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HEIT

Guidance document for ClimateCHIP.org website and the Workplace Heat Effects Assessment Tool (WorkHeat)

PREPARED for HEIT, Mapua, New Zealand
https://ClimateCHIP.org/health-and-environment-international-trust

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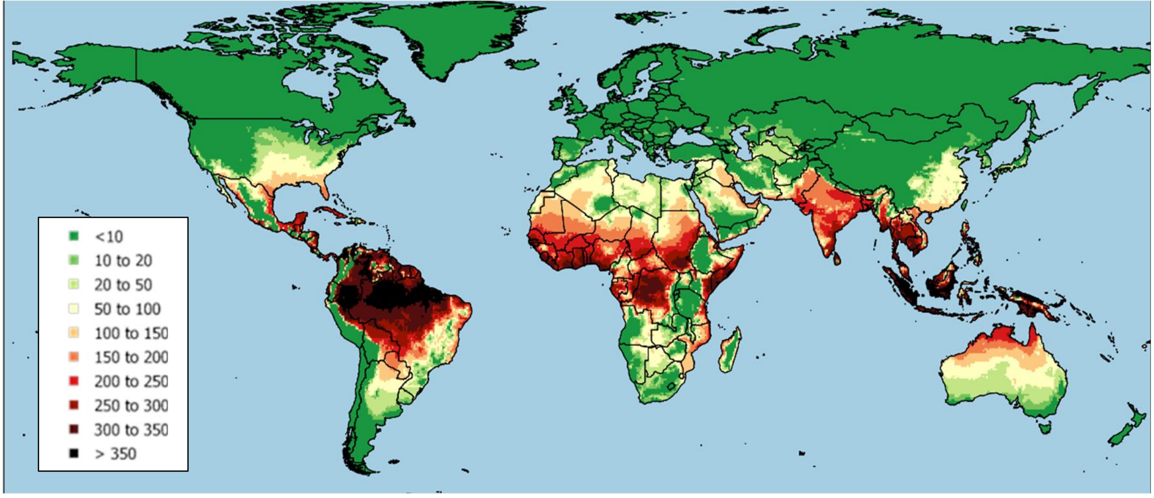
1. Short introduction

Workplace heat is a well-known occupational health hazard affecting working people in many ways (Parsons, 2014; Kjellstrom et al., 2016). The health risks are associated with the need for the human body to maintain a core body temperature (CBT) close to 37°C. If the CBT increases above 39°C serious heat stroke may occur and some people will die. Working people are at particular risk as physical work contributes to the body heat (See Section 2 for more details on health effects).

Climate change, also called global heating, creates increasing challenges to protect working people from heat (Kjellstrom et al., 2009). The ClimateCHIP.org website and the Workplace Heat Effects Assessment Tool (WorkHeat) aim to provide important data and advice for those planning or managing the reduction and prevention of health risks in potentially hot locations. The website is a unique resource for local climate data anywhere in the world as it includes data on heat stress indices that can be interpreted for prevention of effects of heat on health and productivity. The user-friendly analysis, advice and interpretation guidelines makes it possible for a manager, planner or investor to find ways to protect workers from heat effects and to reduce the risk of heat induced productivity and economic losses.

The areas of the world of particular concern are indicated in the global heat map (Figure 1). In the yellow, red or brown areas, more than 100 days each year are hot enough to create serious heat problems for working people. However, even in the green areas a limited number of "heat wave" days can also cause heat challenges. ClimateCHIP provides access to heat data for any part of the world from 1981 to 2099. WBGT (Wet Bulb Globe Temperature, described in Section 2) is a special heat index designed for use in workplace monitoring (as recommended by NIOSH, 2016).

Figure 1. Number of hot days per year with WBGTmax > 26°C, 1995



This map is based on heat estimates from 68,000 grid cells (0.5 x 0.5 land degrees) that cover the whole world's landmass.

2. Heat effects on working people and productivity

Workplace heat has been known to be an important occupational health hazard for more than a century. The basis for the threats to health stem from the basic human physiology concerning heat exposure. Humans need to maintain a core body temperature (CBT) close to 37°C. If the CBT goes just 2-4°C higher, serious heat stroke or even death may occur (Parsons, 2014). Serious health effects can also occur if the body cools by a few degrees below 37°C.

In recent years increased scientific attention to the problems of workplace heat has led to a better understanding of the variety of health effects that may occur and to adverse effects on productivity effects. Table 1 lists specific health effects reported in documents from WHO and IPCC. (Detailed listings of references are not shown in this short guidance document).

The main problem for working people is effects on the heart. I For example, hundreds of migrant workers died during the first years of the major construction work for the 2022 football World Cup in Qatar (see: https://karger.com/crd/article/143/1-2/37/97107/Heat-Stress-Impacts-on-Cardiac-Mortality-in-Nepali).

Another major health threat occurs in work situations where workers sweat profusely, and become dehydrated causes serious chronic kidney disease (see: https://laislanetwork.org/).

Table 1. Climate change related health impacts of heat according to IPCC, WHO and other sources (modified from Kjellstrom et al, 2016)

<table>
<tr><th>Hazard exposure</th><th>Health impact</th><th>Confidence of this impact</th><th>Specific effects at organ level</th><th>Sources</th></tr>
<tr><td><i>Intense heat</i></td><td>Heat stroke death</td><td>Very high</td><td>Heart strain; Central Nervous System (CNS) malfunction; dehydration</td><td rowspan="4">IPCC and WHO reports (before 2016)</td></tr>
<tr><td></td><td>Heat stroke morbidity</td><td>Very high</td><td>Heart strain; CNS malfunction; dehydration</td></tr>
<tr><td></td><td>Heat exhaustion, Work capacity loss</td><td>High</td><td>Heart strain; mental fatigue</td></tr>
<tr><td><i>Forced migration</i></td><td>Under-nutrition; infections; mental stress; injuries</td><td>High</td><td>Work capacity loss, heart disease, fatigue</td></tr>
<tr><td colspan="5">Health concerns not detailed in the IPCC or WHO reports</td></tr>
<tr><td><i>Intense heat</i></td><td colspan="2">Chronic kidney disease linked to dehydration</td><td colspan="2" rowspan="7">References in Kjellstrom et al., 2016</td></tr>
<tr><td></td><td colspan="2">Increased incidence of violent crimes</td></tr>
<tr><td></td><td colspan="2">Increased incidence of suicides</td></tr>
<tr><td></td><td colspan="2">Teratogenic effects of high body temperature in pregnant women; damage to development of featus brain</td></tr>
<tr><td></td><td colspan="2">Interactions with prescription drugs</td></tr>
<tr><td></td><td colspan="2">Deteriorated clinical status in chronic Non-Communicable Diseases</td></tr>
<tr><td></td><td colspan="2">Increased damage due to head trauma</td></tr>
</table>

In order to maintain the CBT at a healthy level the human body reacts to the air temperature outside the body (or water temperature when immersed in water) by adjusting blood flow to the skin and different organs. When the air in the workplace is higher than the body temperature (or skin temperature at 33°C), heat will be transferred to the body in accordance with the basic laws of physics, which include:

Conduction and Convection – direct transfer between body surface and surrounding material touching the skin (convection = due to moving air or water).
Radiation – heat rays from the body or on the body (outdoors usually from sun)
Evaporation – When sweat evaporates, heat is released from the body surface

The net effect of these transfers results in storage or loss of heat in the body and a change in core body temperature. The focus here is on the ways a body interacts with hot air around it, the most common work situation.

An important factor is the generation of heat inside the body when muscles are used. This is the greatest contributor to heat stress in many situations. Only 20% of the energy created inside the body, from food digestion and other metabolic mechanisms, actually creates work by the muscles with as much as 80% of this energy released inside the body as heat. This is why someone carrying out intensive work or sports activity still feels hot even in cooler air than 33°C. The interpretation of the health risk of external heat data needs to include an estimate of the work intensity of the job (the Metabolic Rate, MR). Light work has an MR at about 200W. Moderate intensity work MR is about 300W, and heavy labour MR is about 400W.

The most effective way to transfer heat from the body to surrounding air is by the evaporation of sweat from the skin. The air humidity is a very important factor contributing to heat stress when working. If air relative humidity (RH) is 100% (mist conditions), then no sweat will evaporate and cooling will not take place. Conversely, in a very dry situation with RH at 20%, sweat will rapidly evaporate and reduce stored heat.

Heat stress indices

Heat indices combine both temperature and humidity so they are the best variables for assessing heat risk in workplaces. Occupational health and productivity assessments most often use the index **WBGT (Wet Bulb Globe Temperature**) developed in the 1950s by the US army to protect soldiers in training from severe heat stress effects (Parsons, 2014). Heat protection standards and guidelines with WBGT as a base are available for use in assessments of current and future heat challenges (e.g. NIOSH, 2016). Other heat stress indices are sometimes used in reports (e.g. the Universal Thermal Climate Index UTCI, the US Heat Index, or the Canadian Humidex), but WBGT includes all aspects of heat and is most widely used in workplaces.

The future heat estimates shown on ClimateCHIP.org website, and those used in the Workplace Heat Effects Assessment Tool (WorkHeat), are based on internationally acknowledged ISIMIP3b data from the Potsdam Institute, Germany. Data for two of the “pathways” for future global green-house gas emissions, SSP126 and SSP370 are used in ClimateCHIP. These Shared Socioeconomic Pathways (SSPs) include assumptions about climate change mitigation (prevention) policies, with SSP1 the most protective and SSP3 fitting with current green-house gas emission policies and trends. SSP1 is linked to Representative Concentration Pathway RCP2.6 with radiative forcing from green-house gases at 2.6 W/m2, and SSP3 to an RCP at 7.0 W/m2, which will lead to continuing increase of the global mean temperature beyond 1.5°C.

