Heat Interventions Cost-Benefit Calculator Methodology

Methodology Note

Prepared for HERA

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This methodology note accompanies the cost-benefit analysis for extreme heat tool prepared for HERA. This note provides an overview of the tool structure and underlying calculations and assumptions.

Analytical objective and framework

This tool applies a cost–benefit analysis (CBA) framework to assess the economic efficiency of heat resilience interventions. The objective is to estimate, for a given country and scenario, the monetized benefits associated with reducing heat-related impacts relative to a counterfactual baseline, and to compare these benefits against intervention costs.

The framework is designed for comparative assessment across intervention types, rather than for detailed project-level appraisal. The analysis uses global data sources, and the results for every individual city have not been sense-checked. Results should therefore be interpreted as indicative estimates of the prospective value for money offered by well-designed and effectively implemented interventions. Users are encouraged to document assumptions, conduct sensitivity analyses, and adapt parameters to reflect more granular local empirical evidence where available.

The unit of analysis is the city. The analysis incorporates mortality, productivity, and selected health system impacts regardless of whether benefits accrue to the public or private sector. The cost estimates capture the direct costs of implementing interventions; indirect costs that may pass through the economy are not included.

There are several limitations to note. These include reduced-form climate and impact modelling, limited treatment of behavioral adaptation, lack of uncertainty propagation, and potential double-counting across impact channels in extreme scenarios. These limitations imply that results should be interpreted as indicative estimates suitable for prioritization and screening.

Model structure

This spreadsheet-based tool is composed of modular blocks. These blocks map exogenous climate and demographic inputs to economic outcomes through a set of parameterized impact functions.

The calculations proceed as follows:

1. Climate exposure metrics are generated at the city level.
2. Baseline heat impacts are calculated for mortality, labor productivity, and healthcare utilization.
3. Intervention effects are applied as proportional reductions to baseline impacts.
4. Economic valuation converts changes in heat impacts into monetary terms.
5. Aggregation and reporting produce summary metrics, including net present value and benefit-cost ratios.

Inputs, calculations, and outputs are deliberately separated to facilitate transparency, auditing, and sensitivity analysis.

Climate and heat exposure modelling

The model distinguishes between heat exposure metrics used for different impact pathways. This reflects differences in the empirical literatures linking heat to economic and health outcomes. Labor productivity impacts are modeled using Wet Bulb Globe Temperature (WBGT), while health impacts, including mortality, are modeled using annual heatwave days.

- **Wet Bulb Globe Temperature (WBGT):** WBGT is used exclusively for estimating labor productivity impacts. It captures the combined effects of ambient temperature, humidity, wind speed, and solar radiation, and is widely applied in occupational health and labor economics to model heat-related work capacity reductions.
- **Annual heatwave days:** Heat-related health impacts, including mortality, are modeled using the annual number of heatwave days. Heatwaves are defined as periods in which daily temperatures exceed a specified threshold for one or more consecutive days. This metric reflects the epidemiological evidence linking extreme heat events, rather than average heat stress, to excess mortality.

Baseline annual average WBGT and heatwave days are available at the city level from the Global Human Settlement Layer (GHSL).[1] The GHSL only includes relatively aggregated climate conditions (annual temperature, seasonality). To leverage much richer climate data for the deep-dive cities, we treat the deep-dive cities' distribution of hot days, nights, and compound events (concurrent days and nights) as representative of their respective Köppen–Geiger climate zones.[2,3]

Climate scenarios from the IPCC are used to project both WBGT and annual frequency of heatwave days.[4] This tool is consistent with the climate modelling applied in the accompanying reports and based on the medium ambition scenario SSP3-7.0.

There is a difference between heatwave day estimation between the deep-dive city reports and the tool. For the set of deep-dive cities, the reports retain the heatwave-day method set out in the Technical Appendix accompanying the suite of reports. For the remaining cities in the tool, baseline heatwave days are derived from Global Human Settlement Layer (GHSL) data[5], and the change in heatwave days is estimated by applying the percentage growth in heatwave days through to 2050 is projected under the relevant IPCC scenario[6]. Where baseline heatwave days – according to the IPCC definition of days above 35C – are below one (1), an epsilon of 0.5 is added to both the baseline and end-point values before the growth rate is calculated, to avoid artificially extreme growth rates.

