ANNEX B-2

25 April 2015

Text contribution to the Climate Vulnerable Forum, as requested by Cecilia B Rebong, Permanent Representative, Philippine Mission to the United Nations, 15 April 2015.

Request for "inputs from experts on information gaps ...... on the issue of labor" and specifically on these questions:

1) "potential implications of the current 2°C goal on labor"
2) "whether a strengthening of this goal to 1.5°C would likely result in a different outcome for labor"

Climate Change and increasing heat impacts on Labor Productivity

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Summary

Extreme heat induced by climate change will cause profound adverse consequences for work, human performance, daily life, and the economy in large parts of the world. The increasing temperatures are the most predictable effects of climate change, and all models of future trends show significant increase this century. The heat problems will become even worse in the next one or two centuries, depending on the global climate policies established this year. The global areas worst affected by extreme heat will be tropical countries, including most of the Member States of the Climate Vulnerable Forum. Policymakers need to be made aware of the detrimental effects of labor productivity loss on local economic output and the negative impacts on GDP -- an important factor in considering the cost of climate change and the need for mitigation. The extreme heat effects on labor productivity are substantially worse for models representing a global temperature increase of 2°C than an increase of 1.5°C. The difference may be similar to the losses calculated for the Climate Vulnerability Monitor 2012.

Background

The daily life of most people living in areas with very hot seasons is affected by heat—not only during heat waves. In many work situations labor productivity is reduced, with important economic consequence for businesses, workers and their family members, and entire communities (Parsons, 2014; Kjellstrom et al., 2015).

Increasing temperature, the *global* heat *level rise*, is the most obvious effect of climate change in much of the world (IPCC, 2013). It is also the most commonly modeled impact of increased greenhouse gas concentrations in the atmosphere (IPCC, 2013). Ambient environmental heat is recorded primarily by air temperature, but from the perspective of human and animal physiology, heat is a function not only of air temperature but also of humidity, air movement (wind speed), and heat radiation (outdoors, mainly from the sun) (Parsons, 2014). Heat levels are measured with "heat indexes" that combine these four variables and one of the most widely used is the Wet Bulb Globe Temperature (WBGT) (Parsons, 2014).

The effects of heat on human health have a physiological basis, with heat exposure leading to heat stress and heat exhaustion or even severe clinical heat stroke and death (Parsons, 2014). Humid ambient environments with air temperatures above 35°C are a threat to physiological balance. WBGT is then appr. 29°C and this limits human performance and work capacity, even in moderate-intensity jobs (Kjellstrom et al., 2009a). Heat-related problems are increasing in Member States of the Climate Vulnerable Forum in tropical areas due to increasing temperature levels (DARA, 2012). In several countries, WBGT levels are already high enough to substantially limit outdoor and indoor work during hot periods each year (Kjellstrom et al., 2013). The annual number of days at or above a WBGT of 29°C increased in parts of South-East Asia from approximately 10 in 1980 to more than 70 in 2010 (Kjellstrom et al., 2013).

Estimating impacts on labor productivity

The first report that identified the potential problems for labor productivity when climate change creates hotter workplaces (Kjellstrom et al., 2009a) indicated that impacts on low- and middle-income countries could be severe. Further reports from the Hothaps team (see: www.ClimateCHIP.org) at both global and country level providing increasing evidence of the quantitative impacts.

Analysis of the problem has continued with one global study showing that heat levels undermine habitability in many areas (Sherwood and Huber, 2010). One study in Australia (Maloney and Forbes, 2011) calculated the numbers of days when certain work will be impossible unless air conditioning systems provide heat protection. Economists have also provided estimates of the impacts on local GDP in the USA (Kopp et al., 2014) concluding that high heat reduces the number of hours worked in exposed occupations with billions of dollars lost each year as climate change progresses.

The only global analysis of the heat impacts on labor productivity and the associated economic losses has been produced by DARA (2012) for the Climate Vulnerable Forum. The underlying estimates of climate change impacts on labor productivity in 21 global regions had been published by Kjellstrom et al (2009b) based on the then widely used "scenario A1B" for climate change progress and early models that have now been updated. Analysis of GDP losses in percent and the associated potential economic losses was carried out for each country in the world by DARA, even though the specific country climate conditions and impacts vary from the regional situation. In any case, the global estimates of economic losses due to climate change induced labor productivity losses already in 2030 were extremely large (Table 1): 2.4 trillion US$.

