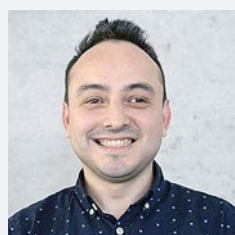


Summary of a paper presented at the joint 45th AIVC conference and ASHRAE 2025 IEQ conference “IEQ 2025: “Rising to New Challenges: Connecting IEQ to a Sustainable Future” will be held on September 24-26, 2025, in Montreal, Quebec together with the 13th TightVent and the 11th venticool conferences.

Indoor Heat-related Harm in Social Housing

Key words: indoor heat; social housing; health impact; disability-adjusted life-years; minimum mortality temperature



GIOBERTI MORANTES

PhD, Post-Doc-Researcher



AKSHIT GUPTA

Junior Researcher



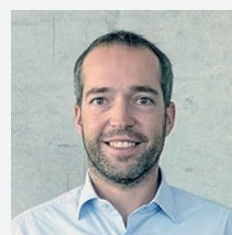
GIULIA PAOLETTI

Architect



ROBERTO LOLLINI

Research Group Leader



FRANCESCO BABICH

PhD, Senior Researcher

EURAC Research, Institute for Renewable Energy, EEB Research Group, Bolzano, Italy

Corresponding author: Gioberti Morantes gmorantesquintana@eurac.edu

This article is based on a paper presented at the joint 45th AIVC conference and ASHRAE 2025 IEQ conference “IEQ 2025: Rising to New Challenges: Connecting IEQ to a Sustainable Future”, held on 24–26 September 2025 in Montreal, Canada.

Indoor temperature conditions can be evaluated relative to an optimal range, yet building-level assessments rarely express indoor heat exposure in health terms. Here we translate monitored indoor temperatures into a health metric—Disability-Adjusted Life Years (DALYs)—using a harm intensity (HI) expressed in DALY per °C of exceedance above a Minimum Mortality Temperature (MMT). We demonstrate the approach using social housing in Bolzano, Italy (summer 2024) and show how the chosen threshold and population group influence estimated daily health burden.

Heat-related mortality and morbidity increase with higher temperatures, and climate change is amplifying the frequency, intensity, and duration of heatwaves. Burden-of-disease frameworks such as the Global Burden of Disease (GBD) quantify these impacts in Disability-Adjusted Life Years (DALYs), combining years of life lost from premature death and years lived with disability. In the GBD framework, harmful heat exposure is defined relative to an optimal temperature range, often reported as a country-specific Minimum Mortality Temperature (MMT), above which risk rises. A health-based metric can connect indoor temperatures to expected harm, making results interpretable for housing providers and public health stakeholders [1].

People spend most of their time indoors. During warm periods, indoor temperatures often track outdoor conditions, and outdoor temperature–mortality relationships can be used as pragmatic proxies for indoor exposure when indoor epidemiological evidence is limited (1). Existing approaches indicate that indoor temperature measurements can be combined with established temperature–health relationships to estimate heat-related health impacts, and that these impacts can be quantified in DALYs by relating temperature exceedance above a threshold to population health burden. This provides a practical pathway for translating indoor overheating into a comparable health-based metric using standard epidemiological inputs.

Methods

This work adapts a burden-of-disease approach and expresses outcomes as Disability-Adjusted Life Years (DALYs). We define exposure using daily mean indoor temperature. We evaluate two thresholds: an Italian MMT (24.4°C) and a thermal comfort threshold (28°C) commonly used in overheating assessments. For communication and comparison across buildings, we express the combined effect of baseline incidence (γ_0), the temperature–risk coefficient (RR), and the damage factor (DF) as a harm intensity (HI), the expected DALY increase per °C of indoor exceedance per person per day, via two formulations:

Log-linear risk formulation:

$$HI = \frac{\gamma_0 (1 - e^{-(\beta \cdot (T^\circ - MMT^\circ))}) \cdot DF}{T^\circ - MMT^\circ} \quad (1)$$

Linear approximation:

$$HI = \gamma_0 \cdot \beta \cdot DF \quad (2)$$

Using this metric, daily harm can be approximated as:

$$\text{Harm} = HI \cdot (T^\circ - MMT^\circ) \cdot P \quad (3)$$

These epidemiological and exposure inputs are summarised in **Table 1**.

Case study: social housing in Bolzano, Italy

This work contextualizes the method to the Casette Inglesi social housing estate in Bolzano, Italy (~344 dwellings). The estate houses have a substantial proportion of older adults. Indoor air temperature was monitored in 12 occupied dwellings between 17 July and 16 September 2024. Sensors (primarily Aranet4 PRO; $\pm 0.3^\circ\text{C}$) were placed in frequently occupied rooms, away from direct solar gains and local heat sources. Daily mean indoor temperatures were computed and evaluated. Across monitored homes, the mean indoor temperature was 27.26°C and peak values reached 33°C.

Table 1. Harm Intensity Inputs.