Heat-related mortality

Heat-related mortality is estimated using an exposure–response framework based on population size, baseline mortality rate, risk ratio, and number of heatwave days. This is the same equation used to estimate heat-related mortality for the Summary Report.

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[1] GHS Urban Centre Database (R2024A) Climate
Marí Rivero I., Melchiorri M., Florio P., Schiavina M., Krasnodębska K., Politis P., Uhl J., Pesaresi M., Maffenini L., Sulis P., Crippa M., Guizzardi D., Pisoni E., Belis C., Oom D., Branco A., Mwaniki D., Kochulem E., Githira D., Carioli A., Ehrlich D., Tommasi P., Thomas K., Lewis D. **GHS Urban Centre Database 2024, multitemporal and multidimensional attributes, R2024A.** European Commission, Joint Research Centre (JRC). PID: https://data.jrc.ec.europa.eu/dataset/1a338be6-7eaf-480c-9664-3a8ade88cbcd
[2] The deep-dive cities are Ahmedabad, Bangkok, Freetown, and Monterrey. Deep-dive cities (and all cities included in the tool) are linked to Köppen-Geiger climate zones. The Köppen-Geiger classification system categorizes the Earth's climate systems using seasonal temperature, precipitation, and vegetation patterns.
[3] For cities that are not in the same climate zone as a deep-dive city, the best proxy is used.
[4] IPCC Interactive Atlas
[5] GHS Urban Centre Database (R2024A) Climate
[6] IPCC near-term to medium-term projection of Days with TX above 35ºC SSP3-7.0 scenario

Formally, excess mortality in city c is calculated as:

$$\Delta D_c = \sum_z P_{c,z} \cdot M_c \cdot RR_z \cdot H_{c,z}$$

where:

- $P_{c,z}$ is population[7] in climate zone z
- M_c is the baseline mortality rate
- RR_z is the heat-related relative risk
- $H_{c,z}$ is the number of extreme heat days

Deaths (and avoided deaths) are evaluated for public policy purposes using a Value of Statistical Life (VSL) approach. Base VSL values from the OECD are scaled across countries using income-adjustment elasticities consistent from empirical literature.[8] For low- and middle-income countries, the OECD estimated value for low- and middle-income countries is applied.[9] This may imply a relatively high VSL for the poorest countries, which can be reflected in a higher-than-expected benefit-cost ratio for interventions that primarily affect mortality.

Labor productivity losses

Labor productivity impacts are estimated using a workability function that maps WBGT to fractional reductions in effective labor time. Losses are concentrated among workers in heat-exposed occupations, particularly outdoor and non-air-conditioned indoor labor.

Total productivity losses are calculated as:

$$\Delta Y_c = \sum_s L_{c,s} \cdot w_{c,s} \cdot (1 - \phi(WBGT_c))$$

where:

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[7] Population by city is drawn from GHSL. GHSL offers population figures by metropolitan area. This approach is different from the detailed approach leveraged for the deep-dive cities, so tool results do not line up exactly with what is reported in *Heat, inequality, and long-term development: Building a case for action.*

[8] OECD (2025)

[9] OECD (2025)

- $L_{c,s}$ is employment in sector s
- $w_{c,s}$ is average earnings or output per worker
- $\phi(\cdot)$ is the workability function

Workability functions are specific to work context (outdoors, indoors without climate control, and indoors with climate control) and physical activity level (light, moderate, intensive).[10]

Intervention modelling

The tool includes structural, behavioral, technological, and financial interventions. This includes urban greening, cool surfaces, cooling access, occupational protections, and insurance mechanisms. Each category is modeled through its primary effect on heat exposure or vulnerability. Interventions reduce mortality by lowering effective exposure $H_{c,z}$ or by attenuating relative risk through protective measures. Interventions reduce labor productivity losses by either reducing exposure or improving cooling.

Each intervention i is characterized by:

- Coverage rate κ_i
- Effectiveness parameter ϵ_i
- Target population or area

The impact reduction attributable to an intervention is modeled as:

$$\Delta Impact_i = \kappa_i \cdot \epsilon_i \cdot Impact_{baseline}$$

This linear structure allows for partial deployment and straightforward sensitivity testing but does not capture non-linearities or interaction effects between interventions.

