

One heatwave, many definitions: Implications for global building performance analysis

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ABSTRACT

Heatwave definitions vary widely across countries, yet their implications for building performance analysis remain poorly understood. This study reviews heatwave definitions from 25 countries, classifying them by meteorological parameters, threshold types (absolute, percentile-based, and hybrid), and duration criteria. The analysis reveals that 88% of definitions rely exclusively on air temperature, only 12% incorporate humidity, and required durations that trigger the heat event as a “heatwave” range from one to six consecutive days clustered at three and five days. This study proposes a classification framework that organizes these definitions into distinct pathways based on meteorological parameter, threshold method, and duration requirement. The variabilities in heatwave definitions can undermine cross-study comparability in thermal resilience evaluations, cooling energy demand assessments, and passive design strategy testing. To bridge global comparability with local relevance, this study recommends standardized humidity-inclusive reference heatwave scenarios for international benchmarking alongside region-specific criteria for local building code compliance and design optimization.

1. Introduction

Heatwaves are prolonged periods of abnormally high temperatures that pose severe risks to human health, infrastructure, and energy systems. Heatwaves are characterized by their intensity, duration, and frequency. As climate change accelerates, heatwaves have become more frequent, more intense, and lasting longer across the globe [1]. The year 2024 was confirmed as the warmest on record, with global average temperatures exceeding 1.5 °C above pre-industrial levels for the first time in a calendar year [2]. The 2025 report of the Lancet Countdown on Health and Climate Change documented that heat-related mortality has risen by 63% since the 1990s, now averaging approximately 546,000 deaths per year, with the average person experiencing 16 days of dangerous heat in 2024 that would not have occurred without climate change [3]. The European heatwave of 2003 was associated with over 70,000 excess deaths, while the summer of 2024 alone resulted in an estimated 62,775 heat-related deaths across Europe, a 23.6% increase over the previous year [4,5]. The 2021 Pacific Northwest heat dome in the US similarly caused hundreds of fatalities and unprecedented strain

on health systems and power grids [6,7]. Beyond acute health impacts, heatwaves compound urban heat island effects, elevate cooling energy demands, and accelerate material degradation in the built environment [8].

The escalating frequency and severity of heatwaves have placed building thermal resilience at the forefront of climate adaptation research. A multistakeholder review by Krelling et al. [9] found that limited coordination and the absence of standardized assessment procedures continue to undermine extreme-temperature mitigation across the building life cycle. Similarly, Bracht et al. [10] conducted a systematic review of 93 peer-reviewed studies on the interaction between heatwaves and building performance, finding that heatwave detection methods and performance metrics remain highly heterogeneous across the literature, with relative threshold definitions identified as most effective for building performance analysis but external heatwaves not necessarily coinciding with periods of extreme indoor heat. Furthermore, there is increasing recognition that humidity plays a critical yet underrepresented role in heatwave characterization. Cvijanovic et al. [11] demonstrated that defining and communicating dangerous

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heatwave conditions based on temperature alone leads to insufficient perception of health risks, as heat stress indices incorporating both temperature and humidity reveal substantially different spatial extents and timing of peak danger compared to temperature-only maps. Yet most national heatwave definitions continue to rely exclusively on air temperature. Regional heatwave hotspots are emerging faster than climate models predicted [12], underscoring the urgency of globally consistent frameworks for assessing building resilience under compound heat and humidity.

