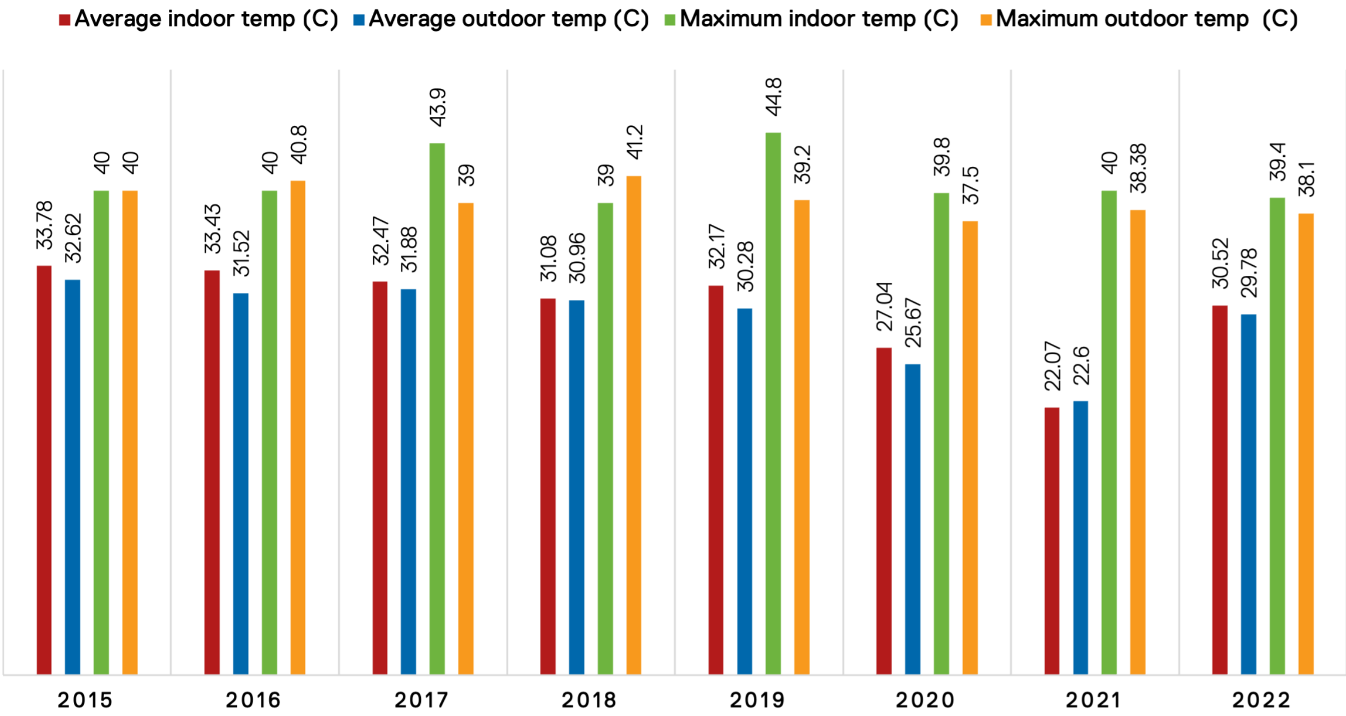


Sources: Cornell and ILO Better Work. Analysis undertaken July 2023.

We are particularly concerned about the effects on workers when the temperature inside the factory is above 32 °C and higher than the temperature outside the factory. On hot days, the design and activity of these factories is adding heat to the indoor environment. This measure shows improvement over the period, 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.

Figure 4 allows us to compare the average and maximum indoor temps across all factories by year, and although relatively few factories recorded these high maximum temperatures, they are indicative of the high levels of heat stress that could be produced.

Figure 4. Average and maximum indoor and outdoor temperatures, by year 2015 - 2022.



Sources: Cornell GLI, ILO Better Work. Analysis undertaken July 2023.

Has there been improvement over time? Yes. We note the general decline in indoor temperatures. But progress has been slow: 70.8 percent of factories that exceeded the 32 °C standard were non-compliant more than once.

We note too that the biggest year-on-year improvements came in 2020 and 2021 during the COVID-19 pandemic when some ILO assessments were conducted remotely and temperature and ventilation readings were not taken. In those cases, findings of non-compliance from previous assessments were carried over. ILO measures resumed in the waning months of the pandemic and violations and indoor-hotter-than-outdoor measures both bounced back up in 2022.

Recognizing that the simple averaging of temperature readings across a year does not take into account seasonal variations, we examined average indoor temperatures from assessments during the hottest months in Cambodia—March to May—and the most humid months, from June to August. As expected, average indoor temperatures were higher between March and May in these years, and that violations of the 32 °C standard run at 80 percent.

What if the ILO (and employers) reported wet-bulb readings? The average indoor (dry-bulb) temperatures between June to August were slightly lower that in March to May, but average humidity is considerably higher in the rainy season (78.7 percent vs 71.0 percent). This means that wet-bulb measures would likely be higher between June and August when, typically, employers and workers are under pressure to complete orders for year-end holiday shopping in the U.S. and Europe.

COOLING SYSTEMS, HIGH HEAT AND HEAT STRESS.

The flip-side of the indoor temperature violations in Cambodia are of course compliant with the ILO Better Factories Cambodia threshold. Data provided to us for this report by a long-time, large-scale apparel manufacturer near Phnom Penh allow us to see inside using daily dry-bulb and humidity readings from July, August and December 2022. Using an evaporative water-cooling system, exhaust fans, 13-meter-high ceilings and a heat shield on the roof, the factory kept recorded dry-bulb temperatures within the 32 °C threshold.

Calculating a 'simple' wet-bulb temperature index for the factory, we see that the combination of indoor heat and humidity would have pushed the wet-bulb index past the 30.5 WBGT threshold, at which the recommended work-rest ratio is 50/50, on only one of the 90 days for which we have data. And the indoor average index in July—the hottest of the three months—is 27.8 °C WBGT, only 1.5 °C WBGT higher than the average in December, the coolest month.

We note a similar effect in a major textile and apparel manufacturer near Lahore, Pakistan. Data from this factory provided to us for this report is less detailed but also includes monthly energy-usage totals for its cooling systems. Its combination of exhaust fans, chillers (refrigerant air-cooling systems) and water-evaporative air-coolers, held average monthly indoor temperatures between 27 and 31 °C in April, May and June 2022—the hottest months in the year.

The indoor monthly averages were in all cases lower than the outdoor monthly averages recorded for Lahore: 27.8 °C (indoor) vs 31.6 °C (outdoor) in April, 30.0 vs 33.4 in May, and 28.0 vs 30.0 in June. The cooling systems used a monthly average of 1.48 million kilowatt hours (kWh) to cool the buildings in 2022, and usage in April, May and June ran only 6.2, 7.5 and 19.0 percent ahead of the factory's monthly average.

These brief studies of adaptation effects and the alternative scenarios analyzed above provide some encouragement, and we take up the costs and financing of factory-level adaptation in our second report. The growing academic literature on heat and manufacturing output is likewise encouraging. Economic arguments for investments in workers that address both social and environmental challenges are clear and getting stronger.

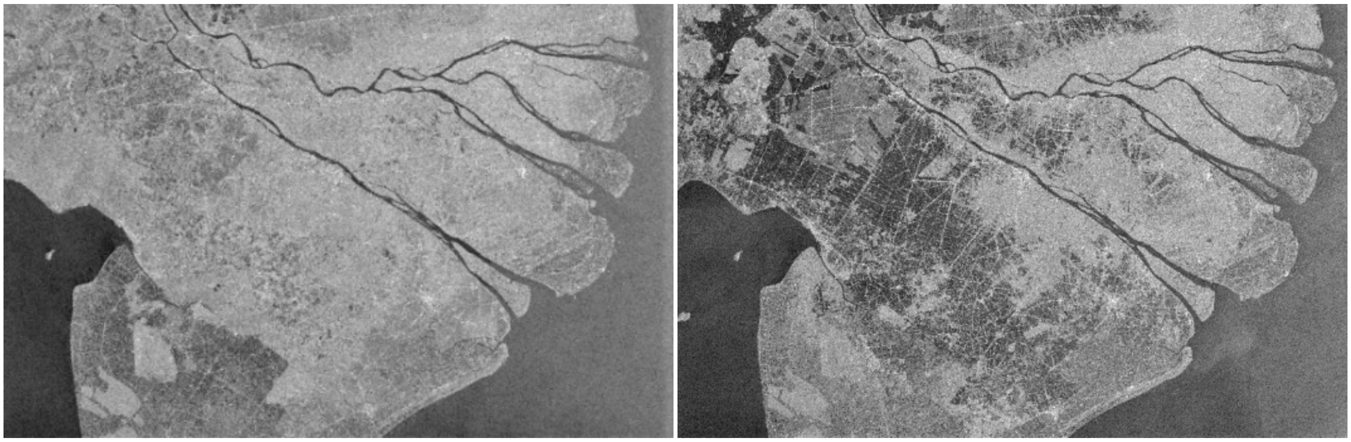
However, our industry-level analyses of heat levels—persistently high indoor temperatures, looming increases in wet-bulb temperatures—and the prospects for significant damage to future apparel earnings and job creation are worrying. In the following section, we drop the other shoe. What do our flood projections mean for interruptions to output and earnings?

Faisalabad, Pakistan. Photo credit: Cornell GLI

2.3 Flooding impact estimates on industry earnings and employment

Vietnam's tropical maritime climate and extensive seasonal flooding rank it among the most climate-vulnerable countries in the world. It nonetheless has developed a critical role in apparel and footwear production and export, second only to China. Nike sourced 44 percent of its footwear from Vietnam in 2022, and most of that in southern Vietnam. The figure for Adidas was 32 percent (Duc, 2023).

Figure 5. **Satellite images of southern Vietnam in the dry season of April 2022 (left) and during extensive flooding (in darker areas) in October 2022.**



Sources: Sentinel 1 (EU/Copernicus), Intensel.

We performed a geospatial analysis of the impact of flooding for apparel production and its workers across our four focus countries. The projected impacts are expressed in the same terms as for heat: changes in export earnings and jobs in 2030 and 2050.

Using flooding models based on our middle-of-the-road climate scenario (RCP 4.5),[25] we are able to project and map inundation levels for more than eight thousand apparel and footwear factories based on their topographies and flood patterns.[26] We estimate annual 'disruption days'—the production days lost to flooding and recovery—in a non-adaptive scenario for each factory in 2030 and 2050 using the maximum 'inundation depths' from coastal and riverine flooding for two-, ten- and one hundred-year events, or 'return periods' (RP2, RP10, and RP100). As with heat-productivity impacts above, we convert these disruptions into aggregate annual impacts on export earnings and jobs.

In the maps below, coastal flooding is represented in gold and riverine flooding in red. Deeper shades signal higher inundation levels at 0.25 m. intervals, up to 1 m. and higher. Apparel and footwear factories are shown in blue.

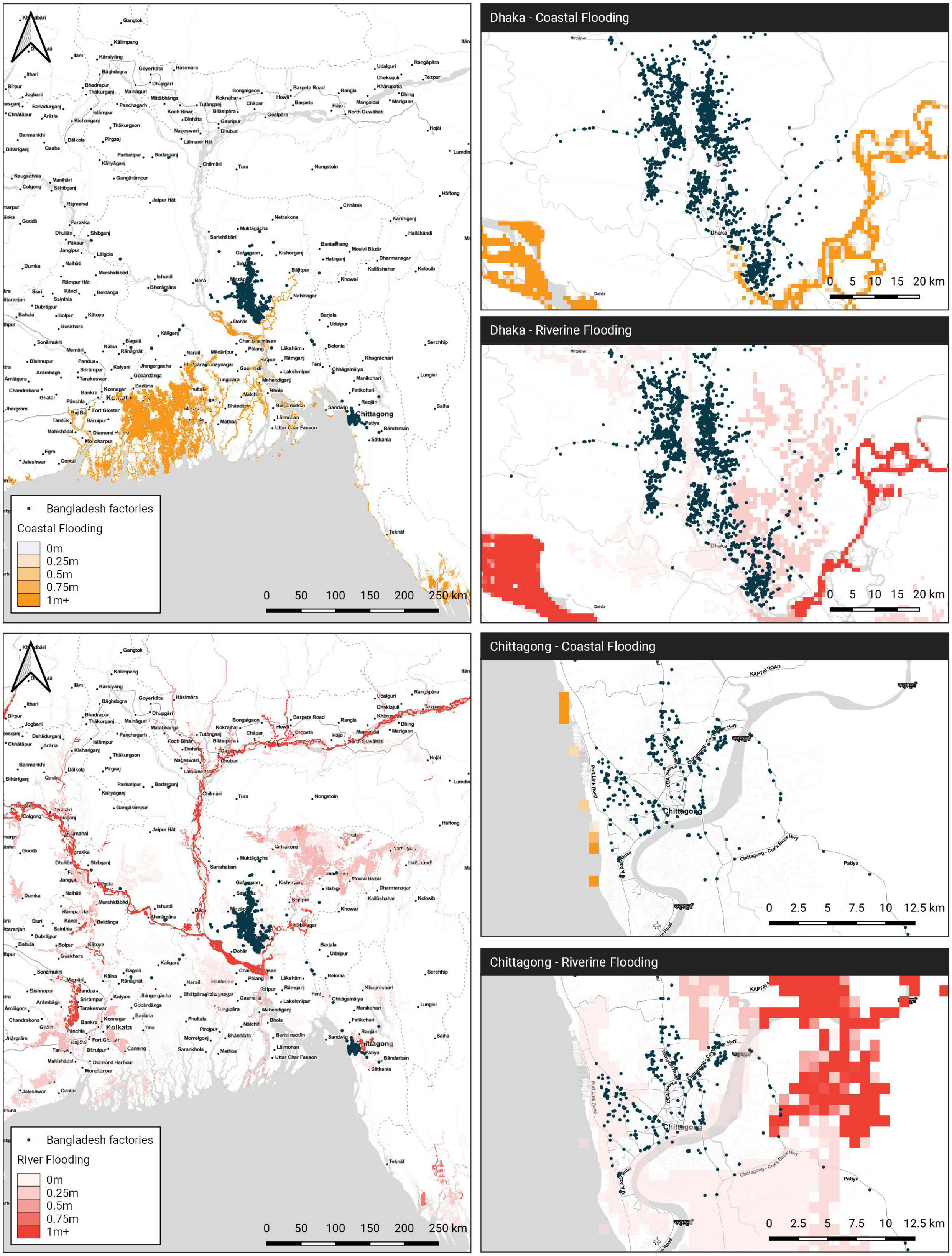
We illustrate the approach first with our analysis of flooding in the Bangladeshi industry. Figure 6a presents near-term and relatively routine flooding: projected flooding for 2030 for a two-year return period (RP2). Swathes of factories in Dhaka and Chattogram, in close-up below, will be aggravated by riverine flooding (red). Coastal flooding and tidal surges (gold) will have less impact. Apparel factories near Narayanganj, southeast of Dhaka, are at risk of flooding as are factories along the coast and the Karnapuli River in Chattogram—a few of them at 1 meter or more.

The second group of maps marks a dramatic change. Our 2050 projections of 10-year event (RP10) for both coastal and riverine flooding show significant and widespread inundation for factories in Dhaka and Chattogram. The riverine flooding in particular has spread widely and at depths of 1 m. and more, presents a significant risk for apparel manufacturers, their buyers and workers.

