



1 Towards a global database on building architecture and 2 construction materials for urban climate models

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12

13 Abstract

14 Due to regional climate change exacerbated by the Urban Heat Island (UHI) effect, the population of dense urban
15 areas is vulnerable to heat stress. Accurate urban climate models are essential for quantifying UHI mitigation
16 strategies and supporting climate adaptation efforts. These models require input data on urban form, materials, and
17 function. However, existing frameworks, such as Local Climate Zones (LCZ) and Geoclimate, only provide urban
18 morphological parameters and lack detailed information on building materials and systems.

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20 To address these limitations, architects, engineers, urban climatologists and researchers in many countries have
21 been contacted via a survey platform to provide information on building materials and systems. The survey has
22 been translated into 11 languages to enable global coverage. This approach captures significant architectural and
23 construction trends by collecting key data on building systems and envelope characteristics (e.g., walls, roofs,
24 windows, and insulation).

25

26 The survey yielded 521 responses from 141 countries, demonstrating substantial global coverage. A multi-step
27 imputation strategy was applied to create a comprehensive global database, and residential building typologies are
28 defined for each country. Global homogeneous typologies are defined for non-residential buildings. The resulting
29 datasets are freely available and can easily be combined with LCZ maps. These datasets provide a valuable
30 resource for urban climate modeling and facilitate more accurate climate assessments on a global scale. Future
31 work may enhance data granularity further, for instance, by providing typologies at the subnational level.

32 1 Introduction

33 In 2025, over half of the world's population will reside in urban areas, with projections reaching 70% by 2050
34 (United Nations, 2023). Understanding the interplay between cities and their environment is therefore crucial for
35 climate resilience and adaptation. One of the most pressing challenges is the urban heat island (UHI) effect,



36 wherein urban areas typically experience higher temperatures than their rural surroundings (Oke et al., 2017),
37 posing significant threats to human thermal comfort and health.

38

39 Buildings, as key constituents of the urban landscape, influence the urban microclimate through heat release from
40 heating, ventilation, and air-conditioning (HVAC) systems (Bueno et al., 2012; de Munck et al., 2012), and due to
41 their intrinsic design features and material compositions that impact heat storage capacity and exchange with the
42 surrounding environment (Synnefa et al., 2008; Mirrahimi et al., 2012; Alghamdi et al., 2022). Indeed, the urban
43 environment, and especially buildings, can absorb and retain significant amounts of heat during daytime, that is
44 released during nighttime. Heat stored in buildings could also extend thermal discomfort after a heatwave (Van
45 Oldenborgh et al., 2022). Therefore, accurate characterization of buildings is crucial for advanced urban climate
46 models, enabling reliable predictions of UHI intensity and facilitating the development of effective mitigation
47 strategies.

48

49 Sensitivity analyses have highlighted the impact of various building parameters on urban climate model outputs.
50 Oleson et al. (2008) demonstrated that urban materials thermal parameters, such as thermal conductivity and heat
51 capacity, can have a similar influence on sensible and storage heat flux than urban morphology parameters. Tornay
52 et al. (2017) performed a sensitivity study focusing on French building archetypes and identified three highly
53 influential characteristics crucial for accurate urban energy balance simulations: roof material albedo, the presence
54 and thickness of insulation materials in walls and roofs, and the location of the insulation (interior or exterior).
55 Schoetter et al. (2023) found that overlooking pitched roofs can significantly influence the simulated solar
56 radiation budget, particularly at low solar elevation angles. These findings underscore the importance that input
57 data of urban climate models precisely represent the morphological, thermal, and radiative properties of buildings
58 to enhance model accuracy.

59

60 Presently, data regarding urban forms are available in most countries. Land cover maps of Local Climate Zones
61 (LCZ) can provide information on building form, such as low-rise, mid-rise, high-rise and large low-rise buildings
62 around the world (e.g. Demuzere et al., 2022). Additionally, detailed maps capturing building height, density, and
63 other geomorphological parameters can be computed from building inventories (Bocher et al., 2021) or remote
64 sensing instruments. However, there is a paucity of information regarding other building features required for
65 refined urban climate modeling and a critical gap persists in the availability of national-level data on building
66 construction materials, wall and roof albedo, window types, and HVAC systems.

67 Existing databases, such as the Global Data Set of Urban and Building Properties developed by Jackson et al.
68 (2010), hereafter referred to as GDUBP, describe building typologies considering 33 zones globally but lack
69 country-level detail and comprehensive coverage of required parameters. The Danube database (Tornay et al.,
70 2017) offers more detailed information regarding spatial variability, but is limited to the French building stock.
71 Other databases do not explicitly cater to urban climate models despite their potential utility in describing building
72 typology at national level. Such are the Tabula Web Tool (IEE, 2012), which provides residential building
73 typologies for 21 European countries aiming to estimate building energy consumption, and the World Housing



74 Encyclopedia (World Housing Encyclopedia, n.d.), which describes specific residential buildings across 46
75 countries in the seismically active areas of the world.