Interventions are assumed to be additive in costs and benefits. Total portfolio benefits are calculated as the sum of individual intervention effects, without adjustment for interactions. This assumption has two main weaknesses. First, it does not capture potential synergies: for example, combining urban greening with cool roofs may produce compounding cooling effects that exceed the sum of each intervention in isolation. Second, additivity may overstate benefits when multiple interventions act on the same impact pathway: if one

10 Climate CHIP (2024)

intervention has already substantially reduced baseline mortality, a second intervention targeting the same channel is still credited with its full proportional reduction applied to the original (unreduced) baseline, rather than to the already-attenuated residual. Users should therefore treat combined portfolio benefit estimates with additional caution and consider running interventions individually before combining.

Costs are estimated on a per-unit basis and scaled according to coverage assumptions. Per-unit cost parameters are drawn from implementation cost evidence in the empirical literature and international program data and represent direct public-sector costs only. They do not capture indirect costs falling on third parties, which would be required for a full social cost-benefit assessment. Capital and recurrent costs are treated separately where relevant. Upfront capital costs are incurred at the point of installation or deployment; recurrent costs include ongoing maintenance, staffing, and administration. The cost profile for each intervention is described in the sub-sections below. Capital and recurrent costs are treated separately where relevant. When costs are derived from international estimates, they are adjusted to reflect local prices, with the adjustment factor depending on with the cost component is capital intensive (using a PPP adjustment estimated from Penn World Tables) or labor intensive (using a cost of labor adjustment estimated from variation in relative income per capita).[11] No endogenous cost learning or scale economies are modeled.

Heat action plan (HAP)

The tool treats a heat action plan as a bundled intervention comprising:

- heat early warning and risk communication,
- community outreach and behavior change messaging,
- health system readiness / emergency response protocols.

This is modelled as a binary selection (“Yes/No”) in the inputs. The HAP is modelled as a proportional reduction in heat-related excess mortality, applied to the baseline mortality estimate driven by annual heatwave days. The tool uses an effectiveness parameter consistent with evaluation evidence from Ahmedabad’s Heat Action Plan, which found a meaningful reduction in heat-attributable mortality risk after implementation.[12]

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[11] Penn World Tables
[12] Hess et al. (2018)

Modelled costs include three components: costs to develop an early warning system[13], interagency coordination costs[14], and healthcare surge capacity costs[15]. All three cost components are scaled by city population and adjusted for cross-country comparability.

Cool roofs

Cool roofs are specified as the share of residential roofs retrofitted (e.g., reflective coatings, insulation). The intervention scale κ_{roof} is set as a fraction of eligible roofs/households and ramps up to the target year. The tool links cool roofs to benefits through heat-health impacts (mortality). Conceptually, cool roofs reduce indoor and neighborhood thermal stress via increased roof albedo and reduced sensible heat storage, lowering exposure during extreme heat events. The tool's mortality effectiveness assumption is anchored to modelling evidence suggesting substantial potential mortality reduction under full citywide adoption in extreme heat conditions (order-of-magnitude ~25-32% in studied contexts).[16]

Cool roof costs are modelled at the household level. Unit cost assumptions are sourced from ARUP's cool roof cost guidance[17] while recurring maintenance costs are triangulated across several sources. Total costs are scaled to the number of eligible households covered under the user-specified coverage rate.

Urban green space

Urban green space is specified as an end-year target share of city area that is greened. The tool computes:

- current green space share[18],
- incremental new green space needed to reach the target,
- annual additions (implemented as a cumulative series) to reach the target year.

This structure is consistent with the reality that green space interventions accrue benefits as planted/constructed areas accumulate and mature. To capture effects of increasing

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13 Mizutori (2023)
14 Ebi et al. (2023)
15 Derived from healthcare expenditure data: World Bank
16 Simpson et al. (2024)
17 Arup
18 Default data is from UN-Habitat

green space on heat-related mortality, a dose-response function from the literature is applied.[19] The tool also captures the effect of green space on urban temperatures using an empirically derived cooling efficiency parameter from the literature. [20,21,22] WBGT is recalculated based on this cooling, generating new productivity impacts.

Where a city's target green-space share is below its existing share, the tool reports the benefit-cost ratio as "NA". These cities may still realize net benefits from increasing green space, but the marginal value of additional green space cannot be estimated from the parameters within this tool.