25 RCP 4.5/SSP2 scenario used the World Resources Institute's Aqueduct Floods Tool corresponds to SSP 2-4.5 used in our heat analyses.

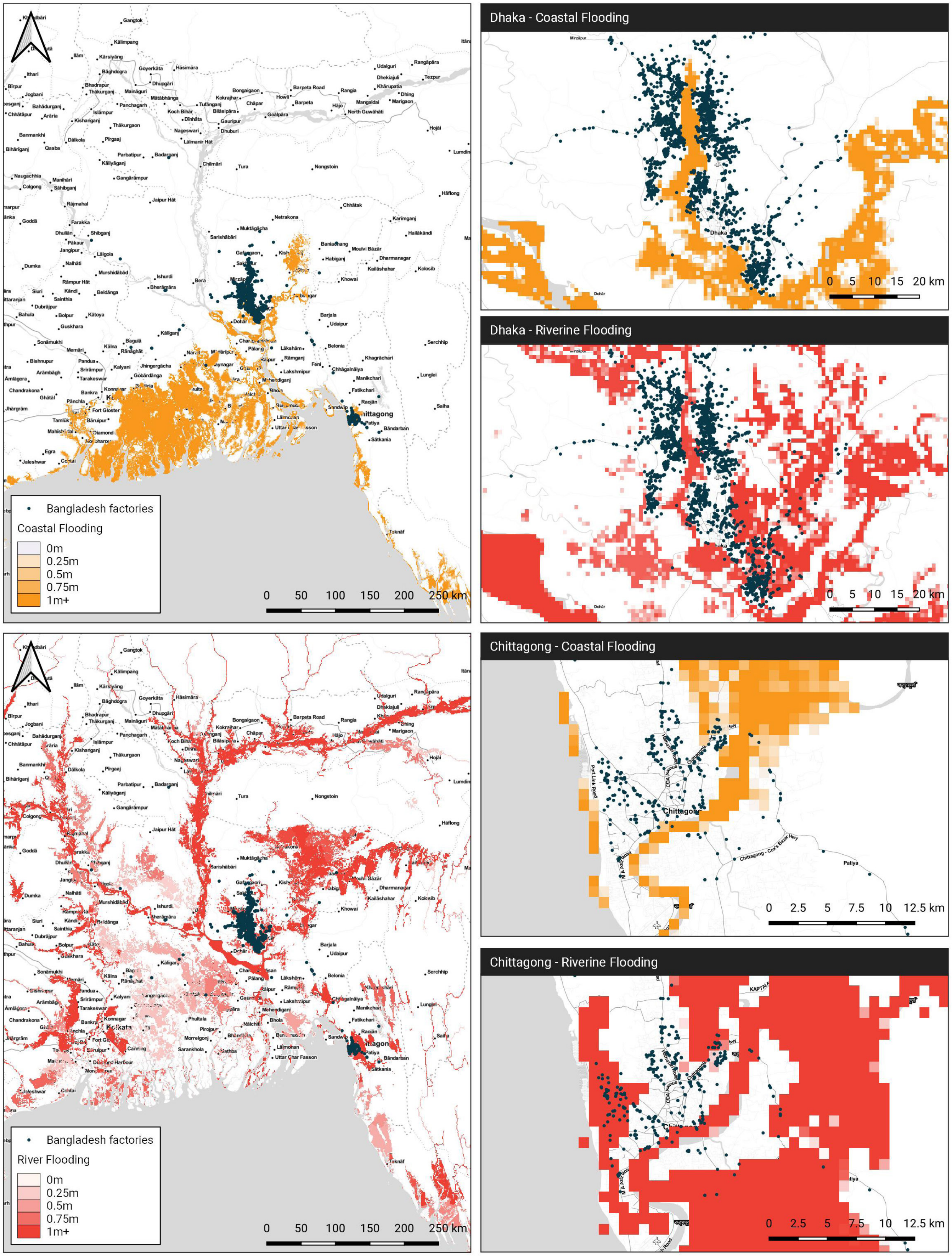
26 Apparel and footwear factory locations (geospatial coordinates) used in these analyses come from disclosures by brands, Mapped in Bangladesh, and Open Supply Hub.

Figure 6a. Coastal and riverine inundation levels for 2030 (RP2), Dhaka and Chattogram (Chittagong), Bangladesh



Sources: Schroders, WRI, brand disclosures, Mapped in Bangladesh, OSH. Analysis undertaken July 2023.

Figure 6b. Coastal and riverine inundation levels for 2050 (RP10), Dhaka and Chattogram (Chittagong), Bangladesh



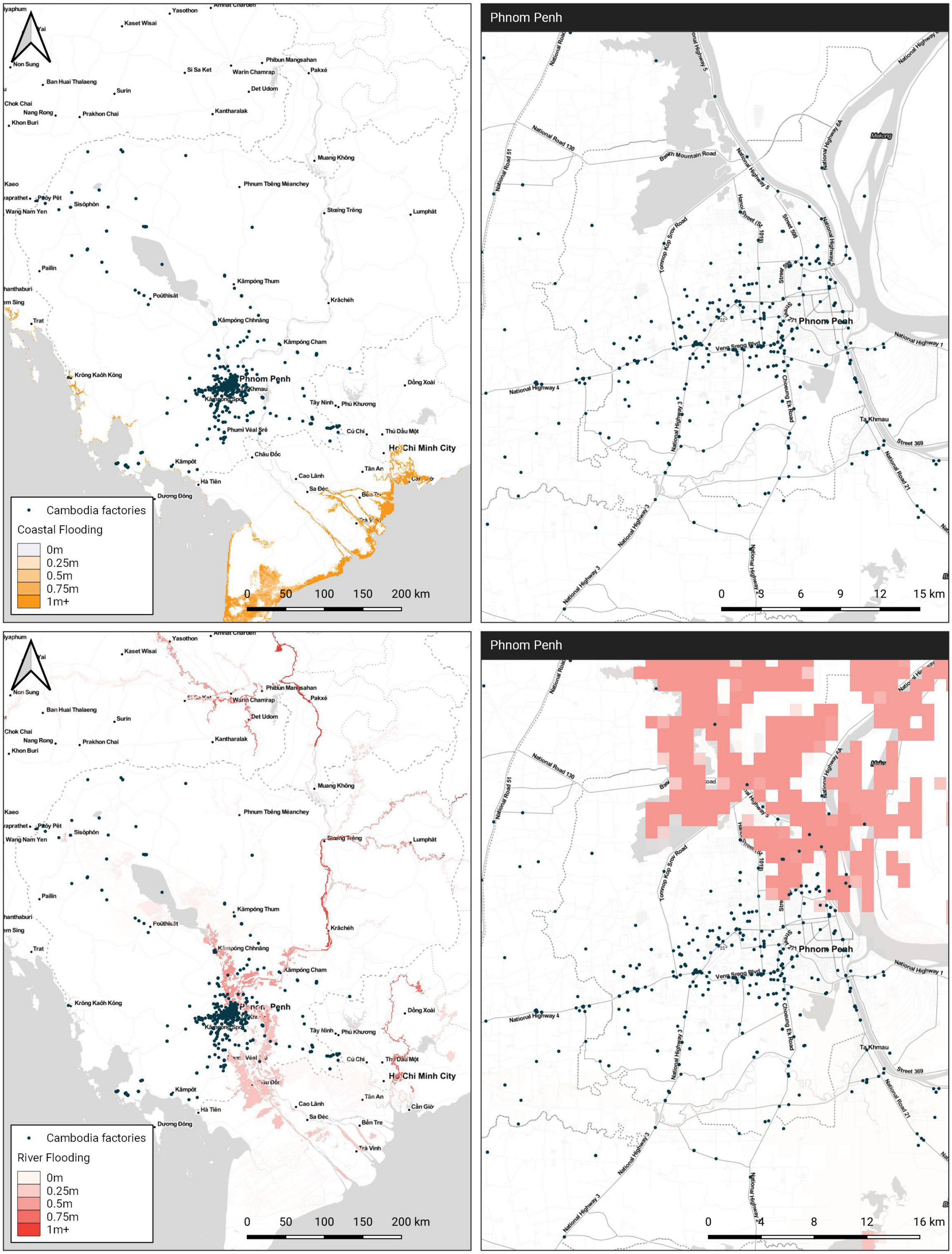
Sources: Schroders, WRI, brand disclosures, Mapped in Bangladesh, OSH. Analysis undertaken July 2023.

Across the 2030 and 2050 flood analyses, nearly 82 percent of factory disruptions in Bangladesh will be caused by riverine rather than coastal flooding. Notable in the riverine analysis is the number of factories at risk of significant flooding in 2050 in a 10-year flood scenario—349 factories, or nearly 10 percent of the industry—and the jump in the number of factories (108) by 2050 facing severe flooding of more 1 meter. The comparable figure for 1 meter or more of coastal flooding in 2050 is 92 factories.

A worst-case scenario in 2050, with distinct riverine and coastal RP100 flooding events, shows 26.6 percent of the Bangladeshi apparel industry inundated at 0.5 meters or higher.

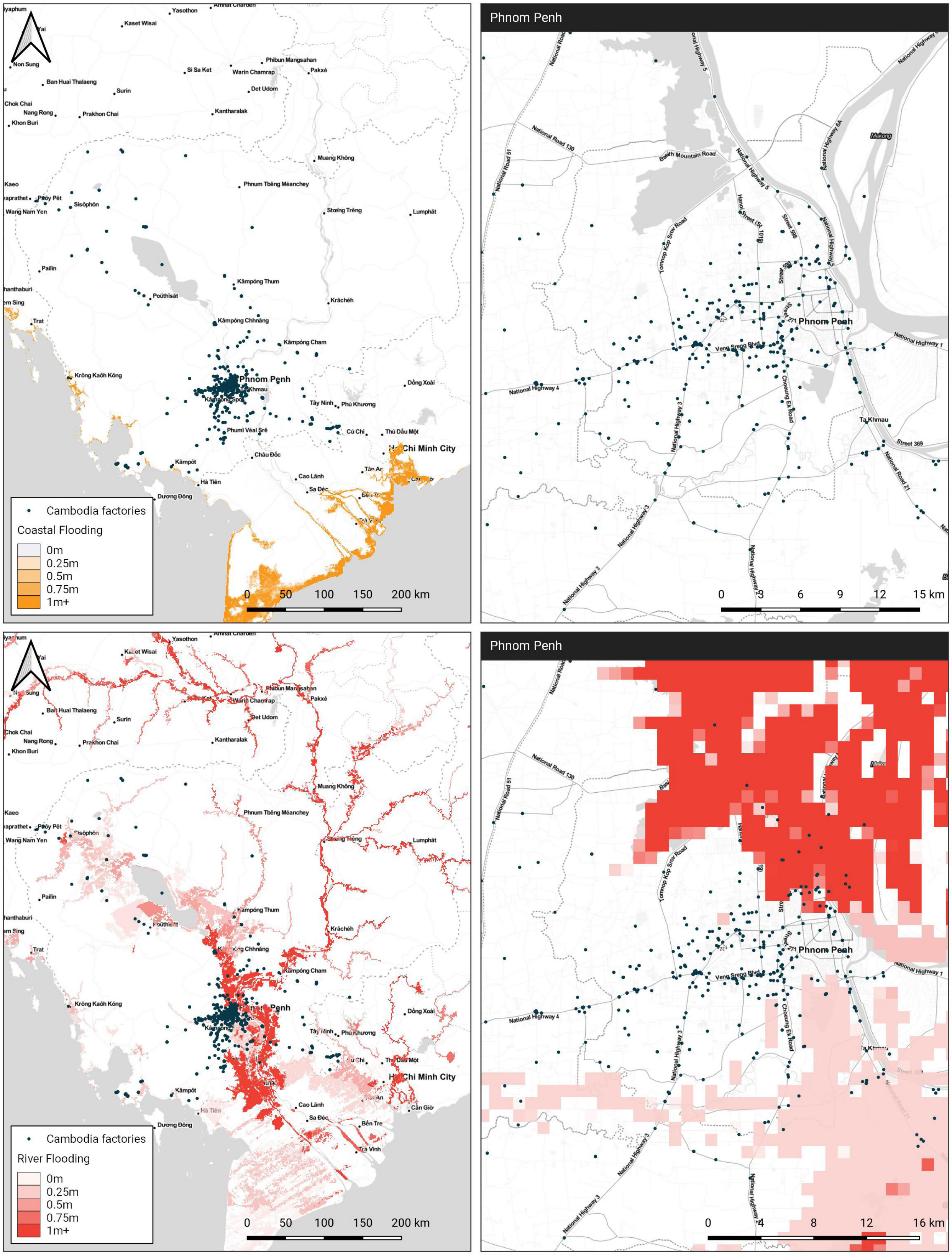
We present below the flooding analyses for two- and ten-year return periods in 2030 and 2050 under the RCP 4.5 scenario for Cambodia, Pakistan and Vietnam. Flooding for both Hanoi and Ho Chi Minh, and for Karachi and Lahore and nearby Faisalabad, are included.

Figure 7a. Coastal and riverine/rainfall inundation levels for 2030 (RP2), Phnom Penh, Cambodia.



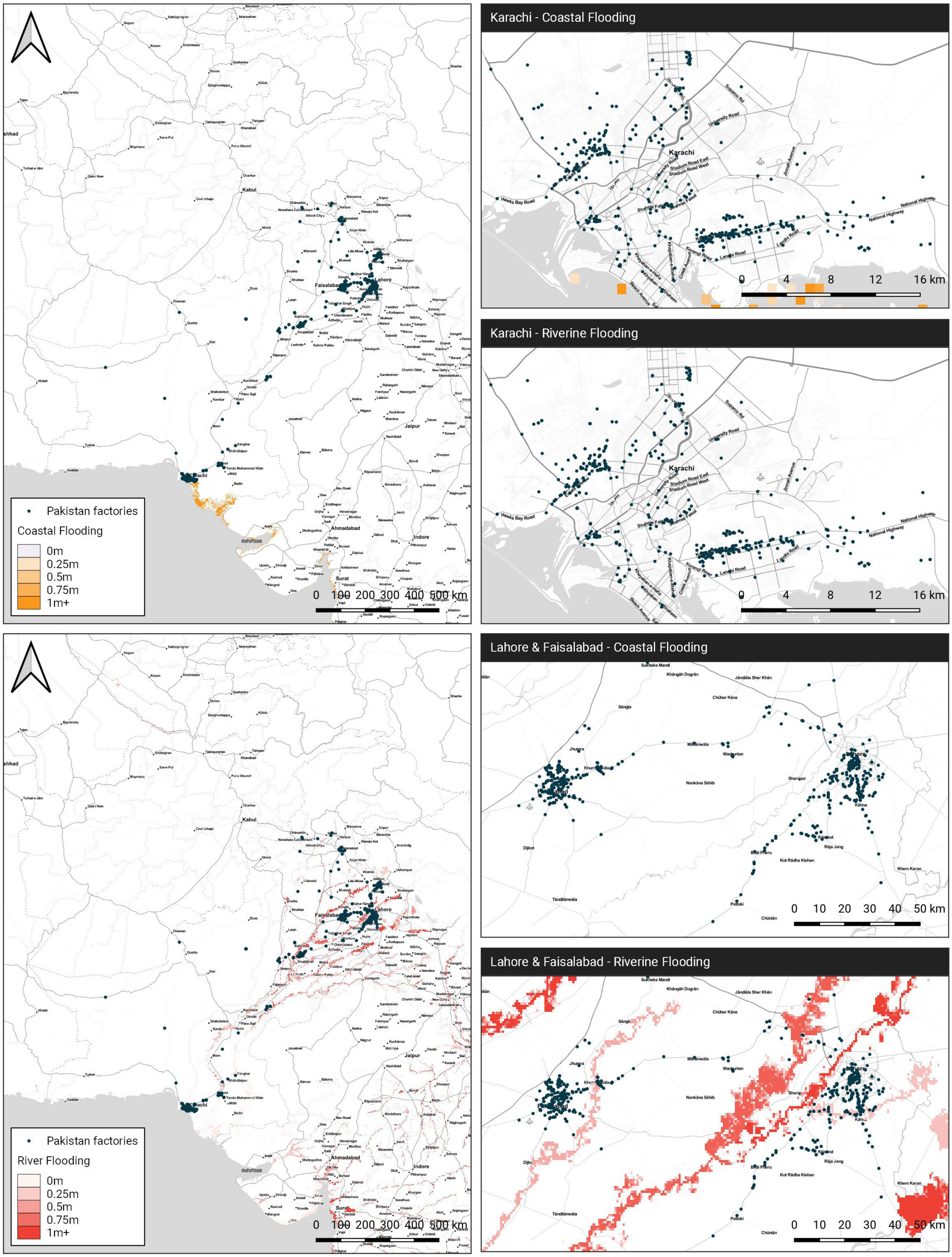
Sources: Schroders, WRI, brand disclosures, Mapped in Bangladesh, OSH. Analysis undertaken July 2023.