Despite the escalating threat, there is no universally accepted standard definition for what constitutes a heatwave [13,14]. Perkins-Kirkpatrick and Lewis [15] note that the diversity of metrics, datasets, and study periods used in the literature has made it hard to draw consistent regional comparisons. This definitional inconsistency creates fundamental challenges for building performance research. In the absence of a common framework, studies assessing thermal resilience, cooling energy demands, or passive design strategies cannot be reliably compared or replicated across different locations. A building simulation conducted under one country's heatwave criteria may yield entirely different performance outcomes when evaluated against another country's thresholds, undermining the transferability of research findings and the development of international design guidelines. At the same time, a single universal definition is unlikely to serve every building-performance context equally well. For building energy analysis and thermal comfort assessment, standardized and replicable heatwave scenarios are essential to ensure that performance benchmarks are meaningful across geographic and climatic contexts. The objective of this study is to systematically map existing heatwave definitions across 25 countries, examining temperature thresholds, humidity criteria, threshold determination methods (absolute vs. percentile-based), and duration requirements across countries, to reveal the scope of global inconsistency and propose a path toward harmonized approaches for building performance analysis.

2. Existing definitions

The relationship between heatwave definitions and building performance outcomes has been investigated in several recent studies, each employing different criteria. Amaripadath et al. [16] evaluated thermal resilience in a renovated nearly zero-energy dwelling during intense heatwaves using the methodology proposed by Ouzeau et al. [17]. Al-Assaad et al. [18] assessed passive cooling strategies across five ASHRAE climate zones (2A, 3A, 3B, 4A, and 6A) using the methodology from Ouzeau et al. [17], applying a single heatwave detection method uniformly across all locations. Sengupta et al. [19] examined building and system design impacts on thermal resilience during heatwaves in Belgian apartments using heatwaves detected from 30-year weather datasets. Flores-Larsen et al. [20] proposed a performance-based heatwave detection method for building resilience analysis, finding that the methodology from Ouzeau et al., was the most suitable for building applications. In another study, Flores-Larsen et al. [21] applied the definition from Ouzeau et al. [17] to evaluate the thermal resilience of a passive bioclimatic office building in an arid region of central Argentina during five heatwaves, finding that existing overheating metrics could not fully capture the building's daily thermal behavior, proposing additional metrics to account for thermal history and high solar irradiance. Similarly, Chen et al. [22] adopted China's absolute-threshold definition to assess residential overheating during power outages in hot-humid Guangzhou, proposing the Heat Index, which combines temperature and relative humidity, as the basis for indoor overheating metrics rather than temperature alone. More recently, Liu et al. [23] compared twelve outdoor heatwave indicators against simulated indoor overheating in Beijing and found that the events identified change with the indicator used, and that the indicators that best matched indoor overheating included one combining temperature and humidity.

The Ouzeau et al. approach is particularly relevant because it

establishes heatwave thresholds from a 30-year temperature baseline, and when extended to include 30-year humidity data, would provide a more physiologically representative characterization of heat stress conditions that buildings must withstand. Radiation is a further parameter that no national definition addresses, even though solar and radiant conditions affect cooling loads and comfort through mean radiant temperature; this can now be estimated from low-cost globe thermometers [24], and within-city radiant exposure varies substantially during extreme heat [25], pointing to a practical path toward radiation-inclusive criteria.

National heatwave definitions are typically established and maintained by each country's meteorological service or civil protection authority, resulting in criteria that reflect local climatological conditions, historical weather patterns, and public health priorities rather than internationally coordinated standards. While most criteria in Table 1 are issued directly by the responsible national agency, several entries are documented through peer-reviewed studies or technical reports that describe the operational definition used by that agency rather than through the agency's own publication. Where available, these criteria were also cross-checked against peer-reviewed studies that apply the same national definitions, as cited in Table 1. As documented in Table 1, these institutional definitions vary substantially in their operational parameters, threshold determination methods, and duration requirements. Some countries rely on absolute temperature thresholds tied to specific numeric values (e.g., the Netherlands requires five consecutive days at 25 °C with three exceeding 30 °C [31,32]), while others employ percentile-based approaches anchored to local climatology (e.g., Argentina uses the 90th percentile of warm-semester temperatures). A minority of countries incorporate humidity through composite indices such as the humidex (Canada [51]) or Heat Index (South Korea [52]). The complete set of 26 definitions from 25 countries, including their responsible organizations, is listed in Table 1 and illustrated geographically in Fig. 1. Belgium accounts for two of the 26 definitions: the Royal Meteorological Institute applies a long-running absolute threshold for climatological monitoring, while the Federal Heat Plan uses a separate combined T_{min}/T_{max} criterion to trigger public-health responses [27]. It also classifies these definitions by threshold category and maps each country's declared heatwave temperature to a building performance level, ranging from conditions manageable by passive cooling to those exceeding standard HVAC design limits, as detailed in Table 2.

