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CLIMATE CHANGE AND LABOUR: IMPACTS OF HEAT IN THE WORKPLACE

CLIMATE CHANGE, WORKPLACE ENVIRONMENTAL CONDITIONS, OCCUPATIONAL HEALTH RISKS, AND PRODUCTIVITY – AN EMERGING GLOBAL CHALLENGE TO DECENT WORK, SUSTAINABLE DEVELOPMENT AND SOCIAL EQUITY



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This Issue Paper was prepared by academic and institutional experts as well as experts from the CVF country members to inform policy formulation. The information contained in this document is not necessarily intended for use in other contexts such as UN resolutions or UNFCCC negotiations and interested groups are encouraged to take contact with initiative partners for follow-up.

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KEY FINDINGS¹

- ▶ Excessive workplace heat is a well-known occupational health and productivity danger: high body temperature or dehydration causes heat exhaustion, heat stroke and in extreme cases, death. A worker's natural protection is to slow down work or limit working hours, which reduces productivity, economic output, pay and family income.
- ▶ A range of key international and national labour standards informed by decades of ergonomic and occupational health and safety research are designed to protect workers from adverse thermal conditions (high heat levels).
- ▶ Levels of heat in many tropical locations are already very high with respect to thermal tolerances even for acclimatised populations. Hot days and hot hours affect virtually all workers operating outdoors or in non-climate controlled conditions across several world regions. The continued changes to the climate with growing heat worsen the situation.
- ▶ Highly exposed zones, with effects experienced on a macro-scale, include the Southern United States, Central America and the Caribbean, Northern South America, North and West Africa, South and South East Asia.
- ▶ By the mid-1990s, heavily exposed countries, such as Bangladesh, have been estimated to have lost approximately 1 to 3% of the entirety of available daylight work hours due to heat extremes, underscoring the current nature of the problem with workers and employers needing protection now.
- ▶ Future climate change will increase losses. Even if the current commitments of the world governments to combat climate change are realized, losses by the end of this century to most vulnerable economies of all available daylight work hours will double or triple.
- ▶ The IPCC's 5th Assessment Report confirmed that labour productivity impacts could result in output reductions in affected sectors exceeding 20% during the second half of the century—the global economic cost of reduced productivity may be more than 2 trillion USD by 2030.
- ▶ The lowest income-bracket work – heavy labour and low-skill agricultural and manufacturing jobs – are among the most susceptible to climate change.
- ▶ Through this and other challenges altered thermal conditions also undermine development and present multi-faceted hurdles for the achievement of the Sustainable Development Goals (SDGs) related to poverty (SDG1) and hunger (2), health (3), education (4), gender (5) and income inequalities (10), good jobs and growth (8), and sustainable cities and communities (11), as well as climate change (13).
- ▶ Heat extremes also affect the very habitability of regions, especially in the long term, and may already constitute an important driver of migration internally and internationally.
- ▶ Since November 2015, the ILO adopted Guidelines for governments and other labour organizations to address the health and safety ramifications of climate change. But no international organization has established a programme to assist countries vulnerable to the challenges of climate change for the workplace.
- ▶ Limiting warming to 1.5 Celsius degrees as enshrined in the UNFCCC Paris Agreement would still result in a substantial escalation of risks but increases the viability of adaptation measures and contains the worst impacts in health, economic and social terms.
- ▶ Actions are needed to protect workers and employers now and in the future, including low cost measures such as assured access to drinking water in workplaces, frequent rest breaks, and management of output targets, carried out with protection of income and other conditions of Decent Work.
- ▶ Further analysis of the health and economic impacts of climate change in the workplace is needed to understand the full impacts of current and future climate. This should be linked to application of specific heat protection methods based on sustainable energy systems and conditions of Decent Work. Current and emerging analysis results should be the basis for effective national adaptation and mitigation policies.

¹ See the full list of references at the end of this document.

FIGURE 1.

Typical workplaces with excessive heat exposures during several months each year.

▶ Sugar cane cutting by hand in Nicaragua, 2003.



T.Kjellstrom photos

- ▶ This work and other heavy labour agricultural activities in many tropical areas have to be carried out during the hottest season each year. Solar heat radiation adds substantially to the ambient air heat. Heat stress and heavy work create injuries, clinical health risks and daily productivity losses. Many of these workers are paid by production output, so heat causes longer workdays or reduced daily income.

▶ Shoe manufacture in Haiphong, Viet Nam, 2002.



T.Kjellstrom photos

- ▶ Factories in low and middle income countries that produce consumer goods, many of which are destined for consumption by high income countries, seldom have air conditioning or other effective cooling and ventilation systems. Heat stress and the same daily production targets in all parts of the year means that the workers have to work longer each day in the hot season than in cool seasons; but the salaries typically remain the same.

OVERVIEW

Excessive heat while working, generally at temperatures above 35° Celsius, creates occupational health risks and reduces work capacity and labour productivity (Parsons, 2014). Maintaining a core body temperature close to 37°C is essential for health and human performance, and large amounts of sweating as a result of high heat exposure while working creates a risk of dehydration. Excessive body temperature and/or dehydration causes “heat exhaustion”, slower work, more mistakes while working, clinical heat effects (heat exhaustion, heat stroke, and even death; Bouchama and Knochel, 2002) and increased risk of accidental injuries (Schulte and Chun, 2009). These health effects lessen labour

productivity, whether the worker is in paid work in a range of industries, in traditional subsistence agriculture or farming, or in other daily life activities (examples in Figure 1). Daily family activities, such as caring for children or the elderly, are equally affected.

The rapid increase of heat levels due to climate change is making such risks more severe for large shares of the global working population (Kjellstrom et al., 2009a). In January 2016, the World Meteorological Organization confirmed the likelihood that the average global temperature change had already reached 1 degree Celsius (or 1.8° Fahrenheit) (WMO, 2015). In West Africa, for

instance, the number of very hot days per year doubled since the 1960s, with an increase of approximately 10 additional hot days with each decade (McSweeney et al., 2010). Heat waves that are more prevalent as a result of climate change bring punctual spells of intense heat that are particularly dangerous for exposed workers. However, global warming is also altering the average climate experienced throughout the year (WMO, 2015).

This rising heat in the workplace is a significant concern to any person working out-of-doors or in indoor conditions without climate control or with ineffective control of ambient temperatures. Primary sectors of the economy, especially agriculture, are worst affected. It also presents challenges for the manufacturing sector, including construction and industrial work wherever heat is poorly controlled. Certain service sector professions are also affected, such as sports, tourism and transport. Work that involves high levels of physical exertion, such as heavy lifting and manual labour, are particularly affected since individuals tire faster and metabolise heat less effectively under exertion. However, even basic office and desk tasks are compromised at high levels of heat as exhaustion sets in. Physiological acclimatization provides some protection, but it has limits and requires 1-2 weeks of heat exposure to fully develop. During the hot season in hot countries workers have usually reached their acclimatization limit, and increased heat still creates the risks referred to in this paper.

As a challenge to Decent Work, this issue needs more attention. The workplace heat concern was first mentioned in the fourth (2005-07) assessment report of the Intergovernmental Panel on Climate Change (IPCC) and given a much stronger focus in the fifth (2013-15) IPCC assessment. Effective understanding of the issue required combining long-standing research into physiological responses to heat with the emerging science of climate change. Late recognition in science has delayed policy responses. No major international organization has established a programme of response to the challenges it presents. Trade Union materials on occupational health usually refer to heat as a hazard, but the link to climate change impact has not been pursued.

Because of the scale of the challenge, its impact is likely to be a major economic effect of climate change. Economic losses occur at worker and family level, enterprise level and community level. For heavily exposed economies, effects are meaningful enough to alter national output, affecting in turn the global outlook. The economic, social and health effects are a challenge for efforts to tackle poverty and promote human development including the global Sustainable Development Goals (SDGs) where it could undermine progress towards SDGs 1 (poverty), 2 (food), 3 (health), 4 (education), 5 (women), 8 (economy), 10 (inequality), 11 (cities) and 13 (climate). The shifting of the thermal conditions of many of the world's workplaces is leading to breaches of international



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ISO standards and International Labour Organization (ILO) Codes of Practice on hot workplace environments. It is also likely to amplify current migration patterns for the most vulnerable workers.

The impact analysis of different possible global temperature increases this century show that lost working hours have already been substantial and expand rapidly even for a 1.5° Celsius increase of global temperature (see analysis later in this paper). Impacts worsen much more considerably for 2 °C and for the 2.7°C level of warming implied by governments' existing commitments under the new UN Framework Convention on Climate Change (UNFCCC) Paris Agreement. Business-as-usual warming (4°C) could yield output reductions for some sectors in excess of 20% during the second half of the twentieth century.