76

77 Despite the available data on urban form and generic building types, crucial information regarding construction
78 materials, wall and roof albedo, window types and HVAC systems remains scarce at national levels at a global
79 scale. To bridge this gap, there is an urgent need for a comprehensive, global building typology database with
80 country-level information that is accessible to the community in open-source Geographical Information System
81 (GIS) format. Such data should be integrable with other data describing urban morphological parameters, such as
82 LCZ, to enable more accurate simulation of UHI effects, building energy consumption, and human thermal
83 comfort.

84

85 To address this critical gap, this article introduces an open-source GIS database providing global building and
86 material data for urban climate models, developed through a collaborative approach. It outlines the development
87 process, starting with the definition of objectives and complementarity with LCZ (Sect. 2) key variables (Sect. 3),
88 survey distribution and response overview (Sect. 4), and strategies for ensuring data quality and completeness
89 (Sect. 5). Section 6 presents the resulting building typologies, by country for residential and globally for non-
90 residential buildings, followed by a discussion. Section 6 concludes with perspectives for future developments,
91 and Sect. 7 provides access to the compiled data.

92

93 **2 Objectives**

94 The goal of this paper is to complement the description of the urban fabric for climate studies by providing
95 architectural information at country-scale for various types of buildings. Land cover information dedicated to
96 urban areas already exist, such as LCZ maps (e.g. Demuzere et al., 2019, 2022) and urban Atlas (provided by
97 Copernicus). These land cover classes provide insight on the morphological structure of the neighborhoods
98 (Stewart and Oke 2012), typically density and building form. These classifications can be applied to represent the
99 diversity of the urban forms throughout the world.

100

101 Urban Canopy Models, in addition to urban form information (translated as building density and height,
102 impervious surfaces fraction, wall surfaces or sky-view-factor, etc.), require separate input data on materials for
103 roofs and walls (such as albedo, heat capacity, thermal conductivity, window share, etc...) and HVAC systems (to
104 compute anthropogenic fluxes with a building energy Module) (Masson et al 2020, Lipson et al 2024). However,
105 Stewart and Oke (2012) only provide ranges for broad ranges for 3 parameters for the materiality and use: surface
106 admittance and albedo, and anthropogenic fluxes.

107

108 An issue with building materials, architectural practices, practices and systems is that they are much more variable
109 from one place to another across the globe, as already shown by Jackson et al (2010). Two objectives are then
110 followed here:

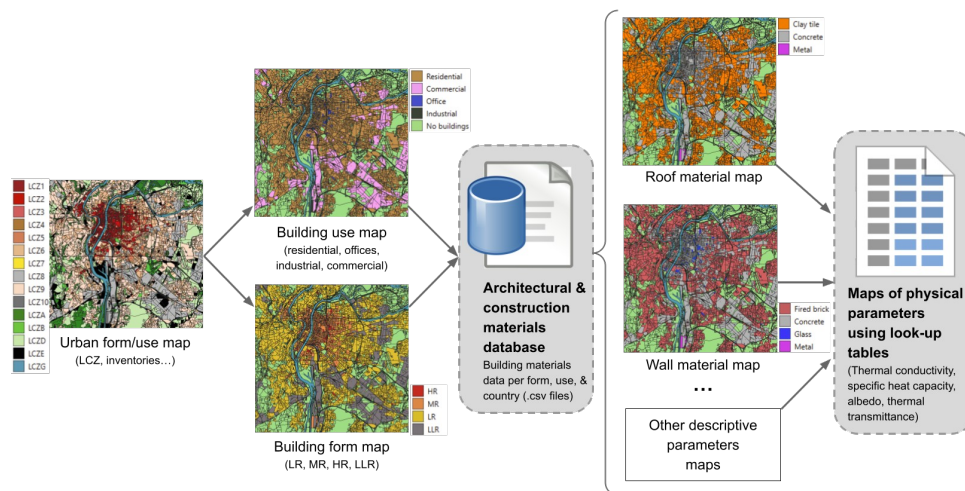


- 111 - To provide the needed information for urban canopy models of all complexity level (see Lipson et al
112 2024) on buildings materials and structure (roofs, walls, windows) and systems, for various types of
113 buildings
114 - To take into account the spatial variability across the globe, aiming to reach the country scale.

115
116 In order to reach these, the methodology is to gather information from specialists across the world using a
117 dedicated survey (see Sect. 3 and 4). Then, the information is treated in order to provide data for each type of
118 building (low-rise, mid-rise, high-rise and large low rise) and use (residential or not) and each country to describe
119 all the needed parameters. One should note that these data are not spatially localised within each country.