Table 1. Projected Economic Impacts of Climate Change in 2030, in billions of U.S. dollars (with purchasing power parity, PPP)

Impact Component	**Total Global Net Cost (Percent of Total Climate) (billions US$)**		**Net Cost in 2030 in Specific Country Types (billions US$)**		
	2010	**2030**	**Developing, low GHG emitters**	**Developing, high GHG emitters**	**Developed**
Total climate change	$609 (100%)	$4,345 (100%)	$1.730 (100%)	$2,292 (100%)	$179 (100%)
Labor productivity loss due to workplace heat	$311 (51%)	$2,436 (56%)	$1,035 (60%)	$1,364 (60%)	$48 (27%)
Clinical health impacts	$23 (3.7%)	$106 (2.4%)	$84 (4.9%)	$21 (0.9%)	$0.002 (0.001%)

GHG = greenhouse gas

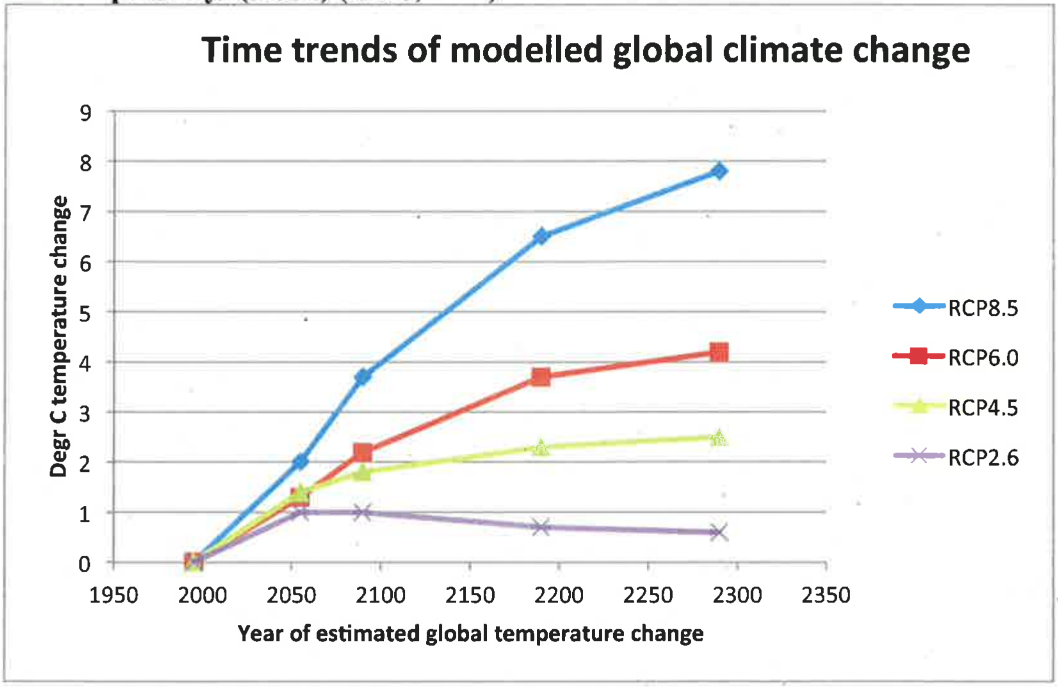
(*Source:* DARA. Climate Vulnerability Monitor 2012. Madrid: Fundacion DARA Internacional, 2012. also included in Kjellstrom et al., 2015; http://daraint.org/climate-vulnerability-monitor/climate-vulnerability-monitor-2012/. Accessed April 18, 2015.)

The estimated impacts in developing countries were much larger than in developed countries (Table 1). For example, the annual cost of lost work productivity was projected to increase from 2010 to 2030 from $55 to $450 billion in India, from $40 to $450 billion in China, from $10 to $95 billion in Malaysia, from $2 to $15 billion in Ghana, and from $1.25 to $9 billion in Costa Rica (DARA, 2012).