Climate change is also among the root causes of migration, which was recognized by the UNFCCC Paris Agreement with the formal inclusion of “migrants” in the Preamble and 2015 UNFCCC Paris decision on Loss and Damage. Climate change and climate change-related environmental degradation is driving environmental migration with a potential to change labour migration patterns. Migrant workers are often among the most harshly affected by climate-related risks in a world where the importance of migrants in the global economy continues to grow. Migrant workers frequently find themselves—at origin, transit and destination—engaged in occupations that are highly exposed to rising heat, such as in the

construction or agricultural sectors. Migration also represents a viable adaptation strategy to climate change with practical examples of temporary and circular labour migration.

The economic, health and social ramifications of rising heat in the workplace requires an urgent response to protect workers, families, businesses, and vulnerable economies through investment in appropriate climate change adaptation measures. A number of adaptation responses have been identified, including establishing or reinforcing worker rehydration regimes, shade, insulation and air conditioning. An immediate opportunity also exists with implementation of the 2015 ILO Guidelines for a just transition towards environmentally sustainable economies and societies for all, which include a focus on climate change and health, safety and social protection in the context of climate change. Nevertheless, the ability to manage the impact of climate change on labour diminishes at higher heat levels, while unavoidable losses and damage are an additional reason to pursue more ambitious emission control responses to mitigate climate change.

This Issue Paper explains the underlying mechanisms of the impact of climate change through altered thermal conditions in the workplace, shows examples of the current and likely future impacts and provides indications of policy response options to these challenges.

BASIC MECHANISMS FOR HOW HEAT IN THE WORKPLACE AFFECTS PRODUCTIVITY, HEALTH AND SAFETY

The conflict between health and productivity that workplace heat creates

It is well known that physical work creates heat inside the body and that this affects occupational health and performance when combined with excessive workplace heat (Parsons, 2014). The physiological mechanisms have been known for more than 100 years, and during the last 50 years hundreds of laboratory and field studies have documented heat risks and injury causing heat exhaustion and heat stroke (Bouchama and Knochel, 2002), and even deaths (MMWR, 2008). When heat exposed workers slow down or take more rest to avoid the health effects of heat, their hourly work output and productivity goes down

(Kjellstrom et al., 2009a). This is the conflict between health and productivity that workers and employers face.

Climate change has and will continue to exacerbate workplace heat as highlighted in the latest IPCC assessment (Smith et al., 2014). For many middle and lower income countries, more than half of the work force is currently exposed to this type of hazard (DARA and the CVF, 2012). Figure 1 shows examples of agricultural and factory work that can be affected in locations with long hot seasons and expectations of high productivity.

The occupational and ergonomic sciences have long examined the effects of heat extremes on the safety, health and productivity of workers. Occupational guidelines for heat have existed in Europe and the United States since the 1980s (NIOSH, 2015). International ISO standards have also been in place since the 1980s (ISO, 1989a, b), complemented additionally now by ILO codes of practice (ILO 2001) among other guidelines. In particular, ISO 7243 (1989a) specifies the health based limits (body temperature) for heat stress on workers, and ISO 7933 (1989b), specifies a method for the analytical evaluation and interpretation of the thermal stress experienced by a subject (excessive sweating) in a hot environment. Moreover, the ILO Code of Practice on “Ambient Factors in the Workplace” deals with both heat and cold, including prevention and control measures in hot environments. Growing heat extremes for working people also undermine Decent Work as promoted by the International Labour Organization (ILO, 2013; UN, 2015).

Considerable industry-focused analysis exists, explaining, for example, how the climate conditioning of call centres can promote optimal worker productivity (Niemelä et al. 2002). Furthermore, many of today’s military combat operations in regions with thermal extremes are guided by the latest knowledge of this field, such as the United States defence force (USDAAF 2003).

From the perspective of climate change, the most predictable and highest confidence outcome of global warming is the increase of local heat levels in most of the world, as demonstrated by the IPCC (Collins et al., 2013). This makes predicting the impacts of changing thermal conditions in the workplace more reliable than for estimates of changing storm patterns, rainfall regimes, wind and other aspects of the consequences of climate change.

“CLIMATE CHANGE HAS AND WILL CONTINUE TO EXACERBATE WORKPLACE HEAT”

The physiological foundation of the work-heat challenges

The core body temperature of every human needs to be kept close to 37°C in order to avoid serious health risks (Parsons, 2014). When the external temperature is higher than 37°C, the only way for the body to stay at a healthy temperature is through loss of heat via sweat evaporation. However, high external air humidity, and the clothes worn in some jobs, limit sweat evaporation and core body temperature goes up. In many situations the only way to avoid clinical “heat stroke” is to reduce the work rate, take more rest, and drink water frequently (Parsons, 2014). As mentioned earlier, acclimatization to heat reduces the health risks, but the limit is reached within a week or two, and field studies in hot locations usually already account for acclimatized workers in their analysis.

Epidemiological studies show the quantitative impacts of high workplace heat (Wyndham, 1969; Sahu et al., 2013), and recent interview studies of workers in hot countries highlight these hazards in various sectors and occupations (Zander et al., 2015; Venugopal et al., 2016a, b). One detailed review (de Blois et al.,

2015) highlights the considerable public health risks that environmental heat exposure effects on the heart and vascular system will create.

To quantify the workplace heat exposures and estimate associated health and economic risks, it is essential to find formulas that combine the four elements that contribute to the relevant external heat levels: temperature, humidity, air movement (wind speed) and heat radiation (outdoors mainly from solar radiation). During the last century more than 160 different heat indices were developed (De Freitas and Grigorieva, 2015). Several indices are described in a recent heat wave guidance document (WMO and WHO, 2015), and the applications and interpretations of the resulting data varies. Only one of the indices has achieved widespread global use in occupational health, namely the Wet Bulb Globe Temperature (WBGT), which is an important proxy measure for how people experience heat (Parsons, 2014). WBGT combines temperature, humidity, wind speed and heat radiation into one number. It was developed long ago for the US Army (Yaglou and Minard, 1957) to protect

soldiers from heat stress and serious clinical effects, and it can be calculated from routine weather station data (Lemke and Kjellstrom, 2012).

Actual heat stress on a working person is also affected by the intensity of work (metabolic rate) and the clothing used, so the interpretation of a WBGT value, or any other heat estimate, needs to take these factors into account. When heat stress and core body temperature becomes too high the working person may suffer exhaustion or fainting and in serious cases more severe heat stroke with effects on the brain and heart (Bouchama and Knochel, 2002). If the person has sweated profusely, and not been able to replace the lost body liquid with drinking water, dehydration may occur contributing to exhaustion and possibly leading to chronic kidney disease

as has happened in sugar cane farms in Central America (Wesseling et al., 2013).

More than 100 studies in the last decade have documented the health risks and labour productivity loss experienced by workers in hot locations. The most recent report (Venugopal et al., 2016a) of perceived heat impacts in 18 workplaces with both male and female workers concluded that 87% of workers experience health problems during the hottest 3 months and 48% reported lost productivity. Another report (Venugopal et al., 2016b) highlighted the problems for women workers, in particular, pregnancy creates additional problems with heat stress. Another vulnerable group is migrant workers.



FIGURE 2.
Heat exposed workplaces with many women workers.

▶ Construction work in India, 2008.



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▶ Millions of women earn small daily cash income in labouring jobs, carrying material on to roofs where male workers perform the tradesmen tasks.

▶ Shoe manufacture in Haiphong, Viet Nam, 2002.



T.Kjellstrom photos

▶ These factories employ mainly women and exposure to hazardous chemicals is common. Glues used to join different parts of a shoe contain volatile solvents that can damage the brain, injure the foetus of a pregnant woman and cause other health effects. Some solvents, such as benzene, are potential cancer causing agents. The solvents evaporate faster in hotter environments, so climate change will increase the health risks.

Occupational health impacts of climate change other than direct heat effects

This Issue Paper is focused on the effects of changing thermal conditions in workplaces and the related economic, health and social repercussions. However, climate change is also responsible for a range of other occupational health and productivity threats (Bennett and McMichael, 2010; Schulte and Chun, 2009; NIOSH, 2015).

Climate change entails, for instance, more extreme weather events and these create injury risks for affected populations as well as for the emergency workers trying to help the other victims. Violent storms, floods and resulting landslides, as well as forest fires due to drought, are all creating occupational health and safety hazards for outdoor and indoor workers, as well as for the relief workers (Brearley et al., 2013; Smith et al., 2014). There are mental health effects (Smith et al., 2014) including suicides among farmers whose harvests fail due to climate change.