3. Results

Analysis of 26 heatwave definitions from 25 countries revealed consistent patterns in how these criteria are structured. As shown in Table 1, the vast majority, 23 definitions (88%), rely solely on air temperature, while only three (12%) account for humidity including Canada that uses the humidex, South Korea that uses the Heat Index, and the United States whose National Weather Service uses a qualitative descriptor ("abnormally hot and unusually humid") rather than a numeric threshold. Unlike the humidex (Canada) and Heat Index (South Korea) thresholds, the U.S. definition specifies no numeric value of any composite index [51–53]. Duration requirements cluster around two values: 14 countries (54%) require three consecutive days, and six countries (23%) require five consecutive days. There is no clear north-to-south pattern in duration requirements, suggesting that local climate conditions and institutional decisions play a larger role than geographic location in shaping how countries define heatwaves (Fig. 1).

Table 1 reveals the specific threshold values employed within each category. Among absolute-threshold countries, declared values span from 18.2 °C (Belgium, Netherlands, Sweden) to 48 °C (Algeria, Saharan regions), with a distinct clustering around 25 to 30 °C among temperate European countries and progressively higher thresholds in tropical and arid-climate nations such as Kenya (32 to 37 °C) and Algeria (40 to 48 °C). This range means that two countries both classified as using

Table 1

Heatwave definitions, threshold classification, operational parameters, and responsible organizations for all 26 national definitions from 25 countries.