Updated analysis of labor productivity loss

An ongoing analysis project is using the new RCP pathways for greenhouse gas emissions and several updated models for the related climate change. These are the updated input data from the IPCC (2013) used in new labor productivity loss analysis presented here. There are four RCP pathways with the highest one (RCP8.5) basically presenting the "business as usual" situation, meaning that greenhouse gas emissions continue as for now. RCP6.0 and RCP4.5 involve greenhouse gas emission restrictions at increasing ambition level, and RCP2.6 basically means stopping all such emissions in the next few years. The time trends for global mean temperature rise from the level in 1995 is shown in Figure 1.

Figure 1. Global mean temperature rise since 1995 depending on the greenhouse gas emission pathways (RCPs) (IPCC, 2013)

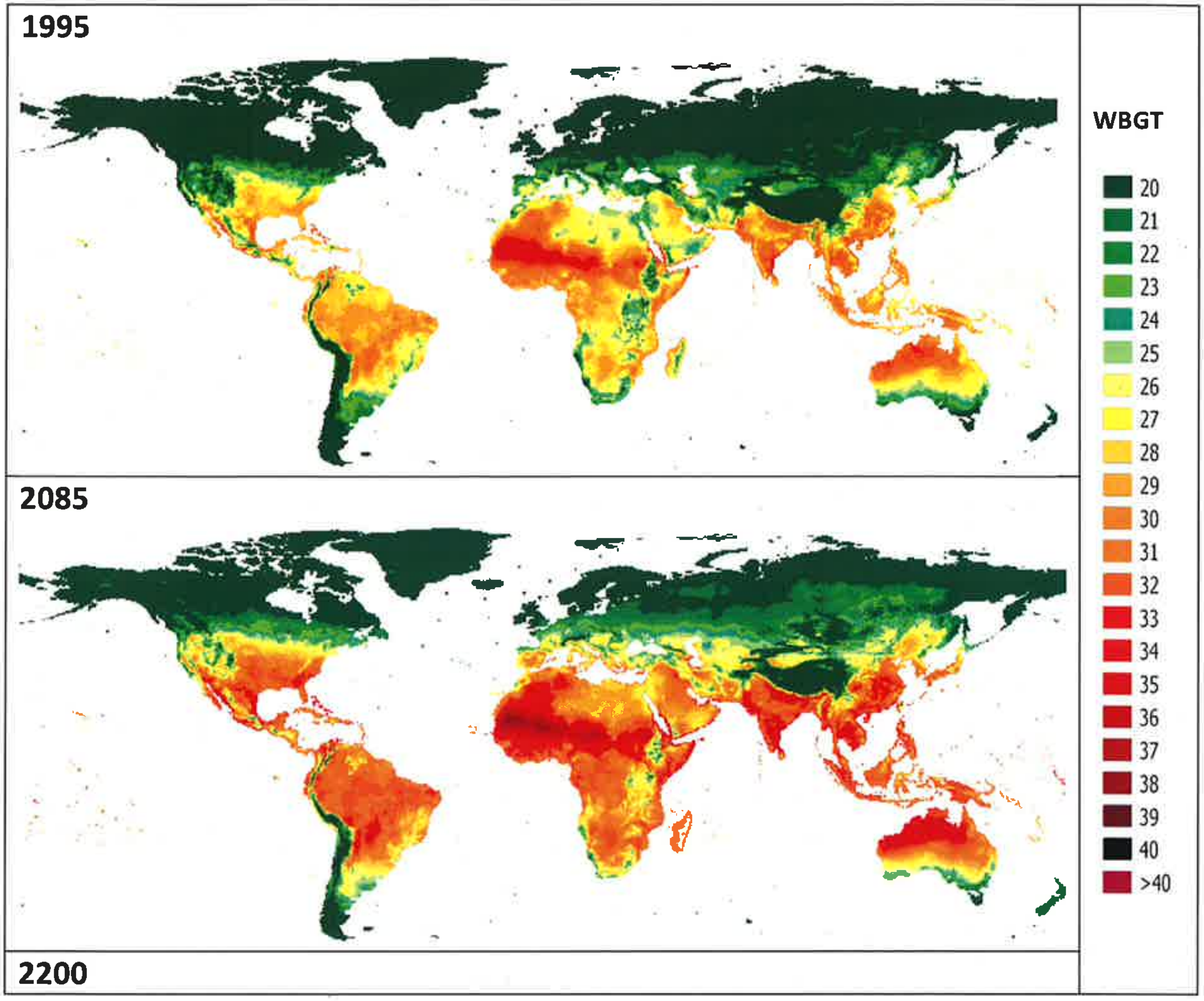


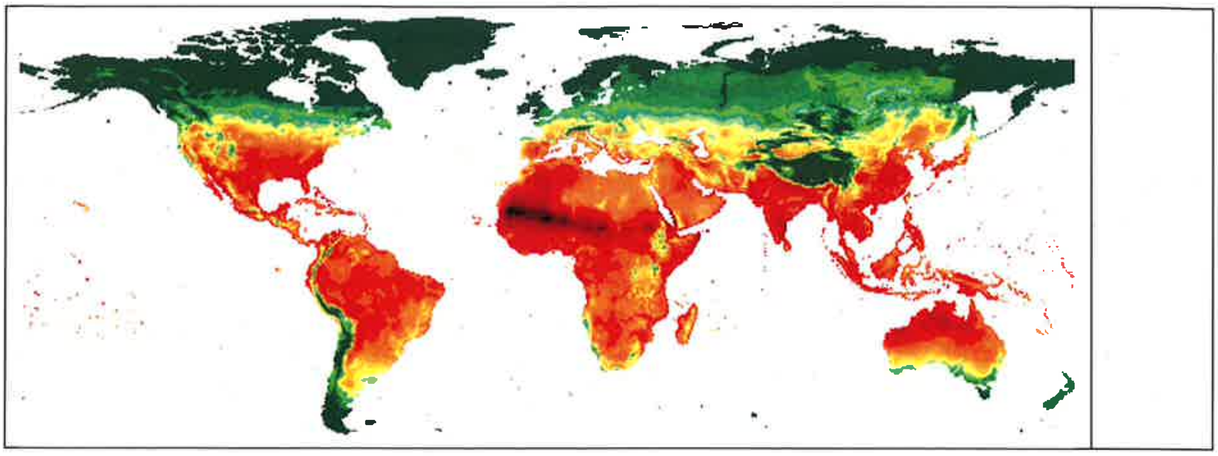
It should be pointed out that much of the debate about climate change impacts is focusing on what will happen by 2050 or 2100. The following centuries are considered too far away to make any comments on. However, the impacts of increasing heat on daily life and labor productivity can only be protected against by spending all ones time in air conditioned indoor environments. The heat may even get so high that local people die within a few hours. This highlights the need for prevention (mitigation) of climate change, and the problems will most severe in tropical countries.

