LABOUR PRODUCTIVITY

ESTIMATES GLOBAL CLIMATE IMPACT

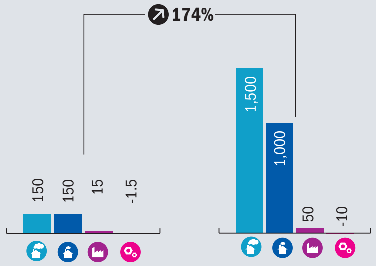
2010 EFFECT TODAY

USD LOSS PER YEAR **300** BILLION

2030 EFFECT TOMORROW

USD LOSS PER YEAR **2.5** TRILLION

ECONOMIC IMPACT



CONFIDENCE
ROBUST

SEVERITY

AFFECTED

INJUSTICE

PRIORITY

MDG EFFECT

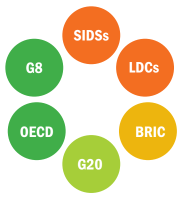
- People work less productively in hot conditions
- As the workplace warms, occupational heat exposure standards defined by the International Organization for Standardization (ISO) and other bodies are being breached
- Heat stress affects employees working outdoors or in non-cooled environments, except for the coldest and highest-altitude areas
- Effects are most serious for subsistence farmers in developing countries who cannot avoid daytime outdoor work
- Adapting to these changes can be cost-effective, such as through sun protection measures, but the full extent of adaptation is not well studied and could be extremely limited, especially for outdoor workers
- For indoor situations, air conditioning or insulation would need to be increased, but equally incur a cost

RELATIVE IMPACT

HOTSPOTS

2010	$	2030
55	INDIA	450
40	CHINA	450
35	MEXICO	250
30	INDONESIA	250
15	THAILAND	150

GEOPOLITICAL VULNERABILITY



$ Economic Cost (2010 PPP non-discounted)
Developing Country Low Emitters
Developed
Developing Country High Emitters
Other Industrialized

$ = Losses per 10,000 USD of GDP

Change in relation to overall global population and/or GDP

$ = Billions of USD (2010 PPP non-discounted)

Labour productivity is one of the principal factors in contemporary economics, and a generalized loss of productivity results in economic loss (Samuelson and Nordhaus, 1948; Solow, 1956). Workers are less efficient and less productive when subjected to excess heat both outdoors and in inadequately climate-controlled working conditions (Ramsey, 1995; Pilcher et al., 2002; Niemelä et al., 2002; Hancock et al., 2007; Su et al., 2009). International ergonomic standards define highly specific thermal conditions for differing degrees of occupational exertion and stipulate clear threshold limits (ISO, 1989). Similar national standards are effective since the mid-1980s (NIOSH, 1986). Precise directives for personnel heat stress management are also imbedded in military operational guidelines, since it may affect combat outcomes (USDAAF, 2003). Science is more certain about the warming of the planet than any other aspect of climate change (IPCC, 2007). As the increase in hot days and hot nights continues, worker heat stress has the potential to become a significant drain on the world economy (Hansen et al., 2012; Kjellstrom et al., 2009a). Adapting to labour productivity impacts is costly, but not doing so will result in further costs through deteriorating health, cooling costs, or slower gains in competitiveness (Hanna et al., 2011a; CDC, 2008; Kjellstrom ed., 2009). Thus, incentives to adapt are high, but may be out of reach for three-quarters of the world's developing poor, who live in rural areas with few options (Kjellstrom et al., 2009b; Ravallion et al., 2007).

CLIMATE MECHANISM

As the planet warms, thresholds regulated in international and national occupational standards are increasingly surpassed. Unless measures are taken, more hours of work will be needed to accomplish the same tasks, or more workers to achieve the same output (Kjellstrom et al., 2009a-b). Thermally optimal working conditions increase productivity (Fisk, 2000). Incremental increases in temperature are well understood, with business-as-usual economic development set to raise the average temperature by 3°C (5°F) above today's levels in 50–60 years (Betts et al., 2009). An additional 4°C (7°F) above that level—not ruled out for this century—would make outdoor activities of any kind impossible in large tropical areas of human habitation (Sokolov et al., 2009; Sherwood and Huber, 2010).