Secondly, in assessments of climate change health impacts, the changing patterns of vector-borne diseases are routinely highlighted (Smith et al., 2014). One aspect of such health risks that is likely to be a health hazard for

workers, particularly agricultural workers (Figure 1), is the probability that daily work has to be shifted to cooler dawn and dusk periods as the middle of the day is too hot to work (Bennett and McMichael, 2010). Disease spreading vectors such as mosquitoes are more likely to bite people during these cooler hours, and so the risk of malaria and other diseases may increase.

Another indirect effect of increasing heat is a likely increase of exposures to hazardous chemicals (Figure 2). At higher temperatures chemicals in workplaces evaporate more quickly and the chemical amounts that the workers inhale from the workplace air will increase (Bennett and McMichael, 2010) creating an increased risk of poisoning.

“ANOTHER INDIRECT EFFECT OF INCREASING HEAT IS A LIKELY INCREASE OF EXPOSURES TO HAZARDOUS CHEMICALS”

Estimated work capacity loss in different settings

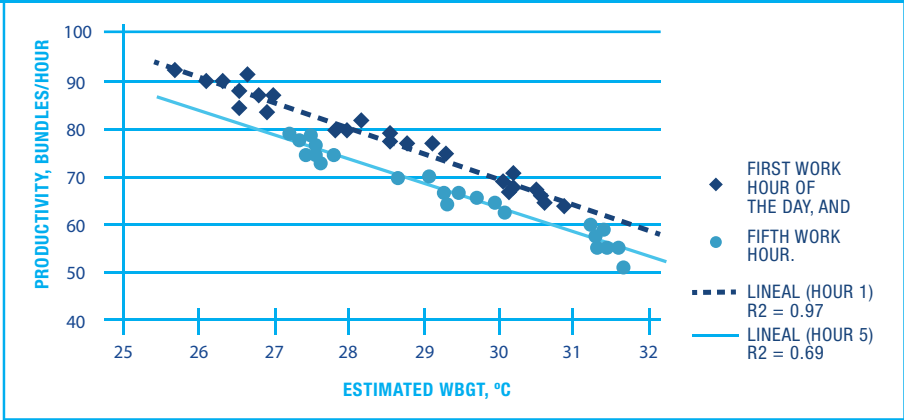
The clinical ill health effects mentioned above will contribute to work capacity and labour productivity loss, and in addition there are the effects of the amount of rest and breaks that the worker takes to avoid clinical effects (“self-pacing”). Figure 3 shows data from the only recent epidemiological study (Sahu et al., 2013) which indicates the loss of approximately one third of the hourly labour productivity when hourly heat increases from 26° C to 31° C (measured by WBGT). Similar results for South African gold mine workers were reported more than 50 years ago (Wyndham, 1969), and other studies are now emerging. The ISO international standard (Nr 7243, 1989a) recommends that regular rest periods are taken when heat is above 26° C (WBGT) in the context of heavy physical work if clinical health effects are to be avoided.

FIGURE 3.

Reduced labour productivity due to heat.

- ▶ Bundles of rice harvested per hour (productivity) at different environmental heat levels (WBGT). Regression lines and equations and correlation coefficients shown. (Each point is a group average of 10-18 workers); (Sahu et al., 2013).

RELATIONSHIP BETWEEN ESTIMATED WBGT AND HOURLY PRODUCTIVITY



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It should be pointed out that in South-East Asia, for example, the heat stress level is approximately 2-3°C (WBGT) higher in the sun during the afternoon than it is in full shade or in indoor workplaces without cooling systems (Kjellstrom et al., 2013). This is why it is essential for the interpretation of workplace heat stress issues to consider whether outdoor workers are protected by shade, workplace cooling systems, special clothing, or other parameters.

Analyses of the annual losses of daylight work hours due to excessive heat exposure (Kjellstrom et al., 2009b, 2014) show substantial losses in many regions of the world. The losses in the 1980-2009 period are already up to 5-7% for several regions. Estimates for 2030 showed that the worst affected regions would be South Asia and West Africa, and ten regions in Asia, Africa and Latin America have more than 2% of work hours lost by this date.

The underlying physiological and ergonomical science for these calculations of health risks and productivity loss are very robust and well established. The key question is whether to focus on the increased clinical health effect risks as workers keep their work activity going at usual speeds, or on the labour productivity loss risks as workers slow down to avoid health effects. Many health professionals and scientists appear to consider the productivity loss as a "non-health effect" and therefore not worth including in health impact analysis. But this oversight undermines efforts to achieve Decent Work, which includes both health protection and fair income protection.

SCALE AND IMPORTANCE OF EFFECTS IN REGIONS, COUNTRIES, SECTORS AND POPULATION GROUPS

Extent of current climate threats to labour

It is now well recognized and established in science that the global climate is already changing towards higher temperatures (Collins et al., 2013). Much of the analysis by climatologists and in public debate focus on the average global temperature change, which increased by 0.74° C per century (or 0.074° C per decade) in the period 1906-2005. More recently, the World Meteorological Organization (WMO) announced the likelihood that the planet has already warmed by 1° C since the pre-industrial era (WMO, 2015). The bulk of that warming occurred in recent decades in an accelerating trend whereby all but one of the ten hottest years since records began have occurred since the year 2000, the warmest yet being 2015 (WMO, 2015).

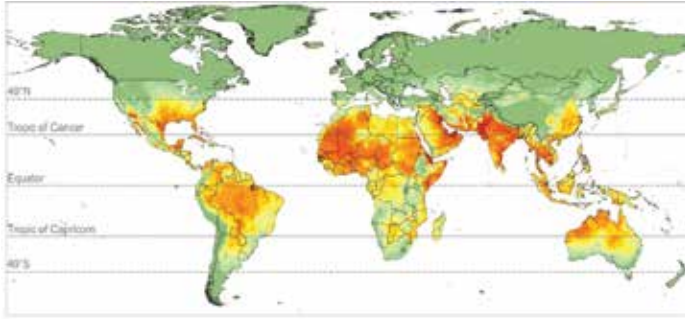
These changes are not the same everywhere in the world and according to routine recordings at weather stations in Asia and Africa (US NOAA and Hothaps-Soft; see Resources later on), the increase of annual mean temperature from 1980 to 2012 is often 0.2-0.8° C per decade (and even > 1° C per decade), much faster than the global average from 1906 to 2005. Using existing

climate data for 67,000 geographic sections over land around the world (0.5 x 0.5 degree sections, data from ISI-MIP at Potsdam Institute, Warshawski et al., 2014), analysis can show the levels of different heat stress indexes. Figure 4 shows the current heat situation in the hottest months in each part of the world (employing the WBGT measure). All the areas in other colours than green will experience workplace heat challenges, and often for several months (WBGT levels higher than 25° C as stipulated by ISO, 1989a).

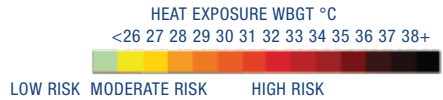
The future modelling of climate change impacts is based on the analysis carried out for IPCC by a large number of scientists (Collins et al., 2013). This Issue Paper uses two well tested models (HadGEM2-es and GFDL-esm2m). Estimates can therefore be considered robust and can be used as indications of how climate change will affect labour conditions and productivity. This report does not include the details of methods used, which are available in published references.

FIGURE 4.

Geographic distribution of heat exposure around the planet.



▶ The *hottest month* average level of the heat stress index WBGT in each part of the world, afternoon values in shade or indoors, 30-year averages 1980-2009. The colour scale shows the heat levels.



The increasing heat trend can be demonstrated at many locations. For instance, it can be shown that for each decade in Kolkata, India (Figure 5) there are 12 additional days where WBGT levels in the shade are at or above 29° C. The tropical and sub-tropical parts of the world, where very hot seasons are already commonplace, are also where most of the world population lives and works, or approximately 4 billion people (see Figure 6). A recent analysis comparing the daily

distributions of high heat level days during the 20th century and the most recent period, concluded that most of the days with extremely high temperature or humidity (linked to precipitation) are caused by human induced climate change (Fischer and Knutti, 2015). The trends in Kolkata can then be considered a symptom of the climate change that emissions of greenhouse gases can cause.

FIGURE 5.

Increasing heat in Kolkata, India.

▶ Annual number of days when WBGT indoors or in full shade in the afternoons (=WBGTmax) exceeded 29 oC at the airport in Kolkata, a level that reduces work capacity (greater than 30 more days in 2012 than in 1980). Source: Hothaps-Soft with data from US NOAA website (Sahu et al., 2013).