One should also consider that children born this year are likely to be alive in the year 2090 or 2100, and their children will be alive in 2030, and their grandchildren's grandchildren in 2200. So, if we are keen to give our grandchildren a good life in a healthy world, and we consider that our grandchildren will think in the same way, then the year 2200 should be within our family vision.

In order to give an idea of the future situation in the Member States of the Climate Vulnerable Forum we have analyzed the impacts of climate change on heat in different parts of the world. The likely impacts are strongest in tropical countries (Figure 2), and WBGT values above 26°C limits strenuous work, while 29°C limits moderate level work.

Figur 2. Grid cell based analysis (67,000 grid cells) av mean temperatures during afternoons within the hottest month at each location in the world. RCP8.5, Modell GFDL





We can apply these estimated changes during each month of the year and with suitable modeling approaches calculate the distribution of hourly heat levels for each grid cell and month. As shown in Figure 1, the RCP6.0 model estimates reach appr. 2°C increase of global mean temperature in 2090 and just below 1.5°C in 2055 (IPCC, 2013). We will therefore use these time points in RCP6.0 for our comparison of the impacts as requested by the Philippine Mission to the United Nations. The productivity loss values at different hourly WBGT values are those we used in a WHO analysis in 2014 (see: Technical Report 2014:4 on: www.ClimateCHIP.org).

Table 2. Population and labor productivity loss (% of daylight work hours) at different work intensities in the northern Tropical area from Equator to 13 degr. North; RCP6.0, GFDL model.