IMPACTS

The global impact of climate change on labour productivity is already estimated to cost the world economy 300 billion dollars a year—around 0.5% of global GDP. It is overwhelmingly the single most significant negative impact included in this assessment.

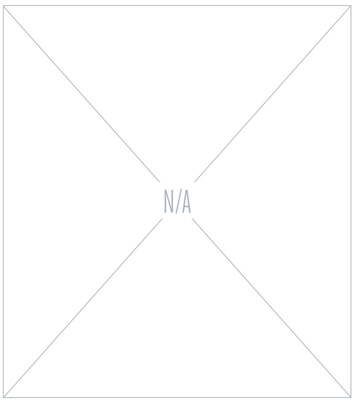
Hot and humid tropical and sub-tropical countries of Africa, Asia, Latin America, and the Pacific are already severely affected. The greatest total losses affect the world's major emerging economies: China, India, Indonesia, and Mexico, whose development due to labour productivity set-backs alone could be impeded by more than 200 billion dollars a year by 2030, when China and India's annual losses could approach half a trillion dollars each.

Approximately 0.6°C (1°F) of heat absorbed by the world's oceans will be released back into the atmosphere in the coming decades, effectively committing the world to a labour productivity loss estimated to reach 2.5 trillion dollars a year by 2030, stunting global GDP by over 1% (Hansen et al., 2005). Parts of West and Central Africa may even have 6% lower levels of GDP by 2030. Comparatively few people in colder zones of the planet, such as Australia and the United States, are expected to reap a modest gain in productivity: 3 billion dollars in 2010 and 18 billion dollars in 2030. The skewed workforce structure of developed economies, heavily reliant on low-exertion indoor work reduces vulnerability. However, numerous studies also indicate concern for exposed workers in developed countries (Graff Zivan and Neidell, 2011; Hanna et al., 2011a; Hübler et al., 2007).

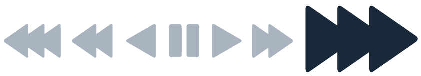
THE BROADER CONTEXT

Labour productivity drives profitability and higher living standards (Ingene et al., 2010). Labour productivity is surging almost everywhere, even in the world's wealthiest and slowest growing economies (Jorgenson and Vu, 2011; OECD, 2012). Comparisons of labour productivity growth between the US (faster) and Europe (slower) have shown the importance of information technology (IT) as a positive driver (Ark

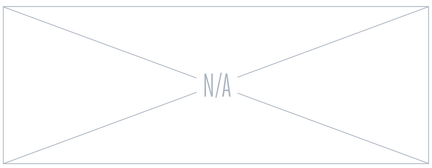
BIGGER PICTURE



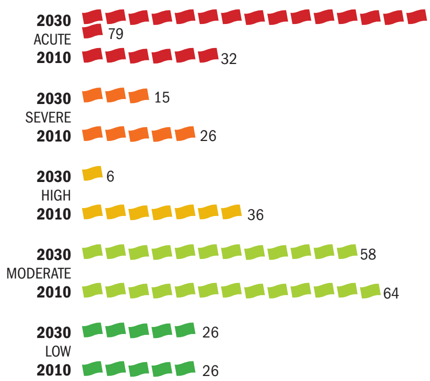
SURGE



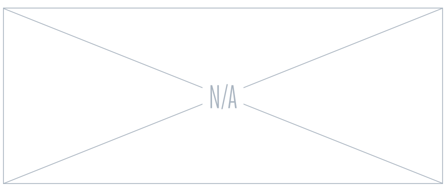
OCCURRENCE



VULNERABILITY SHIFT



PEAK IMPACT



GENDER BIAS

INDICATOR INFORMATION

MODEL: Euskirchen, 2006; Kjellstrom et al., 2009

EMISSION SCENARIO: SRES A2 (IPCC, 2000)

BASE DATA: Kjellstrom et al., 2009

= 5 countries (rounded)

Acute Severe High Moderate Low

et al., 2008; Holman et al., 2008). Above all, climate change is limiting the productivity potential otherwise achievable by developing countries, as they make structural shifts in workforce employment towards higher productivity economic sectors (Kjellstrom et al., 2009a; McMillan and Rodrik, 2012).