Figure 7b. Coastal and riverine/rainfall inundation levels for 2030 (RP2) and 2050 (RP10), Phnom Penh, Cambodia.



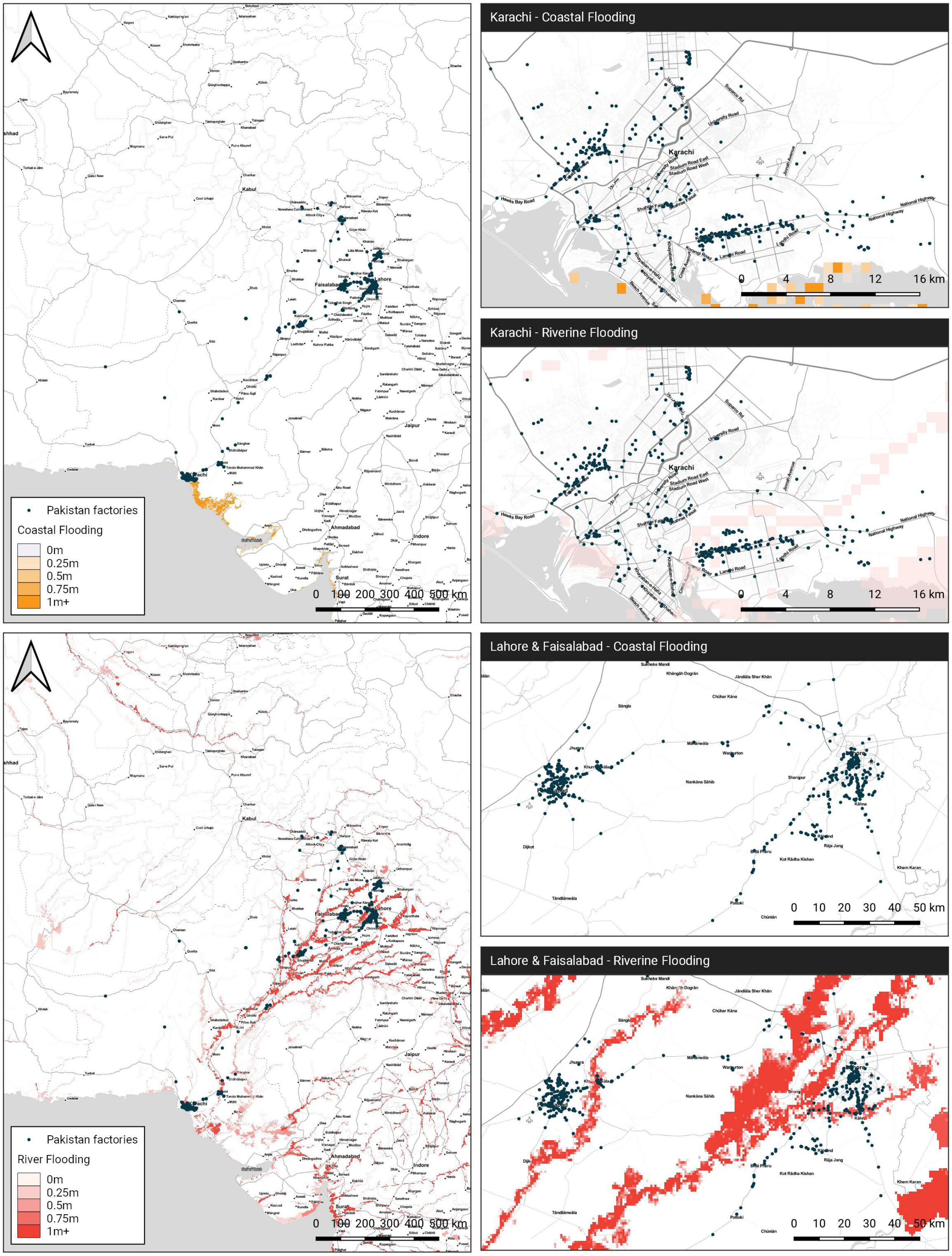
Sources: Schroders, WRI, brand disclosures, OSH. Analysis undertaken July 2023.

Figure 8a. Coastal and riverine/rainfall inundation levels for 2030 (RP2), Karachi and Lahore/Faisalabad, Pakistan.



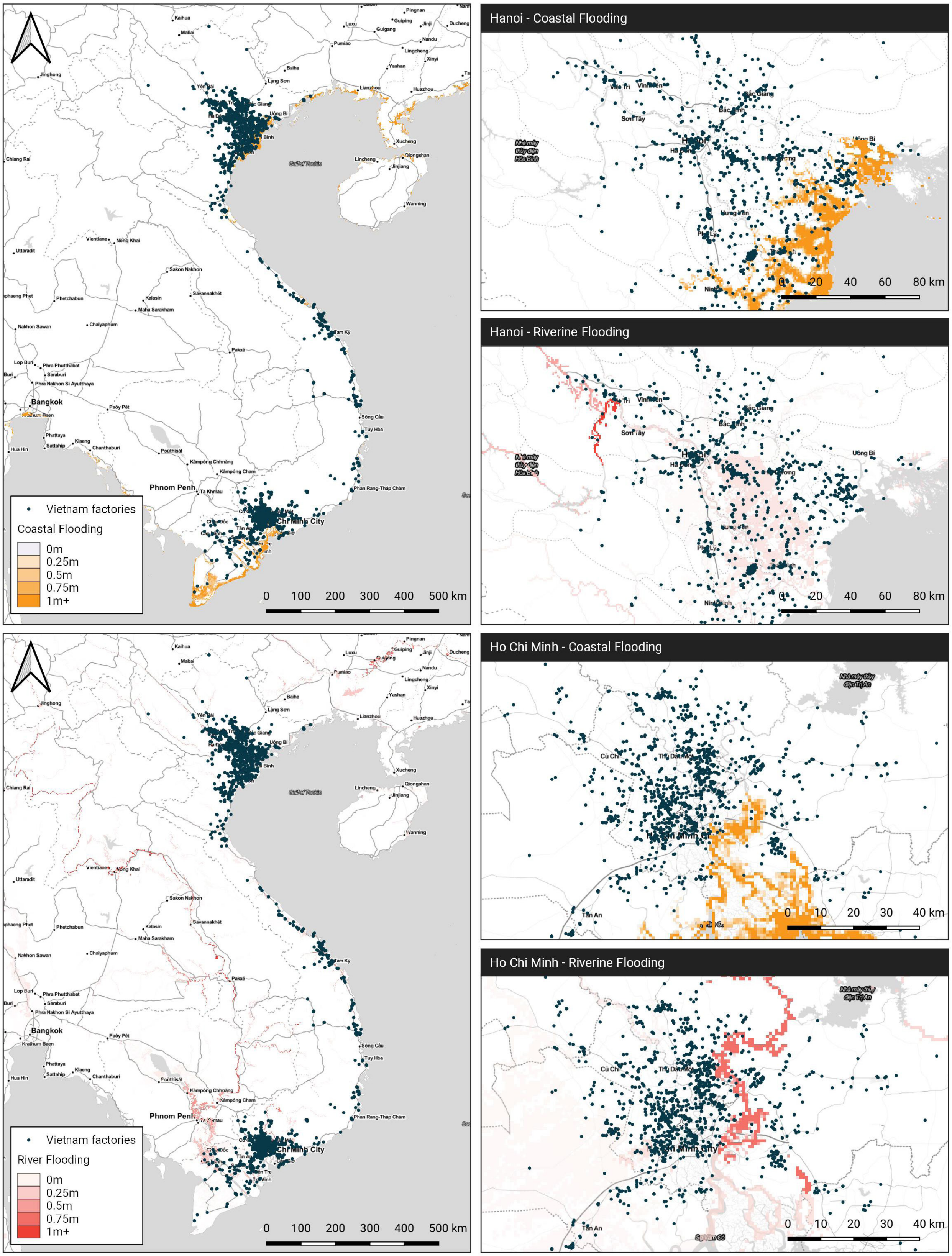
Sources: Schroders, WRI, brand disclosures, Mapped in Bangladesh, OSH. Analysis undertaken July 2023.

Figure 8b. Coastal and riverine/rainfall inundation levels for 2050 (RP10), Karachi and Lahore/Faisalabad, Pakistan.



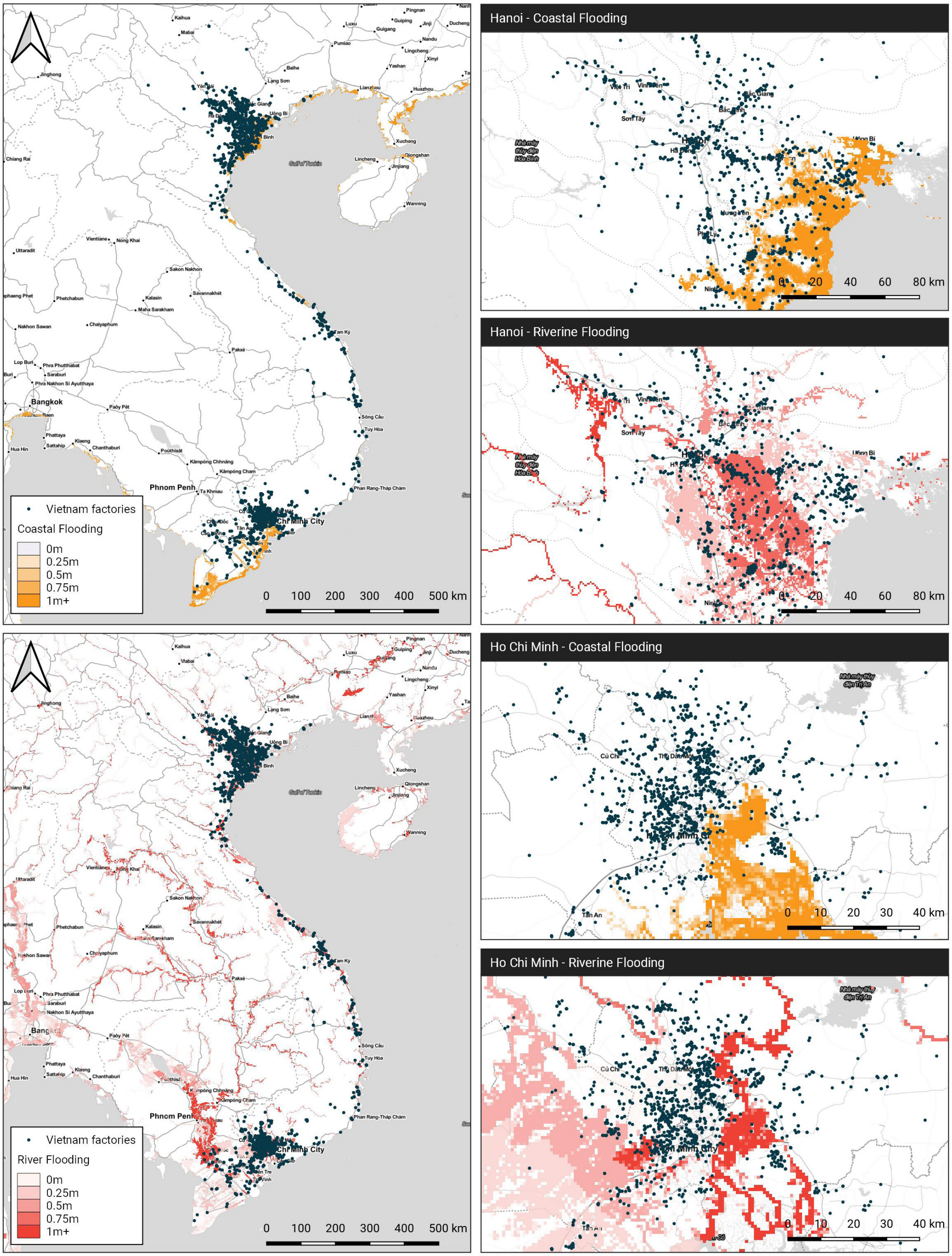
Sources: Schroders, WRI, brand disclosures, Mapped in Bangladesh, OSH. Analysis undertaken July 2023.

Figure 9a. Coastal and riverine/rainfall inundation levels for 2030 (RP2), Hanoi and Ho Chi Minh City, Vietnam.



Sources: Schroders, WRI, brand disclosures, Mapped in Bangladesh, OSH. Analysis undertaken July 2023.

Figure 9b. Coastal and riverine/rainfall inundation levels for 2050 (RP10), Hanoi and Ho Chi Minh City, Vietnam.



Sources: Schroders, WRI, brand disclosures, Mapped in Bangladesh, OSH. Analysis undertaken July 2023.

Riverine and coastal flooding impacts for apparel and footwear factories in Chattogram, Dhaka, Hanoi and Ho Chi Minh City are greatest. Their spread and depth of inundation grows, as expected under RP10 in the 2050 projections.

Vietnam is arguably better prepared for flooding. Measures of 'preparedness' from the University of Notre Dame's GAIN index for climate breakdown put it ahead of the other three countries in this survey. But the Hanoi region's factories are threatened by significant coastal flooding in the near term and widespread coastal flooding by 2050. Riverine flooding is significant in both Ho Chi Minh/Mekong River delta and Hanoi and the source of nearly two-thirds of disruption in Vietnam. Our 'worst-case' flooding in 2050—separate riverine and coastal RP100 events—shows 21.9 percent of Vietnam's apparel industry inundated at 0.5 meters or higher.

Routine riverine flooding (RP2) in Phnom Penh in 2030 is concentrated north of the city where factories are relatively few. But the contrast with 10-year flooding events in 2050 is marked. Production there will face more and higher flooding, including south of the center where apparel production is relatively dense. Cambodia's 2050 'worst-case' puts 7.2 percent of its apparel industry at risk of inundation in flooding of 0.5 meters or higher. While Karachi fares well in the flooding scenarios, riverine flooding in Lahore and Faisalabad encroaches on apparel (and textile) production there in 2050. Pakistan's 'worst-case' has less than four percent of factories at risk of significant flooding, but our modeling misses, for example, the impacts of widespread rural flooding in 2022 and its effect on apparel production as workers tend to families in those regions.