CALCUTTA/DUM ANNUAL WBGT (MAX) [°C], DAYS > 29°C

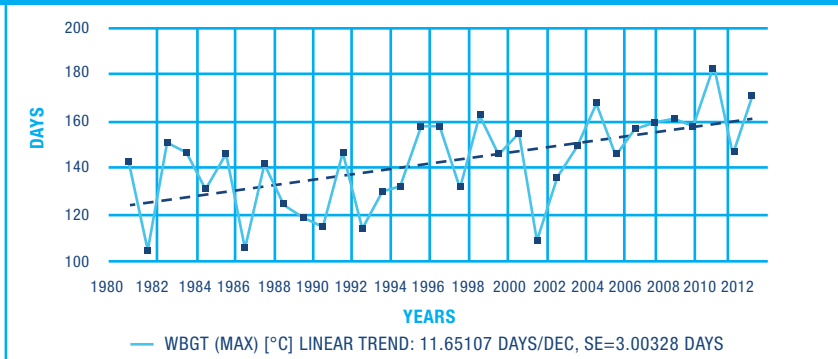
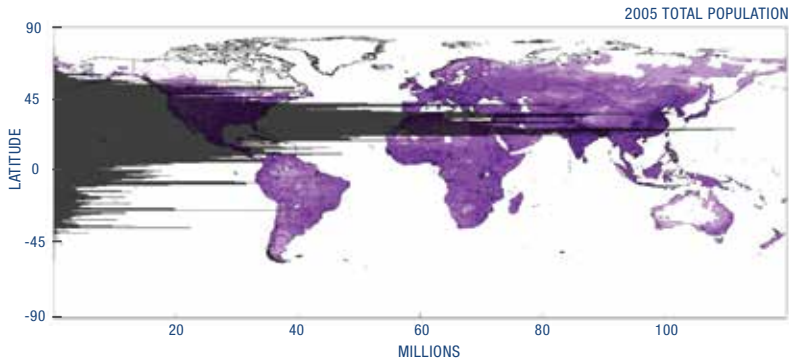


FIGURE 6.

Global population distribution by latitude in 2005.

- ▶ Number of people in each 0.5 degree latitude band is shown; most people live in the tropical and sub-tropical range.



Future trends of heat impacts

Heat impacts in terms of health and productivity loss start occurring at approximately 26°C (WBGT) for heavy physical labour impacts as indicated by ISO standards (ISO, 1989a). The trends can be put into the context of the agreements reached at the UN Climate Change Conference at Paris in December 2015 (UNFCCC COP21). Modelling by IPCC scientists now employs four scenarios (or representative pathways, RCPs) for emissions and the warming it generates. These RCPs are used to study potential future trends of the global climate (Collins et al., 2013). The "business as usual" pathway (RCP8.5) with very limited mitigation actions results in global warming of 4°C in the last decades of this century. A pathway based on some extent of mitigation (RCP6.0) results in warming of 2.7°C, which compares with the combined commitments for mitigation action by the world's governments in the context of the UN Paris Agreement in 2015 (UNFCCC COP21). Stricter mitigation actions (RCP4.5) would be needed to limit warming to 2.4 °C. But only the IPCC's most ambitious scenario (RCP2.6) shows consistency with the "well below 2°C" with "efforts to limit" warming to 1.5°C as stipulated in Article 2 of the UNFCCC Paris Agreement.

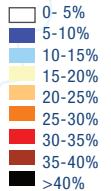
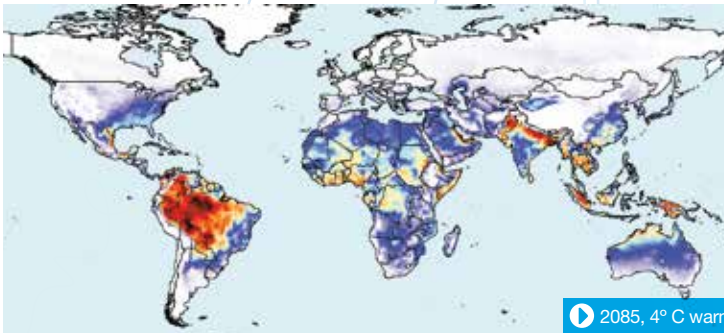
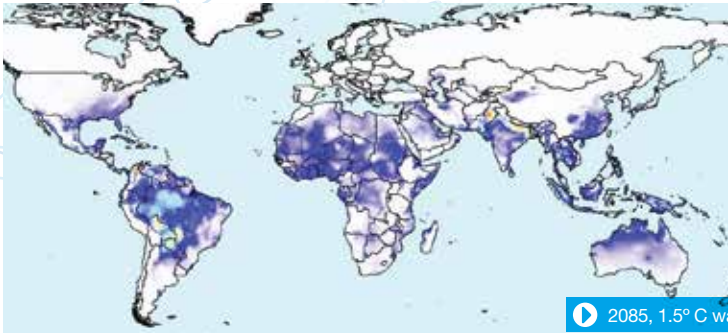
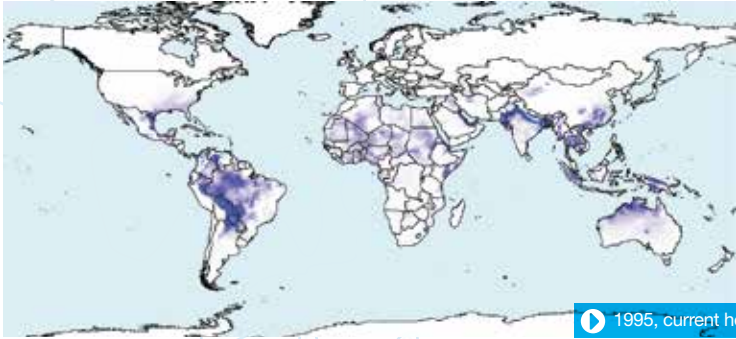
Figure 7 shows estimated losses of work capacity for 30-year periods around 1995 and 2085 at different global warming levels between 1.5 °C (RCP2.6) and 4 °C (RCP8.5). Lost work hours are calculated based on the geographic distribution of adult (working age) population numbers for the year 2000, and expressed as the annual percent of daylight hours lost due to heat (as indicated by the data in Figure 3). Already now, up to 10-15% of annual daylight hours are so hot that productivity is lost. By the end of the century this will increase in the hottest areas even if global temperatures are held at 1.5 °C (RCP2.6), but the increase is much higher for the business-as-usual scenario of 4 °C (RCP8.5), reaching more than 30% (Figure 7). The details of the calculation methods are described in the Appendix.

"ALREADY NOW, UP TO 10-15% OF ANNUAL DAYLIGHT HOURS ARE SO HOT THAT PRODUCTIVITY IS LOST"

FIGURE 7.

Workplace heat health risks and loss of labour productivity due to heat.

▶ The percentages refer to potential annual daylight hours when health and productivity problems due to heat start occurring for moderate work and labour productivity falls as workers slow down or take more rest (Kjellstrom et al., to be published)



Impacts by region and country

Using a limited mitigation scenario (RCP6.0) we calculated the losses in different countries at different times (Table 1). This table currently includes a select range of countries from different regions, to illustrate the breadth of the concern and its varying repercussions across locations and geographic characteristics. More detailed results for all individual Member States and other countries are expected to be produced as the Hothaps project, an ongoing research initiative mapping changing thermal conditions for exposed populations around the world.

Table 1 shows that for a range of countries, increases in lost work hours between current situation and 2.7 °C of warming is often considerable and can be as high as 10% by 2075.

Already in the current situation (2015) several percent of working hours can be lost in highly exposed regions. There is a 10-times or more increase of work hours lost from 2015 to 2085 for a number of countries. The worst impacts are estimated for Asia and the Pacific region with similar impacts also in West Africa. Latin America and the Caribbean have lower impacts and in Europe some impacts occur in the South, but it is much less than in the worst affected countries in Asia and Africa.

TABLE 1.

Regional and country level losses of labour productivity.

- ▶ These are preliminary and indicative results for a selection of countries based on model data by IPCC analysis. Updated analysis will be produced in 2016. The 2015 numbers in the table range from a linear extrapolation of trends since 1980, and interpolation point between 1995 and 2025. Each year point is a 30-year average estimate around that year. The data apply to work in the shade at moderate work intensity (300W). The RCP6.0 model outputs fit well with the national mitigation policies presented at COP21.