Green space costs are modelled on a per-square-meter basis. Unit costs are drawn from a 2024 meta-analysis of urban green space implementation and maintenance costs across European and Chinese contexts.[23] These are applied to the incremental new green space added each year on the path to the user's target, with maintenance costs accumulating as the stock of green space grows.

Outdoor worker interventions (rest, shade, water)

This intervention is specified as a policy/standard package that increases access to:

- shaded rest areas,
- potable water,
- mandated breaks (and enforcement / compliance mechanisms).

In the inputs, it is selected as a binary "Yes/No," reflecting that cities often implement it as a regulation or standard rather than as a continuously scalable infrastructure program.

The tool treats this intervention as affecting:

1. **Mortality among outdoor workers** (health protection / fatality reduction), and
2. **Working conditions / heat exposure at work** (with downstream implications for productivity in the workability module).

[19] Choi et al. (2022)
[20] Yang et al. (2022)
[21] Li et al. (2024)
[22] Wang et al. (2024)
[23] Panduro et al. (2024)

The mortality effectiveness assumption is grounded in quasi-experimental evidence on workplace heat standards, where strengthened regulations are associated with sizable reductions in outdoor worker deaths relative to comparable jurisdictions without equivalent standards.[24]

For productivity, the tool uses WBGT-based workability functions that are standard in the occupational heat stress literature and commonly used to map heat exposure into effective labor time losses. The intervention is conceptually represented as raising effective workability by lowering exposure intensity (through shade) and lowering physiological risk (through rest/hydration), with the magnitude depending on:

- the share of workers in exposed occupations,
- the intensity of work (where differentiated),
- and compliance/uptake.

Labor protection costs are modelled as recurrent OPEX only; no capital cost is separately estimated for regulation development. The per-worker annual cost is drawn from a regulatory impact assessment by the US Occupational Safety and Health Administration, representing the annualized compliance cost per covered worker, and adjusted for variations in labor costs (income) in different countries.[25]

Heat-related income loss insurance (parametric / wage insurance)

Heat-related income loss insurance is designed to reduce welfare losses from foregone earnings when extreme heat prevents safe work (especially in informal or low-income settings where paid leave and formal protections may be absent). The tool models insurance as a financial protection mechanism (income smoothing), not as a reduction in physical heat exposure. Accordingly, it is treated separately from mortality and productivity impact functions. The user specifies enrollment (number of covered people), which is constrained by estimates of the eligible population (e.g., informal employment). Benefits are only calculated for enrolled individuals.

Parametric heat insurance products commonly pay out when a weather index exceeds a predefined threshold (e.g., temperature over a set number of days), rather than requiring

[24] Dean and McCallum (2025)
[25] OSHA (2024)

individual loss assessment. This design enables rapid payouts but introduces basis risk (payouts may not perfectly match realized losses).

The tool represents expected payout (and associated benefits) as a function of:

- enrollment,
- the frequency of trigger events (heatwave days),
- an assumed wage loss per trigger day (or per season),
- and an assumed payout rate/benefit fraction.

This structure is consistent with real-world pilots, including schemes developed for informal workers that trigger payouts when extreme heat thresholds are reached.

Insurance costs are represented as program costs (premiums/subsidies, administration, or expected payouts) depending on the intended payer perspective. The tool is designed to allow the insurance intervention to be assessed as part of a broader adaptation portfolio (e.g., combining protections that reduce physical risk with instruments that reduce residual financial vulnerability).

Economic valuation and discounting

All impacts are monetized and aggregated to produce total benefits and costs. The tool supports discounting using user-specified rates, although results can also be interpreted on an annualized basis. Prices are expressed in constant terms, and transfers are excluded to avoid double-counting.

Outputs and decision metrics

Key outputs include:

- Total and category-specific benefits
- Total intervention costs
- Net present benefits
- Benefit-cost ratios

The estimated benefit-cost ratios appear high for many interventions, which may in part reflect the limited costs estimated within the tool. For example, the tool primarily includes direct public sector costs associated with interventions. Costs have been estimated as the direct cost to the public sector; additional indirect costs, for example the business cost of increased labor regulations, have not been fully estimated and would be required for the development of a full business case. It should also be recognized that these policies have limited impact without sufficient enforcement (which would incur additional unaccounted-for costs). For example, a heat action plan can facilitate additional measures that are included in the benefits calculations, but without implementation, these benefits would not be realized.

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