Using our projections for maximum inundation levels for individual apparel factories, we are able to estimate the costs of disruptions to apparel and footwear production.[27] Table 6 includes the numbers of factories inundated by coastal and riverine flooding at intervals from 0.25 – 1 m. and higher. Higher inundation levels require longer discharge and recovery periods. We estimated these conservatively based on interviews for this report with factory managers, workers and climate analysts: three 'disruption' days for inundation up to 0.5 m., six days for 0.5 to 1 m. and 12 days for inundation levels over 1 meter.

Well-prepared or -defended manufacturers may avoid serious delays. Poorly-sited or -prepared manufacturers may suffer longer interruptions. To account for the relative quality of infrastructure investments designed to limit flooding risk, we adjust each country's total disruptions days in the table below using the GAIN index of relative 'preparedness' scores (2023). Bangladesh is least prepared in the scoring among our focus countries so its totals are unadjusted (1.0). Cambodia is a very close second (1.01), followed by Pakistan (1.18), and Vietnam (1.53).

As with heat-related impacts above, aggregate annual flood disruption days allow us to calculate impacts for industry export earnings and employment in a non-adaptive scenario.

27 Most latitude and longitudinal coordinates comes from buyer-disclosed lists of Tier 1 apparel and footwear manufacturers.

Table 6: Apparel and footwear export earnings (nominal USD) and jobs impacts from coastal and riverine flooding in 2030 and 2050, by country

Country	Year	Disruption days	Preparedness adjusted days	Earnings change (USD nominal)	Employment change	Riverine share of total (%)
Bangladesh	2030	1,163	1,163	-127.85 m.	-5,057	84
	2050	1,290	1,290	-1,206.57 m.	-7,333	79
Cambodia	2030	148	146	-30.96 m.	-817	100
	2050	157	154	-215.77 m.	-1,557	100
Pakistan	2030	86	77	-5.60 m.	-784	100
	2050	90	81	-53.56 m.	-1,281	100
Vietnam	2030	1,369	896	-130.48 m.	-5,245)	68
	2050	1,549	1,013	-727.37 m.	-14,784	61

Sources: Cornell GLI, Schroders, WRI. Flood return periods are RP2, 10 and 100 based on RCP 4.5, adjusted for probability. Analysis undertaken July 2023.

Projected disruption days run highest in Vietnam, followed closely by Bangladesh and the projected impacts on their respective earnings are similar in 2030. Impacts on earnings in Bangladesh are higher in 2050 because of the latter's higher growth rate and because of it relatively low 'preparedness' for climate breakdown. Cambodia and Pakistan—smaller industries on the whole—see fewer disruptions from flooding and no or nominal coastal flooding impacts.

Export earnings and jobs impacts from both types of flood events are significant by themselves but they are lower than in our analyses of heat-related costs. This holds true in our brand-level analysis in our second report. Why? A few notes on our analysis and its limits help to explain why our projections necessarily *understate* the flooding impacts.

First, inundation levels represent maximum flood levels per return period. That is, only one flood event is scored per factory per return period because flood events are generally more difficult to model than changes in temperature (Joint Global Change Research Institute et al., 2009). Lesser and chronic floods cannot be included in the analysis and those interruptions to production are un-counted. And as noted above, our analysis focuses on the likeliest flood events, using two- and ten-year return periods rather than 50, 100, or even 250. This means our analysis focuses on the near-term, and our earnings and jobs estimates are conservative.

Second, while heat effects are general, flooding is relatively isolated. A one-meter flood that causes a 15-or 25-day pause in production can be devastating for a single factory or an industrial area, with long-term costs that run well ahead of heat-related damage to output and income in those factories. In some formulations, these delays are estimated to last four times longer than the flooding and discharge of water.

The long-term damage to machinery and materials can be costly and slow to repair. Delays in delivery can cost future orders, result in discounts on the completed orders and, in some cases, expensive air-freighting of orders. In an interview for this report, a long-time sourcing director argued that extreme heat is predictable and therefore manageable. Flooding, on the other hand, is an 'intangible' and the material risk is greater.

Finally, our analyses are unable to 'see' factory-level flood defenses or nearby draining infrastructure and are therefore unable to calibrate discharge rates. Flood risk for apparel producers is more than digital topography and proximity to rivers or coast. Urban planning (or its lack), infrastructure design or construction, and corruption of corporate and public officials mean that flooding effects can vary widely, factory-to-factory and block-by-block. In interviews for this report, apparel managers and workers noted demonstrated how routine rainstorms could mean days of hip-high flooding in a poorly planned factory or neighborhood. Severe flooding around well-designed factories or neighborhoods can dissipate by mid-afternoon.

FACTORY FLOODING, UP CLOSE

To illustrate how different climate scenarios and urban-industrial planning affect flooding projections, we look closely at rainfall flood severity levels (up to 3 meters) for individual apparel and footwear factories using a geospatial analysis of the Mekong River delta region of southern Vietnam, conducted for this report by Intensel, a global climate risk analytics firm based in Hong Kong and Singapore.

Moving in much closer, we can see how rainfall floods may potentially affect ten manufacturers for leading global brands in industrial parks in Binh Duong, 15 kilometers northwest of central Ho Chi Minh City. Flood severity levels for these factories—all within a three-kilometer radius—vary from relatively low to very high as a function of topography and flood patterns.

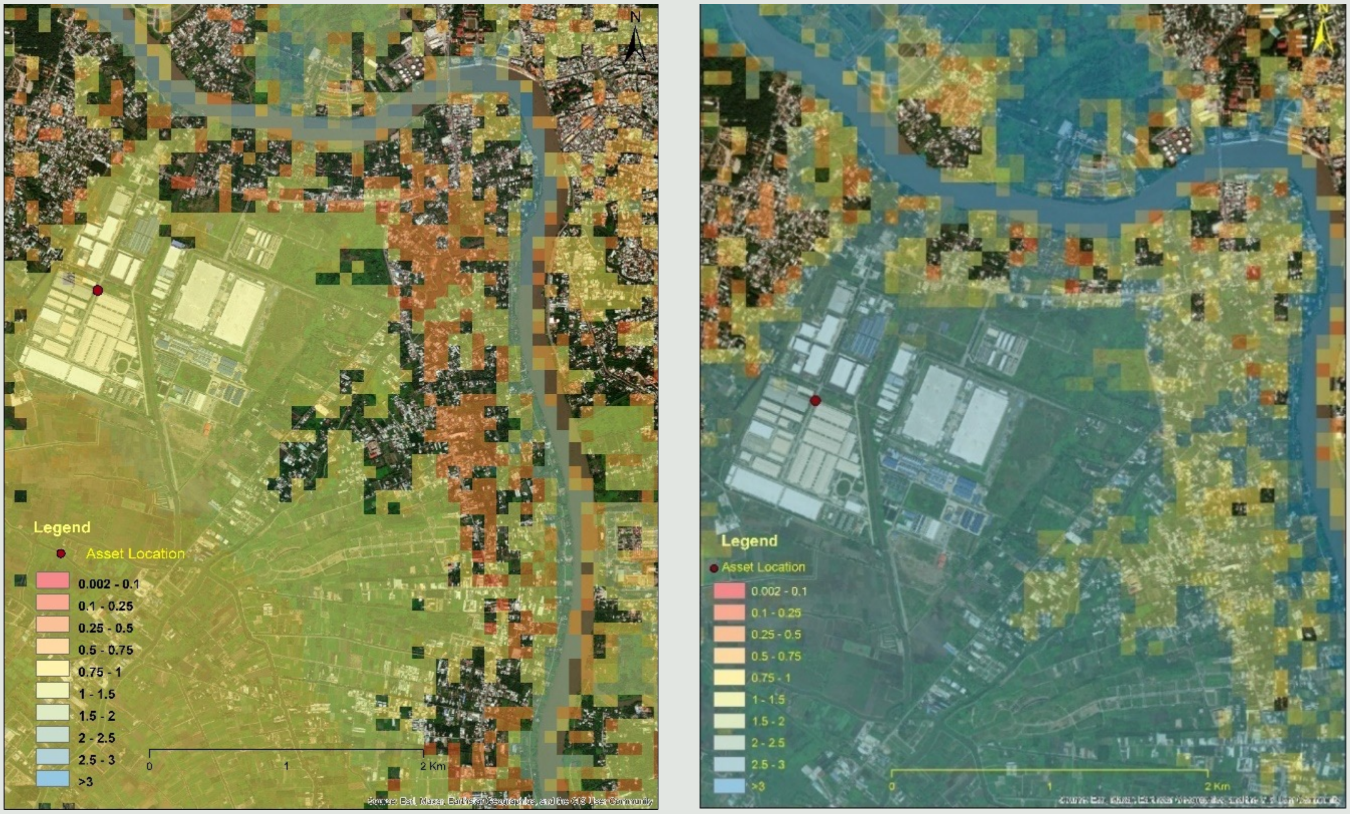
Figure 10. Bin Duong Province rainfall flood hazard, 2030

Source: Intensel. Flooding is based on RP100 Event and SSP 5-8.5.

In 2030 (SSP 5-8.5), the analysis predicts rainfall flood levels for the four factories indicated by the red circle—each sited just a few hundred meters from the next—vary from 0 m. to 0.95 m.

At very close range, we see in Figure 11 how rainfall flood hazard levels threaten a leading apparel manufacturer with more than 5,000 workers housed in a LEED-certified factory built near the banks of the Saigon River. We compare a projected 2030 maximum inundation level of 2.83 meters under the SSP 5-8.5 climate scenario with a 1.0 meter maximum flood inundation level under the SSP 2-4.5 scenario used in flood analyses above.

Figure 11. Factory A rainfall flood hazard, SSP 2-4.5 (l) and SSP 5-8.5 (r), 2030.



Source: Intensel.

A second case is a closer-still look at flooding impacts for production and workers based not on a projection, but on the effects of recent rainfall and riverine inundations on the outskirts of Phnom Penh.

Cambodia is "one of the most disaster-prone countries in Southeast Asia, affected by floods and droughts on a seasonal basis" according to the World Bank (2023). In 2011 and 2013, floods caused by Mekong River spillover resulted in the deaths of 255 and 168 people, respectively (Chhengpor, 2020).

In October of 2020, unprecedented floods were triggered after two weeks of rainfall in the city. Across the city, 25 apparel factories suspended production temporarily and 17,000 workers were furloughed (Techseng, 2020; Chua, 2020). The impact was wide enough that the *Economist Intelligence Unit* revised downward its GDP estimate for 2020 "to factor in the damage caused by the flooding". A manager of a factory with 5,000 employees reported that production stopped for one week and that none of the workers were paid wages during the suspension because the government did not score the flooding as a natural disaster—the legal standard in Cambodia for furlough payments (Techseng, 2020).

Y&W Garment in Phnom Penh flooded dramatically in the 2020 flood. The factory's two complexes are situated on either side of National Road Highway 20 and were built in boom-town fashion in an especially low-lying part of the city that was once a lake and rice fields. Workers interviewed for this report said that flood water from the Prek Th'naot River that meanders a few hundred meters away was up to their hips. The factory was closed—to salvage materials, discharge the water and restart its systems—for nearly three weeks.

2.4 Combined heat and flooding impacts for earnings, employment and national economies

We conclude with the combination of projected heat and flooding impacts and, for a sense of the scale of export earnings and jobs impacts in the economies of our focus countries, their relationship to national income.

Table 7. Combined heat- and flood-related impacts for apparel export earnings under climate-adaptative and high heat and flooding scenarios, 2030 and 2050.

Country	Year	Climate-adaptive export earnings (USD)	High heat + flood earnings (USD)	Change (USD)	Change (percent)
Bangladesh	2021	46.55 b.			
	2030	122.01 b.	95.22 b.	-26.78 b.	-21.95%
	2050	1,038.22 b.	326.90 b.	-711.32 b.	-68.51%
Cambodia	2021	15.24 b.			
	2030	35.64 b.	28.89 b.	-6.75 b.	-18.94%
	2050	235.41 b.	79.09 b.	-156.32 b.	-66.40%
Pakistan	2021	9.07 b.			
	2030	24.54 b.	16,95 b.	-7.59 b.	-30.94%
	2050	224.35 b.	43,70 b.	-180.65 b.	-80.52%
Vietnam	2021	56.99 b.			
	2030	116.80 b.	92,04 b.	-24.77 b.	-21.20%
	2050	575.46 b.	197.12 b.	-378.34 b.	-65.74%

Source: Cornell GLI. Analysis undertaken July 2023.

Table 8. Combined heat- and flood-related impacts for apparel employment under 'climate-adaptative' and high-heat and flooding scenarios, 2030 and 2050.

Country	Year	Climate-adaptive employment	High heat + flood employment	Change	Change (percent)
Bangladesh	2021	4.22 m.			
	2030	4.83 m.	4.57 m.	-0.25 m.	-5.29%
	2050	6.31 m.	5.04 m.	-1.27 m.	-20.17%
Cambodia	2021	0.70 m.			
	2030	0.94 m.	0.89 m.	-0.05 m.	-5.63%
	2050	1.70 m.	1.14 m.	-0.56 m.	-32.76%
Pakistan	2021	2.75 m.			
	2030	3.43 m.	3.14 m.	-0.30 m.	-8.65%
	2050	5.37 m.	3.51 m.	-1.85 m.	-34.56%
Vietnam	2021	2.97 m.			
	2030	4.70 m.	4.34 m.	-0.35 m.	-7.53%
	2050	11.70 m.	6.74 m.	-4.96 m.	-42.38%

Source: Cornell GLI. Analysis undertaken July 2023.

Taken together, projected earnings foregone under the non-adaptive 'high heat and flooding' scenario between 2025 and 2030 are USD 65.89 b. in 2030 dollars. That represents a 22 percent fall-off in export earnings against the 'climate-adaptive' scenario. New jobs foregone are 958,227, or nearly 7 percent, by 2030.

The projected 2050 figures are much higher. The effects of lower year-on-year growth in the non-adaptive scenario widens the gaps between the two scenarios: 68.8 percent lower for earnings in the non-adaptive scenario and 34.5 percent for employment, or 8.64 m. fewer jobs.

The earnings gap grows quickly in part because the figures are not adjusted for inflation. But more important is our assumption of rapid adaptation to heat stress and flooding risks. The gap illustrates the value of the 'prize' attached to adaptation that we mention at the top of this report. But a failure to invest in climate adaptation yields a major penalty, and it will bend apparel's output curve sharply away from the climate-adaptive path. Our 'green' factories exercise above for Bangladesh's industry illustrates a middle path, but the still-significant shortfall there makes plain that adaptation is needed urgently and on a large scale.

Finally, for a sense of the magnitude of possible impacts for the national economies of these four countries, we calculate apparel and footwear export earnings in our baseline year as a share of total exports and of gross domestic product.

Table 9. **Apparel and footwear earnings (2021) as shares of GDP, by country**

Country	Apparel share of all exports (USD, 2021)	All exports relative to GDP (percent)	Apparel exports relative to GDP (percent)	Apparel exports share of goods exports (percent)
Bangladesh	46.55 b.	416.27 b.	11.2%	91%
Cambodia	15.24 b.	26.96 b.	56.5%	66%
Pakistan	9.07 b.	348.26 b.	2.6%	58%
Vietnam	56.99 b.	366.14 b.	15.6%	22%

Sources: World Bank, Atlas of Economic Complexity, ILO (note: uses 2015 – 2019 data).
Analysis undertaken July 2023.