COUNTRY	WORKING AGE POPULATION	POTENTIAL ANNUAL DAYLIGHT WORK HOURS LOST FOR WORK AT 300W, %; BASED ON A BUSINESS AS USUAL SCENARIO (RCP8.5, AVERAGE OF HADGEM2 AND GFDL MODELS) CURRENT (1995) AND UP TO 2085					
		2015, MILLIONS	1995	2015	2025	2055	2085
ASIA AND THE PACIFIC							
Bangladesh	98.65	1.06	1.4 - 2.0	2.53	4.61	8.56	
Cambodia	9.51	1.82	2.2 - 3.4	4.24	6.54	10.93	
China	892.11	0.32	0.33 - 0.56	0.68	1.12	2.12	
India	817.16	2.04	2.6 - 3.1	3.61	5.22	7.98	
Indonesia	164.23	0.33	0.42 - 0.93	1.23	2.56	5.45	
Kiribati	0.06	0.59	0.75 - 1.5	1.95	4.31	8.66	
Maldives	0.12	0.42	0.59 - 1.4	1.90	4.52	9.17	
Nepal	19.7	0.61	0.88 - 1.1	1.27	1.98	3.38	
Pakistan	109.88	3.73	4.1 - 4.7	5.22	7.00	9.97	
Philippines	61.92	0.32	0.33 - 0.79	1.03	2.07	4.41	
Vietnam	60.55	0.80	0.78 - 1.7	2.08	3.44	6.31	

COUNTRY	WORKING AGE POPULATION	POTENTIAL ANNUAL DAYLIGHT WORK HOURS LOST FOR WORK AT 300W, %; BASED ON A BUSINESS AS USUAL SCENARIO (RCP8.5, AVERAGE OF HADGEM2 AND GFDL MODELS) CURRENT (1995) AND UP TO 2085				
		1995	2015	2025	2055	2085
AFRICA	2015, MILLIONS	1995	2015	2025	2055	2085
Burkina Faso	10.25	1.90	2.8 - 3.0	3.56	5.59	9.17
Ethiopia	51.55	0.14	0.19 - 0.24	0.28	0.43	0.72
Ghana	17.34	0.64	1.1 - 1.4	1.71	3.49	6.75
Kenya	29.57	0.05	0.09 - 0.13	0.17	0.32	0.63
Morocco	21.02	0.01	0.03 - 0.03	0.04	0.08	0.22
Nigeria	109.4	0.96	1.6 - 1.8	2.18	3.86	6.69
Tanzania	33.57	0.04	0.08 - 0.11	0.15	0.35	0.83
Tunisia	6.89	0.29	0.65 - 0.56	0.69	1.14	2.15
AMERICAS						
Barbados	0.18	0.05	0.13 - 0.25	0.34	0.78	2.96
Colombia	30.48	0.21	0.32 - 0.49	0.63	1.22	2.41
Costa Rica	3.14	0.28	0.33 - 0.53	0.65	1.19	2.23
Honduras	5.3	0.07	0.11 - 0.24	0.32	0.67	1.51
Mexico	74.94	0.33	0.50 - 0.57	0.69	1.15	2.03
USA	208.12	0.15	0.26 - 0.34	0.43	0.73	1.38
EUROPE						
France	40.56	0.00	0.00 - 0.00	0.00	0.01	0.04
Germany	52.17	0.00	0.00 - 0.00	0.00	0.00	0.02
Greece	7.38	0.00	0.02 - 0.02	0.02	0.06	0.24
Spain	30.69	0.01	0.03 - 0.03	0.04	0.08	0.25
Switzerland	3.56	0.00	0.00 - 0.00	0.00	0.00	0.01

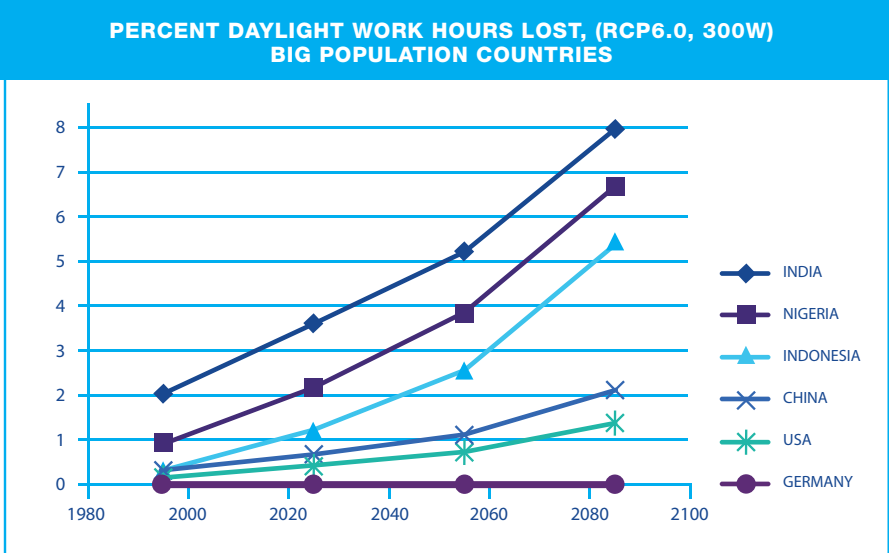
A level of working intensity (metabolic rate) of 300W is a reasonable mid-point level for a variety of jobs in agriculture, industry and construction. The share work capacity losses at very intense physical work (at a metabolic rate of 400W) would be up to twice as high as the numbers in Table 1. The results in that table are also based on work in the shade or indoors without effective cooling. Work in the sun adds to the heat exposure and creates higher hourly losses. Estimates of country based overall work capacity loss need to take into account the percentage of the working population carrying out work at different levels including indoors as well as outdoors. This Issue Paper used an approach in a report for the World Health Organization (WHO) (Kjellstrom et al., 2014), but it can be modified at country level. Continued analysis work should compare different approaches and validate these through comparison with actual country data.

Detailed analysis also shows that the percentage work hours lost due to heat in 2085 for a 2.7° C warming level (using the RCP6.0 data), similar to the UNFCCC COP21 Paris meeting country commitments, may be approximately half of the levels shown in Table 1. Greater emissions control would further limit negative effects.

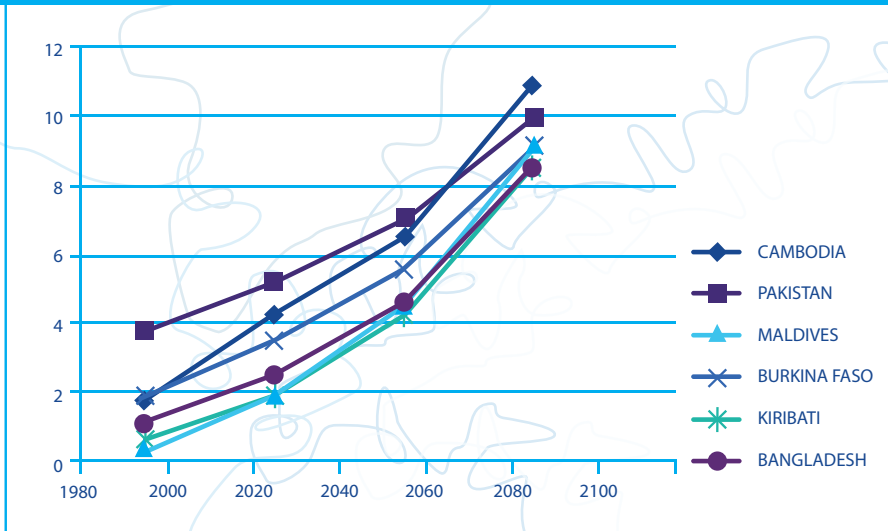
Figure 8 shows the time trends for selected countries. These indicative estimates show substantial differences in the health and productivity impacts between estimates for a global temperature change at 1.5 °C and at 2 °C. This needs to be considered further in global and national climate change policy development.

“WORK IN THE SUN ADDS TO THE HEAT EXPOSURE AND CREATES HIGHER HOURLY LOSSES”

FIGURE 8.
Time trends of work hours lost due to heat.



PERCENT DAYLIGHT WORK HOURS LOST, (RCP6.0, 300W) WORST AFFECTED COUNTRIES



Additional calculations of labour productivity loss

It can be seen in Figure 9 that for countries with the highest climate change impacts there is a major difference in the workplace heat impact between a GTC at 1.5 °C and GTC at 2.0 °C. In India the increased impact goes from approximately 4% work hour loss to 6% loss, and in the Philippines it goes from approximately 1% loss to more than 2% loss.