120
121 To create the spatial maps of the architectural and system parameters, it is necessary to cross the information of our
122 new database with the urban form maps (e.g. from LCZ, Urban Atlas, or other) (Fig. 1). This database would then
123 open promising perspectives for the urban climate research community, as it represents a global architectural
124 typology dataset developed at the national scale specifically for urban climate studies.

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126

127 **Figure 1: Flowchart of the strategy to cross spatial information of existing urban form maps (e.g. LCZ, left) with the**
128 **developed architectural & construction materials database (middle in gray) to produce maps of architectural**
129 **characteristics and their corresponding maps of physical parameters (using look-up tables, right in gray). The**
130 **examples of roof and wall materials are presented for Lyon, France.**

131

132 3 Variable definition

133

134 This study assumes that architecture and construction materials depend on building form, use, geographical
135 location, and construction period. Each plausible combination of these variables defines a unique building type
136 with specific materials and architectural features. Tornay et al. (2017) employed this approach to define building

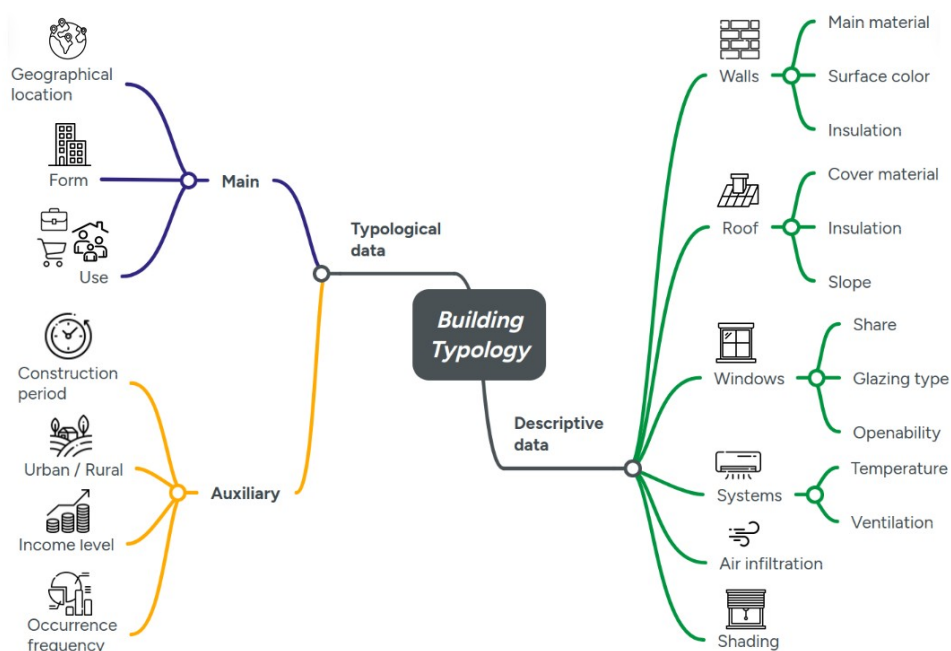
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137 types for France. Here, this approach is adapted to a global context such as to capture the diversity of factors
138 influencing building practices across different countries.
139
140 The survey was designed to characterise building typologies and gather data relevant to urban climate applications.
141 Two main types of information were collected: typological data, used to distinguish buildings, and descriptive
142 data, which provides the characteristics of major building elements (Fig. 2).

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Figure 2: Categories of building data collected through the survey.

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148 In the descriptive data, the survey collected information on the characteristics of major building components that
149 significantly influence the urban climate, which are: external walls, roofs, windows, HVAC systems, solar shading
150 elements, and air infiltration levels. For example, once a typical post-1950s urban single-family house in France
151 linked to a middle-income level is defined, respondents provide detailed information on its materials and
152 architectural characteristics. To ensure comprehensive and consistent data across all categories, a series of
153 multiple-choice questions was used to capture the key features of these elements.

154

155 To gather essential background information, the survey included an additional respondent data section. This
156 section collected the respondent's field of experience (specialist or non-specialist in architecture/civil
157 engineering), serving as a proxy for response reliability. It also gathered email contacts for potential follow-up
158 clarifications. An open-ended comment section at the survey's conclusion captured unaddressed details, offering
159 insights for data verification.

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160 Section 2.1 details the typological variables, their categories, the reasoning behind their selection and their
161 adaptation to a global context. Section 2.2 outlines the criteria for selecting building descriptive data, emphasizing
162 their relevance to a typological approach and their impact on urban climate model results.

163 3.1 Building typological data

164 The building typology categories must capture key dimensions influencing building typologies across diverse
165 international contexts. Their associated categories, therefore, must be broad enough to accommodate this global
166 variation. The specific adaptations and reasoning behind the category choices are detailed below.

167 Geographical location

168 The aim of this study is to obtain building data for every country in the world. Where national data are unavailable,
169 information from neighboring countries may be used as a proxy, taking into account cultural and geographical
170 similarities.