Apparel and footwear's historically high share of goods export earnings in Bangladesh, Cambodia and Pakistan mark export earnings in these three economies as particularly vulnerable to changes in future earnings and employment in apparel production (ILO, 2022b).

We note that government and industry in all four countries have promised or made moves away from reliance on economic growth from cut-and-sew apparel industries. Vietnam is furthest along this path to higher-value exports and has—according to interviews conducted for this report—begun to cut significantly into new apparel production investments by tightening approval for new factories and raising environmental standards and their enforcement. For Cambodia, the strategy includes electronics and bicycles. In Bangladesh and Pakistan, fabric recycling is expected to take a leading role in a 'circular' apparel industry.

But for industry investors and national policymakers, an end-run on projected economy-wide losses from heat stress and flooding is not possible. We recall the ILO estimates of cross-sector losses in GDP are -4.9 percent in 2030 in Bangladesh, - 6.5 percent in Cambodia, - 5.1 percent in Pakistan, and -4.9 percent in Vietnam (ILO, 2019). This means that the costs of just transitions in the mitigation framework and resilience in the adaptation framework are significant. They include not just physical adaptation costs for active cooling systems and local flood defenses, for example, but changes in apparel production processes and the governance of work in climate-vulnerable industries.

The next section examines climate risk and adaptation from workers' perspectives. And Part Four examines how prepared the governance systems for work in apparel—national and global, mandatory and voluntary—are for the era of climate breakdown and the demands of adaptation.

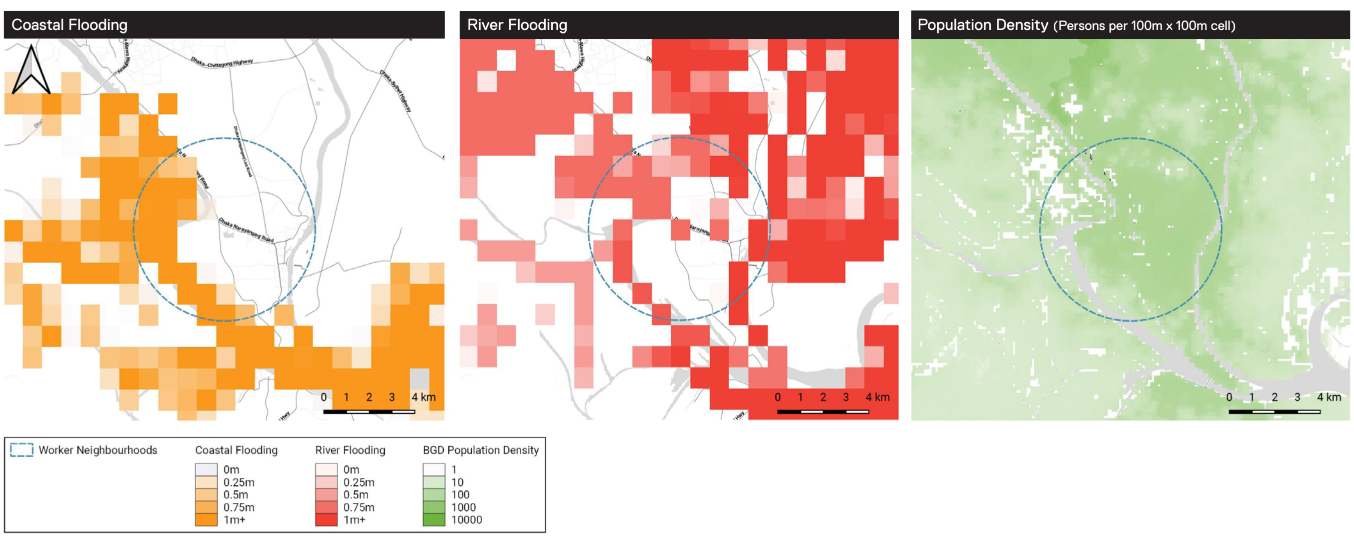
PART 3.
WHAT DOES CLIMATE BREAKDOWN MEAN FOR WORKERS?

Beyond export earnings and employment impacts, what does climate breakdown mean for workers?

Flooding, illness and absenteeism. Flood events in workers' neighborhoods—typically lower-lying areas with relatively poor infrastructure—are not accounted for. These floods can be chronic irritants for workers and their families in the rainy seasons that typically last for several months in south and southeastern Asia. They cause delays in getting to work. Some Dhaka and Chattogram-area factories reported sending boats to collect workers, and lost hours for workers' mean lost income. And they threaten illness from rashes to diarrhea to dengue which mean higher medical costs, lower productivity and lost income. A 2018 BSR report on public health and women apparel workers in Bangladesh touches on the issue of flooding and absenteeism: "an increase in 100 millimeters of average monthly rainfall precipitation—expected between the start of the monsoon season and its peak—is associated with an increase in sick leave rate by 10 percentage points per month" (Sebastio, 2018).

To assess flooding impacts for workers in their neighborhoods, we look first at projected 2030 coastal and riverine flooding levels (RP10) for densely populated industrial areas of several centers. The circle in the maps below demark a four-kilometer radius with population density is denoted in green. The Narayanganj district of Dhaka area appears vulnerable to both significant riverine and coastal flooding in 2030.

Figure 12. Inundation levels in Dhaka industrial neighborhood, 2030.



Sources: Schroders, WRI. Flooding is based on RP10 Event and RCP 4.5. Analysis undertaken July 2023.

Similar projections for densely populated industrial neighborhoods in Ho Chi Minh (Di An in Binh Duong), Karachi (Korangi) and Phnom Penh (Khan Mean Chey) show lower flood risk. See, for example, the relatively low levels of riverine flooding projected for Karachi in 2030 in areas near the port.

Figure 13. Inundation levels in Karachi industrial neighborhoods, 2030.

Sources: Schroders, WRI. Flooding is based on RP10 Event and RCP 4.5. Analysis undertaken July 2023.

However, the flood models again seem to understate potential impacts. Karachi experienced extensive rainfall flooding in 2023 and workers and industry observers in Pakistan reported that the massive and sustained flooding in southern Sindh and Balochistan provinces in mid-2022 that killed more than 1,000 people had a profound effect on Karachi's apparel workers. Many had to leave work in order to care for their families who had lost loved ones, homes and crops in the deluge.[28] For apparel production, the risks posed by intense flooding need to be measured well beyond the boundaries of factories and industrial zones.

Dhaka, Bangladesh. Photo credit: Cornell GLI

28 See, for example, Fihlani and Wright, 2022. https://www.bbc.com/news/world-asia-62699886.

NOT IN THE SAME BOAT: WORKERS AND MANAGERS ON HEAT AND FLOODING DHAKA

To gauge the impacts of extreme heat in workers lives—in the factory and in their homes—we look first at Dhaka where, to understand the effects of heat and flooding for workers and employers, the BRAC University Center for Entrepreneurship Development (CED) conducted face-to-face surveys for this report with managers in ten Dhaka area apparel factories and in four group discussions with approximately 35 workers. Acknowledging that these surveys were not probabilistically representative, the general pattern of responses was clear and consistent.

Workers' over-riding anxiety in all of the group meetings was lost income. Illness or heat stress means loss of wages and bonuses for attendance and productivity. Fear of the consequences for their families means working through illnesses caused or exacerbated by extreme heat and flooding. Both managers and workers in Dhaka apparel factories surveyed for this report spoke of 'just pushing through' the months of May, June and July when high temperatures, high humidity and flooding coincide.

Both managers and workers reported that heat levels in factories in those summer months affected workers in numerous ways: headache, exhaustion from dehydration and lack of sleep at home due to high heat. Workers in the majority of group meetings cited factories which 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.

Workers reported that they were docked pay (marked late) even if they were a few minutes late due to transport hassles or were denied paid leave if they fell sick. They estimated that they were late 10 times per month in May, June, and July, and that even transport costs in flooded streets were higher.

And workers reported missing three full days of work per month due to heat- and flood-related illness in the hottest and rainiest quarter of the year. Those absences can mean losses of BDT 1,200 – 1,500 (USD 11 – 14) per month, or more than 10 percent of their income in the highest-cost months of the year. Both heat and flood impacts for apparel workers require deeper analysis using accurate factory- and industry-level data on sick leave and workdays missed due to illness.

Finally, those interviewed for this report estimated 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. Monthly bills of this size equal 61 percent of average monthly rent payments of BDT 9,000 (USD 83) and workers reported borrowing against their personal belongings and paying high interest rates to afford electricity and medicines in May, June and July.

Employers 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 eight of ten managers interviewed said that there were no complaints about heat from workers or unions. Some managers argued 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.

One senior manager noted that workdays were typically two hours longer in the hottest quarter of the year in order to meet production targets. This corresponds to a 20 – 25 percent decline in productivity in May, June and July which indicates an annualized loss of 5 – 6 percent, not far from the estimates of heat-related productivity declines by the ILO for manufacturing in Bangladesh (4.96 percent in 2030) and the 8 percent decline for outdoor work in Dhaka by 2030 calculated for the Arsht-Rockefeller 'Hot Cities' study. (2022).

The results from the BRAC University surveys align with findings in other reports. The 2022 *Hot Trends* survey of Cambodian workers shows that at least 25 percent of 200 workers across eight factories interviewed report experiencing increased heat stress (Lawreniuk et al.). Fifty-three percent reported that they become unwell, and 22 percent suggested that heat stress affected their ability to work. Six percent noted reduced attendance and, consequently, income.

In Karachi, workers' calculations are necessarily more urgent. Heat waves—when daily maximum temperatures are 5 °C or more above the historical daily average for at least five consecutive days—are an annual phenomenon and becoming more intense and more dangerous. The April 2022 India-Pakistan heatwave produced the hottest month in Pakistan since 1880 with temperatures soaring higher than 48 °C (NOAA, 2022). A 2015 heatwave, combined with power outages, sent 65,000 people to Karachi hospitals to be treated for heatstroke and an estimated 1,200 people died (Al Jazeera, 2015). According to the Edhi foundation—a morgue and ambulance company—the majority of those who died during a 2018 heatwave were factory workers living in the impoverished Landhi and Korangi districts of Karachi (Sayeed, 2018).

In an interview for this report, a long-time buyer and supplier representative pointed out that Karachi factories lack convenient access to water for drinking and production, and that its cost is rising. The representative estimated that 80 percent of Pakistan's larger apparel factories have water evaporation cooling systems, but only the best factories make sure that drinking water is readily available and no factories are known to make changes to working hours to avoid the highest heat of the day.

Worker organizations on climate issues. Union federation leaders in Dhaka, Karachi and Phnom Penh interviewed for this report noted recent rises in temperatures and complaints from workers about factory heat levels. High heat levels were of special concern for unions in Karachi who pointed to heat-related deaths of apparel workers in recent heat waves there as evidence of the gravity and growth of the problem, and to the fueling of heat and humidity levels by machinery for dying, washing and ironing.

In Cambodia, a national apparel worker union leader said that complaints from workers about excessive heat levels are increasing, but that freedom of association is compromised and bargaining strength for apparel worker unions is not high enough to make demands for installation of effective cooling systems.

Ironically, both the union leader and a longtime industry leader noted that apparel workers placed near water-evaporation cooling systems sometimes have to bundle up to avoid chills from the cool, moist air blown into massive production areas. The former regarded it as a problem for workers toggling back and forth between extreme heat and cold, and the latter as evidence that factories are generally comfortable, even cool. Water-evaporative cooling systems are popular among manufacturers because they are much cheaper to install than refrigerant air-conditioning systems and use much less energy. But while they work very well in hot and arid environments, these systems can struggle in hot and humid regions.[29]

A leading Bangladeshi union leader and worker rights campaigner pointed to climate breakdown—more frequent and severe cycles of flooding and drought in particular—as a driver of rural-urban migration. Internal migration to the Dhaka region helps to keep labor markets slack and makes for downward pressure on wages for apparel workers.

Finally, in Ho Chi Minh City, the dynamic is reversed. Apparel and footwear manufacturers facing a tight labor market and competition for workers who would prefer to work in 'white goods' such as smartphones are feeling upward wage pressure. To hold onto workers and entice new applicants, manufacturers are installing effective cooling systems (Interview with sourcing director).

29 "In this [evaporative cooling] system, the temperature of the air cannot be reduced below the wet bulb temperature of the air." For a discussion of evaporate cooling systems, including alternatives and energy consumption patterns, see https://www.sciencedirect.com/science/article/pii/S259012302300186X.

PART 4.
GOVERNANCE OF WORK IN THE ERA OF CLIMATE BREAKDOWN

Extreme heat, flooding and the growing havoc of climate change present material risks for fashion. Our analyses in these two reports put figures to these risks. How will fashion brands located in the Global North react to and 'govern' on these issues in the Global South? What rules apply at this intersection of apparel production, climate breakdown and working conditions?

We examine here the existing mandatory and voluntary standards for climate adaptation issues. Second, we analyze new data that tells us how these standards are showing up, or not showing up, in the lives of workers. And in our second report, we take up the meta-question: How is the behavior of fashion brands and retailers governed in the Global North and on the global level?

4.1 International legal frameworks

In the world of work, the U.N.'s International Labor Organization (ILO) sets global legal standards and the tone for many of the national governments, employers and workers involved in apparel production. The ILO conventions known collectively as the Fundamental Principles and Rights at Work—in addition to freedom of association and collective bargaining, discrimination, child labor and forced labor—now include workplace health and safety. The ILO's Occupational Safety and Health Convention, 1981 (No. 155) and its Promotional Framework for Occupational Safety, 2006 (No. 187) were promoted to the group of ILO core labor standards in 2022 (ILO, 2022a).

These conventions set standards for national governments as their parliaments write rules to prevent accidents and injury arising from work. But the uptake has been relatively slow, and only Vietnam among the four countries surveyed here has ratified both safety and health conventions.[30]

Heat stress for workers is addressed directly in *two non-binding* recommendations. The Hygiene Recommendation, 1964 (No. 120) and Protection of Workers' Health Recommendation, 1952 (No. 97) prompt governments on extreme temperature exposure, ventilation and drinking water access. For example, "a competent authority should establish maximum and minimum standards of temperature", and "all appropriate measures should be taken by the employer" to provide "suitable atmospheric conditions" as to avoid "excessive" humidity and heat (ILO, 1953).

Broad as they are, the additions of safety and health conventions to the set of core labor standards mean a boost for campaigns to introduce or tighten workplace safety rules in the countries covered in this report. Even if ILO member States have not ratified a core Convention they are expected to follow and write the standards into national law (ILO, 2022a).[31]

4.2 National legal frameworks

How detailed and stringent are legal standards for safety and health in the four countries surveyed here? Table 10 summarizes requirements for employers on indoor heat and ventilation, breaks, drinking water, work stoppages and paid

30 C. 155 (in 1994) and C. 187 (in 2014). See ILO (2023) ratifications at https://www.ilo.org/dyn/normlex/en/f?p=NORMLEXPUB:11300:0::NO:11300:P11300_INSTRUMENT_ID:312332:NO.

31 International Labour Organization, 2022. ILO Declaration on Fundamental Principles and Rights at Work and its Follow-up. Geneva.

leave—all important protections for workers in climate-vulnerable industries. (Social protection programs in these four countries are discussed in the 'Entitlement' section below).