	Year	1995	2055	2085
Global temperature increase, °C		0	1.3	2.2
Population, total		652,779,033	1,432,533,966	1,532,638,036
Population, working age, 15-64 years		370,335,910	956,572,111	923,855,052
Loss, % of annual daylight work-hours				
Work intensity, light	200W	0.69%	1.65%	2.73%
Moderate	300W	3.22%	5.96%	8.40%
heavy	400W	9.47%	14.36%	18.02%
Differences in work-hour loss, %			**2055-1995**	**2085-1995**
Work intensity, light	200W		0.96%	2.04%
Moderate	300W		2.74%	5.18%
heavy	400W		4.89%	8.55%

For this part of the world the one billion working people in 2055 (when the global temperature has increased 1.3°C) those who work in light labour loose 0.96% of their work hours and this doubles by 2085 (when the global temperature has increased 2.2°C). In moderate work intensity, the hours lost goes from 2.74% to 5.18%, also a doubling, and for heavy work the trend is the same from 4.89% to 8.55%. The numbers are similar if we use instead the HadGEM model for RCP6.0.

Thus, our initial answer to the question of difference in impacts on labor productivity for the two alternatives is **that going up from 1.5 to 2.0° C will double the impacts of this type**. This is also shown for the country examples shown below.

We have made similar calculations for some of the key Member States of the Climate Vulnerable Forum (Tables 3 - 6). In the Philippines, Vietnam and Bangladesh, the lost work-hours in 2055 and 2085 are at similar levels, up to 22 and 16% in 2085, and the difference between a 2°C global increase and a 1.5°C increase is 3 - 6% for moderate and heavy work.

In Costa Rica the losses and differences are smaller, but they go in the same direction. In Ethiopia the losses are even small and this is related to the fact that much of the population of this country live in places at high altitude with generally cooler temperatures than the coastal and low-lying areas of the other countries.

These are just preliminary results from an ongoing project, but it is clear that the labor productivity losses will improve in these types of countries if more strict global climate policies are established and implemented.

Table 3. Estimated loss of annual work-hours due to heat exposure (in-shade without cooling systems); RCP6.0, GFDL model; the Philippines.

Loss, % of annual daylight work-hours		**1995**	**2055**	**2085**
	Light work, 200W	0.32%	1.08%	2.09%
Philippines	Moderate work, 300W	2.97%	6.14%	9.11%
	Heavy work, 400W	10.74%	17.10%	22.03%
	Differences		**2055-1995**	**2085-1995**
	Light work, 200W		0.76%	1.77%
	Moderate work, 300W		3.16%	6.14%
	Heavy work, 400W		6.36%	11.30%

Table 4. Estimated loss of annual work-hours due to heat exposure (in-shade without cooling systems); RCP6.0, GFDL model; Bangladesh.

Loss, % of annual daylight work-hours		**1995**	**2055**	**2085**
	Light work, 200W	0.35%	1.25%	2.23%
Bangladesh	Moderate work, 300W	2.72%	5.48%	7.73%
	Heavy work, 400W	8.39%	12.90%	16.44%
	Differences		**2055-1995**	**2085-1995**
	Light work, 200W		0.90%	1.88%
	Moderate work, 300W		2.76%	5.01%
	Heavy work, 400W		4.52%	8.05%

Table 5. Estimated loss of annual work-hours due to heat exposure (in-shade without cooling systems); RCP6.0, GFDL model; Costa Rica.

Loss, % of annual daylight work-hours		**1995**	**2055**	**2085**
	Light work, 200W	0.04%	0.16%	0.29%
Costa Rica	Moderate work, 300W	0.51%	1.28%	1.94%
	Heavy work, 400W	2.47%	5.08%	6.86%
	Differences		**2055-1995**	**2085-1995**
	Light work, 200W		0.12%	0.24%
	Moderate work, 300W		0.78%	1.43%

	Heavy work, 400W		2.61%	4.39%

Table 6. Estimated loss of annual work-hours due to heat exposure (in-shade without cooling systems); RCP6.0, GFDL model; Ethiopia.

Loss, % of annual daylight work-hours		**1995**	**2055**	**2085**
	Light work, 200W	0.03%	0.08%	0.16%
Ethiopia	Moderate work, 300W	0.13%	0.33%	0.55%
	Heavy work, 400W	0.44%	0.96%	1.46%
	Differences		**2055-1995**	**2085-1995**
	Light work, 200W		0.06%	0.13%
	Moderate work, 300W		0.21%	0.42%
	Heavy work, 400W		0.53%	1.02%

Table 7. Estimated loss of annual work-hours due to heat exposure (in-shade without cooling systems); RCP6.0, GFDL model; Vietnam.