Different climate models are available for each SSP pathway. For WorkHeat we use the midpoint of two models that span the range of different model results. These models are GFDL from the USA and UKesm from the United Kingdom. The range between results is usually rather narrow, so the midpoint of these two models is a simpler way of showing likely future heat levels. (The abbreviations in the preceding two paragraphs are included when relevant in the following text: SSP126, SSP370, GFDL and UKesm).

It also is important to note that the time duration of a given heat level, (hourly, 24-hour daily mean, weekly, monthly or annual), is an important feature of any heat estimate. Adverse effects on health and productivity occur quickly making <u>hourly data the most valuable</u> for assessing impacts. Occupational health standards and guidelines apply to hourly values. When heat levels vary widely within an hour, and extremely hot short periods occur, it is these short periods (seconds or minutes) that are likely to be the most dangerous in certain occupations, (e.g. fire fighters).

3. Short overview of website, ClimateCHIP

This website was created by the HEIT team (Health and Environment International Trust) in New Zealand (https://ClimateCHIP.org/health-and-environment-international-trust). It was initiated over 10 years ago and has been updated with the latest internationally approved climate modelling data in 2023. The website has a **"Your Area"** page where data for geographic spatial grid cells are presented. The features of the website are listed in Box 1, and on the website itself there are brief descriptions of the data and what can be produced as outputs.

➔ ***Please, spend a few minutes to familiarize yourself with the material on the website.***

Box 1. Features of the "Your Area" pages of the Website ClimateCHIP.org

Map features

- Climate data are shown for map areas and locations using Google Earth maps
- The map and climate data graphics for one initial variable is shown on the screen
- On the map one can choose "Map" or "Satellite" to either see map features or satellite photo details of the location. The latter can be used to judge urbanisation in this location and to find the exact place of a planned activity.

Location specifications

- Spatial rectangular grid cell data; 0.5 x 0.5 degrees (appr.56 x 56 km at the Equator, 30 x 56 km at 40 degrees North, e.g. New York, or South, e.g. Wellington)
- A total of approximately 68,000 grid cells over land, where the land proportion of the grid cell area is more than 10%. Most grid cells are 100% over land.
- Weather station data from approximately 5,000 stations where more than 90% of the daily data from 1980 are available

Time periods; Two time periods for data:

- **"Today"** = 1981 to 2021, monthly data for each year
- "**Tomorrow**" = 1980s to 2090s, monthly mean data for each decade

Climate variables available

- Monthly means of daily data on maximum, mean and minimum Temperature
- Mean daily Relative Humidity (RH), RH at maximum Temperature and Dew-point temperature which indicates the "absolute humidity"
- Monthly means of three daily heat levels (max, mean and min) of three heat indices (WBGT, UTCI and HI), values in the shade (and in sun for WBGTmax)

Time trend graphics

- "**Today**" graphics next to the map show annual or monthly estimates of mean grid cell values for selected climate variables, each year from 1981 to 2021
- The map shows weather station locations and a click brings up similar data reported from the chosen weather station
- "**Tomorrow**" graphics next to the same map show decadal estimates of mean annual or monthly grid cell values; same variables as for Today.
- The graphics and underlying data can be downloaded into Excel for further use by any website user
- **"WorkHeat"** graphics show monthly number of days hot enough to require heat prevention actions (**unsafe work days**) and the likely **productivity loss** if work is carried out in heat.

Other information

- The Workplace Heat Effects Assessment Tool is available in "Assessment Options"
- Heat data analysis tools and quality testing reports
- Guidance for occupational epidemiology studies of heat effects on working people
- HEIT reports and individual country data

4. Location of interest and current heat data

➔ Go to the location of interest on the website map (see Box 2).

Box 2. Steps in finding local climate information at location of interest

1. Choose location using name of area, town or another feature
2. Type this into the "Search" field inside "Your Area, Today"
3. The area of interest should now appear; Zoom in or out until you see that location of interest. You can also get to the location by moving cursor over map, or moving the map. The + and – in the corner can be used to expand or reduce the map scale.
4. You can now choose to see values and time trends 1981-2021 for any of the climate variables listed under "Parameter"
5. The values can be presented on Celsius or Fahrenheit scale, see "Temperature Unit"
6. Values can be shown for any calendar month, annual average or monthly distribution; see "Chart Type"
7. The "Monthly Distribution" is the best to start with, as it shows which month is the hottest and the heat levels reached. These values are the means for the period 1981-2021

- Note that the scale of the output graphics varies so that lowest and highest numbers fit in. Therefore, the visual slopes of fitted time trends are not directly comparable for different parameters and locations.

If you have already used the Workplace Heat Effects Assessment Tool on ClimateCHIP, a map and graph has been preselected to show the current and future WBGT values for the chosen location. This is in the Tomorrow section of the website data.

Figure 2 shows an example of Your Area Today for the grid cell containing most of the city of Hyderabad, India. The grid cell includes data from the central and western parts of Hyderabad and the weather station at the airport.

➔ ***Example: Find the Hyderabad grid cell in India and its airport weather station Begumpet***

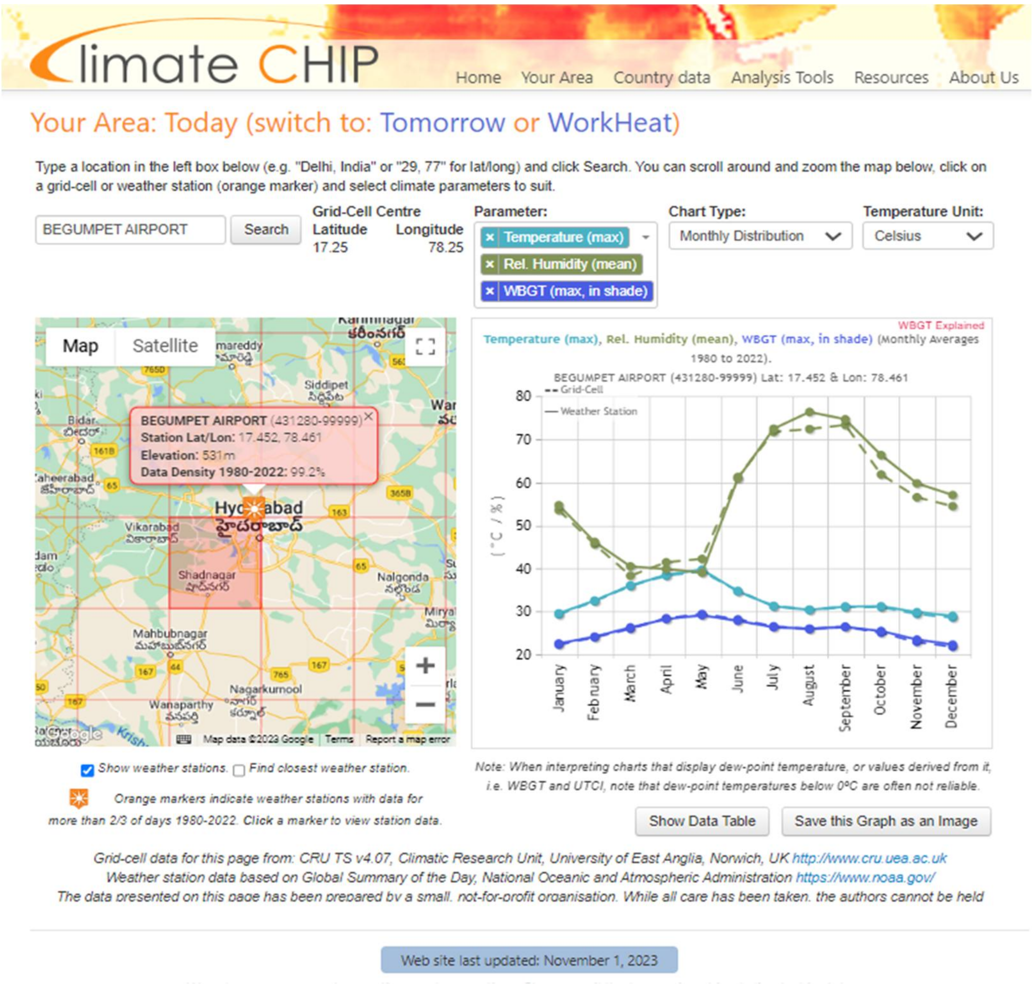
The figure 2 graphic shows Tmax, RHmean, and WBGTmax, averages for 1981-2021. The hottest month is May with an average Tmax at 40°C, while the coolest months are December and January with Tmax close to 30°C. Tmax occurs in the early afternoon, the 24-hour mean temperature is 33°C in May and night-time Tmin is 26°C, (shown by clicking on these parameters). March to May is a dry pre-monsoon period with RHmean at 40%, while the peak monsoon period (July, August) has RHmean in the range 72-75%.

Figure 2 also shows that WBGTmax occurs in the same month as Tmax (May) and has reached 30°C, exceeding the safety guidelines available (see below). From March to September the monthly WBGTmax values are on average above 26°C, a value that requires workers to be protected from heat.

The hatched curves on the graphic shows the values for the grid cell and the continuous lines are data from the weather station. The mean values for the grid cell and the weather station are very similar for each month, which indicates that in this location the grid cell values represent locally measured heat values, i.e. good data quality. By clicking on each month, the time trends are different with the highest in November for the weather station: Tmax increasing 0.59°C per decade and WBGT increasing 0.43°C per decade. In May, the hottest month, the values increase more slowly, 0.29°C and 0.30°C per decade, respectively.