Parameter	Value	Units	Note	Reference
Threshold (MMT)	24.4	°C	Italy	[2]
	28.0		Indoor Comfort	[3]
Population sizes, P	791	People	All Ages	[4]
	514		65+years	
Relative Risks, RR	1.032	--	Non-accidental mortality (Mediterranean)	[5]
	1.015		Non-accidental mortality 65+years	
† Incidence rates, γ_0	0.000014	Case/person/day	Italy-All ages	[6]
	0.000071		Italy-70+ years	
‡ Damage factors, DF	17	DALY/case	Italy-All ages	
	13		Italy-70+ years	

Notes: Beta ‘ β ’ is the log of RR. † Incidence rates (γ_0) estimated by summing annual DALY values from GBD 2021 for four mortality-related causes (CVD, diabetes & kidney disease, LRI, chronic respiratory disease) in Italy. Values were then divided by 365 and by 100,000 to express daily cases per person. Separate values were used for the all-age (499 Cases/10⁵person/year) and 70+ (2,601 Cases/10⁵person/year) populations, <http://www.healthdata.org/>. ‡ Damage factors (DF) calculated by dividing total DALYs by total deaths from four heat-related causes (CVD, diabetes & kidney disease, LRI, and chronic respiratory disease), using GBD 2021 data for Italy (all ages (8288DALYs/499cases) and 70+ (34613 DALYs/2601cases) groups separately), <http://www.healthdata.org/>

Key results

Estimated impacts ranged from about 0.005 to 0.022 DALYs/day (**Figure 1**). Using the Italian MMT (24.4°C) increased estimated harm by roughly a factor of three compared with the 28°C comfort threshold. The elderly group (65+) consistently showed higher daily burden: ~0.022 DALYs/day at 24.4°C versus ~0.006–0.007 DALYs/day at 28°C. For the all-ages population, estimates were ~0.017 DALYs/day (24.4°C) and ~0.005 DALYs/day (28°C).

We tested both a log-linear risk formulation and a linear approximation. Differences were in the order 10^{-3} DALYs/day, suggesting that a simple linear form is adequate for screening-level applications while more detailed studies can propagate uncertainty and explore non-linearities.

To interpret magnitude: 0.005 DALYs/day across 791 residents corresponds to ~0.84 healthy days lost per person per year. Under the highest-burden scenario (65+ with 24.4°C threshold), 0.022 DALYs/day across 514 older adults corresponds to ~5.7 healthy days lost per person per year. These are screening-level estimates for acute summer exposure, but they show how indoor temperatures can be translated into an interpretable health unit. Changing the temperature threshold or the vulnerable population definition has a visible effect on the estimated burden, helping stakeholders choose parameters that match the decision context. Because HI is expressed per degree of exceedance, the metric can support comparisons across buildings, climate years, or retrofit options (e.g., external shading, night ventilation, reduced internal gains).

Conclusion and recommendations

This is a preliminary framework intended for transparent screening-level assessment. Epidemiological inputs were treated as point estimates, and we did not propagate uncertainty in inputs or outputs. The transfer of outdoor-derived RR to indoor exposure remains an assumption and would benefit from dedicated indoor epidemiological evidence. This research provides a practical bridge between indoor monitoring and health-based decision support.

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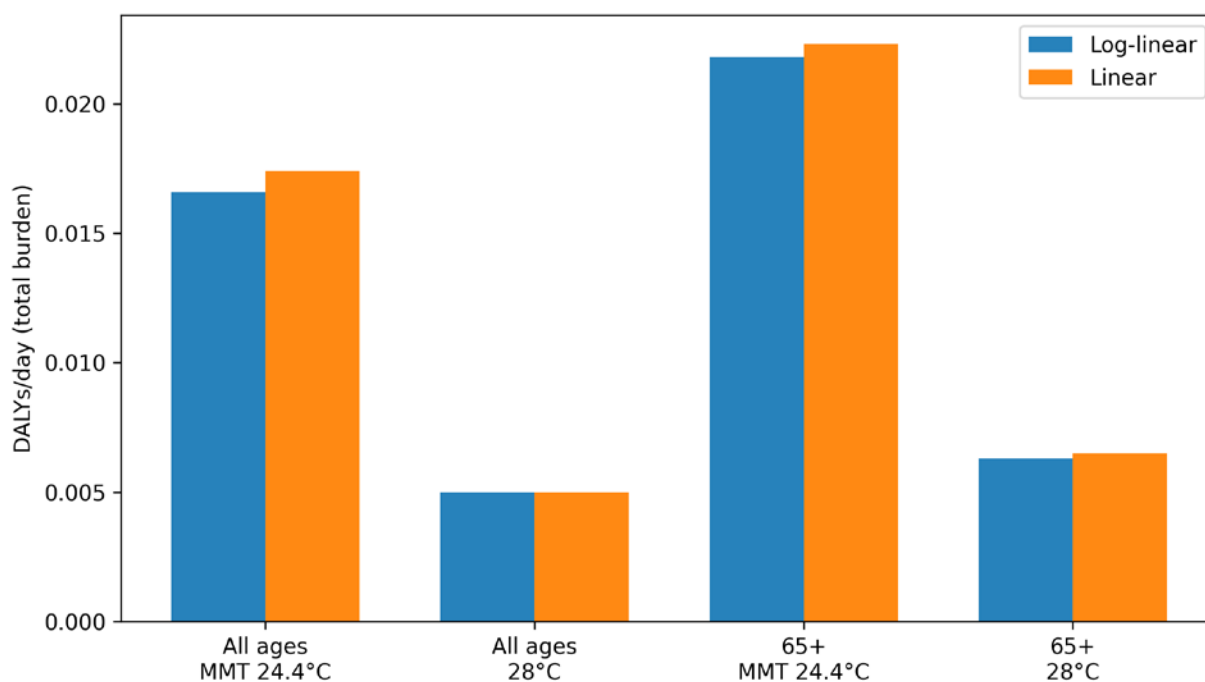


Figure 1. Estimated daily health burden from indoor heat (DALYs/day).