There are two stand-outs in this small survey. Cambodian labor law is silent or designedly vague on six of these eight climate-adaptative labor issues. There are no requirements for paid breaks, pay during work stoppages, or right to stop work in dangerous conditions. Cambodia's legal framework, after 30 years of intensive technical cooperation from the ILO and engagement by fashion brands, is clearly the weakest in this group.

Vietnamese labor law stands out here for its relative stringency on climate adaptation issues, including clear heat thresholds, paid breaks, paid sick leave, pay during force majeure work stoppages, and the right to halt dangerous work. But we note that the dry-bulb temperature thresholds may be too high in high humidity environments to maintain productivity. The stronger standards in this small sample are highlighted in the table below.

Table 10: National legal standards for apparel factory/workplace climate and related standards, by country

Factors	Bangladesh	Cambodia	Pakistan (Sindh)	Vietnam
Indoor heat	Temperature 'limited to a tolerable limit', with requirement for one thermometer per workroom.	'Work [must be] undertaken in a thermal environment that does not affect worker's health... Employer must take appropriate heat reduction measures.' Requirement for 'thermometers in the workplace.'	Maintain indoor temperatures for 'reasonable conditions of comfort and [prevention of] injury to health' with wall and roofs 'of such material and so designed that such temperature shall not be exceeded. 'Correct wet and dry bulb temperatures' recorded three times/day.	Indoor workplace temperatures should not exceed 34°C, 32°C and 30°C for light, medium and heavy work, respectively. Relative humidity should not exceed 80%. Employer contracts for assessment of temperature, humidity, etc.'
Indoor ventilation	A sufficient 'number of opposite facing windows in every workroom' for ventilation, and 'exhaust fans where ventilation is not possible.'	'Employer has to take measures to ensure appropriate air circulation.'	'Ventilating opening' in proportion to 'five square feet for each person' is required 'such as to admit a continuous supply of fresh air.'	'Clean air must be regulated [based on] quantity of people in a room, the demand for manual labor, workshop size, the emission of pollutants, thermal conditions, [and] the light must be sufficient.'
Clean drinking water	'Pure' and cool water for drinking by workers, 'changed at least once in a day' unless using 'modern purifying systems.'	'Workers must be supplied with water for all their needs, in every season.'	'Sufficient supply of whole-some drinking water' at less than 32 Celsius, 'free of charge', 'at the rate of 1 gallon per worker.'	Employer must provide 1.5 liters of clean, tested drinking water 'per person, per shift.'
Breaks	No more than 6 hours without rest of at least 1 hour. No more than 5 hours without rest of at least half an hour.	No more than 8 hours per day for 'full-working period'. Working periods are set by each enterprise.	No more than 6 hours without rest of at least 1 hour. Or no more than 5 hours without rest of at least half an hour.	Six hours or more work shall include at least half an hour break and 45 minutes break for night work.
Paid breaks	No specific standard.	No specific standard.	No specific standard.	The legally required rest period is paid and counted as 'part of the working hours'.

Factors	Bangladesh	Cambodia	Pakistan (Sindh)	Vietnam
Stop work in dangerous conditions	No specific standard.	No specific standard.	No specific standard.	'Workers [can] refuse to perform work or to leave a workplace that clearly presents an imminent and serious threat to life or health' and cannot be required to return/ resume work until danger is eliminated.
Paid work stoppage	Workers must be paid for 1 – 3-day stoppages by 'fire, catastrophe, stoppage of power supply, and epidemics', but may be laid off for stoppages of more than 3 days.	No prior lay-off notice required for 'acts of God' or catastrophe causing material destruction and make it impossible to resume work for a long time.'	No specific standard.	Minimum wage, at least, must be paid for 'force majeure' or 'forced work stoppage'.
Paid sick leave	'Every worker shall be entitled to sick leave with full wages for 14 days' given a 'medical practitioner certifies that the worker is ill.'	'Paid sick leave of 100% pay for the first month, 60% for the second month, 40% for the third month, and no pay for months 4-6.'	'Every worker shall be entitled to 16 days in a year sick leave on full pay.'	Paid sick leave up to 180 days per year with medical certification (based on level and period of social insurance contribution).

Sources: Bangladesh Labour Act (2006); Bangladesh Labour Rules (2015); Labor Law of Cambodia (1992); Prakas No. 147/02; 125/01; AC Award 86/11; Royal Kram Promulgating the Labor Law (1997); Sindh Occupational Safety and Health Rules (2019); Sindh Factories Act (2015); Vietnam Decision Promulgating 21 Labor Hygiene Measures (2002); Vietnam Decree 45 (2013); Vietnam Labor Code (1994); Vietnam Occupational Safety and Health Law (2015). Prakas No. 184/18

All four national legal frameworks clear the low bar of requirements for drinking water. Beyond this, important gaps in the standards persist. Indoor heat standards and extreme heat protocols are vague or missing altogether for apparel workers in Bangladesh, Cambodia and Pakistan. In lax regulatory regimes, vague standards on indoor heat are worse than none; they can produce a careless or subjective 'yes' in a cursory labor inspection by governments or fashion brands that use minimum national standards as their own. And specific requirements—for thermometers, for example—are easily met but effectively meaningless. Where there is no collection of data, evaluation and enforcement of a standard, regulators and brands often take a box-checking approach to worker health.

In Cambodia, assessment of apparel factories is largely left to the ILO's Better Factories Cambodia program, and there is no enforcement role for the program. In Bangladesh, unregulated third parties certify compliance with indoor 'comfort' standards. The Accord on Fire and Building Safety—agreed by unions and apparel buyers in 2013 after the deaths of more than 1,100 workers in the Rana Plaza building—policed safety and health, but indoor heat was excluded from its remit and that of its successor organization. In Pakistan, a longtime industry insider reported that the government does not insist on compliance with its detailed rules for heat management: "Inspectors visit but they do not enforce the law".

What about Vietnam? Measurement and enforcement of its specific indoor temperature standard is left largely in the hands of employers. The government licenses environmental audit firms to record indoor temperatures and certify factory compliance with the law. Gaming of this compliance system is easy. Several interviewees for this analysis reported that certifiers typically record early-morning temperatures. Long-time observers noted that they had never seen a third-party-reported temperature above the 32 °C threshold applied for 'medium' work in apparel production.

In the region, Malaysia provides a relatively strong and clear set of legal requirements and non-binding guidance regarding indoor heat. The obligations of employers will sound familiarly broad: "maintain such temperature as will ensure...

conditions of comfort and prevention from bodily injury". "If the temperature is… unduly high, adequate means shall be provided to cool the air or to create adequate air movement [for workers]". Factory design must include "insulating material or [be] coated with white paint, white-wash or other heat reflecting material" and so on. Its non-binding recommendations include wet-bulb globe temperature limits for different effort levels: 32 °C (WBGT) for light work, 30 °C for moderate, 29 °C for heavy, and 28 °C for very heavy.

DOES 'GREEN POLICY' INCLUDE ADAPTATION FOR APPAREL?

We also surveyed national 'green' and transition policies in our focus countries for indications of attention to adaptation needs generally and working conditions in apparel or manufacturing more specifically. Aims are broad and strategies are largely sketches but Karachi's planning include emergency measures for extreme heat and guidance for workers and employers, and Vietnam's 'Green Growth Strategy' warns of flooding risk for manufacturing.

Bangladesh's National Adaptation Plan of Action 2023 - 2050 lists heat stress as one of the main climate change vulnerabilities for the country but the apparel industry is regarded as only "low to moderately vulnerable" and there are no measures aimed at apparel workers.

Ho Chi Minh City, Vietnam. Photo credit: ILO Better Work

Cambodia's Updated Nationally Determined Contribution (2020) emphasizes the need for "heat stress adaption for industrial production" with a separate section on worker health impacts and apparel workers in particular, "to reduc[e] their exposure to health risks and increase[e] their productivity." The Cambodia Climate Change Alliance, a joint initiative of the Cambodian government and development partners, has produced research on the impact of heat stress on worker's productivity for policy planning.

Pakistan's National Climate Change Policy (2021) and Updated Nationally Determined Contributions (2021) lack worker heat stress reductions targets but the Karachi Heatwave Management Plan provides specific protocols for Karachi: appointment of a heat emergency coordinating committee, recommendations to issue emergency alerts to the population when there is a 42+ °C forecast, training for workers on the impacts of heat, and advice to employers to shift (outdoor) workers' schedules away from peak heat hours (noon to 5 p.m.).

Vietnam's 2021 - 2030 Green Growth Strategy addresses manufacturing in relation to energy usage and waste reduction but its Updated Nationally Determined Contribution to the UNFCC notes the risk to manufacturing posed by flooding. There is no mention of flooding and/or heat impacts for workers.

4.3 Voluntary regulation in the era of climate breakdown

The absence of meaningful standards or effective workplace protections for apparel workers is the rationale for private regulation of working conditions by fashion brands and retailers. While voluntary codes of conduct have been refined and improved since their emergence in the apparel industry in the 1990s, most avoid clear standards for climate-related risks and do not significantly improve on existing legal requirements.

Most multi-stakeholder assessment regimes used by fashion brands and retailers pair broad statements about worker safety and compliance with local standards such as those discussed above. The U.S. based Fair Labor Association—home to Patagonia, Nike, Adidas, Fast Retailing, U.S. universities and other global brands—is typical. It requires that suppliers to its member brands "provide a safe and healthy workplace setting to prevent accidents and injury to health arising out of, linked with, or occurring in the course of work or as a result of the operation of employers' facilities. Employers shall adopt responsible measures to mitigate negative impacts that the workplace has on the environment" (Fair Labor, 2023).

Table 11: Voluntary regulation standards for climate-related workplace issues

Factors	ILO Better Work	Fair Wear	Fair Labor Association	Social Accountability Intl.	Social Labor Convergence
Indoor heat	Is the temperature acceptable? (Specific acceptable temperatures vary by country program)	Temperature is not appropriate.	No specific standard.	Ensure temperatures remain acceptable.	Legal minimum.
Indoor ventilation	Is the ventilation acceptable?	Ventilation is insufficient or inadequate.	Legal minimum and 'prevent /minimize hazardous conditions to workers.'	Facilities should be adequately ventilated.	Legal minimum.
Clean drinking water	Does the employer provide workers enough free, safe drinking water?	Clean drinking water is not available or not tested.	Safe and clean drinking water shall be freely available at all times.	All workers should have access to sufficient potable water.	Are workers provided free, potable drinking water in line with legal requirements and allowed access to drinking water at any time?
Breaks	Legal minimum. (Does the employer fail to provide workers time off for any required breaks?)	Legal minimum.	Legal minimum.	Legal minimum and industry standard.	Legal minimum.

Factors	ILO Better Work	Fair Wear	Fair Labor Association	Social Accountability Intl.	Social Labor Convergence
Paid breaks	Legal minimum. (Does the employer pay any workers incorrectly for any types of paid time off [including] breaks?)	No specific standard.	No specific standard.	No specific standard.	No specific standard.[32]
Stop work in dangerous conditions	Are workers punished if they remove themselves from work situations that they believe present an imminent and serious danger to life or health?	Workers are punished when they remove themselves from hazardous work environment of an imminent and serious danger.	No specific standard.	No specific standard.	Are workers subject to negative consequences if they remove themselves from work situations that they believe present an imminent and serious danger to life or health?
Paid work stoppage	Legal minimum. (Does the employer pay workers correctly during work stoppages?)	Workers are not paid during work stoppages.	No specific standard or prompt.	No specific standard or prompt.	No specific standard or prompt.
Paid sick leave	Legal minimum. (Does the employer provide required sick leave?)	Legal minimum.	Legal minimum.	No specific standard.	Legal minimum.

Sources: ILO & IFC, 2020; Fair Wear, 2020, 2022a, & 2022b; Fair Labor, 2020; Social Accountability International, 2014; Social & Labor Convergence, 2023.

Proponents of voluntary, private regulation in apparel production point to its powers to advance workplace standards, fill enforcement gaps, strengthen national legal frameworks and inspire effective enforcement. This does not work where the industry defaults to a patchwork of legal minimum requirements. In the context of extreme heat and intense flooding already prevalent in production hubs in Bangladesh, Pakistan, India, China and elsewhere, the benchmarks in Table 11 are obviously inadequate.

One apparel brand code of conduct among ten surveyed for this report spells out 'extreme temperatures' requirements: recording of temperature readings, access to water, assessment of air conditioning and ventilation systems, work/rest schedules according to the intensity of work, 'reasonable shifts' and acclimatization periods for new workers, training workers to identify heat stress.[33] A second brand includes in its supplier guidelines a 35 °C indoor temperature limit as its one heat-related requirement.

32 The SLCP Convergence Assessment Framework tool sets paid break-related standards for breastfeeding, but not for general rest breaks.
33 https://tinyurl.com/57h9mtvc

ILO Better Work. The ILO's Better Work program is a stand-out in the otherwise flat landscape of voluntary private regulation. The Cambodia factory data presented in Part 2 of this report is evidence of its relative diligence. ILO staff assess participating factories in three of the four countries surveyed in this report: Bangladesh, Cambodia and Vietnam. However, only in Cambodia do Better Work staff take their own readings against its 32 °C (dry-bulb) indoor heat standard. Better Work staff in other programs assess whether the temperature and ventilation are 'acceptable' in their view, a subjective response that is usually not buttressed by any measurements. Table 12 presents new ILO data on percentages of assessed factories with violations of indoor temperature standards.

Table 12: Percentage of factory indoor heat and ventilation violations ('not acceptable'), 2015 – 2022.

Year	Bangladesh (%, and n)	Cambodia (%, and n)	Vietnam (%, and n)
2015	23 (48)	69 (283)	10 (221)
2016	20 (71)	72 (413)	10 (257)
2017	17 (108)	68 (423)	4 (289)
2018	15 (133)	66 (435)	2 (305)
2019	17 (173)	76 (405)	5 (297)
2020	2 (51)	49 (221)	2 (311)
2021	0 (24)	49 (343)	0 (226)
2022	3 (384)	56 (374)	0.2 (383)
Average	12 %	63 %	4.20 %

Source: ILO Better Work.

The results here are telling. While Vietnamese facilities may be, in the aggregate, cooler than competitors in Bangladesh and Cambodia, the results here—almost zero heat violations—are almost certainly attributable to the behavior described above involving third-party certification of factory temperatures.

Bangladesh temperature violations are similarly hard to credit. Observed outdoor temperatures, the construction of traditional factories there, and the testimony of workers and managers belie the two percent violation rate reported in 2022. The Better Work thermal comfort standard applied in Bangladesh is reportedly 27 °C, and according to long-time factory assessors, heat compliance is largely determined on certification by third parties—largely unregulated, and often conducted in January to March when average temperatures are lowest.

Only the temperature readings from Cambodian factories can be regarded as reliable. They are recorded by ILO Better Factories Cambodia assessors in different departments—ironing, sewing, washing, and so on—using calibrated sensors at the lunch hour or in the early afternoon. Fully, 63 percent of assessments in the 2015 – 2022 period, including 'winter'-time assessments, exceeded the ILO Better Factories Cambodia-defined threshold of 32 °C.

As noted in Part 2 above, the data show improvement but 2022 violations still represent an unacceptably high rate for workers but also for the buyers, manufacturers and government who have benefited from a 20-year inspection regime led by the ILO.