The key issue for worker safety and productivity is the WBGT level. The afternoon value (WBGTmax) in the shade for the grid cell area reaches appr. 22°C in January, 24°C in February and 26°C in March. In the sun during the afternoons these WBGTmax values are approximately 2°C higher. This means that actions for heat protection are required for most of the year in Hyderabad. In case another heat stress index is preferred for the analysis, UTCI and HI estimates can also be found among the parameters on the website.

Figure 2. Monthly data for Hyderabad, India, in "Your Area Today"



Type a location in the left box below (e.g. "Delhi, India" or "29, 77" for lat/long) and click Search. You can scroll around and zoom the map below, click on a grid-cell or weather station (orange marker) and select climate parameters to suit.

BEGUMPET AIRPORT

Grid-Cell Centre Latitude: 17.25 Longitude: 78.25

Parameter: Temperature (max), Rel. Humidity (mean), WBGT (max, in shade)

Chart Type: Monthly Distribution

Temperature Unit: Celsius

BEGUMPET AIRPORT (431280-99999)
Station Lat/Lon: 17.452, 78.461
Elevation: 531m
Data Density 1980-2022: 99.2%

☑ Show weather stations. ☐ Find closest weather station.

Orange markers indicate weather stations with data for more than 2/3 of days 1980-2022. Click a marker to view station data.

Note: When interpreting charts that display dew-point temperature, or values derived from it, i.e. WBGT and UTCI, note that dew-point temperatures below 0ºC are often not reliable.

Grid-cell data for this page from: CRU TS v4.07, Climatic Research Unit, University of East Anglia, Norwich, UK http://www.cru.uea.ac.uk
Weather station data based on Global Summary of the Day, National Oceanic and Atmospheric Administration https://www.noaa.gov/
The data presented on this page has been prepared by a small, not-for-profit organisation. While all care has been taken, the authors cannot be held

Web site last updated: November 1, 2023

The main way to assess heat risks for workers, carrying out work of varying physical intensity, is to assess the WBGT values during different hours of a day. In calculations of these impacts a simple short-cut to hourly data is to assume that the heat level during the four hottest hours (usually between 12 noon and 4 pm) is at the level of WBGTmax, and the heat level at the coolest four daylight hours (at dawn and dusk) is at the WBGTmean for the day. Another four hours is likely to be close to the midpoint of WBGTmax and WBGTmean. This is called the 4+4+4 method (Kjellstrom et al., 2018).

- ➔ ***Example: Find the Managua grid cell in Nicaragua and the airport weather station***

The grid cell data in Today for Managua (Figure 3) show two peaks for the hottest months of WBGTmax, April and August. Most months are similarly hot, except November-December which have 2-3°C lower values. The graphic also shows the WBGTmax for people working in direct sunlight without effective shading or cooling. Sun adds appr. 2-3°C to these high heat values during the afternoon.

These are monthly mean values, so individual hot days will reach higher values. In tropical regions like Managua, the daily variation is small with the hottest days just 1-2°C higher than the monthly mean. The heat risk for working in the shade on typical April days is based on estimates for WBGTmax at 28°C and WBGTmean at 25°C (Figure 3). The heat risk for working in the sun assumes a WBGTmax of 30.5°C and WBGTmean at 25°C. (The risk calculation method is shown in Section 5 below).

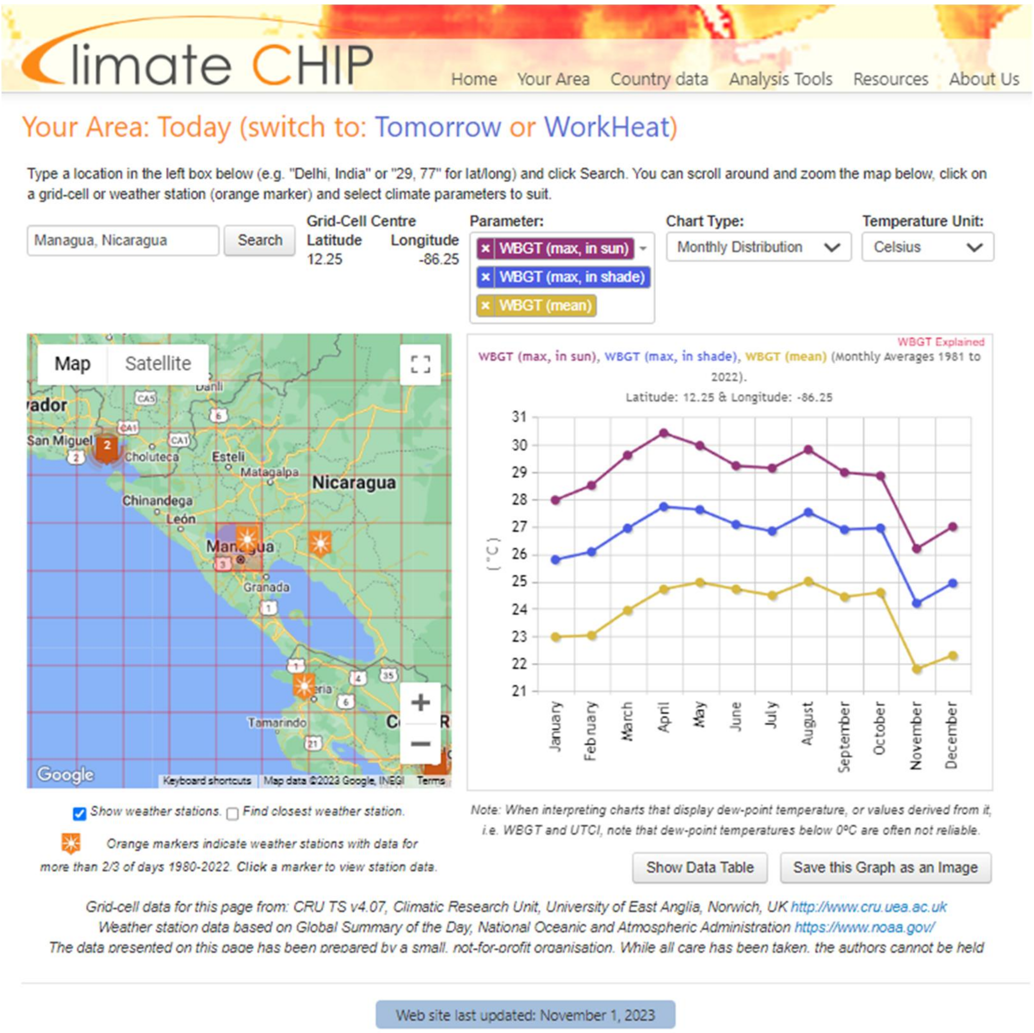
If a WBGT above 26°C is used as a simple threshold for heat levels that require attention, it is clear that the climate in the grid cell at Managua will create heat problems during almost the whole year. Clicking on data for April, the time trends 1981-2021 show increasing trends and WBGTmax has increased by 0.14°C per decade in this period. Clicking on Tomorrow then shows that the future trends are expected to go up faster and WBGTmax in the shade may reach 29-30°C by the end of the century. The recorded data from the weather station at Managua airport is very close to the grid cell estimates (see on ClimateCHIP.org). Exact agreement is unlikely because the grid cell data is an average for an area, while the weather station data measures at one point inside the grid cell.

Another feature that influences the heat risk in workplaces is the contribution of the Urban Heat Island (UHI) effect to local heat (https://www.epa.gov/green-infrastructure/reduce-urban-heat-island-effect). The additional heat exposure from the sun heats dark colour surfaces on the ground. This can add as much as 4-6°C to Tmax or 3-4°C to WBGTmax (air temperatures). Precise estimates cannot easily be made from grid cell-based data as this extra heat is so dependent on the local features of roads, buildings, parks, etc. However, the maps in ClimateCHIP.org can give an indication of potential UHI in the location of interest (Figure 4) using the satellite picture features.

In the satellite picture version of the map (Figure 4) of the Managua area the rural agricultural areas are green and the urban areas are grey. Zooming in closer with the "+ sign" eventually shows every street and building in this location. The likely current and future heat levels can then be adjusted to the potential UHI in the exact location of a workplace. If UHI is likely in a specific location inside this grid cell it means that in April the WBGTmax, in the shade, should not be set at 28°C (Figure 3 and 4), but at 31.5°C, 3.5°C higher. In the sun the WBGTmax is another 2°C higher (Figure 4). WBGTmean will need additions in a similar way.

These values are all monthly mean data so the hottest days will of course be at higher values. Daily data from weather stations are available and can be analysed with the **HothapsSoft database and software**. As a rule of thumb for hot months in tropical places, the three hottest days in a hot month are 1°C higher than the monthly mean. In temperate areas the three hottest days are 2°C higher than the mean.

Figure 3. WBGT data for Managua, Nicaragua



Your Area: Today (switch to: Tomorrow or WorkHeat)

Type a location in the left box below (e.g. "Delhi, India" or "29, 77" for lat/long) and click Search. You can scroll around and zoom the map below, click on a grid-cell or weather station (orange marker) and select climate parameters to suit.

Managua, Nicaragua

Grid-Cell Centre
Latitude 12.25
Longitude -86.25

Parameter: WBGT (max, in sun), WBGT (max, in shade), WBGT (mean)

Chart Type: Monthly Distribution

Temperature Unit: Celsius

WBGT (max, in sun), WBGT (max, in shade), WBGT (mean) (Monthly Averages 1981 to 2022).
Latitude: 12.25 & Longitude: -86.25

☑ Show weather stations. ☐ Find closest weather station.

Orange markers indicate weather stations with data for more than 2/3 of days 1980-2022. Click a marker to view station data.