Loss, % of annual daylight work-hours		**1995**	**2055**	**2085**
	Light work, 200W	1.03%	2.49%	3.72%
Vietnam	Moderate work, 300W	4.78%	8.24%	10.71%
	Heavy work, 400W	12.44%	17.76%	21.27%
	Differences		**2055-1995**	**2085-1995**
	Light work, 200W		1.45%	2.68%
	Moderate work, 300W		3.46%	5.93%
	Heavy work, 400W		5.32%	8.83%

Another aspect of these calculations is to what extent the numbers fit what was reported in the DARA (2012) report for the Climate Vulnerable Forum. The fraction of work-hours loss for a country overall can use a similar method that was used for the underlying calculation in the DARA (2012) report, which applied percentages of the workforce as a starting point (Kjellstrom et al., 2009b). The people in agriculture was assumed to carry out heavy work, and people in industry would carry out moderate work. The people in service jobs were considered in light work, and were assumed not to contribute to the climate change impacts. For the five countries the DARA (2012) report indicates losses between 3 and 6% in 2030.

The "baseline year (1975)" for South-East Asia was assumed to have 50% in agriculture and 20% in industry. If we assume that these numbers have changed until 2055 to 30% in agriculture and 25% in industry, we can estimate the overall country percentages of the difference of daylight work-hours lost due to heat depending on the global temperature change (Table 8).

Table 8. <u>Approximate</u> estimates of the change or difference in lost overall work-hours for five countries between global temperature increase of 1.5°C and 2.2°C. USD/PPP. (GDP data from Ward, 2012)

Global temperature increase, °C	**1.3**	**2.2**			**1.3**	**2.2**
			Change	**GDP in 2050, billion USD**	**Loss USD billions**	**Loss USD billions**
Philippines	2.7%	4.9%	2.2%	1688	46	83

Bangladesh	2.0%	3.7%	1.7%	673	13	25
Costa Rica	1.0%	1.7%	0.7%	124	1.2	2.1
Ethiopia	0.2%	0.4%	0.2%	196	3.9	7.8
Vietnam	2.5%	4.1%	1.6%	451	11	18

If we then apply the estimated GDPs in 2050 for the five countries, and assume that these work-time losses cannot be adjusted for by working at night, etc, we find the losses as listed in Table 8. The DARA (2012) report presented losses due to heat induced work-hour loss at between 6 and 85 billions of USD/PPP, so the numbers in Table 8 are in similar range. **This indicates that the difference between achieving a global temperature increase of 1.5°C and 2°C is likely to be at similar level to the losses calculated for 2030 by DARA (2012).**

References

DARA. Climate vulnerability monitor 2012. Madrid: Fundacion DARA Internacional, 2012. http://daraint.org/climate-vulnerability-monitor/climate-vulnerability-monitor-2012/. Accessed July 18, 2014.

IPCC. Intergovernmental Panel on Climate Change (IPCC), Working Group 1 report. IPCC Fifth Assessment. Geneva: IPCC: 2013. http://www.ipcc.ch/. Accessed July 18, 2014.

Kjellstrom T. Climate change, direct heat exposure, health and well-being in low and middle income countries. Global Health Action 2009; 2: 10.3402/gha.v2i0.1958. doi:10.3402/gha.v2i0.1958.

Kjellstrom T, Holmer I, Lemke B. Workplace heat stress, health and productivity: An increasing challenge for low and middle income countries during climate change. Global Health Action 2009a; Nov 11; 2. doi:10.3402/gha.v2i0.2047.

Kjellstrom T, Kovats S, Lloyd SJ, et al. The direct impact of climate change on regional labour productivity. International Archives of Environmental & Occupational Health 2009b; 64: 217–227.

Kjellstrom T, Lemke B, Otto M. Mapping occupational heat exposure and effects in South-East Asia: Ongoing time trends 1980–2009 and future estimates to 2050. Industrial Health 2013; 51: 56–67.