Country	Category	Threshold Value(s)	Percentile	Parameter	Organization	Threshold Definition
Absolute - fixed numeric temperature thresholds						
Algeria	Absolute	40, 44, 48 °C	-	Tmax	Office National de la Météorologie (ONM)	Tmax ≥ 40 °C (coast) or 44 °C (interior) for 2 days; 48 °C for 1 day (Sahara) [26]
Belgium (FHP)	Absolute	18.2 °C (Tmin), 29.6 °C (Tmax)	-	Tmin + Tmax	Federal Heat Plan	Tmin ≥ 18.2 °C and Tmax ≥ 29.6 °C for ≥ 3 days [27]
Belgium (RMI)	Absolute	25, 30 °C	-	Tmax	Royal Meteorological Institute	≥ 5 consecutive days with Tmax ≥ 25 °C incl. 3 days ≥ 30 °C [27]
China	Absolute	35 °C	-	Tmax	China Meteorological Administration	Tmax ≥ 35 °C for ≥ 3 consecutive days [28,29]
Kenya	Absolute	32, 36, 37 °C	-	Tmax	Kenya Meteorological Department (KMD)	Tmax exceeds city-specific thresholds for 3 consecutive days [30]
Netherlands	Absolute	25, 30 °C	-	Tmax	Royal Netherlands Meteorological Institute	≥ 5 days with Tmax ≥ 25 °C incl. 3 days ≥ 30 °C [31,32]
Norway	Absolute	27 °C	-	Tmax	Norwegian Meteorological Institute (MET Norway)	≥ 5 days with Tmax ≥ 27 °C [33]
Sweden	Absolute	25 °C	-	Tmax	Swedish Meteorological and Hydrological Institute (SMHI)	≥ 5 days with Tmax ≥ 25 °C [34]
Switzerland	Absolute	25 °C	-	Tmean	MeteoSwiss	Tmean ≥ 25 °C for ≥ 3 consecutive days [35]
UK	Absolute	County-specific	-	Tmax (1991–2020 ref.)	Met Office	≥ 3 days with Tmax ≥ county-specific threshold (1991–2020) [36]
Percentile - thresholds relative to local climatology						
Argentina	Percentile	-	90th	Tmax + Tmin	Servicio Meteorológico Nacional (SMN)	Tmax and Tmin ≥ 90th percentile for ≥ 3 consecutive days [37]
Australia	Percentile	-	EHF	Tmax + Tmin	Bureau of Meteorology	Mean of Tmax and Tmin above 95th percentile over 3 days, classified by severity [38,39]
Chile	Percentile	-	90th	Tmax or Tmin (30-yr ref.)	Dirección Meteorológica de Chile (DCM)	≥ 3 days with Tmax or Tmin above 90th percentile (30-yr ref) [40]
Ethiopia	Percentile	-	90th	Tmax (31-day window)	National Meteorological Agency of Ethiopia (NMA)	Tmax > 90th percentile (31-day window) for 3 consecutive days [41]
Iran	Percentile	-	90th	Tmax (15-day window)	Research Institute for Meteorology and Atmospheric Science	≥ 6 days with Tmax > 90th percentile (1961–1990, 15-day window) [42]
Spain	Percentile	-	Jul–Aug avg	Tmax (1971–2000 ref.)	State Meteorological Agency	≥ 3 days above Jul–Aug avg (1971–2000) [43]
Hybrid (P+A) - percentile + absolute value, both required						
Germany	Hybrid (P+A)	>28 °C	98th	Tmax (15-day window)	Deutscher Wetterdienst (DWD)	Tmax > 98th percentile and > 28 °C for ≥ 3 consecutive days [44]
Greece	Hybrid (P+A)	>38 °C	98th	Tmax	Hellenic National Meteorological Service (HNMS/EMY)	Tmax > 98th percentile and > 38 °C for ≥ 3 consecutive days [45]
Hybrid (Dep.) - fixed temperature above climatological baseline						
Brazil	Hybrid (Dep.)	+5 °C above historical avg	-	Tmax	Instituto Nacional de Meteorologia (INMET)	Tmax ≥ 5 °C above historical avg for ≥ 5 consecutive days [46]
France	Hybrid (Dep.)	+5 °C above 30-yr baseline	-	Tmax	Météo-France	Tmax exceeds threshold by > 5 °C for ≥ 5 consecutive days [17]
India	Hybrid (Dep.)	30, 40, 45 °C; or +4.5 °C dep.	-	Tmax	India Meteorological Department	Tmax ≥ 40 °C (plains) / 30 °C (hills) and ≥ 4.5 °C above normal; or actual Tmax ≥ 45 °C [47,48]
Portugal	Hybrid (Dep.)	+5 °C above monthly mean	-	Tmax (1991–2020)	Instituto Português do Mar e da Atmosfera (IPMA)	≥ 6 days with Tmax ≥ 5 °C above monthly mean Tmax (1991–2020) [49]
South Africa	Hybrid (Dep.)	+5 °C above avg Tmax of hottest month	-	Tmax	South African Weather Service	Tmax ≥ 5 °C above avg Tmax of hottest month for ≥ 3 days [50]
Humidity-inclusive - composite indices incorporating humidity						
Canada	Humidex	Humidex ≥ 40–42 °C	-	Humidex (T + RH)	Environment Canada	Humidex ≥ 42 °C for 2 days (south) or ≥ 40 °C for 1 hr (north) [51]
South Korea	Heat Index	Heat Index ≥ 35.5 °C	-	Heat Index (T + RH)	Korea Meteorological Administration	Heat Index ≥ 35.5 °C for 3 consecutive days [52]
USA	T+RH	Qualitative	-	T + RH	National Weather Service (NWS)	Abnormally hot and unusually humid weather for ≥ 2 days [53]

FHP = Federal Heat Plan; EHF = Excess Heat Factor; P+A = Percentile + Absolute floor; Dep. = Fixed amount above local mean; T+RH = air temperature and relative humidity. Qualitative = a descriptive criterion (the U.S. NWS defines a heatwave as “abnormally hot and unusually humid weather”) without specific numeric thresholds for either temperature or humidity.