Related issues. We also combed through ILO Better Work data in the same period to see if requirements for the availability of drinking water—crucial to worker health and productivity during the hot season—were violated. In Vietnam, violations were recorded between 5 and 19 percent of assessments with no definite trend towards improvement. A similar pattern was observed in Cambodia, where the violations ranged between 9 and 16 percent, and between 5 and 48 percent during the same period for Bangladesh, where the percentage of violations appear to be reducing over time.

The Better Work reporting on these assessments is variable, with no clear patterns on most of these questions. On average, the violations of rest breaks and pay for sick leave ranged from 4 – 13 percent and 0 – 8 percent respectively in Bangladesh, whereas the violations of the sick leave provision ranged from 10 – 27 percent in Cambodia. Better Work Vietnam data only reported violations of the break provision, where the violations were high (49 percent) in 2016 to about 10 percent since 2021. The Better Work assessments included questions germane to climate adaptation—adequate water and washing facilities, right to remove themselves from dangerous work—but there was not enough data with regard to these questions.

The above data also needs to be read in conjunction with data on violations of safety and health policies and process. Better Work assessments include questions on factories' *communication* of safety and health policies and procedures, the systems they have introduced for *cooperation* between management and workers on safety and health issues, and whether they *investigate and monitor* those issues. The percentage of violations on *communication* ranged between 55 and 63 percent over the 2015 - 2022 period in Cambodia, and between 59 and 99 percent in Bangladesh during the same period, with most years in the 90 percent range. The latter finding is expected given the focus on safety and health issues under the Accord. (There is no data from Vietnam with regard to these questions). Similar results can be seen for the requirement that management institute a system to engender cooperation on safety and health issues.

Design and planning. Finally, we should note that Better Work reports generally low compliance with legally required construction permits and structural safety requirements with Bangladesh and Cambodia's violation rates actually increasing in 2022. Here the lack of compliance is sometimes a lag in approvals by government. In other cases, it is a lack of accountability attributed to corruption by employers and regulators. A longtime auditor noted that Cambodian factories—both older and some new—are still operating under warehouses permits rather than being registered as factories to exploit the lower requirements, including ventilation, for warehouses. Higher heat is therefore built into both the physical and political structures that the industry uses.

To summarize, there continues to be violations of temperature and water provisions, and fewer reliable measurements and reporting in Bangladesh and Vietnam relative to Cambodia. There remains a significantly large percentage of violations over a range of safety and health provisions, even in Bangladesh, where significant improvements are expected after the Accord and its successor. The inconsistent reporting observed on many questions in the Better Work data is also indicative of the vague standards or silence in national law and in private regulation programs.

4.4 Other voluntary governance programs

Fair Food. Comparison with other private regulation regimes—one for agricultural workers and another for climate mitigation measures—is helpful in plotting a way ahead for fashion. First, the Fair Food Program in agricultural supply chains treats dangerous weather including high heat as a health issue. Workers play a role in negotiating and enforcing the 'Heat Stress Illness Awareness, Prevention, and Response Plan'. The original agreement's requirement that buyers support their growers' compliance costs and higher wages via the 'one penny per pound' payment to workers means that, unlike other private regulation schemes, these programs are legally enforceable (CIW, 2021).

Higg. The second example is the fashion industry's voluntary self-assessment scheme for environmental compliance, the Higg Index, organized by the Sustainable Apparel Coalition in 2012. Its tools provides manufacturers and brands with guidance on how to collect primary data and organize them to set science-based targets for water usage and carbon emissions.

For some brands and suppliers interviewed for this report, the Higg system is notoriously detailed and complex. It is also open to abuse. Norwegian authorities in 2022 flagged 'sustainable' claims based on greenwashing and brands and retailers are under pressure to back up claims of sustainability based on Higg 'compliance'. But Higg matters because brands and retailers rely on Higg certification to make sourcing decisions.

But nothing in the Higg program requires measures of indoor heat, for example, or flood vulnerability.

SLCP. The Higg program's social-labor off-shoot is the SLCP, included in the table above. Unless required under national law, SLCP does not expect manufacturers to collect and disclose to assessors daily maximum and humidity temperature readings from production areas.

Faisalabad, Pakistan. Photo credit: Cornell GLI

Clothing Factory. Photo credit: huyvinhnhon, Freepik

'ENTITLEMENT' AND APPAREL PRODUCTION IN COVID-19 AND THE CLIMATE CRISIS

Concluding our discussion of governance approaches for climate adaptation, we revisit lessons learned in the COVID-19 crisis. The ultimate lesson of the 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.

Pay and health protections for apparel workers during a sudden work stoppage—from cancelled orders or pandemics to extreme heat and dangerous flooding—are their most urgent needs. The COVID-19 pandemic provided a stress test for rules on pay for workers during furlough, sick leave and for workplace injuries or illness, 'social protection' for workers more generally, and the availability of credit for employers. The emergency protections for workers and employers that followed revealed both how spare the provisions for workers were in the pre-pandemic era, and how they might expand. Two working papers from the Cornell Global Labor Institute, "Repeat, Regain, or Renegotiate? The Post-COVID Future of the Apparel Industry" (2021) and "Learning from Crisis: Apparel Industry Experts on Mitigating the COVID-19 Pandemic and Future Crises" (2022) catalogue the recent changes in social protection.

Bangladesh. The government introduced income support for furloughed workers in the amount of 60 per cent of wages (USD 57) for a duration of three months. Government and private lending were given to employers at below-market, subsidized interest rates with a 2-year repayment plan.

Cambodia. The government provided worker income support amounted to USD 70 per furloughed worker in the garment, footwear, and textile sectors through December 2021. Employers were responsible for USD 30 and government provided USD 40. The government also provided paid sick leave that equaled 100 per cent of wages for one month, 60 per cent for months 2 - 3, and unpaid for months 4 - 6. Employer assistance included deferred social contribution and tax breaks.

Pakistan. The national government issued a "no layoff" order and full salary payments by employers during closure/lockdown. Workers remained entitled to the standard sick leave of 16 days at 50 per cent of pay and 10 days of casual leave with full pay. The government offered loan deferrals and interest rate reductions for employers maintaining workforce and payroll.

Vietnam. Dismissed workers received USD 43 for three months; furloughed workers received USD 77 for three months plus employers' match; and total wages must exceed 85 per cent of regular minimum wage. In lieu of layoffs, leave without pay was offered. Employers received tax breaks, including delayed tax and land-use fees payments for five months; interest rates reduced by 0.5 – 1 percent; and suspended social benefit contributions.

These policies were largely improvised in the emergency and the ILO reports that government, employer and worker interest in social protection systems has boomed since the pandemic. Drawing a line between pandemic support for workers and employers and the need for protections in a slower-moving climate crisis could provide more impetus for the building-out of social protection systems.

PART 5.
WHAT DO WE DO?

Given the scale of risk and potential costs detailed in this report for national governments, manufacturers and workers as well as brands and retailers, their investors and policymakers, what do we need to do?

We frame our recommendations with three of fashion's long-standing cost or accountability issues that work against effective climate adaptation.

First, the lack of measures to combat factory-level climate impacts is a symptom and not a cause of weak protections for workers and inattention by employers. The cause is fashion's insistence that most costs and risks for suppliers and workers are not shared by the brands and retailers. That is, they are externalities. A long-time sourcing chief based in Asia reported that fashion has taken on global mitigation goals such as carbon emissions reductions and energy efficiency, but not adaptation. Heat can be "dealt with by suppliers as a worker wellness and compliance issue" but that "when the flooding comes, it will be a surprise".

Second, fashion sourcing for the mid- and value markets does not much care about place. In interviews with sourcing directors and industry investors for this report we heard variations on this theme. 'The industry is volatile'. 'It is made to move. It moved to these places [such as Bangladesh, Cambodia and Vietnam] and it will move again.' There is a risk that brands and retailers will 'cut and run' where they think that climate havoc and adaptation costs overwhelm their sourcing calculus.

Third, the economic incentives for brands and retailers—established or new entrants—to disregard sustainability and adaptation-related topics is driven by overconsumption, intense pricing competition and an industry-wide addiction to growth.

We see four counter forces.

First, climate impacts are getting worse. Our projections above—made more real by heat events in recent months that produced factory shutdowns and energy-rationing in China, Bangladesh, Vietnam and Pakistan—mean that quality, delivery and price are threatened. This means that return on investment for climate adaptation is real. Brands, their manufacturers and worker organizations will be more demanding.

A 2021 study of adaptation decisions makes the argument:

> *The loss in output caused by high temperatures encourages adaptive responses by firms. In the short term, decisions to invest in climate control depend on the costs of cooling, relative to the expected output losses resulting from heat stress. Over longer time periods, firms may increase automation, relocate plants, or change the composition of output. Firms may also selectively invest in climate control. If labor productivity plays an important role in output losses associated with hot days, we would expect that processes that are labor intensive and add high value would be preferentially protected." (Somanathan et al, 2021).*

Second, they are getting worse not just in Asia but in many of fashion's favorite production centers. So, if brands and retailers are tempted to 'cut and run', where will they go to avoid a share of the risks and costs of climate breakdown? It is clear from the overview in Part One of this paper that some of these alternative centers will not escape the effects of climate breakdown. And these alternatives may be unable to deliver on a large scale—even in the longer term—the seemingly infinite production capacity of Asia's apparel industry. Asia's share of U.S. apparel and footwear imports to the

U.S., for example is up in 2022 to 73.5 percent but largely unchanged since the start of the pandemic with its attendant disruptions to apparel production.[34] Assuming that high-touch, small-batch apparel and footwear production moves closer to U.S. and E.U. markets, much of fashion production is certain to remain in Asia.

Third, the costs and risks detailed above that ultimately count as financially material will be treated as urgent and solvable business problems, not the stuff of voluntary sustainability programs and human rights initiatives. Finance officers, general counsels and investors will be more demanding.

The final counter vailing pressure is regulation by policymakers in major markets. For European Union policymakers, in particular, climate breakdown and worker rights may no longer be matters for opaque private regulation. Regulators will be more demanding.

Finally, one issue, or force, can work both ways.

Does the fashion industry's focus on climate mitigation come at the expense of adaptation efforts? Brands may choose a zero-sum approach. But their familiarity with and commitment to mitigation means investments in resilience are natural and urgent extensions of the approach. Those investments may also make economic sense. Spending to cool people and factories and reduce flood vulnerability may have a strong return on investment. This analysis is taken up in detail in our second report.

Working from the catalog of risks and costs described in this report, we recommend actions for national governments, brand and retailers, manufacturers and worker organizations. (Our second report takes up costing, financing and global oversight of climate adaptation).

For national governments in tropical and subtropical centers for apparel and footwear production, the existing legal standards and their enforcement are no match for the threats that high heat stress and flooding pose for workers' health, output, earnings and employment.

The same goes for private regulation and—to a much lesser degree because of their effective suppression in many of fashion's favorite centers—collective bargaining and worker organizing rights.

In the era of rapid climate change, these public and private regulatory systems lag badly. Here are four urgent changes for regulators, employers, fashion brands and workers to negotiate:

1. Standards and protocols. Set protocols for work hours, effort levels, rest and hydration based on indoor wet- and dry-bulb standards appropriate to the region. It also likely requires earlier start times, longer breaks, less overtime, more access to drinking water. The examples of the Malaysian government and a handful of brands are more guidance than requirements but, if made mandatory, set basic standards and protocols.[35]

These protections obviously require rules for daily collection, reporting and action on temperature and humidity readings in the production areas of factories. Occasional third-party certification of factory temperatures is nonsense and, arguably, bad faith by regulators and employers.

2. Worker health and leave. Regulators (public and private) should treat heat and flood events as health hazards. This means that workers must have paid leave for these events and related illnesses, and the right to stop work, individually and collectively, when their health is endangered without penalty—that is, loss of income. Early warnings about heat

34 See U.S. import data at https://www.trade.gov/otexa-import-data and analysis at https://shenglufashion.com/.

35 For examples of city- and sector-specific policies, see proposed outdoor heat protocols for sports in the U.S. in Brown, 2023. https://www.marylandmatters.org/2023/06/21/heat-related-illness-bill-honoring-late-md-university-football-player-introduced-in-congress/ For examples of appointments of Chief Heat Officers in cities around the world, see Arsht-Rock, 2023. https://onebillionresilient.org/project/chief-heat-officers/#:~:text=Bargianni%20succeeds%20Eleni%20Myrivili%2C%20who,Heat%20Officer%20for%20UN%2DHabitat

stress or flooding for apparel workers should come from government and employer warning systems (via smartphones, for example) and public awareness campaigns.

‘Force majeure’ definitions in labor law, in contracts between fashion buyers and manufacturers, and in collective agreements between employers and workers’ organizations should recognize the risk from climate events and make allowances in production schedules, delivery, workers’ emergency leave and income (Dadush, 2022).[36]

3. Sanctions/incentives. Enforce meaningful sanctions for violations of indoor heat standards. For labor, health and commerce/trade authorities this includes fines, suspension of production and even the revocation of export licenses.

Tighten factory-permitting and climate-hazard planning requirements and practices. New construction and renovation of factories must include designs (and outcomes testing) for active and passive cooling of spaces and people, and defenses against inundation.

Costing of and financing for large-scale climate adaptation are taken up in our second report, as well as in the literature cited above regarding return of investment in adaptation systems (Adhvaryu et al, 2020). The obvious model for binding collaboration among brands, manufacturers, unions and governments is the Accord on Fire and Building Safety in Bangladesh signed in 2013. It includes obligations for brands and retailers to stay with manufacturers while they make needed safety improvements, and to help with the financing of them.

Large-scale public infrastructure to reduce heat and flooding are generally government-led: shading of streets, reflective or ‘cool’ roofs on homes, public drinking-water systems, artificial barriers against flooding, separate sewage systems, and waste-collection. These are reliably missing in workers’ neighborhoods visited for this report.[37] Estimates of their costs and financing are taken up in the accompanying report.

4. Wages and social protection. 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. 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. Responses to inadequate social protection systems in apparel industry production centers are outlined in Cornell GLI’s “Learning from Crisis” (Judd et al., 2022).[38]

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36 See, for example, Dadush (2022) for examples of brand-manufacturer contract terms that address worker rights.

37 For a longer list, see Arsht-Rock, 2022b. https://onebillionresilient.org/hot-cities-chilled-economies/

38 Regarding India workers climate-linked micro-insurance programs, see Arsht-Rock, 2023.

CONCLUSION

The climate vulnerabilities of workers, manufacturers and of fashion's massive output in tropical and subtropical centers are measurable, and our (and others') projections show them growing. They are cutting deeply into export earnings, employment and worker health. Without rapid adaptation, these falloffs in earnings and jobs will compound.

In fact, our projections likely understate the urgency of the problem. In 2023, manufacturers and industry leaders interviewed for this paper reported that demand for apparel in several of our focus countries is down, 'soft'. Lower productivity from extreme heat is driving up labor costs in an environment in which some buyers are pushing for lower prices from their manufacturers and even discounts on completed orders. That combination can lead to uncompetitive factories—or wage theft or other violations, or all three—and a fall in apparel employment and investment not only in 2030, but now.

The more urgent recommendations made above are obvious, or should be. With years of experience and a constant flow of relevant climate reporting, do global fashion brands, manufacturers and governments really need to be confronted with these data? Probably not.