171

172 Building use

173

174 To optimise data collection, this study focuses on the most frequent building uses in urban and peri-urban areas,
175 which are most relevant for urban climate applications. These are residential (Res), commercial (Com), office
176 (Off), and industrial (Ind).

177 Building form

178 The building form is categorised according to the established Local Climate Zones (LCZs) to facilitate the
179 combination of the results from this study with LCZ maps (e.g. Demuzere et al., 2019, 2022). The following
180 building forms are considered in this study depending on the number of storeys and the surface of the building.

- 181 • Low-rise (LR) - 3 stories or less.
- 182 • Mid-rise (MR) - from 4 to 9 stories.
- 183 • High-rise (HR) - more than 9 stories.
- 184 • Large low-rise (LLR) - 3 stories or less and large building footprint area.

185 The choice of these four broad building forms allow to make the link with the Local Climate Zones (LCZ) and the
186 Urban Atlas by enabling the development of a cross-reference table (Table 1).

187

188 *Table 1: Correspondence between the building typologies and land cover classifications (LCZ and Urban*
189 *Atlas).*

Building typology	Associated LCZ classes	Associated Urban Atlas classes (Europe)
Low-rise residential	LCZ3: Dense low-rise LCZ6: Open low-rise LCZ9: Sparse low-rise	1.1.2.3 Discontinuous Low Density Urban Fabric 1.1.2.4 Discontinuous Very Low Density Urban Fabric

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Mid-rise residential	LCZ2: Dense mid-rise LCZ5: Open mid-rise	1.1.1 Continuous Urban Fabric 1.1.2.1 Discontinuous Dense Urban Fabric 1.1.2.2 Discontinuous Medium Density Urban Fabric
High-rise residential	LCZ1: Dense high-rise LCZ4: Open high-rise	No land cover class is predominantly occupied by HR buildings in European cities
Large low-rise non-residential	LCZ8: Large low rise	1.2.1 Industrial, Commercial, Public, Military and Private Units
Not covered in the present data	LCZ7: Informal settlements LCZ10: Heavy industry	1.2.3 Port Areas 1.2.4 Airports

190

191 Some land cover classes are not included in the database. For instance, Informal Settlements (LCZ7) are omitted.
 192 Accurately capturing these would require a more detailed classification of lower social strata, and global
 193 simplification is challenging due to the wide variation of materials used in informal settlements within and
 194 between countries. Heavy industry (LCZ10 or Urban Atlas Port classes) are not described, because the variability
 195 of the buildings presented in these classes is largely variable and dependent on the activity. However, these land
 196 cover classes do not cover in general a large surface at the scale of an agglomeration or city.

197

198 **Building construction period**

199 The relevance and specificities of construction periods as a variable for characterising building architecture and
 200 construction materials vary considerably across different countries. Each nation possesses unique construction
 201 traditions, historical trajectories, and regulatory frameworks that shape its building stock. For example, in France,
 202 rapid reconstruction was required after the World Wars (Abram, 2021), while the 1973 oil crisis spurred the
 203 development of the first building thermal regulations (Boesch, 2020). Other historical events, such as the Soviet
 204 era's impact on construction practices and material selection in former USSR countries (Van Assche, 2011;
 205 Saravan, 2024), must be considered. Similarly, in formerly colonized nations, construction practices can vary
 206 considerably across pre-colonial, colonial, and post-colonial periods (Lambert, 2017; James-Chakraborty, 2021).
 207 These and countless other regionally specific influences highlight the complex challenge of establishing
 208 construction periods that accurately reflect the diverse evolution of building practices worldwide.

209 Despite these variations, a broad international shift toward the Modern architecture movement emerged in the
 210 early 20th century, characterised by the widespread adoption of steel, concrete, and glass (Lucchi, 2023). To
 211 account for the global impact of World War II and the rapid urbanisation of recent decades, the 20th century is
 212 divided into two periods. Buildings constructed before the 20th century are categorised to include vernacular
 213 architecture and local practices, which utilized regionally distinct materials and techniques. Finally, the 21st
 214 century is distinguished to capture contemporary concerns in architecture, such as sustainability and the revival of
 215 traditional practices. To encompass diverse historical and architectural contexts, the following broader
 216 construction period categories are selected:

12

13



- 217 ● Before the 20th century.
- 218 ● First half of the 20th century.
- 219 ● Second half of the 20th century.
- 220 ● 21st century.

221 These categories enable the inclusion of diverse architectural traditions while minimising the need for highly
222 specialised local expertise from respondents. Although they are less specific to any single national context, they
223 provide a pragmatic framework for comparative architectural analysis across different regions.

224 To account for potential changes in building envelope insulation levels, an *insulation thickness* variable has been
225 introduced in the descriptive data for each decade starting from 1970, when increased attention started to be given
226 to building thermal efficiency. This strategy simplified the building construction period classification, making it
227 easier for non-experts to respond to the survey, while allowing experts to provide more detailed input on insulation
228 levels.