Note: When interpreting charts that display dew-point temperature, or values derived from it, i.e. WBGT and UTCI, note that dew-point temperatures below 0ºC are often not reliable.

Grid-cell data for this page from: CRU TS v4.07, Climatic Research Unit, University of East Anglia, Norwich, UK http://www.cru.uea.ac.uk
Weather station data based on Global Summary of the Day, National Oceanic and Atmospheric Administration https://www.noaa.gov/
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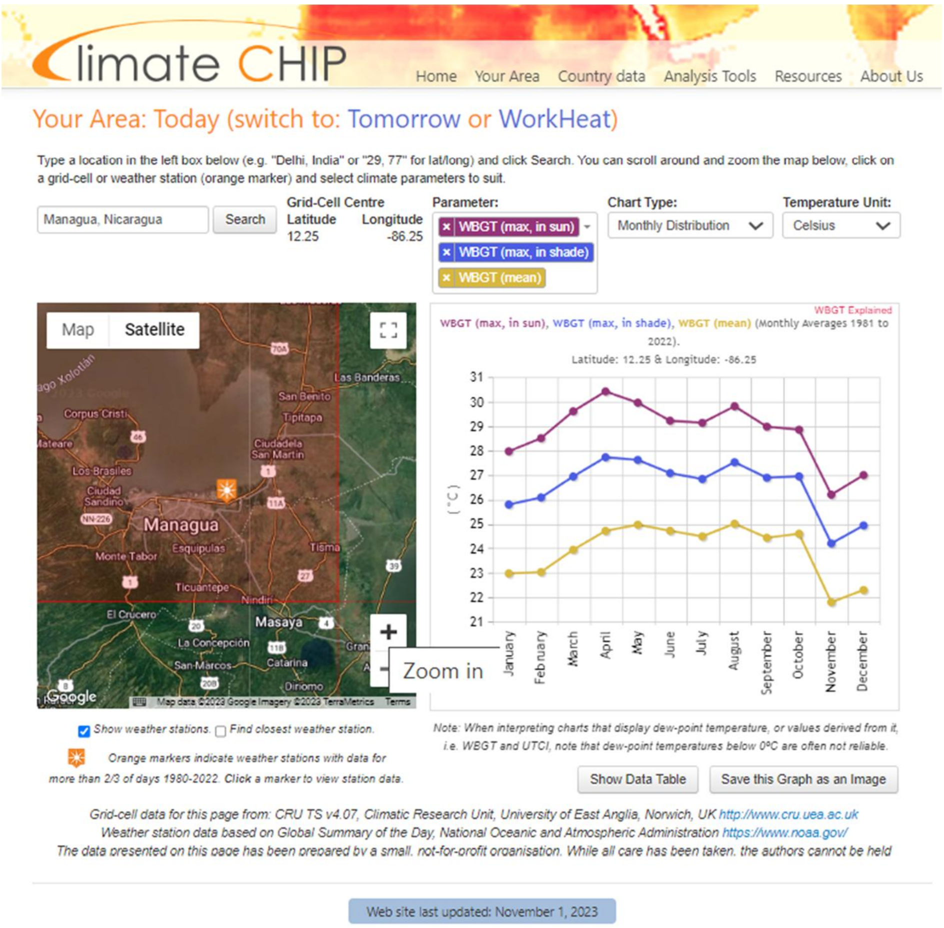
Figure 4. Managua grid cell area showing “Satellite” picture.



Your Area: Today (switch to: Tomorrow or WorkHeat)

Type a location in the left box below (e.g. "Delhi, India" or "29, 77" for lat/long) and click Search. You can scroll around and zoom the map below, click on a grid-cell or weather station (orange marker) and select climate parameters to suit.

Managua, Nicaragua

Grid-Cell Centre
Latitude 12.25
Longitude -86.25

Parameter: WBGT (max, in sun), WBGT (max, in shade), WBGT (mean)

Chart Type: Monthly Distribution

Temperature Unit: Celsius

WBGT (max, in sun), WBGT (max, in shade), WBGT (mean) (Monthly Averages 1981 to 2022).
Latitude: 12.25 & Longitude: -86.25

☑ Show weather stations. ☐ Find closest weather station.

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➔ ***Results of your view of data on the website:***

a. Overall understanding of the heat situation within the grid cell of interest
b. Knowledge of monthly heat distribution during a year in the period 2081-2021
c. Understanding of the additional heat from working in the sun or from UHI
d. Selection of WBGTmax and WBGTmean values to use in assessment of risks for health and productivity impacts of heat

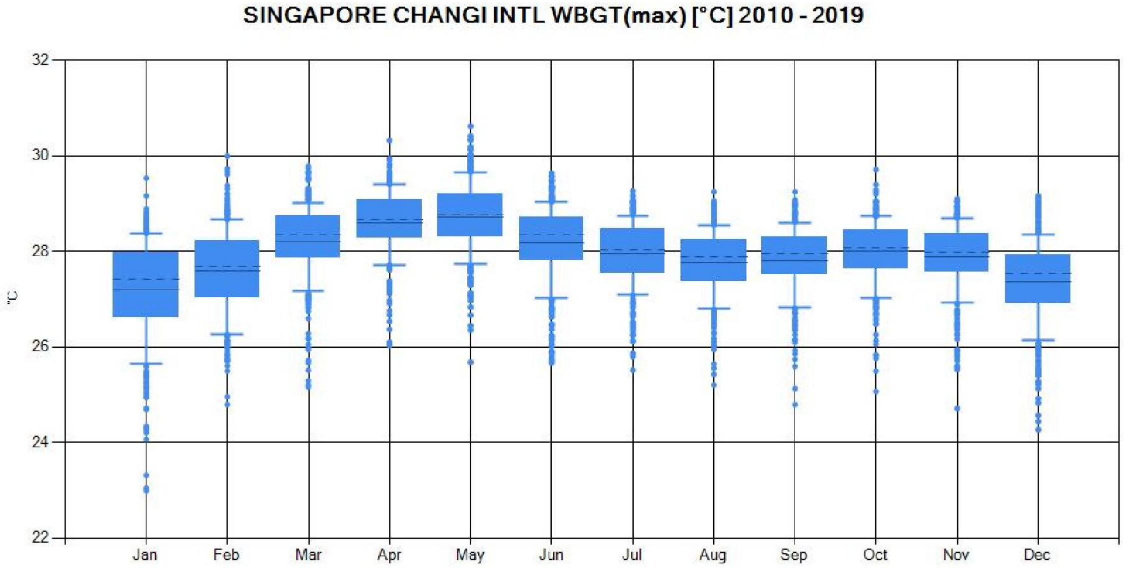
➔ ***You may wish to record WBGT values for different analysis:***

Value selection	**WBGTmax**	**WBGTmean**	**WBGTmax**	**WBGTmean**
	Monthly values, degr.C		**Hottest days, degr.C**	
Grid cell values, hottest month				
Grid cell values, coolest month				
With additions of UHI impact				
Weather station values ……				

Additional analysis with weather station data is possible with the use of the **HothapsSoft** database and software when a weather station is placed in the vicinity of the location of interest. This software has daily data on all routinely recorded meteorological variables at more than 18,000 weather stations around the world. Many stations have gaps in the data but more than 5,000 stations include data for at least 90% of the days since 1980. (ClimateCHIP provides links to the software and database).

Figure 5 shows an example of an output graphic from **HothapsSoft**. The presentation of actual daily measurements makes it possible to estimate heat stress levels on the hottest days. The data for each day in the period 1980-2022 can be downloaded into Excel and used for epidemiological and other impact studies.

Figure 5. HothapsSoft output for the main weather station in Singapore. Monthly WBGTmax data showing range of 50% of daily data (boxes), 80% of daily data (whiskers) and the values outside the whisker range (decadal data; which means appr. 300 days in each calendar month).



5. Current heat risks for health and productivity

The WBGT heat index combines temperature, humidity, air movement and heat radiation into one number that reflects the health and productivity risks for workers in a specific locality. A number of studies have reported on the risks for various effects, summarized in Figure 6 (Kjellstrom et al., 2018). We used the cumulative normal distribution function as a default for fitting curves to data based on the assumption that the curves should represent biological variation in heat sensitivity. We are currently reviewing this assumption. The red curve is the international standard (ISO, 2017), identical to the NIOSH (2016) guidelines in the USA. It shows the recommended reduction of hourly work time, for a person working at a moderate intensity of 300W metabolic rate, as the heat level rises. This is a method that can be used to prevent health effects from heat exposure at work. According to this guideline an hourly WBGT of 25°C does not require a reduction of work time for work of moderate intensity.

Figure 7 shows further safety recommendations. There are three fitted curves for the guideline values at 200W, 300W and 400W metabolic rates. By using the 10% work time reduction points as limits for “safe work in heat”, we find that the limits are 27°C at 400W, 29°C at 300W and 31°C at 200W. Therefore, we use WBGT at 27°C as a limit for “unsafe work days in heat” in the website calculations for WorkHeat (see Section 8 for an example).

The blue solid curves in Figure 6 and 7 show the fitted relationship to the combination of the two detailed studies available (Wyndham, 1969, and Sahu et al., 2013). This shows the actual reduction of work output (productivity) for workers in actual workplaces in underground gold mines and harvesting of rice fields, and it indicates that these workers can sustain work output beyond the safety recommendations for heat. Fifty % loss of work output occurs at WBGT = 34°C in these jobs (at appr. 300W intensity) while the safety recommendation for 50% rest is at 31°C. This difference highlights the “safety factor” included in the ISO and NIOSH guidelines, aimed at protecting the workers most sensitive to heat while the solid blue curve shows the output from the workers who could best cope with the heat at work. The period of rest time required in the guidelines are shown in section 8.