VULNERABILITIES AND WIDER OUTCOMES

Geographical and structural vulnerabilities are determined by levels of income or human development. Geography is important since only the coldest zones experience gains, while the hottest ones approach the limits of physiological habitability (Sherwood and Huber, 2010). Structurally, economies with mostly outdoor workers are particularly vulnerable, as are economies with slower industrialization rates and few climate controlled workspaces—middle and low-income countries (Kjellstrom et al., 2009d). Some evidence indicates that women are less resistant to heat stress, while men are more exposed, due to the proportion of men in heavy, outdoor work (Luecke, 2006; ILO, 2011). Subsistence farmers typically inhabit geographically vulnerable regions and would need to commit to higher levels of activity in order to deliver equal output; however, since they need to see the land, displacing their working shifts into the cooler night hours is impossible (Kjellstrom ed., 2009). This raises food security concerns. Nutrition can compound matters by contributing to, or detracting from, labour productivity (Maturu, 1979).

RESPONSES

Six key strategy and measurement areas for adapting to growing thermal stress on the workforce follow:

1. Education and awareness campaigns directed at behavioural change of employees and workers to drink water (hydrate) and minimize sun exposure; e.g., municipal initiatives to increase tree cover and shade, or movable screens (McKinnon and Utley, 2005);
2. Strengthened labour institutions, guidelines, protection, regulations, and labour market policies for workers (Crowe et al. 2010; ILO, 2011);
3. Climate control to increase use of air conditioning or building insulation systems, assisting some indoor workers; not all indoor workplaces can be adequately cooled;
4. Gaining productivity by expanding use of IT, improving capital equipment, or modernizing agricultural technology (Storm and Naastepad, 2009; Wacker et al., 2006; Restuccia et al., 2004);
5. Fiscal and regulatory intervention to stimulate a faster structural transition of the economy away from outdoor labour; e.g., coordinating industrial systems or transitioning from natural resource-intensive growth plans that detract from macroeconomic productivity gains (Storm and Naastepad, 2009; McMillan and Rodrik, 2012);
6. Promotion of individual health to improve body thermal responses (Chan et al., 2012).

THE INDICATOR

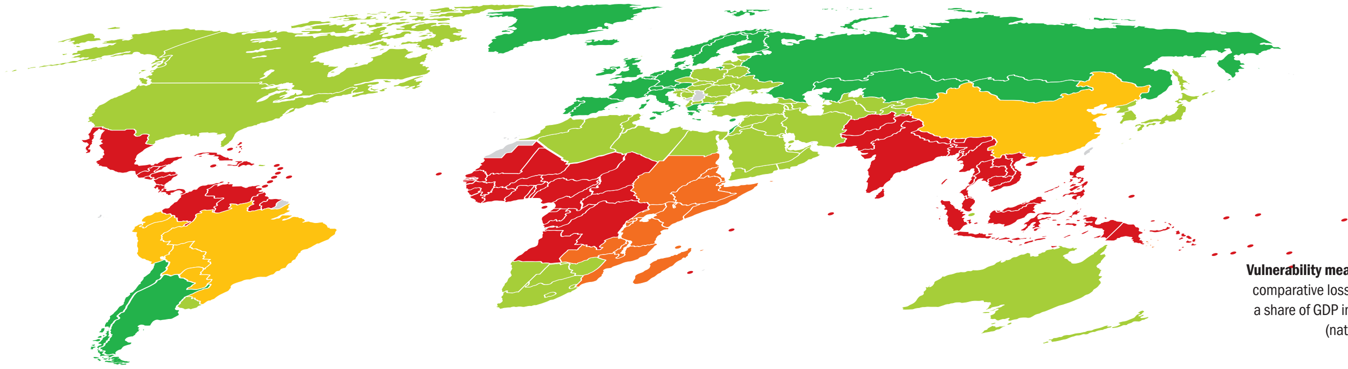
Certainty about increasing temperature, the main climate variable at play, contributes to the robustness of the indicator, although humidity levels are another important determiner of thermal stress and are less certain (Wang et al., 2010). The indicator relies on a global/sub-regional scale model for estimating the loss of labour productivity, based on international labour standards and estimates of wet bulb globe temperature (WBGT) change for populations assumed to be acclimatized (Kjellstrom et al., 2009a). It takes into account both the productivity of outdoor and indoor workers, although the heaviest forms of labour are not considered. The changing structure of the workforce over time, in particular, the industrial shift of developing countries away from outdoor agriculture is also factored in. Productivity gains to countries in high latitudes that will experience a reduction in extreme cold were also accounted for, over and above the base model (Euskirchen et al., 2006).