229 **Household income level**

230 Socio-economic factors could have a marked influence on building construction practices especially in countries
231 with a low average income level. A study addressing multiple factors associated with housing material inequality
232 in low and middle-income countries, revealed that factors such as wealth quintile (poorest, poorer, middle, richer
233 and richest), and building environment (rural or urban) have an important influence on housing characteristics in
234 most low and middle-income countries (Morakinyo, Fagbamigbe, Adebowale, 2022). Other studies reinforce
235 significant differences in building characteristics according to household income level (Daly, 2021; Wells and
236 Harris, 2007; Gooding, 2016). Therefore, household income level was incorporated as a variable in the survey for
237 residential buildings. The three following categories, low, medium, and high income are distinguished.

238 **Building environment**

239 The building environment can significantly influence construction practices, impacting materials and building
240 design. Strong differences in building characteristics for urban or rural environments have been found by Sun et al.
241 (2023) and Wang et al. (2024). Rural areas, characterised by lower population densities, may use traditional,
242 locally sourced materials and building construction practices can more strongly correlate with socioeconomic
243 factors. Urban, high-density areas typically employ standardised, large-scale construction and adhere to modern
244 building regulations. To account for these differences, the following building environment categories are included
245 in the survey: rural, urban or both.

246

247 **Building occurrence frequency**

248 Data on building frequency within a given location was collected to indicate the prevalence of specific building
249 typologies. This helps to evaluate the representativeness and generalizability of those building typologies,
250 reducing the risk of overgeneralization from atypical or uncommon buildings, which may be disproportionately



251 recalled due to their distinctive nature. The variable is categorised into three groups: very common, somewhat
 252 common, uncommon.

253 3.2 Building descriptive data

254 Buildings exchange sensible heat with the environment through radiation, conduction, and convection. They also
 255 store sensible heat in their thermal mass. Anthropogenic heat, for example due to temperature control systems,
 256 electrical appliances, or cooking, is released inside buildings. Equation 1 shows the sensible heat balance of a
 257 single zone building (Senave, 2019; Fig. 3).

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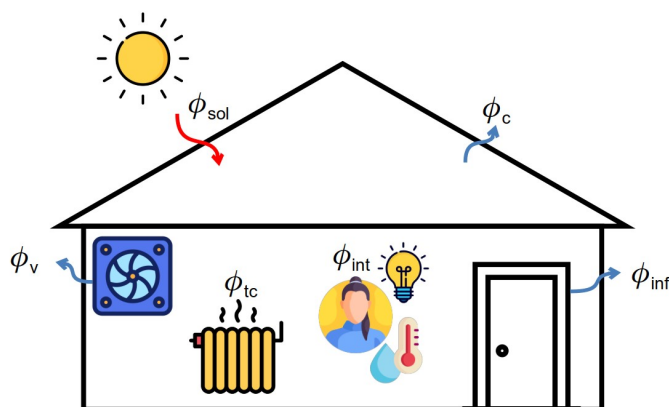


Figure 3: Heat fluxes in single zone building heat balance.

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$$C \times \frac{\partial T}{\partial t} = \phi_{tc} + \phi_{int} + \phi_{sol} + \phi_v + \phi_{inf} + \phi_c \quad (1)$$

262 Where:

263 - T is the average interior temperature of the zone (K);

264 - C is the effective heat capacity of the zone thermal mass (J/K);

265 - ϕ_{tc} is the sensible heat flux from temperature control systems (W);

266 - ϕ_{int} is the internal heat gain (W);

267 - ϕ_{sol} is the solar heat gain (W);

268 - ϕ_v is the sensible heat flux due to ventilation (W);

269 - ϕ_{inf} is the sensible heat flux due to infiltration through the building envelope (W);

270 - ϕ_c is the heat transfer due to conduction through the building envelope (W).



271 Table 2 shows how the parameters in Eq. 1 are related to the building materials and temperature control systems
 272 and how they have been translated into non-technical survey questions. For example, wall and roof colour have
 273 been used as a proxy for the physical parameters albedo and emissivity. Once identified, continuous variables,
 274 such as the wall and roof colour, insulation thickness, glazing ratio, and perceived air infiltration, are categorised
 275 into discrete ranges. This categorisation addresses the trade-off between data granularity and respondent
 276 accessibility. Although finer-grained data would have provided more detailed insights, it could have increased
 277 respondent burden and hindered data collection among non-specialists. Therefore, broader categories were chosen
 278 to optimise data collection.

279 Table 2 - Conversion between physical parameters relevant to the building sensible heat balance and the
 280 building descriptive variables in the survey.