Figure 6. Level of heat impact on working people, expressed as a percentage of productivity loss (international standard = ISO; Wyndham and Sahu = available epidemiological data)

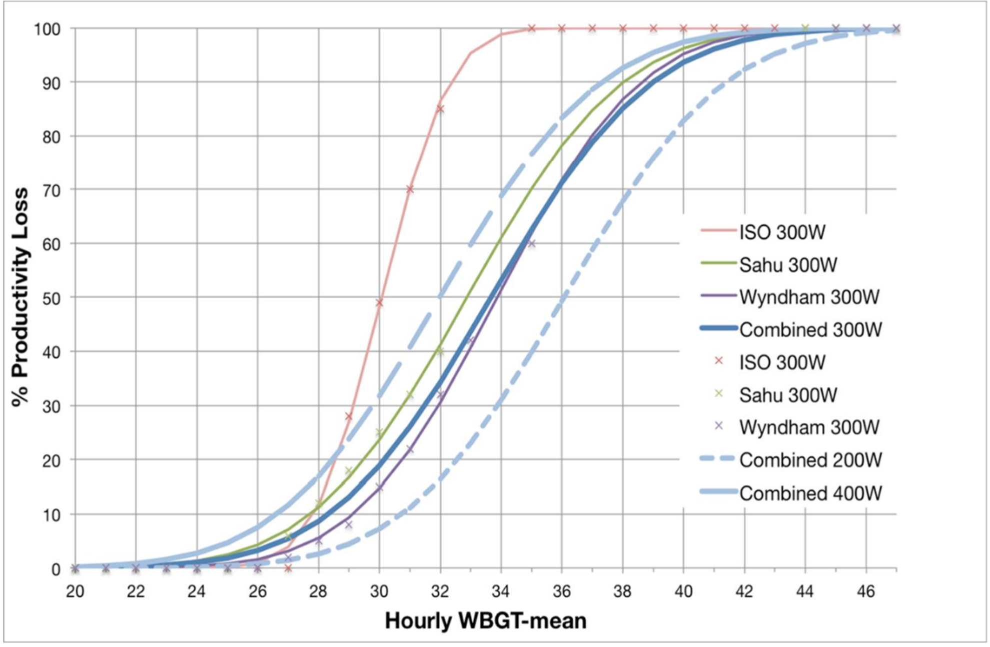
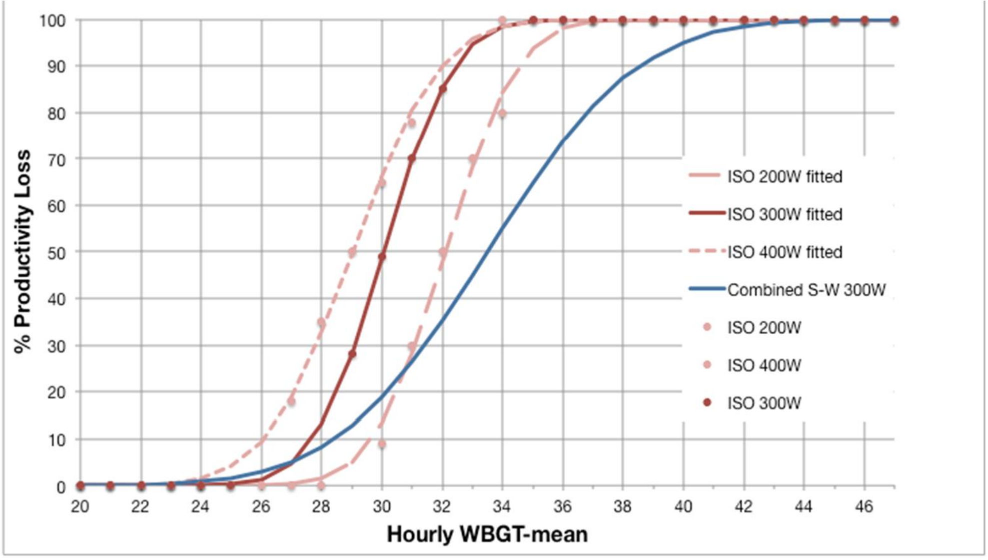


Figure 7. Recommended reduction of work time per hour, in percentage, hour required to protect against heat (ISO = international standard at three work intensities; S-W = combined epidemiology data)



We can use this type of information to estimate how the health risks and productivity loss are likely to increase at different hours of the day due to heat exposure in workplaces. In the section of the website named "Workplace Heat Effects Assessment Tool" (WorkHeat), you will find estimates of the number of days per year or month that are "unsafe for work", i.e. where WBGTmax is higher than the limits for 200W at 31°C, 300W at 29°C and 400W at 27°C). The outputs also include estimates of the percentage lost productivity per year or month at the estimated heat levels in the selected location.

Based on the heat data shown in the sections TODAY or TOMORROW on the website, one can also calculate productivity loss for additional time periods. The following three tables show the likely productivity loss during days with different combinations of daily WBGTmax and WBGTmean. Table 2 shows the expected loss for workers in intensive physical work at 400W (e.g. much of agriculture and construction). Table 3 shows loss in moderate physical work at 300W (e.g. manufacturing), and Table 4 shows loss in light work at 200W (e.g. service and office work).

We can use the climate data on the website ClimateCHIP.org (expressed as WBGTmax and WBGTmean) when planning a new workplace in a specific location. The following tables show how an assessment of the future heat impacts on productivity in any location can be made.

Productivity loss is just one way of quantifying effects. Health risks will occur if workers are not protected by frequent rest breaks, access to clean drinking water, or by cooling systems that reduce the actual heat exposure. The climate data on the website presents outdoor conditions in the sun or shade. The heat levels for "indoors" also applies to workshops and factories that don't have surrounding walls or air-cooling system because it is likely that the heat exposure will be at the same level as outdoors in the shade, or even higher if local heat sources exist, such as dark metal (corrugated iron) roofs or heat emitting machinery.

Table 2. Estimated work output loss per day with different WBGTmax and WBGTmean combinations for work at 400W (intensive physical work). X = mean cannot be higher than max.

Work-loss @ 400W	WBGTmax										
WBGTmean	25	26	27	28	29	30	31	32	33	34	35	36
18	1.2%	2.0%	3.2%	5.1%	7.3%	9.9%	13.0%	16.4%	19.9%	23.5%	26.8%	29.9%
19	1.2%	2.0%	3.5%	5.2%	7.4%	10.2%	13.3%	16.8%	20.4%	24.0%	27.4%	30.6%
20	1.2%	2.4%	3.7%	5.4%	7.7%	10.4%	13.6%	17.2%	20.9%	24.6%	28.2%	31.5%
21	1.6%	2.5%	3.8%	5.6%	8.0%	10.8%	14.1%	17.7%	21.5%	25.3%	29.0%	32.4%
22	1.7%	2.7%	4.1%	5.9%	8.3%	11.2%	14.6%	18.3%	22.3%	26.2%	30.0%	33.5%
23	2.3%	3.3%	4.7%	6.7%	9.1%	12.1%	15.6%	19.4%	23.5%	27.5%	31.4%	35.1%
24	2.8%	3.9%	5.4%	7.4%	10.0%	13.1%	16.7%	20.6%	24.7%	28.9%	32.9%	36.7%
25	3.6%	4.8%	6.4%	8.5%	11.1%	14.3%	18.0%	22.1%	26.3%	30.6%	34.7%	38.6%
26	X	6.0%	7.7%	9.9%	12.6%	15.9%	19.8%	23.9%	28.3%	32.7%	36.9%	40.8%
27	X	X	9.5%	11.7%	14.6%	18.1%	22.0%	26.3%	30.7%	35.2%	39.5%	43.5%
28	X	X	X	14.2%	17.1%	20.7%	24.7%	29.1%	33.7%	38.3%	42.6%	46.6%
29	X	X	X	X	20.2%	23.9%	28.1%	32.5%	37.2%	41.8%	46.2%	50.3%
30	X	X	X	X	X	27.7%	31.9%	36.5%	41.2%	45.9%	50.3%	54.3%
31	X	X	X	X	X	X	36.2%	40.9%	45.6%	50.3%	54.7%	58.8%
32	X	X	X	X	X	X	X	45.6%	50.3%	55.0%	59.4%	63.4%
33	X	X	X	X	X	X	X	X	55.1%	59.8%	64.1%	68.0%

Table 3. Estimated work output loss per day with different WBGTmax and WBGTmean combinations for work at 300W (moderate physical work). X = mean cannot be higher than max.