ESTIMATES COUNTRY-LEVEL IMPACT

COUNTRY	$ 2010	$ 2030	🚹 2010	🚹 2030
ACUTE				
Afghanistan	350	3,000	29%	23%
Angola	2,500	15,000	52%	43%
Antigua and Barbuda	25	200	49%	38%
Bahamas	150	1,250	44%	35%
Bangladesh	3,500	30,000	44%	34%
Barbados	90	700	45%	35%
Belize	40	300	41%	32%
Benin	400	2,750	59%	48%
Bhutan	55	400	44%	34%
Burkina Faso	600	4,000	67%	54%
Cambodia	900	9,250	52%	40%
Cameroon	1,250	8,750	55%	45%
Cape Verde	60	400	50%	41%
Central African Republic	75	500	59%	48%
Chad	550	3,750	55%	45%
Colombia	9,750	75,000	40%	31%
Congo	350	2,500	53%	43%
Costa Rica	1,250	9,000	40%	31%
Cote d,Ivoire	1,000	7,250	53%	43%
Cuba	1,750	15,000	38%	30%
Dominica	15	100	49%	38%
Dominican Republic	1,250	9,500	38%	30%
DR Congo	500	3,250	54%	44%
El Salvador	950	7,500	38%	30%
Equatorial Guinea	500	3,250	65%	53%
Fiji	75	600	27%	18%
Gabon	500	3,250	41%	33%
Gambia	100	700	59%	48%
Ghana	2,000	15,000	55%	45%
Grenada	20	150	49%	38%
Guatemala	1,500	10,000	44%	34%
Guinea	350	2,000	57%	47%
Guinea-Bissau	55	350	55%	45%
Guyana	80	600	37%	29%
Haiti	150	1,250	41%	32%
Honduras	750	5,750	40%	31%
India	55,000	450,000	35%	27%
Indonesia	30,000	250,000	40%	31%
Jamaica	350	2,500	39%	30%
Kiribati	10	90	33%	23%
Laos	450	4,750	49%	38%
Liberia	50	350	48%	39%
Malaysia	10,000	95,000	37%	29%
Maldives	75	550	37%	28%
Mali	500	3,250	40%	32%
Marshall Islands	5	45	33%	23%
Mauritania	200	1,250	30%	24%
Mauritius	550	3,500	35%	27%
Mexico	35,000	250,000	39%	30%
Micronesia	10	90	33%	23%
Myanmar	2,250	15,000	48%	37%
Nepal	500	3,750	53%	41%
Nicaragua	400	3,000	40%	31%
Niger	350	2,250	50%	41%
Nigeria	10,000	75,000	42%	34%
Pakistan	6,500	50,000	33%	25%
Palau	5	25	33%	23%
Panama	1,000	7,750	41%	32%
Papua New Guinea	300	2,250	33%	23%
Philippines	10,000	85,000	38%	29%
Saint Lucia	30	250	49%	38%
Saint Vincent	20	150	49%	38%
Samoa	20	150	33%	23%
Sao Tome and Principe	10	60	58%	47%
Senegal	700	4,750	57%	46%
Seychelles	60	400	45%	35%
Sierra Leone	150	900	54%	44%
Solomon Islands	30	250	30%	21%
Sri Lanka	3,000	25,000	33%	26%
Suriname	70	500	33%	25%
Thailand	15,000	150,000	45%	35%
Timor-Leste	90	750	35%	27%
Togo	200	1,250	61%	50%
Tonga	15	100	33%	23%
Trinidad and Tobago	400	3,000	43%	34%
Tuvalu	1	5	33%	23%
Vanuatu	20	150	33%	23%
Venezuela	8,000	60,000	41%	32%
Vietnam	8,000	85,000	48%	37%
SEVERE				
Burundi	35	250	61%	50%
Comoros	10	55	43%	35%
Djibouti	20	150	56%	46%
Eritrea	40	250	62%	51%
Ethiopia	950	6,000	64%	52%
Kenya	700	4,750	48%	39%
Madagascar	200	1,250	67%	55%
Malawi	150	900	61%	50%
Mozambique	250	1,500	63%	51%
Rwanda	150	850	68%	55%
Somalia	65	400	42%	34%
Sudan/South Sudan	1,000	7,500	39%	32%
Tanzania	650	4,000	63%	51%
Uganda	450	3,000	60%	48%
Zambia	200	1,500	54%	43%