Kjellstrom T, Lemke B, Otto M, Dear K. Occupational heat stress. Contribution to WHO project on global assessment of the health impacts of climate change, which started in 2009. 2014 (Technical Report 2014: 4). www.ClimateCHIP.org

Kopp R, Hsiang S, Muir-Wood R, et al. American climate prospectus. Economic risks in the United States. New York: Rhodium Group, 2014. http://rhg.com/wp-content/uploads/2014/06/RHG_AmericanClimateProspectus_June2014_LowRes1.pdf. Accessed July 18, 2014.

Maloney SK, Forbes CF. What effect will a few degrees of climate change have on human heat balance? Implications for human activity. International Journal of Biometeorology 2011; 55: 147–160.

Parsons K. Human thermal environments. The effects of hot, moderate and cold temperatures on human health, comfort and performance (3rd ed.). London: Taylor & Francis, 2014.

Sherwood SC, Huber M. An adaptability limit to climate change due to heat stress. PNAS 2010; 107: DOI/10.1073/pnas.0913352107.

Ward K. The world in 2050. London, HSBC, 2012.

Appendix

Figure A1. Hourly WBGT vs Productivity loss. The only two field studies available (Sahu and Wyndham), the fitted function for an assumed "cumulative normal distribution" relationship, and a fitted function (in red) to the standard recommendation at moderate work intensity (300W) (Freyberg et al., unpublished)

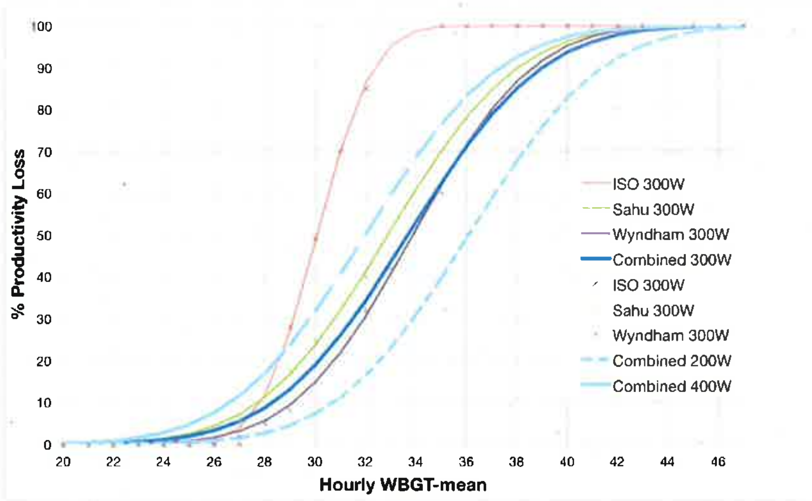


Table A1. CMIP5 annual mean surface air temperature anomalies (degr C) from the 1986-2005 reference period (midpoint 1995) with 5-95% ranges of model distributions (IPCC, AR5, WG1, Ch 12, 2013).

Time	**RCP2.6**	**RCP4.5**	**RCP6.0**	**RCP8.5**
2046-2065 *(2055)*	1.0 (0.4-1.6)	1.4 (0.9-2.0)	1.3 (0.8-1.8)	2.0 (1.4-2.6)
2081-2100 *(2090)*	1.0 (0.3-1.7)	1.8 (1.1-2.6)	2.2 (1.4-3.1)	3.7 (2.6-4.8)
2181-2200 *(2190)*	0.7 (0.1-1.3)	2.3 (1.4-3.1)	3.7 (x - x)	6.5 (3.3-9.8)
2281-2300 *(2290)*	0.6 (0.0-1.2)	2.5 (1.5-3.5)	4.2 (x - x)	7.8 (3.0-12.6)
Land, 2090	1.2 (0.3-2.2)	2.4 (1.3-3.4)	3.0 (1.8-4.1)	4.8 (3.4-6.2)
Tropics, 2090	0.9 (0.3-1.4)	1.6 (0.9-2.3)	2.0 (1.3-2.7)	3.3 (2.2-4.4)
Polar, Arctic, 2090	2.2 (-0.5-5.0)	4.2 (1.6-6.9)	5.2 (2.1-8.3)	8.3 (5.2-11.4)

The HadGEM model (from the UK) gives global modelling results for temperature at the upper 95th percentile gives results at the 5th percentile.

Figure 4B, HadGEM, RCP8.5, 2200, hottest month, 7 hottest days