TABLE 2.**Regional and country level losses of labour productivity.**

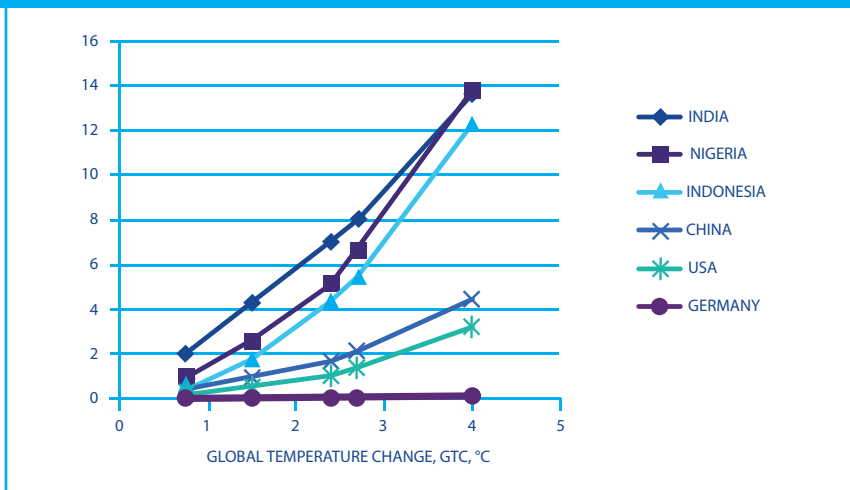
▶ These are preliminary results based on model data by IPCC analysis. Updated analysis will be produced in 2016. The work capacity loss (300W metabolic rate work) due to heat in 2085 is related to the four RCPs and the associated GTCs.

COUNTRY	WORKING AGE POPULATION	POTENTIAL ANNUAL DAYLIGHT WORK HOURS LOST (%) FOR WORK (AT 300W; BASED ON AVERAGE OF HADGEM2 AND GFDL MODELS)				
		GLOBAL TEMPERATURE CHANGE, °C (APPROXIMATE)	0.74	1.5	2.4	2.7
ASIA AND THE PACIFIC	2015, MILLIONS	1995	2085	2085	2085	2085
Bangladesh	98.65	1.06	3.43	7.57	8.56	14.92
Cambodia	9.51	1.82	5.09	8.94	10.93	18.97
China	892.11	0.32	0.95	1.63	2.12	4.44
India	817.16	2.04	4.31	7.03	7.98	13.60
Indonesia	164.23	0.33	1.75	4.35	5.45	12.28
Kiribati	0.06	0.59	2.46	6.19	8.66	18.50
Maldives	0.12	0.42	2.73	7.16	9.17	18.22
Nepal	19.7	0.61	1.63	2.86	3.38	6.19
Pakistan	109.88	3.73	6.04	8.63	9.97	15.27
Philippines	61.92	0.32	1.37	3.27	4.41	10.32
Vietnam	60.55	0.80	2.58	5.09	6.31	12.72
AFRICA						
Burkina Faso	10.25	1.90	4.11	7.02	9.17	17.11
Ethiopia	51.55	0.14	0.33	0.58	0.72	1.57
Ghana	17.34	0.64	2.18	5.10	6.75	14.62
Kenya	29.57	0.05	0.22	0.47	0.63	1.57
Morocco	21.02	0.01	0.06	0.12	0.22	1.04
Nigeria	109.4	0.96	2.61	5.17	6.69	13.79
Tanzania	33.57	0.04	0.17	0.57	0.83	2.72
Tunisia	6.89	0.29	0.92	1.75	2.15	4.66

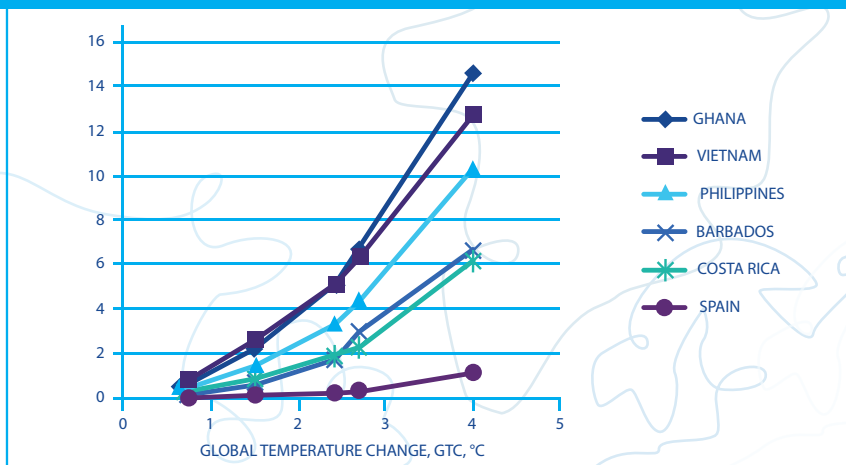
COUNTRY	WORKING AGE POPULATION	POTENTIAL ANNUAL DAYLIGHT WORK HOURS LOST (%) FOR WORK (AT 300W; BASED ON AVERAGE OF HADGEM2 AND GFDL MODELS)				
		0.74	1.5	2.4	2.7	4
GLOBAL TEMPERATURE CHANGE, °C (APPROXIMATE)		0.74	1.5	2.4	2.7	4
AMERICAS	2015, MILLIONS	1995	2085	2085	2085	2085
Barbados	0.18	0.05	0.52	1.67	2.96	6.65
Colombia	30.48	0.21	0.80	1.83	2.41	5.20
Costa Rica	3.14	0.28	0.80	1.80	2.23	6.14
Honduras	5.3	0.07	0.43	1.22	1.51	4.37
Mexico	74.94	0.33	0.87	1.61	2.03	4.01
USA	208.12	0.15	0.49	1.03	1.38	3.20
EUROPE						
France	40.56	0.00	0.01	0.02	0.04	0.29
Germany	52.17	0.00	0.00	0.01	0.02	0.12
Greece	7.38	0.00	0.04	0.17	0.24	1.15
Spain	30.69	0.01	0.06	0.15	0.25	1.07
Switzerland	3.56	0.00	0.00	0.01	0.01	0.13

FIGURE 9. Trends of work capacity loss as a function of Global Temperature Change.

PERCENT DAYLIGHT WORK HOURS LOST, GLOBAL TEMPERATURE CHANGE LEVELS, 300W, LARGE POPULATION COUNTRIES



PERCENT DAYLIGHT WORK HOURS LOST, GLOBAL TEMPERATURE CHANGE LEVELS, 300W, OTHER COUNTRIES



Economic consequences and poverty risks

Climate change and heat will affect the large share of the global workforce that operates outdoors and in non-climate controlled conditions in populous affected regions, implying significant economic costs. Effects are felt at a range of levels. For instance, the worker faces income loss when less is achieved within the same period of time, or a loss of leisure/family time if more work is required. Employers and businesses experience losses when their workers fail to deliver the same daily outputs as before due to hotter conditions. Injury rates also increase with extreme heat entailing health and economic consequences for workers and employers. Where workers receive less income due to diminished productivity, family incomes are also affected. Child health, women's health and elderly health risks increase when family incomes are reduced. Effects for small-scale and subsistence farmers are further compounded in many situations by the inability to displace working hours into the evening because of the importance of terrain sight and the need to operate during daylight hours. This is an important development challenge since loss of working hours for subsistence farmers would directly affect family food security and hold back progress on eradicating extreme forms of rural poverty. As an adaptation strategy to climate change, people might decide to migrate to leave

extreme climatic conditions, in particular areas affected by extreme heat due to consequences for work, income, food security and health, and/or to diversify their livelihood.

At industry level, economic consequences are concentrated on sectors that have high proportions of the labour force out-of-doors, engaged in moderate to heavy work tasks, or who operate in non-climate controlled conditions in offices, factories or health, education and other facilities. Economic effects are most severe for the primary sector, in particular, agriculture. Other industries, however, such as mining and construction, are also exposed to heat risks. While the bulk of manufacturing and service sector workers operate indoors, the extent to which indoor conditions are effectively controlled through air conditioning, insulation or other measures, varies considerably between high, middle and lower-income countries (Kjellstrom, 2009; Dahl, 2013). Faced with growing heat extremes, many secondary and tertiary sector workers in emerging economies and Least Developed Countries are therefore experiencing heightened risks, and poverty is an underlying risk factor. Slum workshops and basic industries will be directly affected by ambient climate and heat conditions (examples, Figure 10).

FIGURE 10.

Basic manufacturing work situations where preventive actions are urgently needed.

- ▶ Climate change will bring increasing heat problems in such workplaces.



T.Kjellstrom photos

- ▶ Slum workshops like this one in Tanzania, expose the workers to increasingly severe ambient heat levels and associated hazards.