Heat balance parameter	Building typology related ? If yes, which physical parameters are researched and what is their link with the UHI?	Adaptation to non-technical language style and associated survey questions
C	The volumetric heat capacity of the building envelope depends on the roof and wall materials and their thickness. The storage of heat in the building materials during the daytime and its subsequent release during the nighttime is a crucial process for the UHI.	<ul style="list-style-type: none"> - Wall materials and thickness - Roof materials and thickness - Insulation materials and placement if any
ϕ_{tc}	The heat release from heating and air conditioning systems can be the dominant part of the anthropogenic heat flux. Depending on the season and city type, the anthropogenic heat flux can be an important contribution to the UHI.	- Presence of heating or cooling systems
ϕ_{int}	The internal heat gains are primarily driven by occupant behavior (e.g., appliance use, lighting). They are not directly related to the construction practices, but rather to building use. Therefore, these parameters are excluded from the survey.	Not included
ϕ_{sol}	The window solar gains can influence the heat storage in the building materials, and the anthropogenic heat release due to heating and air conditioning.	<ul style="list-style-type: none"> - Share of windows on the facade - Presence and type of shading
ϕ_v	The ventilation flow rates can influence the anthropogenic heat release due to heating and air conditioning.	<ul style="list-style-type: none"> - Possibility of opening windows - Presence of mechanical ventilation



ϕ_{inf}	The air infiltration rate that is governed by the building's air tightness can influence the anthropogenic heat release due to heating and air conditioning.	- Perception of air drafts with closed windows and door
ϕ_c	The conductive heat flux through the building envelope depends on the solar reflectivity and terrestrial radiation emissivity of the wall and roof cover materials and the thermal resistance of the building envelope.	- Insulation presence - Wall insulation thickness range - Roof insulation thickness range - Wall insulation evolution over time - Roof insulation evolution over time - Color tone of wall surfaces - Wall main material - Roof cover material - Window glazing type

281 **4 Survey**

282 **4.1 Survey distribution**

283

284 To maximise global reach and data quality, Zoho Forms was selected as the survey platform due to its global
 285 accessibility, multilingual support, ability to include photographs and to implement branching logic. These are
 286 crucial for ensuring broader comprehension among a diverse public. Branching logic streamlined the user
 287 experience by presenting only relevant questions and answer categories, optimising data collection efficiency and
 288 avoiding irrelevant inquiries. While questions related to the main building typology were mandatory for clear
 289 identification, the other questions were made optional. This strategy was intended to prevent respondent
 290 discouragement due to questions for which they do not know the answer, leading to higher completion rates, even
 291 with some incomplete data for certain questions.

292

293 The survey was translated from English into ten languages (Arabic, Chinese, French, German, Indonesian,
 294 Japanese, Portuguese, Russian, Spanish, and Swahili), with native speaker verification for each. These languages
 295 were strategically chosen for maximum global accessibility, considering the number of speakers and the number of
 296 countries in which they are official languages. Photographs were also included to enhance comprehension,
 297 particularly for non-native speakers. The English version of the survey is detailed in Table A1, Appendix A.

298 The survey dissemination relied on multiple complementary channels to ensure broad international coverage while
 299 engaging qualified respondents. The following actions were implemented to promote participation:

- 300 • **Distribution via the Météo-France mailing list:** the survey was shared through the mailing list of
 301 Météo-France, targeting a local network of researchers and employees.
- 302 • **Distribution to participants of the International Meeting on Statistical Climatology (IMSC):** the
 303 survey was shared with international attendees of the IMSC, held at Météo-France.

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- 304 • **Distribution via the International Association for Urban Climate (IAUC) mailing list:** the survey
305 was disseminated through the mailing list of the IAUC. This initiative aimed to reach a global community
306 of researchers and professionals engaged in urban climate studies.
- 307 • **International network outreach:** the survey was disseminated through the first author's international
308 academic and professional networks, using a direct and personalized outreach. This approach expanded
309 geographic coverage and integrated valuable local knowledge from nationals in diverse countries. While
310 accessible to a wide audience, this strategy primarily targeted individuals with postgraduate education.
- 311 • **Targeted LinkedIn outreach for underrepresented regions (2024-11-15):** this strategy complemented
312 the outreach by identifying countries with no responses and directly contacting architects and civil
313 engineers from leading universities in those regions. This approach engaged qualified professionals in
314 underrepresented areas, improving both the global coverage and quality of the survey data.

315 The largest share of responses resulted from international network outreach (38%), which facilitated
316 geographically diverse participation and incorporated local knowledge from nationals across multiple countries.
317 Targeted outreach via LinkedIn (28%) further addressed geographic gaps by identifying countries with no initial
318 responses and directly contacting architects and civil engineers affiliated with leading universities, thereby
319 improving representation in underrepresented regions. Dissemination through the mailing lists of the IAUC
320 (22%), Météo-France (4.2%), and participants of the IMSC (1.9%) primarily reached researchers and
321 professionals specialized in climate-related fields. Overall, the survey predominantly attracted respondents with
322 higher education and technical expertise, supporting informed assessments of architecture, engineering, and
323 climate-sensitive building characteristics, yet its design and accessibility also enabled non-experts to provide
324 meaningful contributions.