Hybrid (Dep.) countries define heatwaves as temperatures exceeding climatological means by a fixed amount and are classifiable as either Absolute or Hybrid; treated as Hybrid in this study.

absolute thresholds may nevertheless identify fundamentally different weather events as heatwaves. Among countries using percentile-based or hybrid approaches, the 90th percentile serves as the most common benchmark, while hybrid definitions, such as those of Germany and Greece, combine higher percentiles (98th) with absolute values. These threshold values are also mapped to their practical impact on building cooling systems (Table 2), ranging from passive-cooling adequacy (≤30 °C) to conditions beyond standard HVAC design (>46 °C).

Fig. 2 presents a hierarchical decision framework that classifies global heatwave definitions across four levels. At the first level, all 26 definitions are arranged into five color-coded pathway groups. At the second level, definitions branch by meteorological parameter with air temperature only (23 definitions, 88%) versus humidity-inclusive approaches (3 definitions, 12%), with the latter further subdividing into the Heat Index (South Korea), the humidex (Canada), and a general temperature–humidity characterization (USA). At the third level,

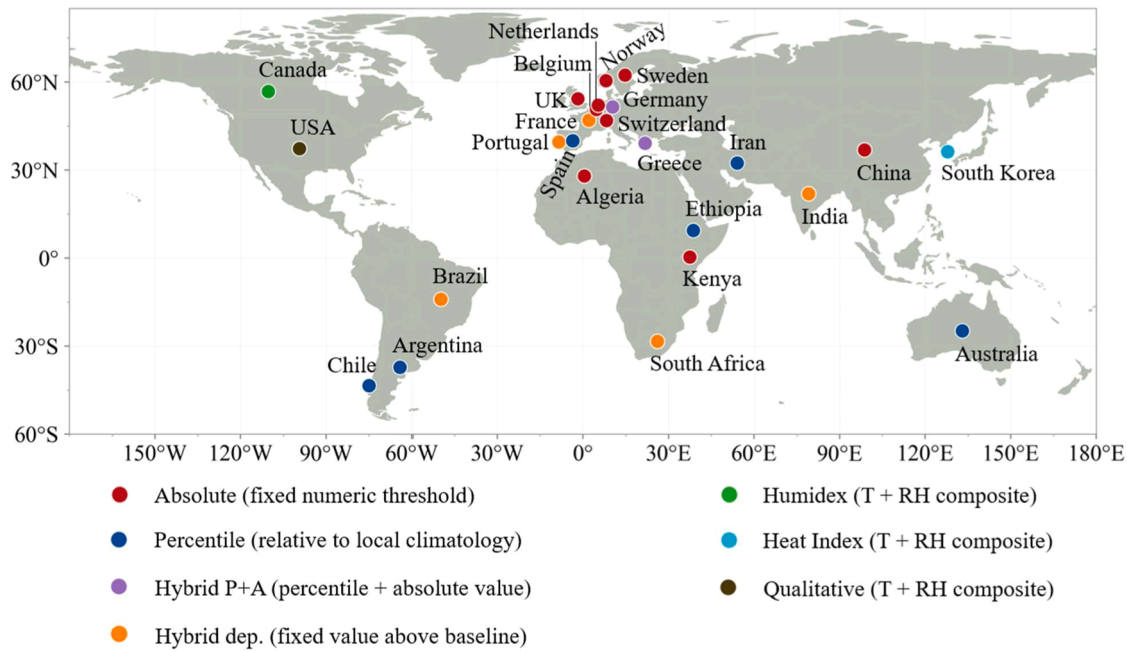


Fig. 1. National heatwave definitions categorized by threshold ($n = 25$ countries). Color coding corresponds to the seven categories in Fig. 2.