This factory for recycling car batteries in Vietnam have few opportunities to provide cooling systems at the workplace. ◀



T.Kjellstrom photos

At a macro level, a number of studies have examined the potential economic impact of climate change on labour productivity. One study for the USA (Kopp et al., 2014) estimated a several billion US\$ loss in 2030 for the American economy. With different methods and similar results for the USA in 2030, another study estimated US\$300 billion in losses globally and rising to \$2.5 trillion by 2030 (DARA and the CVF, 2012). Vulnerability was assessed as highest among emerging economies and Least Developed Countries, with the greatest overall losses in China, India, Mexico and Indonesia (DARA and the CVF, 2012).

Another macro-economic study and application of the World Bank's ENVISAGE model (Mensbrugge and Roson, 2010) estimated the impact of climate change on labour to be the single most costly effect of climate change.

The IPCC's 5th Assessment Report also recognized the effects of changing thermal conditions in the workplace and the links between productivity and output. The IPCC has considered the translation of labour productivity losses into economic losses at an output elasticity of labour of 0.8, meaning labour productivity impacts would be felt as economic losses at 80% of their scale (and not as a 1:1 equivalent). It recognized that labour productivity impacts for affected sectors could entail 8–22% reductions in output during the second half of the century (Kjellstrom et al., 2009b). 2100 impacts for severely affected regions, such as India and Sub-Saharan Africa, have been estimated by another study to result in adverse deviations of more than 6% of GDP (Mensbrugge and Roson, 2010).

Analysis of work capacity and labour productivity loss can calculate likely economic impacts and consider potential impacts on future GDP due to heat-related labour productivity losses. For instance, a situation can be considered whereby at the middle of this century the loss in moderate intensity work (300W) is 10% and 50% of the working age population is engaged in work at least at 300W, and half of the labour productivity loss is creating GDP loss (as some workplaces can

reduce the impact of heat via cooling systems), and an output elasticity of labour of 0.8 is assumed. In such a situation, the annual GDP loss would be approximately 2% due to the loss heat levels. Further analysis of the economic impacts based on detailed estimates of work force distribution and occupational practices is urgently needed to integrate this issue into climate change policy and the study of response actions.

SOCIAL AND DEVELOPMENT IMPACTS AND RELATIONSHIP TO SDGs

The social settings of work and the impacts of climate change

Work is an essential part of social and economic development at all levels: the family, the local community, the country, the region and the whole planet. Global development objectives provide an opportunity to analyse and explore the links between work and other development challenges via policies and actions in families, communities and enterprises. The 2005-2015 Millennium Development Goals (MDGs), for instance, included labour productivity as an indicator of progress for extreme poverty (MDG1). Assessment of the MDG1 labour productivity indicator demonstrated very marginal progress in the chief poverty lag regions, which also correspond with the regions severely affected by the impact of climate change on labour (Kjellstrom et al., 2009b).

The UN's 17 new Sustainable Development Goals (SDGs) now constitute the international community's primary development objectives.

The effect of rising heat in the workplace will continue to present multi-faceted challenges for many of the new global SDG goals, in particular the eight goals related directly to incomes, family health and nutrition, inequalities and jobs, community sustainability and climate change. Key challenges for each of these goals are highlighted in Table 2.

“ASSESSMENT OF THE MDG 1
LABOUR PRODUCTIVITY
INDICATOR DEMONSTRATED
VERY MARGINAL
PROGRESS IN THE CHIEF
POVERTY LAG REGIONS”

TABLE 2.**Climate change impacts on work and Sustainable Development Goals.**

GOAL	FOCUS	CLIMATE CHANGE RISING WORKPLACE HEAT IMPACT
1	No Poverty	The lowest-income groups, in particular agricultural sector workers and small-scale and subsistence farmers, in tropical and sub-tropical developing countries are worst affected.
2	No Hunger	Impacts for small-scale and subsistence farmers curtailing available work hours and outputs are likely to affect household food security.
4	Quality education and Learning	Heat-exposed students and teachers are less likely to access and provide quality education and learning.
3	Good Health	Large-scale exposure to heat injury and health risks such as heat stroke, exhaustion and even death will frustrate efforts to improve health. Migrants can be especially vulnerable to health risks as they may not have access to health care and occupational safety and health services in their destination country.
5	Gender Equality	Many heat-exposed occupational functions involve women, especially in developing countries, and pregnancy adds to the heat exposure risks. Men and boys are at risk as they often perform the heaviest loaded outdoor work in industries like agriculture and construction.
8	Good Jobs and Economic Growth	New heat extremes make it more difficult for international standards and guidelines for occupational health and safety of workers to be respected, and economic consequences are large in scale.
10	Reduced Inequalities	High income temperate regions are much less affected than tropical and sub-tropical developing regions which counteracts efforts to achieve improved globally.
11	Sustainable Cities and Communities	Heat extremes will challenge the built environment (houses and workplaces) and its sustainability, while heat waves are most intense in urban areas.
13	Climate Action	The impact of climate change on labour presents a large-scale challenge to climate resilience that has yet to be effectively recognized or addressed by international and national measures.

OPTIONS TO REDUCE SOCIAL, ECONOMIC AND HEALTH IMPACTS FOR WORKING PEOPLE

The impacts of increasing heat on working people is a key feature of climate change and can undermine efforts to reduce poverty and to achieve the SDGs. Preventive policies and actions are therefore sorely needed at local, national, regional and global level. The first preventive approach includes those that reduce climate change itself through greenhouse gas emission control measures, or climate change mitigation. As described earlier, the difference in heat impacts between policies that limit warming to below 2° C and the heat impacts associated with a 3 or 4° C world are major. Thus, much of the negative health and physiological effects of climate change on labour can be prevented by stricter greenhouse gas policies. This was highlighted in previous assessments (e.g. Costello et al., 2009; DARA, 2012; Watts et al., 2015) but the connection of mitigation to the impact of rising heat on the workforce could be better integrated into policy.

A second approach to prevention is what termed adaptation, or finding healthy and productive ways to live and work in the hotter environment. This can involve any way of reducing the actual workplace heat exposure or finding ways to avoid the heat stress caused by a changing climate. It has been pursued with national adaptation policy development in a number of countries, as it is clear that some impacts of climate change cannot be avoided by mitigation, as the climate is already changing (Collins et al., 2013). Guidance on how to protect communities from increasing heat have been produced by WMO and WHO (2015) and this has been followed up with national guidelines in a number of countries.

Another dimension approach to prevention focuses on resilience strengthening, such as through strengthened poverty reduction efforts and measures to improve population health status aimed at enhancing the ability of communities to withstand adverse changes.

It is important to consider the geographic scale of policies and actions to reduce climate change impacts on labour. The global and regional scale is important for setting targets for future greenhouse gas emissions and warming limits, as was done in Paris in December 2015 (UNFCCC COP21). At national and local scale various methods to achieve stronger resilience and effective adaptation are available. Finally, actions at individual scale are also of great importance, especially as the exposure to potentially damaging climate conditions can be acted on by the individual worker.

In terms of policies building on the ILO Decent Work framework and considering the impacts on individuals, we can highlight the following. First of all, working people who need to carry out continuous heavy or moderate labour in very hot work environments should be provided with basic occupational health programs and actions as outlined in ILO documents (ILO 2016). The protection would involve sufficient access to drinking water at hot work sites, so that sweat loss of liquid can be replaced. A person in this type of work may sweat 1-1.5 litre/hour.

Rest breaks in cool locations should also be made available, but as pointed out earlier, this will reduce hourly productivity and could reduce the working persons income. Therefore, some people have an incentive to not take rest, as their hourly income will then be higher, and they may risk their health and even their life by not slowing down when their bodies are overheated.

Possible heat protection measures



▶ **Direct:** engineering solutions, such as cooling and air conditioning, building insulation, shade and worker rehydration stations, and protective clothing; administrative controls, education and awareness campaigns and worker practice and monitoring programs (e.g. rest, scheduling and acclimatization regimes, bio-physical monitoring and other related measures); strengthening labour institutions, guidelines, regulations, protection programs, and policies.

▶ **Indirect:** fiscal and regulatory intervention to speed structural shifts of economies towards industries involving non-outdoor work (especially in the service and industrial sectors); compensating for productivity losses via other means, such as expanding the use of information and communications technologies or modernized agricultural technologies.

Creating cooler work environments with air conditioning consumes energy and costs money. It is often not possible to use this solution in small workshops and in outdoor work. In addition, the provision of sustainable energy sources need to be considered. For instance, solar panel driven air conditioning systems are already available and should be assessed as a part of national policies.