And yet there is real risk that brands and retailers will reach only for the lowest fruit on the tree: heat measures as part of worker 'wellness' programs and commissioning of flood hazard certifications, for example. Why? The recommendations above represent financial costs and political risks that fashion brands, manufacturers and governments may not want to bear, or even share. Brands may continue to regard them as externalities. And the fashion industry's long-standing collective-action problem means that the costs are instead borne by manufacturers and, more directly, by workers: longer hours, exhaustion and illness from extreme heat and flooding, and higher costs for medicine, electricity and drinking water.

So, where is the higher ground?

It is where these financial, social and environmental risks overlap: adaptation and mitigation, productivity and earnings, worker income and worker health, and jobs. For workers, the need is clear enough. For manufacturers, the re-couping of heat- and flood-related shortfalls in earnings makes adaptation feasible, if not attractive. For governments, new jobs and export earnings are crucial. For fashion brands and their regulators, higher ground is where new rules generate action and accountability for a just resilience.

Our second report takes up the Higher Ground? questions with an analysis of physical climate risk for fashion brands, and both costs and accountability for climate adaptation.

Disclosure

Appendix

Methodology and Limitations

The analytical outputs for these two Higher Ground? reports are different: export earnings and employment projections for the first report, and cost as shares of cost of goods (COGs) and net operating profit after tax (NOPAT) in the second. But analyses for both reports make use of the same data and approaches for heat and flood impacts, and projections based on the same climate models.

1. Climate scenarios.

Our temperature and flood analyses are based on models developed and data organized by others: chiefly the European Union's Copernicus Climate Change Service for temperature and the World Resources Institute Aqueduct flood model. Both produce datasets using our preferred 'middle-of-the-road' climate scenario, SSP 2-4.5 (and RCP 4.5). As noted in the introductions to both reports, we aim to avoid "both understating risk using the most optimistic SSP 1-2.6 or catastrophizing with the relatively pessimistic SSP 5-8.5. And stopping our analysis at 2050 means we largely avoid the greater uncertainty that accompanies longer-term projections (IPCC, 2007; Riahi et al., 2017).

2. Heat impacts on output, export earnings and employment.

We provide in the Introduction to Part 1 and 1.1 of this report our rationale for use of wet-bulb globe temperature (WBGT) and daily maximum surface air temperature data as proxies for heat stress. Our WBGT projections are composite results from 10+ CMIP6 models, effectively a comparison of results across models developed by 10+ independent institutions. We compared the historical baseline period of 1980 – 2010 for each CMIP6 model we analysed against the observed ERA5 historical values for daily maximum 2m air temperature. Systematic distortions from the observed ERA5 values were then applied via Quantile Delta Mapping to the forward period CMIP6 projections. This process preserves trends in the forward data whilst minimising systematic bias (over- or under- prediction).

Wet-bulb globe temperature. For background and datasets, see Sandstad, M., Schwingshackl, C., Iles, C., (2022). "Climate extreme indices and heat stress indicators derived from CMIP6 global climate projections." Copernicus Climate Change Service (C3S) Climate Data Store (CDS). DOI: 10.24381/cds.776e08bd (Accessed on 07-Jun-2023)

Daily Maximum Surface Air Temperature data come from Copernicus Climate Change Service, Climate Data Store, (2021): CMIP6 climate projections. Copernicus Climate Change Service (C3S) Climate Data Store (CDS). DOI: 10.24381/cds.c866074c (Accessed on 07-Jun-2023). Daily Maximum Surface Air Temperature was bias adjusted using BiasAdjustCXX against ERA5 historical data by Schroders. Hersbach, Bell et al (2017): Complete ERA5 from 1940: Fifth generation of ECMWF atmospheric reanalyses of the global climate. Copernicus Climate Change Service (C3S) Data Store (CDS). DOI: 10.24381/cds.143582cf (accessed on 07-Jun-2023).

In Part 2, we present two scenarios for apparel industry growth to contrast the impacts on output in climate-adaptive and non-adaptive scenarios. To illustrate the difference in outcomes under the two scenarios, our analyses make no allowance for adaptation investments by employers or governments. (In this way, our analyses are similar in design to the projections made by the IPCC climate scenarios.)

Using 2021 apparel and footwear export earnings by country as a baseline measure of national apparel and footwear output, we project annual increases (2025 – 2050) in earnings using each country's 2016 – 2021 compound annual growth rate. These 'climate-adaptive' estimates represent a growth trajectory for apparel industries that move quickly—that is, by 2030—to off-set the current and future accelerating effects of heat stress on workers and their output.

(Recall that among cities in our focus countries—Karachi, Dhaka, Ho Chi Minh City and Phnom Penh—the average number of 30.5 WBGT exceedance days climbs 50.9 percent from 39 days in 2014 to 59 by 2030. Exceedance days more than double by 2030 in Ho Chi Minh City (and Hanoi) and Phnom Penh. Starting from relatively higher levels, Dhaka's exceedance days will already be 63 percent higher and Karachi's 20 percent by 2030.)

The second scenario—a business-as-usual or 'high heat-stress' scenario—adjusts growth in export earnings using observed changes in manufacturing worker productivity due to heat stress. Our approach for productivity-heat interactions follows Hsiang et al (2012), and Somanathan et al (2021). Hsiang's finding that manufacturing worker output declines by 1 – 2 percent for each 1 C increase in the wet-bulb globe temperature above 25 C WBGT provides us with a relatively conservative formulation for projecting changes in output using our temperature exposure projections (WBGT) presented in Part 1.

We calculate and stack daily output declines in manufacturing for each temperature 'bin' on days above five thresholds for heat stress: 25, 28, 30.5, 32 and 35 C WBGT. These daily reductions in output are expressed in terms of lower daily industry export earnings in the 'heat high-stress' projections. For example, an industry facing 17 'exceedance' days with WBGT between 32 and 34 C in 2030 will, in our calculation, experience a 10.5 percent decline (7 C WBGT x 1.5 %) in output on those 17 days. The total export earnings loss is 10.5 percent of the industry's projected daily earnings (projected annual export earnings/297 production days per year).

(Variations in temperature and relative humidity between major apparel production centers in the same country produce different export earnings projections. We ran Karachi and Lahore/Faisalabad, and Ho Chi Minh City and Hanoi estimates separately then combined by country based on each center's relative share of the national apparel and footwear factory counts using OSH data cleaned by Schroders.)

These national exceedance days 'losses' (more accurately, opportunity costs) are combined across all WBGT bins for estimates of 'high heat stress' export earnings in 2030 and 2050. The gaps between projected export earnings under the two scenarios allow us to calculate the annual percent decline in apparel export earnings by country. We reduce the CAGR used in the 'climate-adaptive' earnings projections by this annual 'loss' rate to arrive 2030 and 2050 projections (compounded) for export earnings in the heat-stress scenario. (See Table A2 below).

We project employment growth in a similar way: annual growth rates in employment between 2015 and 2019 are used for 2030 and 2050 projections based on changes in annual earnings under the climate-adaptive scenario. We then adjust those jobs figures (downward) in our high heat-stress scenario using the ratio of export earnings in the climate-adaptative and heat-stress scenarios.

Table A1. **Apparel and footwear jobs CAGR, 2015 – 2019 by country.**

Country	Employment CAGR
Bangladesh	1.35 %
Cambodia	3.00 %
Pakistan	2.26 %
Vietnam	4.67 %

Sources: Cornell GLI, ILOStat.

(Note that employment data reporting for apparel and footwear is less robust than export earnings data. Where data is intermittent in ILOStat, industry association reports and annual statistical yearbooks, we interpolate employment levels for 2015 and 2019.)

We conducted a robustness check using an alternative approach in which we adjusted apparel industry CAGR for past (recent) effects of heat on export earnings. Using country- and sector-specific heat-productivity loss estimates from the ILO's Working on a Warmer Planet analysis (2019), we estimated 2025 – 2030 export earnings for two scenarios. The first scenario simulates 'climate-adaptive' growth: we calculated future earnings based on the 2010 – 2019 CAGR plus the absolute value of ILO estimates of historic heat-related productivity changes for the same period. The second scenario 'backs out' the ILO's (higher) 2030 productivity loss rate for a 'high-heat' scenario. (The ILO method uses RCP 2.6 data which corresponds to a more optimistic SSP than the scenario we use in our analysis).

This alternative approach allowed us to use longer-term changes in productivity to estimate the net effect of higher heat from 2025 forwards on a country's 2030 and 2050 earnings. Using Bangladesh data, we found that the 2025 – 2030 difference in earnings between the two scenarios was -21.85 percent, vs -19.36 percent in our WBGT exceedance days approach in Part 2. Between 2030 and 2050, we found very similar results: -67.98 vs -68.40 percent. A more thorough-going analysis would 'back out' heat effects for 30 years or more, but our limited analysis here seems to confirm the robustness of the effects we describe in the report.

Table A2. **Annual estimated apparel output change based on exceedance days (WBGT >25 C, 2030 and 2050) and ILO 2030 'manufacturing' estimates, by country**

Country/Center	2030	2050	Change	ILO 2030 estimates
Bangladesh	-4.48	-5.29	0.81	-4.96
Cambodia	-3.76	-5.51	1.75	-7.26
Karachi	-7.59	-8.62	1.03	-5.83 Pakistan
Faisalabad/Lahore	-5.93	-6.07	0.13	
Ho Chi Minh City	-5.17	-6.15	0.99	-4.96 Vietnam
Hanoi	-2.49	-3.08	0.59	

Sources: Cornell GLI, Schroders, EU Copernicus, ILO Work on a warmer planet (2019). Analysis undertaken July 2023.

3. Flood impacts on output, export earnings and employment.

To calculate flood-related impacts in terms of export earnings and jobs in a non-adaptive scenario, we performed a geospatial analysis of flooding on production centers in 2030 and 2050 in our four focus countries. We employed World Resources Institute 'Aqueduct' coastal and riverine/rainfall flooding models built around RCP 4.5/SSP 2 (gridded at 10 x 10 km at the equator).

(WRI Aqueduct "[simulates] flood risk using a cascade of models within the Global Flood Risk with IMAGE Scenarios (GLOFRIS) modeling framework (Winsemius et al. 2013), and used GLOFRIS to assess the influence on river flood risk of natural climate variability (Ward et al. 2014) and future climate and socioeconomic change (Winsemius et al. 2016)". Cornell GLI and Schroders identified production areas and lat./long. coordinates of factories using supplier disclosure data from brands and retailers, and data from Mapped in Bangladesh and Open Supply Hub.

Schroders and Cornell GLI mapped three inundation levels (0 - 0.5 meter, 0.5 – 1 meter and 1+ meter) for both types of flooding for more than 8,100 apparel and footwear factories. We estimate production 'interruption days' in 2030 and 2050 using a formula based on disaster recovery research and Intensel's analysis of flood recovery timelines, as well as observations from apparel industry flooding events in S.E. Asia: three days of recovery for rainfall flooding between 0 - 0.5 m, 6 days for 0.5 – 1 m and 12 days for 1+ m of flooding.

(Cornell GLI and Schroders maps demonstrate the worst-case scenario (within RCP 4.5) among the five WRI models we use. But the factory inundation analyses take the average of the five models and, as a result, Ho Chi Minh City maps may appear to show greater impacts than the inundation data. The other centers show only small discrepancies.)

As with heat-related impacts above, we stacked projected days lost to flooding and recovery in affected factories into daily changes in industry annual export earnings for 2030 and 2050. In recognition of the evident differences in physical infrastructure and climate impact 'preparedness' between our four focus countries, we adjust each country's projected 2030 and 2050 export earnings under the non-adaptive scenario using the University of Notre Dame (U.S.) GAIN readiness measures. These are widely used measures of a country's "ability to leverage [infrastructure] investments and convert them to adaptation actions" based on economic readiness, governance readiness and social readiness.

Table A3. **GAIN climate impact readiness scores and index values, by country.**

Country	ND-GAIN readiness scores	Indexed
Bangladesh	0.278	1.00
Cambodia	0.282	1.01
Pakistan	0.311	1.12
Vietnam	0.425	1.53

Source: ND-GAIN.

Similar to our temperature exposure analysis, we calculated flood impacts on national apparel employment levels by applying the ratio of 2030 and 2050 earnings-to-employment in the climate-adaptive scenario to lower earnings projections in the non-adaptive scenario.

The conversion of heat-productivity impacts and flood disruption days into daily and annual export earnings allows us to stack them and estimate the combined effects of extreme heat and flooding on apparel export earnings and employment.

Table A4. **Combined heat- and flood-related impacts for apparel export earnings under climate-adaptative and high heat and flooding scenarios, 2030 and 2050.**

Country	Year	Climate-adaptive export earnings (USD)	High heat + flood earnings (USD)	Change (USD)	Change (percent)
Bangladesh	2021	46.55 b.			
	2030	122.01 b.	95.22 b.	-26.78 b.	-21.95%
	2050	1,038.22 b.	326.90 b.	-711.32 b.	-68.51%
Cambodia	2021	15.24 b.			
	2030	35.64 b.	28.89 b.	-6.75 b.	-18.94%
	2050	235.41 b.	79.09 b.	-156.32 b.	-66.40%
Pakistan	2021	9.07 b.			
	2030	24.54 b.	16,95 b.	-7.59 b.	-30.94%
	2050	224.35 b.	43,70 b.	-180.65 b.	-80.52%
Vietnam	2021	56.99 b.			
	2030	116.80 b.	92,04 b.	-24.77 b.	-21.20%
	2050	575.46 b.	197.12 b.	-378.34 b.	-65.74%

Source: Cornell GLI. Analysis undertaken July 2023.

Table A5. Combined heat- and flood-related impacts for apparel employment under 'climate-adaptative' and high-heat and flooding scenarios, 2030 and 2050.

Country	Year	Climate-adaptive employment (no. of jobs)	High heat + flood employment	Change	Change (percent)
Bangladesh	2021	4.22 m.			
	2030	4.83 m.	4.57 m.	-0.25 m.	-5.29%
	2050	6.31 m.	5.04 m.	-1.27 m.	-20.17%
Cambodia	2021	0.70 m.			
	2030	0.94 m.	0.89 m.	-0.05 m.	-5.63%
	2050	1.70 m.	1.14 m.	-0.56 m.	-32.76%
Pakistan	2021	2.75 m.			
	2030	3.43 m.	3.14 m.	-0.30 m.	-8.65%
	2050	5.37 m.	3.51 m.	-1.85 m.	-34.56%
Vietnam	2021	2.97 m.			
	2030	4.70 m.	4.34 m.	-0.35 m.	-7.53%
	2050	11.70 m.	6.74 m.	-4.96 m.	-42.38%

Source: Cornell GLI. Analysis undertaken July 2023.

But we note in closing that the disparity between heat- and flood-related impacts in both reports reflect one of the limitations of flood modeling—chiefly, its reliance on maximum flood events in each return period while temperature and humidity can be projected by the day, even hourly. We conclude that while both heat and flood damage estimates in these reports are conservative, flood risk is considerably higher and less predictable than our analyses suggest.

ILR Global Labor Institute

Housed in the Cornell University School of Industrial and Labor Relations, the Global Labor Institute (GLI)—formerly the New Conversations Project—is dedicated to independent quantitative research and action on a new generation of strategies that the evidence says measurably improves labor conditions for large numbers of workers in global production.

To get there, the Global Labor Institute pulls together fragmented constituencies—brands and retailers, manufacturers, unions, farmers, civil society organizations, regulators, investors—for evidence—based conversations and decisions.

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Bangladesh. Photo credit: ILO Better Work