$ Additional economic costs due to climate change (million USD PPP) - yearly average

CLIMATE VULNERABILITY



Vulnerability measure: comparative losses as a share of GDP in USD (national)

CLIMATE UNCERTAINTY

COUNTRY	$ 2010	$ 2030	🚹 2010	🚹 2030
HIGH				
Bolivia	200	1,750	46%	36%
Brazil	6,000	45,000	43%	34%
China	40,000	450,000	36%	25%
Ecuador	500	4,000	43%	33%
Paraguay	90	700	46%	36%
Peru	1,250	9,500	48%	37%
MODERATE				
Albania	1	5	5%	5%
Algeria	100	750	18%	12%
Armenia	5	40	25%	19%
Australia	45	100	6%	6%
Azerbaijan	35	200	36%	27%
Bahrain	10	60	31%	21%
Belarus	15	95	5%	5%
Bosnia and Herzegovina	1	5	4%	4%
Botswana	60	400	53%	43%
Brunei	1	15	6%	6%
Bulgaria	1	15	5%	5%
Canada	300	950	7%	7%
Croatia	1	15	5%	5%
Czech Republic	5	40	5%	5%
Egypt	200	1,000	21%	14%
Estonia	5	20	5%	5%
Georgia	10	60	32%	24%
Hungary	5	30	5%	5%
Iran	400	2,750	19%	13%
Iraq	30	250	16%	11%
Japan	400	1,000	6%	6%
Jordan	10	70	17%	12%
Kuwait	55	350	31%	21%
Kyrgyzstan	5	25	36%	27%
Latvia	5	25	5%	5%
Lebanon	25	150	20%	13%
Lesotho	5	50	39%	32%
Libya	40	250	23%	16%
Lithuania	5	45	5%	5%
Macedonia	1	5	4%	4%
Moldova	1	10	4%	4%
Morocco	65	450	21%	14%
Namibia	30	200	33%	27%
New Zealand	5	15	6%	6%
North Korea	90	900	37%	26%
Oman	25	150	26%	18%
Poland	15	100	5%	5%
Qatar	65	450	40%	27%
Romania	5	40	5%	5%
Saudi Arabia	200	1,250	22%	15%
Singapore	25	200	6%	6%
Slovakia	1	20	5%	5%
Slovenia	1	10	5%	5%
South Africa	1,250	7,250	32%	27%
South Korea	150	1,000	6%	6%
Swaziland	15	85	36%	30%
Syria	35	200	18%	12%
Tajikistan	5	25	35%	26%
Tunisia	40	250	19%	13%
Turkey	400	1,250	20%	14%
Turkmenistan	15	90	32%	24%
Ukraine	30	200	5%	5%
United Arab Emirates	95	600	36%	24%
United States	15,000	50,000	6%	6%
Uruguay	10	75	41%	32%
Uzbekistan	25	150	32%	24%
Yemen	20	150	20%	13%
Zimbabwe	25	150	69%	56%
LOW				
Argentina	-150	-1,000	38%	29%
Austria			6%	6%
Belgium			5%	5%
Chile	-50	-400	37%	29%
Cyprus			6%	6%
Denmark			6%	6%
Finland	-150	-500	6%	6%
France			5%	5%
Germany			6%	6%
Greece			5%	5%
Iceland	-10	-25	7%	7%
Ireland			5%	5%
Israel			5%	5%
Italy			4%	4%
Kazakhstan	-250	-1,750	40%	30%
Luxembourg			5%	5%
Malta			5%	5%
Mongolia	-15	-150	34%	26%
Netherlands			6%	6%
Norway	-200	-650	6%	6%
Portugal			6%	6%
Russia	-2,000	-15,000	6%	6%
Spain			5%	5%
Sweden	-300	-950	6%	6%
Switzerland			6%	6%
United Kingdom			6%	6%

🚹 Share of workforce particularly affected by climate change (%) - yearly average