However, it is important to consider mitigation as the key feature of labour protection, and energy policies and programs that broaden the use particularly of renewable energy for electricity production is of high priority. This is because effectively adapting to climate change that is already expected to occur will require a significant increase in air conditioning in hot regions of the world. Under the current energy mix for such regions, those measures – vital for protecting workers from heat extremes – would generate significant additional emissions, counteracting efforts to cap further warming in a vicious cycle.



“IT IS IMPORTANT TO CONSIDER MITIGATION AS THE KEY FEATURE OF LABOUR PROTECTION”

CONCLUSION: SUMMARY OF KEY FINDINGS AND POLICY RECOMMENDATIONS

- ▶ When it is too hot, people work less effectively out-of-doors, in factories, the office or on the move due to diminished ability for physical exertion and for completing mental tasks.
- ▶ Heat extremes also increase accident risk and expose people to serious heat-related health risks including heat stroke, severe dehydration and exhaustion, while a body temperature above 40.6° Celsius is life-threatening.
- ▶ That is why governments and international organizations have long put in place standards on thermal conditions in the workplace. But climate change has already altered thermal conditions in the work place, and additional warming is a serious challenge for any worker or employer reliant on outdoor or non-air conditioned work.
- ▶ The challenge is that workers are required to work longer hours to achieve a targeted output, or more workers are needed for the job; this creates costs due to a lower hourly productivity of labour.
- ▶ The world's warmest regions – tropics and sub-tropics – are worst affected due to pre-existing heat extremes and because of high concentrations of exposed sectors (agriculture and manufacturing).
- ▶ More than one billion workers already grapple with dozens of additional extremely hot days in a year due to climate change alone. While every decade brings a similar amount of additional hot days for exposed regions with warming set to continue for decades no matter what degree of emissions control is realized.
- ▶ Unmanaged, the impact of climate change results in lost work hours that can be substantial at a macro-economic level, with losses for most vulnerable countries already exceeding 2% of all available work time.
- ▶ Rising heat in the workplace will undermine progress towards the Sustainable Development Goals (SDGs), the UNFCCC's Global Adaptation Goal, and makes Decent Work and respecting international Labour standards on thermal environments of workers a serious challenge.
- ▶ An emerging concern, most national climate or employment policies do not address the impact of climate change on health and productivity in the workplace, but new ILO Guidelines address occupational health and safety and social protection linked to climate change and provide a starting point for a more substantial response.
- ▶ Workers and employers need protection now and measures to manage risks to health, income and output do exist, but often entail costs and may compound challenges as in the case of air conditioning, a costly and energy and emissions intensive response.
- ▶ Risks become increasingly less manageable and costly to deal with at higher levels of warming as even 1.5 °C of warming entails substantial increased heat and workplace impacts that is a strong incentive for ambitious action to reduce emissions and limit warming in-line with the new UN Paris Agreement on climate change.
- ▶ More detailed research and analysis of this issue is urgently required.

Policy recommendations

- ▶ The most relevant international organizations have yet to establish any major programmes to address the major challenges of rising heat in the workplace. In November 2015, however, the ILO Governing adopted the “Guidelines for a just transition towards environmentally sustainable economies and societies for all”, which include occupational safety and health and social protection policies within the context of climate change.
- ▶ These guidelines recognize the need for enterprises, workplaces and communities to adapt to climate change to avoid loss of assets and livelihoods and involuntary migration.
- ▶ Under the Occupational Safety and Health (OSH) item, these guidelines call on social partners, to conduct assessments of increased or new OSH risks resulting from climate change; improve, adapt or develop and create awareness of OSH standards for technologies and work processes related to the transition; and review policies concerning the protection of workers.
- ▶ The Social Protection Policies item mentions the promotion of innovative social protection mechanisms that contribute to offsetting the impacts of climate change and tripartite mechanisms to identify and understand challenges posed by climate change.
- ▶ The guidelines will be revised within the next two years and the adaptation angle could be reinforced in this process.
- ▶ These guidelines will be implemented in two or three pilot countries; special attention needs to be paid to the climate change impacts on labour during the implementation phase.
- ▶ There are also a range of options that can be explored to further develop research and advocacy initiatives, review labour standards, and implement practical preventive measures in the workplace in the context of climate change adaptation.
- ▶ Swift efforts by all countries to live up to the UN Paris Agreement objective of well below 2 degrees of warming with efforts to limit temperatures to not more than 1.5 degrees will also constitute the most significant preventative measure against a tremendous escalation of workplace heat risks this century.



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ONLINE RESOURCES

Hothaps Program and Hothaps-soft are described in the website: <http://www.ClimateCHIP.org>

ILO guidelines for a just transition towards environmentally sustainable economies and societies for all (2015): http://www.ilo.org/wcmsp5/groups/public/---ed_emp/---emp_ent/documents/publication/wcms_432859.pdf

ILO Standards and other instruments on occupational safety and health (2016): <http://www.ilo.org/safework/info/standards-and-instruments/lang--en/index.htm>

Hothaps Program and Hothaps-soft: <http://www.ClimateCHIP.org>

ILO guidelines for a just transition towards environmentally sustainable economies and societies for all (2015): http://www.ilo.org/wcmsp5/groups/public/---ed_emp/---emp_ent/documents/publication/wcms_432859.pdf

ILO Standards and other instruments on occupational safety and health (2016): <http://www.ilo.org/safework/info/standards-and-instruments/lang--en/index.htm>

WHO Heat Stress session on the ATLAS of Health and Climate <http://www.who.int/globalchange/publications/atlas/report/en/>

WHO Country Profiles: <http://www.who.int/globalchange/resources/countries/en/>

WHO "Heatwaves and health: guidance on warning-system development": <http://www.who.int/globalchange/publications/heatwaves-health-guidance/en/>

WHO guidance to protect health from climate change through health adaptation planning: <http://www.who.int/globalchange/publications/guidance-health-adaptation-planning/en/>

WHO Quantitative risk assessment of the effects of climate change on selected causes of death, 2030s and 2050s: <http://www.who.int/globalchange/publications/quantitative-risk-assessment/en/>

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APPENDIX: CALCULATION METHODS

Calculation of occupational heat stress and impacts on health and productivity

The climate data for recent years (30-year period around 1995) are from the detailed analysis of 67,000 grid cells by the Climate Research Unit (CRU), University of East Anglia, Norwich, United Kingdom.

Modelling towards the end of this century uses the HadGEM2 and GFDL models, developed for the IPCC assessments (Collins et al., 2013). These two models produce Global Temperature Change estimates by 2085 (30-year average) for RCP8.5 at 2.5-percentile (GFDL) and 97.5-percentile (HadGEM2) of the 25 models calculated by IPCC. That means that their range covers most of the different model outputs for the whole planet.

The heat effects are calculated based on HadGEM2 and GFDL separately. Then the average of these models is calculated as an estimate for the average of different models. A comparison of the average of all models and the average of the two models shows very similar results.

Using the monthly averages of daily maximum temperature, daily average temperature, and daily absolute humidity (water vapour pressure) the monthly averages of daily values for average WBGT (Wet Bulb Globe Temperature) and maximum WBGT are then calculated using methods described by Lemke and Kjellstrom, (2012). This produces heat levels in the shade or indoors without cooling.

The daily variability within each calendar month, and the hourly variability within a typical monthly day is estimated from available daily modelling data. These variability estimates are then used to calculate the number of hours each month when WBGT values are at specific 1-degree levels. If the number of hours at a certain WBGT level is less than 0.5 hours, we truncate the heat exposure calculation at that level. Any higher WBGT level fractional hour exposures are not included.

For each hour the exposure-response function for heat impact on health and productivity based on the Sahu et al. (2013) paper (Figure 3) and the similar results Wyndham (1969) paper. The loss of productivity in % of each heat exposure hour is calculated for each of the 67,000 grid cells, and then weighted by the grid cell working age population to be added up for each country into a weighted loss (%) of potential daylight work hours for each country at different times and using different RCPs.

The resulting work hours lost due to heat are shown in the Tables and Figures, and the counteraction between occupational health risk due to heat and the loss of work hour productivity means that the resulting numbers can be interpreted for both effects. If X % of the potential daylight work hours are "lost" due to heat if the workers slow down and take more rest, as is the natural prevention method, then also X % of the hours are high risk hours for clinical health effects if the workers try to keep their work pace up to normal.

The conceptual structure of the analysis fits with the description in the reference Kjellstrom et al., (2014), but the current Issues Paper uses the latest climate modelling data is grid cell based (67,000 grid cells) for country specific estimates rather than just regional estimates based on cruder climate data.





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