Work-loss @ 300W	WBGTmax										
WBGTmean	25	26	27	28	29	30	31	32	33	34	35	36
18	0.5%	1.0%	1.7%	2.7%	4.3%	6.3%	9.2%	12.3%	15.7%	19.3%	22.9%	26.2%
19	0.5%	1.0%	1.7%	2.7%	4.3%	6.7%	9.3%	12.5%	16.0%	19.6%	23.3%	26.7%
20	0.5%	1.0%	1.7%	2.7%	4.6%	6.8%	9.5%	12.7%	16.3%	20.0%	23.8%	27.3%
21	0.5%	1.0%	1.7%	3.1%	4.8%	7.0%	9.8%	13.0%	16.7%	20.5%	24.4%	28.0%
22	0.5%	1.0%	2.0%	3.3%	5.0%	7.2%	10.1%	13.4%	17.2%	21.1%	25.1%	28.8%
23	0.5%	1.3%	2.2%	3.5%	5.2%	7.5%	10.5%	13.9%	17.8%	21.8%	25.9%	29.8%
24	0.9%	1.5%	2.4%	3.7%	5.5%	7.9%	10.9%	14.5%	18.4%	22.6%	26.8%	30.9%
25	1.6%	2.2%	3.2%	4.5%	6.4%	8.9%	12.1%	15.7%	19.8%	24.1%	28.4%	32.6%
26	X	2.9%	3.9%	5.4%	7.4%	10.0%	13.2%	17.0%	21.2%	25.6%	30.1%	34.3%
27	X	X	5.0%	6.6%	8.7%	11.4%	14.7%	18.6%	23.0%	27.5%	32.1%	36.5%
28	X	X	X	8.2%	10.4%	13.3%	16.7%	20.8%	25.2%	29.9%	34.6%	39.1%
29	X	X	X	X	12.8%	15.7%	19.3%	23.5%	28.1%	32.9%	37.6%	42.2%
30	X	X	X	X	X	18.8%	22.5%	26.8%	31.5%	36.4%	41.3%	45.9%
31	X	X	X	X	X	X	26.4%	30.8%	35.6%	40.5%	45.4%	50.1%
32	X	X	X	X	X	X	X	35.3%	40.1%	45.1%	50.1%	54.7%
33	X	X	X	X	X	X	X	X	45.0%	50.1%	55.0%	59.6%

Table 4. Estimated work output loss per day with different WBGTmax and WBGTmean combinations for work at 200W (light physical work). X = mean cannot be higher than max.

Work-loss @ 200W	WBGTmax											
WBGTmean	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**
18	0.0%	0.0%	0.5%	0.9%	1.6%	2.7%	4.2%	6.2%	8.7%	11.6%	15.2%	18.7%
19	0.0%	0.0%	0.5%	0.9%	1.6%	2.7%	4.2%	6.2%	8.7%	12.0%	15.4%	18.9%
20	0.0%	0.0%	0.5%	0.9%	1.6%	2.7%	4.2%	6.2%	9.1%	12.1%	15.6%	19.2%
21	0.0%	0.0%	0.5%	0.9%	1.6%	2.7%	4.2%	6.5%	9.2%	12.3%	15.8%	19.5%
22	0.0%	0.0%	0.5%	0.9%	1.6%	2.7%	4.6%	6.7%	9.4%	12.6%	16.1%	19.9%
23	0.0%	0.0%	0.5%	0.9%	1.6%	3.1%	4.7%	6.9%	9.6%	12.9%	16.5%	20.3%
24	0.0%	0.0%	0.5%	0.9%	2.0%	3.2%	4.9%	7.1%	9.9%	13.3%	17.0%	20.9%
25	0.0%	0.0%	0.5%	1.3%	2.1%	3.4%	5.1%	7.4%	10.3%	13.7%	17.6%	21.6%
26	X	0.0%	0.9%	1.5%	2.3%	3.6%	5.4%	7.8%	10.8%	14.3%	18.2%	22.4%
27	X	X	1.5%	2.1%	3.1%	4.4%	6.3%	8.8%	11.9%	15.5%	19.6%	23.9%
28	X	X	X	2.8%	3.8%	5.3%	7.2%	9.8%	13.0%	16.8%	20.9%	25.4%
29	X	X	X	X	4.9%	6.4%	8.5%	11.2%	14.5%	18.4%	22.7%	27.2%
30	X	X	X	X	X	8.1%	10.2%	13.0%	16.5%	20.5%	24.9%	29.6%
31	X	X	X	X	X	X	12.5%	15.5%	19.0%	23.2%	27.7%	32.5%
32	X	X	X	X	X	X	X	18.5%	22.2%	26.5%	31.2%	36.0%
33	X	X	X	X	X	X	X	X	26.1%	30.4%	35.2%	40.1%

These tables can be used to analyse current heat impacts on working people as well as typical impacts in the past. Weather forecasts include data that can be converted to WBGT with an Excel formula on the website (www.ClimateCHIP.org).

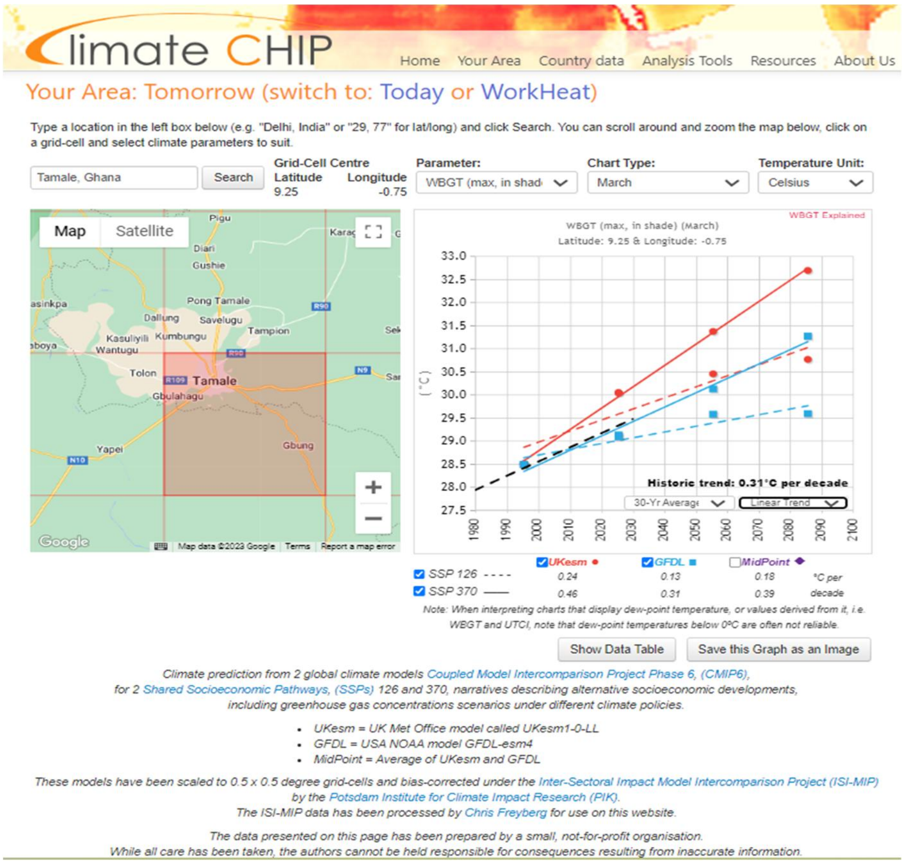
6. Future heat data

Another feature of heat risk assessment based on the ClimateCHIP.org website, is the ability to estimate future trends of heat levels based on ISIMIP3b, the internationally approved climate modelling data. Figure 8 shows the “Tomorrow” data for WBGTmax in shade the “Tomorrow” data for WBGTmax in shade for Tamale, Ghana. Clicking on “linear trend” in this grid cell also shows four 30-year averages for the two GHG pathways, SSP126 and SSP370. The historic trend from 1981 to 2021 is also shown with a black striped line.

The historic trend and the future SSP126 trend are very similar in this grid cell but this is not always the case. Climate modelling is not perfect, and the data are designed for estimations of global rather than local change. However, the data in ClimateCHIP.org gives an indication of what may happen locally. Other factors, like urbanization and related UHI, may become important factors that influence local heat levels.

Figure 8 shows the differences in estimated future heat levels based on two models (UKesm and GFDL) and two pathways (SSP126 and SSP370). There is approximately 1.5°C difference at the end of the century (5% of the approximate midpoint value at 30°C) between the two models and between the two pathways. The pathways are determined by current and future climate policies in countries around the world, while the two models reflect the range of values produced by the use of different modelling based on the same pathways, i.e. the “error range” for the estimates can be the range between the models (approximately 2.5%).

Figure 8. Future trends of WBGTmax in shade in the grid cell for Tamale, Ghana (March data).



Your Area: Tomorrow (switch to: Today or WorkHeat)

Type a location in the left box below (e.g. "Delhi, India" or "29, 77" for lat/long) and click Search. You can scroll around and zoom the map below, click on a grid-cell and select climate parameters to suit.

Tamale, Ghana — Search

Grid-Cell Centre Latitude: 9.25 Longitude: -0.75

Parameter: WBGT (max, in shad

Chart Type: March

Temperature Unit: Celsius

	☑ UKesm ●	☑ GFDL ■	☐ MidPoint ◆	
☑ SSP 126 - - - -	0.24	0.13	0.18	°C per
☑ SSP 370 ——	0.46	0.31	0.39	decade

Note: When interpreting charts that display dew-point temperature, or values derived from it, i.e. WBGT and UTCI, note that dew-point temperatures below 0ºC are often not reliable.

Climate prediction from 2 global climate models Coupled Model Intercomparison Project Phase 6, (CMIP6), for 2 Shared Socioeconomic Pathways, (SSPs) 126 and 370, narratives describing alternative socioeconomic developments, including greenhouse gas concentrations scenarios under different climate policies.

- *UKesm = UK Met Office model called UKesm1-0-LL*
- *GFDL = USA NOAA model GFDL-esm4*
- *MidPoint = Average of UKesm and GFDL*

These models have been scaled to 0.5 x 0.5 degree grid-cells and bias-corrected under the Inter-Sectoral Impact Model Intercomparison Project (ISI-MIP) by the Potsdam Institute for Climate Impact Research (PIK).
The ISI-MIP data has been processed by Chris Freyberg for use on this website.

The data presented on this page has been prepared by a small, not-for-profit organisation.
While all care has been taken, the authors cannot be held responsible for consequences resulting from inaccurate information.

7. Future heat risks

When planning investments in workplaces in locations with hot periods, current heat problems are only part of what considerations are needed. Many workplaces are intended to operate in a particular location for a number of years into the future. Figure 8 shows that at this location in Ghana (in March), between 2025 and 2055 the WBGTmax may increase by as much as 1.5°C in the high results model (UKesm) based on pathway SSP370. By 2085 there is another 1.5°C increase. The website ClimateCHIP.org provides data for each location that can be used to estimate future heat impacts (see Tables 2 - 4).