Table 2

Building performance implications at different heatwave temperature levels. Each row shows the outdoor temperature range at which a heatwave is declared and what it means for building cooling systems.

Temperature Range (°C)	Building System Context	Implications for Building Performance Simulation
≤ 30	Passive cooling range	Natural ventilation, night cooling, and thermal mass can manage indoor conditions. Most well-designed residential buildings cope without mechanical cooling. Heatwave detection at these thresholds means simulation should test passive survivability and overheating hours [54,55].
30–35	Mechanical cooling transition	Passive strategies alone become insufficient for most occupied buildings. Standard HVAC systems operate within design envelope. Simulations should evaluate cooling energy demand and the effectiveness of hybrid (passive + active) strategies [16,56].
35–40	High cooling demand	Air-cooled condenser COP begins to decline. Indoor overheating risk rises even in mechanically cooled buildings if undersized. Humidex and Heat Index thresholds also fall in this range. Simulations should assess HVAC capacity margins and peak demand [57,58].
40–46	Extreme load / equipment stress	Approaching typical HVAC design outdoor temperature limits (most air-cooled equipment rated to ~ 46 °C). Significant COP degradation and risk of compressor cycling. Simulations should include equipment de-rating curves and passive survivability during power outages [58].
> 46	Beyond standard design	Exceeds the AHRI testing envelope for most commercial air-cooled HVAC equipment. Only purpose-designed systems maintain safe indoor conditions. Relevant to Algeria's Saharan criterion (48 °C). Simulations require extended equipment performance models and resilience-focused metrics [58].

temperature-only definitions branch by threshold determination method into three subcategories, including absolute thresholds ($\sim 43\%$), percentile-based thresholds ($\sim 26\%$), and hybrid approaches combining both absolute and percentile criteria ($\sim 30\%$). At the fourth level, each pathway terminates at its required duration of consecutive days, ranging from one day (Algeria, Saharan regions) to six days (Iran, Portugal). The flowchart reveals that percentile-based approaches strongly favor three-day durations (5 of 6 definitions), while absolute threshold methods show greater heterogeneity, splitting between three-day (5 of 10) and five-day (4 of 10) requirements, with the five-day cluster primarily reflecting northern European definitions.

Notably, several countries present classification challenges within this framework. Brazil, Portugal, South Africa, and France all define heatwaves as temperatures exceeding a local climatological mean by a fixed amount (typically 5 °C), which creates ambiguity, the amount itself is absolute, but the reference baseline is derived from local climate history, giving these definitions characteristics of both absolute and percentile-based approaches. India's definition is similar, as it combines an absolute criterion ($T_{\max} \geq 40$ °C for plains, 30 °C for hills) with a requirement that temperatures exceed the local normal by at least 4.5 °C, making it classifiable as either absolute or hybrid depending on which criterion is emphasized. These borderline cases highlight that the boundaries between threshold categories are not always clear-cut, and that some national definitions blend elements of multiple approaches in ways that resist simple classification.

4. Discussion

The analysis presented in this study reveals that despite the growing urgency of heatwave-related risks to buildings and their occupants, the global research community continues to operate without a unified definitional framework. Multiple studies have demonstrated the sensitivity of building performance outcomes to heatwave definition choice, yet each has necessarily adopted a particular set of criteria, limiting the comparability of their findings. Flores-Larsen et al. [20] developed a building-performance-based method to detect and characterize heatwaves for resilience analysis, in recognition that conventional meteorological definitions may not align with a building's thermal response, and Xu et al. [14] showed that heat-related mortality risk estimates shift