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326 **4.2 Overview of the responses**

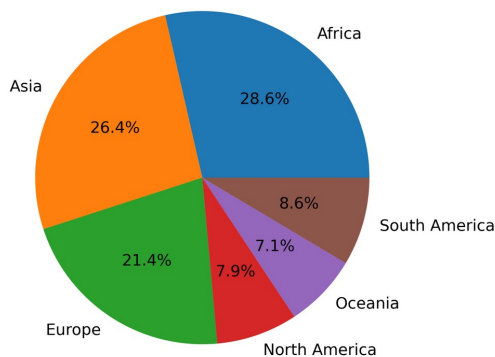
327 The survey was conducted from August 6, 2024, to May 24, 2025. During this period, the survey page received
328 2,933 visits, resulting in 521 responses from 141 countries. Of these, 272 responses came from participants with
329 backgrounds in architecture, civil engineering, or climatology, representing 100 countries. Figure 4 shows some
330 pictures of described building typologies in different countries and Fig. 5 shows the percentage of described
331 buildings per continent.



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334 **Figure 4: Example of described buildings in different countries: a) LR in the Republic of the Congo (photo by Rolains**
 335 **Elenga), b) LR in Australia (photo by Henrique Rossi), c) HR in China (photo by Sun Rui Ze), d) LR in Belgium**
 336 **(photo by Sara Top), e) LR in Kenya (photo by Valéry Masson), f) LR in Canada (photo by Nubia Rezende), g) HR in**
 337 **Tajikistan (photo by Osim Jon), h) MR in Argentina (photo by Natalia Vergara), i) LR in Luxembourg (photo by**
 338 **Robert Schoetter), j) LR in Finland (photo by Minttu Havu), k) LR in Brazil (photo by Ana Luíza Araujo).**

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Figure 5: Percentage of survey responses per continent.

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346 The distribution of survey responses across building use and form was uneven, with some combinations well
 347 represented and others lacking sufficient data. Table 3 shows the total number of responses per building use and
 348 form. From the total number of responses, 80% concern buildings of residential use, and 20% all other building
 349 uses combined: commercial, industrial and offices.

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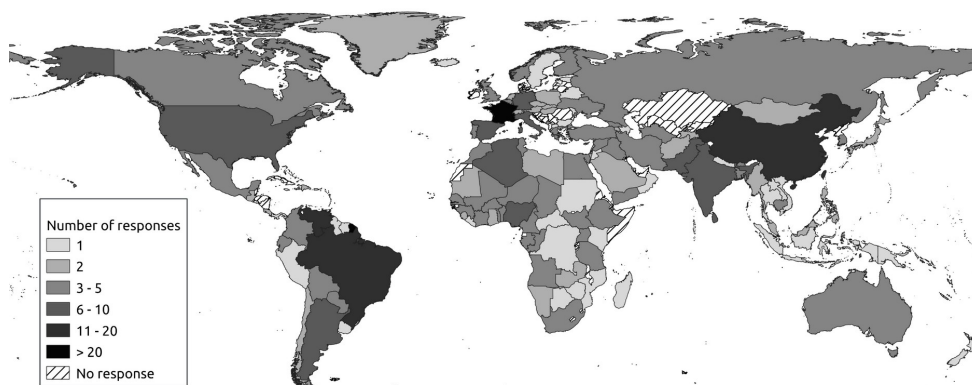
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Table 3 - Number of survey responses per building use and form.

Building use \ form	Low-rise	Mid-rise	High-rise	Large low-rise	Total
Commercial	0	17	12	26	55
Industrial	0	0	0	14	14
Offices	0	19	11	4	34
Residential	236	128	54	0	418
Total	236	164	77	44	521

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Figures 6 and 7 illustrate respectively the number of survey responses for residential and for combined non-residential buildings. The collected data yielded substantial global coverage for residential building typologies, particularly for LR forms. However, even by combining all non-residential building uses, sufficient global coverage was not achieved. These findings prompted the provision of country-level data for residential buildings, while offering global typologies for non-residential typologies.



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 360

Figure 6: Number of survey responses for residential buildings per country.

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362
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Figure 7: Number of responses for non-residential buildings per country.

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365 5 Data quality and completion

366 This section outlines the process of transforming survey data into a uniform database, aiming for a consistent level
367 of information across the countries. It begins with analyzing survey response agreement and correcting descriptive
368 variables where necessary (Sect. 4.1). Then, a unique description is selected for each building typology with
369 multiple responses (Sect. 4.2), followed by a comparison of this unique description with external databases (Sect.
370 4.3). Finally, gaps in country-level information are addressed using additional data sources and assumptions (Sect.
371 4.4). These methodological steps, specifically applied to residential buildings, are elaborated upon in the
372 subsequent sections.