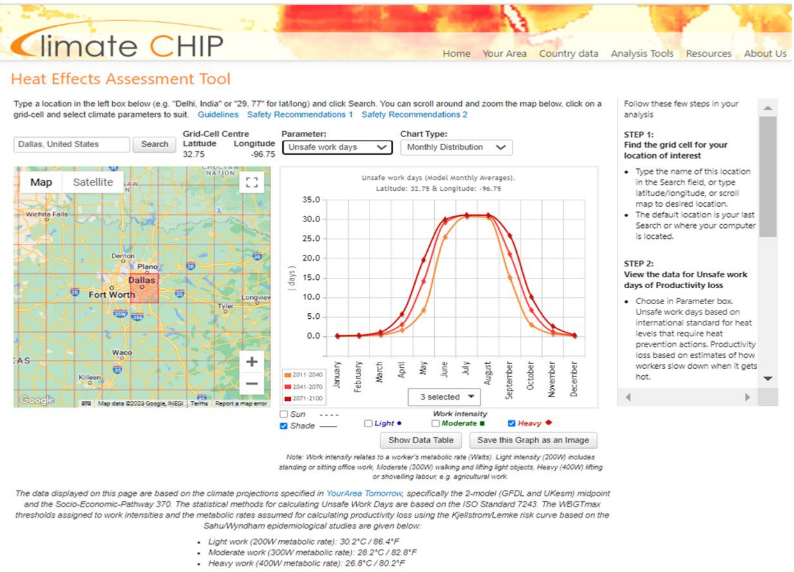
In certain locations the current heat levels do not reach the risk levels described in Section 5, but after some years the heat risk will become substantive. Future risk analysis can provide information on the need for heat protection that may be easier and less costly to provide than after the workplace is established.

8. The Workplace Heat Effects Assessment Tool (HEAT)

This new feature of the website estimates the likely effects of heat exposure in local workplaces in each grid cell. Two basic heat effects are included. The number of “**Unsafe work days**” per month or year in three time periods, is based on the number of days when WBGTmax (afternoon levels) exceed the safety limits mentioned earlier (31°C for 200W, 29°C for 300W and 27°C for 400W). Figure 9 shows Dallas, USA, as an example. The orange curve shows the estimates for 2025 with every day in July and August above the safety limit for 400W metabolic rate. The number of unsafe days in other months will increase in the future. At the right of the graphic is a box with guidance information for first time users of the site.

The WorkHeat tool also includes the parameter "**Productivity loss**", an estimate of the percent of monthly or yearly work output, lost due to heat-induced slow-down of workers during daylight hours (Figure 10). In Dallas the current productivity loss in July is 18%. This is likely to increase to 36% by the end of this century (Figure 10). This part of the website also includes a link to this Guidelines document and two lists of Safety Recommendations for actions at personal level or workplace level.

Figure 9. Unsafe work days per month in Dallas, USA.



Heat Effects Assessment Tool

Type a location in the left box below (e.g. "Delhi, India" or "29, 77" for lat/long) and click Search. You can scroll around and zoom the map below, click on a grid-cell and select climate parameters to suit. Guidelines Safety Recommendations 1 Safety Recommendations 2

Dallas, United States

Grid-Cell Centre
Latitude 32.75
Longitude -96.75

Parameter: Unsafe work days

Chart Type: Monthly Distribution

☐ Sun - - - -
☑ Shade ——

Work intensity
☐ Light ●
☐ Moderate ■
☑ Heavy ◆

Note: Work intensity relates to a worker's metabolic rate (Watts). Light intensity (200W) includes standing or sitting office work, Moderate (300W) walking and lifting light objects, Heavy (400W) lifting or shovelling labour, e.g. agricultural work.

Follow these few steps in your analysis

STEP 1:
Find the grid cell for your location of interest

- Type the name of this location in the Search field, or type latitude/longitude, or scroll map to desired location.
- The default location is your last Search or where your computer is located.

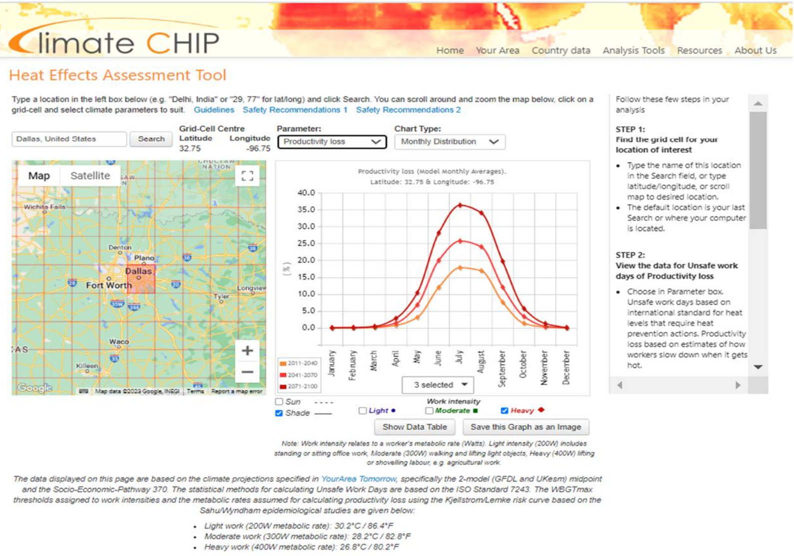
STEP 2:
View the data for Unsafe work days of Productivity loss

- Choose in Parameter box. Unsafe work days based on international standard for heat levels that require heat prevention actions. Productivity loss based on estimates of how workers slow down when it gets hot.

The data displayed on this page are based on the climate projections specified in YourArea Tomorrow, specifically the 2-model (GFDL and UKesm) midpoint and the Socio-Economic-Pathway 370. The statistical methods for calculating Unsafe Work Days are based on the ISO Standard 7243. The WBGTmax thresholds assigned to work intensities and the metabolic rates assumed for calculating productivity loss using the Kjellstrom/Lemke risk curve based on the Sahu/Wyndham epidemiological studies are given below:

- *Light work (200W metabolic rate): 30.2°C / 86.4°F*
- *Moderate work (300W metabolic rate): 28.2°C / 82.8°F*
- *Heavy work (400W metabolic rate): 26.8°C / 80.2°F*

Figure 10. Productivity loss per month in Dallas, USA.



Heat Effects Assessment Tool

Type a location in the left box below (e.g. "Delhi, India" or "29, 77" for lat/long) and click Search. You can scroll around and zoom the map below, click on a grid-cell and select climate parameters to suit. Guidelines Safety Recommendations 1 Safety Recommendations 2

Dallas, United States

Grid-Cell Centre
Latitude 32.75
Longitude -96.75

Parameter: Productivity loss

Chart Type: Monthly Distribution

☐ Sun - - - -
☑ Shade ——

Work intensity
☐ Light ●
☐ Moderate ■
☑ Heavy ◆

Note: Work intensity relates to a worker's metabolic rate (Watts). Light intensity (200W) includes standing or sitting office work, Moderate (300W) walking and lifting light objects, Heavy (400W) lifting or shovelling labour, e.g. agricultural work.

Follow these few steps in your analysis

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- *Heavy work (400W metabolic rate): 26.8°C / 80.2°F*

9. Current heat impact prevention approaches

a. Reduction of heat levels at the workplace during the design phase
b. Provision of cooling systems at the workplace
c. Provision of basic occupational health services and access to drinking water
d. Appropriate managerial decisions to protect workers such as monitoring heat levels, and providing rest breaks
e. Clothing and personal protection equipment (PPE)
f. Reduce heat with climate change mitigation

The first step in prevention of heat hazards at a workplace is relevant information and guidance materials. One source is the Global Heat Health Information Network (GHHIN), a joint project between WMO and WHO (https://ghhin.org/). A detailed description is also available in the NIOSH (2016) report. Advisory material from a variety of agencies can be found by searching for “heat protection in workplaces” in Google. The main issues are described below.

a. Workplace location and design

If a planned workplace involves building premises, heat problems can be reduced by placing any structure in a position to avoid direct sunlight during the day. Trees that shade parts of a building can significantly reduce indoor heat (and outdoors in the shade); these may be existing or new trees. A detailed analysis by the Asian Development Bank has provided guidance in this context (ADB, 2022).

Any building should be suitably insulated in walls and ceilings. Roofs can be painted white or designed as a green plant roof with plants which vastly reduce heat absorption. (Dark coloured corrugated metal roofs on an uninsulated building are the worst from a heat protection viewpoint.) Roofs can be used to provide solar electricity that can be used for production processes. Modern technologies can also convert incoming solar energy on a roof directly to cooling of air in a building (https://en.wikipedia.org/wiki/Solar_air_conditioning).

b. Providing cooling systems and monitoring heat levels

The website data will give estimates of likely heat exposures in any grid cell location around the world. However, the actual heat conditions vary inside each grid cell so measurements of heat levels at a worksite is an important source of information. Low-cost data loggers (e.g. Hobo or Lascar) that can measure temperature and humidity can be used for continuous monitoring of heat levels in any workplace.

Air conditioning systems can provide effective cooling for interior spaces but cooling large volumes of air in bigger buildings is difficult and expensive. In some workplaces cool wind blowing on workers can be a solution. In outdoor jobs with a worker in a tractor cab or other confined space, air conditioning can be applied inside that space.