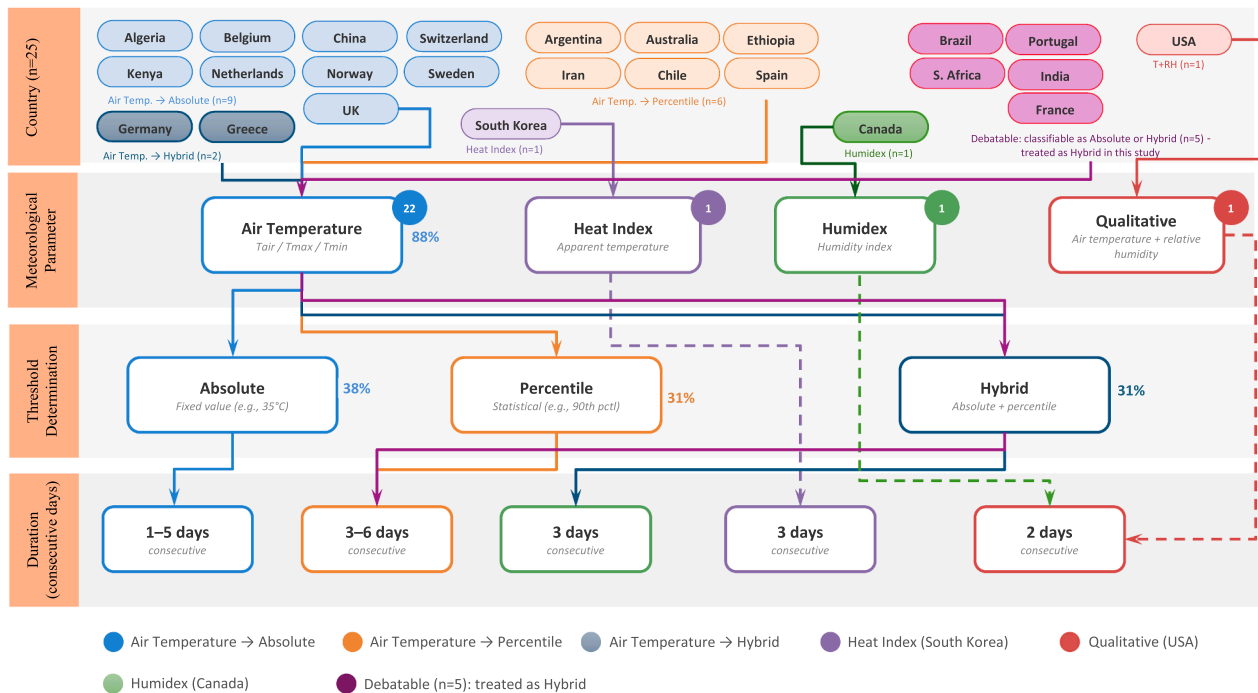


Fig. 2. Hierarchical classification of national heatwave definitions by meteorological parameter, threshold determination method, and minimum duration. Color coding distinguishes seven pathway groups: absolute (blue), percentile (orange), and hybrid (teal) temperature thresholds; debatable countries treated as Hybrid (dark purple); Heat Index (light purple); Humidex (green); Qualitative (red). Circles show country counts; dashed arrows denote humidity-inclusive pathways using composite indices.

under different heatwave definitions; together these indicate that the same building can be judged resilient or vulnerable depending on which definition is applied. The recent comprehensive review by Bracht et al. [10] identified the relative threshold definition as an effective method for building performance analysis. Whereas that review focused on the detection and characterization methods used within building-performance studies, the present work instead maps the heatwave definitions issued by national meteorological, civil-protection authorities, and literature across 25 countries and links them to building-performance implications, addressing a complementary gap. The uniform application of a single detection method across five ASHRAE climate zones, as in Al-Asaad et al. [18], illustrates a fundamental disconnect: a single definition applied across diverse climatic contexts may not adequately capture the locally relevant characteristics of heat stress that buildings must withstand. The present study addresses this gap by providing, for the first time, a systematic mapping and classification of how heatwaves are defined across 25 countries, revealing the scope of operational inconsistency and thereby informing efforts to develop harmonized approaches that balance global comparability with local climatic relevance.