An important consideration with air conditioning is the energy required to run the system and how this energy use adds to the GHG emissions from the enterprise. Systems that use energy from solar radiation directly to cool the air provided in the air conditioning, should be considered at the planning stage (https://cielowigle.com/blog/solar-powered-air-conditioner/). In some situations, with limited heat exposure, the installation of fans to create air movement over work areas can be an effective solution. However, when the heat goes above the recommended levels referred to in Section 5, further prevention is needed.

c. *Basic Occupational Health services and drinking water access*

In order to ensure that any remaining heat problems are fully dealt with, it is essential to provide basic occupational health management in every workplace. Such a service is not only an essential part of heat protection but also helps to protect workers from a broader range of other health hazards. A primary need for workers is clean drinking water to replace liquid loss due to sweating. Individual needs vary, so unlimited supply of clean drinking water at the actual worksite is essential. In very hot jobs a worker can sweat as much as 10-15 L in a day. During intensive sweating body salts are also lost and need to be replaced by mineral drinks.

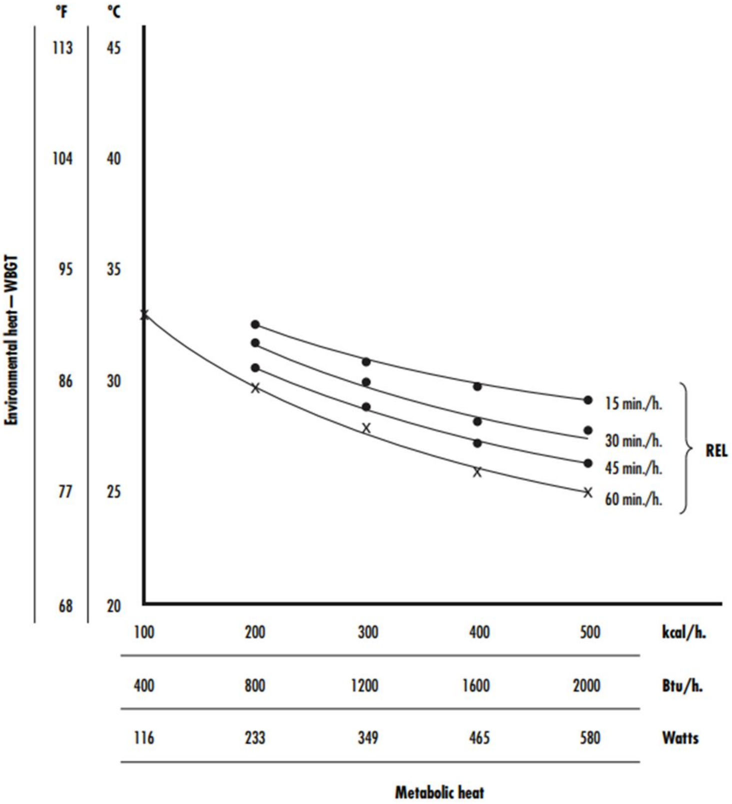
Depending on the size of the workforce, the services of a health and safety expert, a nurse, a medical doctor or other staff with health training should be made available. Their role is to supervise the monitoring and interpretation of heat exposure levels, to provide advice on the cooling and protection actions needed, and to manage any clinical health problems that occur. Features of good occupational health services are described in documents from the ILO:
(https://www.ilo.org/global/standards/subjects-covered-by-international-labour-standards/occupational-safety-and-health/lang--en/index.htm#:~:text=The%20convention%20provides%20for%20the,and%20to%20improve%20working%20conditions.).

d. *Managerial protection decisions by providing rest breaks*

An important way to protect workers from heat is to schedule breaks as stated in the international standard (ISO, 2017) and the USA national guideline (NIOSH, 2016) as discussed earlier. The need for breaks or cooling depends on the work intensity in each operation, so the application of such measures needs to be analysed for the specific job tasks to be carried out in this location. Figure 11 shows the percentage of work time at different work intensity (metabolic heat) that is recommended at different hourly WBGT levels. Light work (e.g. office) has a metabolic heat level between 150 and 250 W; moderate work in a factory 250-350 W; heavy work 400W and higher.

Scheduling intensive work to cooler parts of the day (or night) or cooler parts of the year is another way to manage heat exposure and related productivity loss. The tables above in Section 5 are a guide to how work slows down when it is excessively hot. If workers are working under stress because of heat, Negative effects on health and productivity will emerge.

Figure 11. Recommended heat stress exposure limits and need for rest periods for heat acclimatized workers (NIOSH, 2016). X-axis = work intensity expressed as total Metabolic Rate in Watts. Y-axis = hourly WBGT level. Four different curves for safety limits shown based on fraction of the work hour that the worker takes rest (hourly work = 60 minutes, 45, 30, or 15 minutes.)



e. Clothing and personal protection equipment (PPE)

In certain work situations, the cooling of a building or other protections are still not sufficient so PPEs can be used for protection. For example, there are special garments that have cold water flowing through them and others are made of special materials that melt at workplace temperatures (Ren et al., 2022). This provides cooling underneath the garments. Protective helmets with face screens can have a fan inside to provide extra air flow; such a device provides some comfort but does not cool the air.

Local cool air supply equipment that targets individual work stations is also a type of PPE. Another feature of personal protection is the type of clothing worn by workers. In hot environments loose light clothing is best from a heat protection viewpoint, but some jobs may involve chemical or other hazards that require protective clothing, which in turn can add significant heat risk as the evaporation of sweat in hot conditions is reduced. The guidelines from ISO and NIOSH include methods to adjust the heat levels at which protection action is needed. Figure 11 shows the guidance for rest breaks for workers wearing light clothing. If workers use double-layer cloth clothing this adds 3°C to the WBGT values in Figure 11. If workers use limited use vapour barrier overalls, 11°C should be added (meaning that a WBGT level as low as 19°C creates heat risks even for light work).

One example of such heat problems with protective clothing was the heat stress that occurred inside plastic clothing worn by health staff during the Ebola epidemic in West Africa in 2016 (Kuklane et al., 2015). The protection from the highly infectious Ebola virus was vital for the nurses and doctors attending to their patients so they needed to use totally sealed clothing with filtered air supply via pumps. Even in relatively moderate heat conditions, staff were sweating so heavily that they could only work for 30 minutes before having to rest and change their clothing. Taking the protective clothing off added to the risk of infection for staff. The hot working environment in this country at the time was a major underlying problem.

f. *Reducing increase of local heat levels via climate change mitigation*

It should be emphasized that the heat conditions in the future will deteriorate as climate change brings about global heating; already hot locations will become even hotter. Limiting the degree to which such heating will occur is an essential step to protect workers health in the future and reduce the economic consequences of productivity loss.

10. Importance of climate change mitigation

New enterprises may be actively producing economic output, enhancing social well-being and producing commercially valuable products and employment for decades to come. It is therefore vitally important to consider the potential future heat conditions at a location of interest at the planning stage.

Analysis of future heat challenges is a part of the WorkHeat tool and it is possible to estimate the difference in future heat levels that mitigation can achieve (see Section 8). SSP370 data is based on current green-house gas (GHG) emission trends and shows what is likely to happen if further mitigation is not implemented. SSP126 is the most ambitious GHG emission pathway which shows the reduced heat levels with advanced mitigation of climate change. The difference can be large and can save investors substantial resources in reducing future cooling costs or productivity loss.

Mitigation primarily involves reducing energy use from fossil fuels. This can be achieved by:

- Low carbon footprint of the building materials used for the workplace
- Use of local renewable energy for electricity supply for production
- Use of renewable energy for transport of raw materials, workers and products
- Recycling and reuse of raw materials or product parts for new products

Investors and enterprise managers can also contribute effectively to mitigation efforts beyond their own production activities, by promoting technologies with low carbon footprint, cooperating with other enterprises to reduce their carbon footprint, and supporting government policies and regulations that aim to strengthening mitigation.

11. Conclusions

Workplace heat is an important occupational health hazard that not only threatens workers health but also reduces labour productivity. I It is essential to make assessments of the potential heat risks in locations of interest when planning for investment. This Workplace Heat Exposure Assessment Tool provides a method and data to carry out such an assessment and can also be used to assess the heat situation in existing workplaces.

For investments in new workplaces, the decisions to make include:

- The choice of location
- What job types will be involved and what is their required work intensity?
- How many workers will there be in each job type?
- What are the current heat challenges for workers in this location?
- How can the current heat challenges be overcome with investments?
- What are the costs for protecting this workforce from the heat challenges?
- What are the future heat challenges in this location?
- What are the additional costs for future heat protection?
- How can this workplace be designed and operated with a minimum carbon footprint?

12. References and further reading

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Appendix. Survey of user experiences of this WorkHeat tool.

Users are asked to go through the process of choosing a location for a new enterprise and assessing the current and future workplace heat exposure risks.

After spending an hour reading the WorkHeat tool, consulting the ClimateCHIP.org website and preparing short notes on the heat risks, they will complete the following questionnaire.

WorkHeat tool test questionnaire

What type of industry is your intended investment?

____

Where in the world was this to be located?

____

On a scale of 1 to 5 please respond to the following questions.
Answers should fit with:

1= not at all 2=a little bit 3=yes, in parts 4=yes, to a greater degree 5=yes, absolutely

Question	Answer
A. Did you learn useful information about heat stress challenges in workplaces from reading this tool?	
B. Was the ClimateCHIP.org data useful to assess the heat situation your investment may face?	
C. Did the step-by-step process in the tool help you find the information of importance on the website?	
D. After completing the tool process do you feel more confident about actions needed to be taken to achieve heat protection?	
E. Would you recommend this tool to others seeking climate relevant information for future investment decisions?	
F. Are there any changes in the tool you would suggest for its improvement? Please write a list of suggested changes below.	

Many thanks for your help.