The implications of inconsistencies in definitions affect practical building design and policy. The overwhelming share of temperature-only definitions (88%) represents a significant limitation for building performance applications, as indoor thermal comfort and occupant heat stress depend critically on humidity through its effect on evaporative cooling capacity [59]. The relative importance of outdoor humidity in fact depends on which aspect of “building performance” is being assessed. For mechanically cooled buildings under normal operation, outdoor humidity drives latent cooling load and HVAC efficiency, but indoor conditions are largely decoupled from outdoor humidity because air conditioning dehumidifies the supply air. For free-running, naturally ventilated, or minimally conditioned buildings, and for any building during a power outage, indoor humidity tracks outdoor humidity and directly governs occupant heat stress and passive survivability [60,61]. It is also worth noting that many definitions reviewed in this study

originate with a national meteorological or weather service whose primary focus is on outdoor environment rather than indoor building performance, which helps explain why most rely solely on air temperature and do not consider indoor conditions. The same definitions are nonetheless equally relevant to indoor thermal comfort, public-health surveillance, and labor productivity, so improving them benefits a broader set of applications. The choice between percentile-based and absolute threshold approaches reflects competing objectives, such as percentile-based definitions ensure local relevance and account for population acclimatization, making 30 °C genuinely extreme in Stockholm but common in New Delhi, while absolute thresholds enable direct cross-regional comparison but ignore acclimatization effects. Duration requirements have important consequences for passive cooling strategy effectiveness, as buildings with high thermal mass can dampen short-duration heat increases through thermal inertia but eventually saturate during extended events. The clustering of duration criteria (three versus five days) suggests that building designs optimized for short-duration heatwaves may prove inadequate for extended events, and performance evaluation protocols should therefore test buildings against multiple duration scenarios.

A baseline understanding of how heatwaves are defined is also needed for research on concurrent heatwaves and power outages. Studies of grid failure during extreme heat [62], of indoor heat exposure in homes that lose cooling [61], and of passive strategies that keep dwellings habitable when both events coincide [63,64] each start by selecting a heatwave to simulate, and their results depend on that selection. Amaripadath et al. [63] detected the event used in their outage simulations with the percentile-based method of Ouzeau et al. [17], while Chen et al. [22] applied China's absolute 35 °C threshold and Sedaghat and Sailor [64] defined the event as the hottest three consecutive days above 32 °C; in the same climate record, these approaches would identify different events with different durations and intensities. A recent review similarly notes that misalignment between event definitions and metric selection limits the comparability of thermal resilience studies [65]. The classification presented here gives this

line of research a starting point for reporting which definition was applied and how it compares with the alternatives.

Future building performance research requires a dual-track approach combining standardized reference heatwave scenarios based on absolute temperature and humidity exceedances at multiple duration thresholds for international comparison, complemented by region-specific definitions informed by local climatology for building code compliance and design optimization. Local thresholds, whether set as percentiles of the regional temperature history or as fixed values linked to health data, reflect these differences in ways that a single global standard cannot. This dual framework should be coordinated through international organizations such as the IEA Energy in Buildings and Communities Programme and the WMO to establish harmonized reporting protocols, with periodic revision based on observed climate trends and post-occupancy performance validation during actual heatwave events. Implementing such a coordinated framework will not be straightforward, because many of the national definitions mapped here are embedded in operational public-health warning systems and would be difficult to replace without disrupting established alert protocols. A more practical near-term path is voluntary adoption of standardized reference scenarios by bodies such as the IEA EBC Programme or ASHRAE for research and benchmarking, while national warning criteria remain in place.

CRediT authorship contribution statement

Soroush Samareh Abolhassani: Conceptualization, Formal analysis, Investigation, Methodology, Visualization, Writing – original draft. **Alimohammad Sedaghat:** Data curation, Investigation, Visualization. **David J. Sailor:** Funding acquisition, Supervision, Writing – review & editing. **Deepak Amaripadath:** Conceptualization, Investigation, Supervision, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

Data will be made available on request.

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