373

374 5.1 Agreement and correction of responses

375 In cases where multiple responses were submitted for the same building typology, the consistency of descriptive
376 variables across respondents was assessed. Specifically, survey responses corresponding to the same set of
377 typological variables were examined to determine whether they produced similar outcomes. Cohen's Kappa (for
378 two responses) and Fleiss' Kappa (for more than two) are used to assess the reliability of agreement among survey
379 responses. Both measures quantify whether the degree of agreement between survey responses is in excess over
380 that which would be expected by chance, according to the Eq. 2 (Landis & Koch, 1977):

381

$$k = \frac{P_o - P_e}{1 - P_e} \quad (2)$$

382

383 Where P_o represents the observed agreement and P_e represents the expected agreement if random judgment. Table
384 4 presents the results of these measures of agreement, where N is the number of typologies analysed with more
385 than one response and non-null values for the analysed variable.

386

387 *Table 4 - Cohen's and Fleiss' kappa measures of agreement among responses.*

388

389 Variable	Cohen's kappa		Fleiss kappa	
	N	k	N	k
390 Wall material	51	0.46	28	0.44
391 Roof material	53	0.62	27	0.47
392 Window share	51	0.51	25	0.22

393

28

29



394 All agreement levels exceed what would be expected by chance, with most variables showing moderate agreement
395 according to Landis and Koch (1977). Fleiss' Kappa for window share is lower, likely due to a higher probability
396 of chance agreement stemming from the concentration of responses in the "Many windows" category, which
397 accounts for 69% of responses for this variable. The strict requirement for exact matches, despite the ordinal nature
398 of the variable, also contributes to this score. These findings suggest that responses are not random, supporting the
399 reliability of the survey while also reflecting natural variation in architectural practices across similar typologies.

400 A thorough plausibility check of the survey responses led to the removal of unreliable entries and the correction of
401 others. These checks addressed inconsistencies such as the use of modern materials in pre-industrial buildings,
402 HVAC systems or insulation not aligned with climate zones (based on the Köppen-Geiger classification), and
403 mismatches between roof materials and slopes. Window and glazing data were revised based on open-ended
404 responses and visual verification when necessary. Additionally, general comments submitted by respondents
405 informed targeted corrections to variables. Details on the plausibility checks and on the calculation of agreement
406 levels are available in the intermediate data files of the data repository (de Carvalho Araujo et al., 2025).

407 5.2 Choice of a representative typology per building form and use

408 In order to integrate the collected data into a GIS database, it is essential to ensure consistency in the quantity and
409 regularity of the data across different countries. In some countries, multiple responses were obtained for a given
410 building typology. For instance, in France, 25 responses were recorded for LR and MR buildings, whereas in other
411 countries, only a single survey response was available for LR buildings. To maintain a uniform level of
412 information across countries, a single representative set of descriptive variables was selected for each building
413 typology .

414

415 To select one description for a building typology for a specific country, form, and use, selection criteria prioritised
416 the majority categories of each variable and the level of representativeness of each individual survey response.
417 When no clear majority existed, representativeness was evaluated through a combination of variables, favouring
418 buildings described as *very common* over those described in the survey as *uncommon*. Additional criteria guided
419 the decision process for the least representative categories, in descending order of influence: subnational data
420 scale, high social level, rural buildings and period of construction predating the 20th century. If these criteria were
421 still equivalent, the respondent's professional background in architecture or civil engineering was considered, as
422 33% of participants reported such expertise, assumed to indicate higher data quality. Finally, if equivalence
423 persisted, responses with fewer empty columns were favoured, and in cases of complete parity, the earliest
424 submitted response was chosen.

425

426 In some instances, the available descriptions did not fully reflect the broader building stock. For example,
427 responses might describe only modern buildings with thermal performance superior to the national average or an
428 atypical building. In such cases, a review of the literature was conducted to adjust specific variable values and
429 improve alignment with the typical characteristics of the building stock.



430 **5.3 Comparison with external databases**

431 Data from the Tabula and World Housing Encyclopedia external data sources at the country level are used to
432 compare the residential building typologies provided by the survey. The Tabula database describes different
433 building typologies for twenty-one European countries and is dedicated to improving the estimation of energy
434 consumption in the European building stock (IEE, 2012). In each country, the building typologies are classified
435 according to period of construction and form. The period classes can vary according to the construction
436 specificities in each country.

437 The Earthquake Engineering Research Institute (EERI) World Housing Encyclopedia (WHE) served as another
438 external data source. Developed as part of the United States Geological Survey Prompt Assessment of Global
439 Earthquakes for Response (USGS PAGER) project (2007-2011), WHE is an initiative designed to enhance the
440 understanding and classification of global construction types (Greene & D'Ayala, 2010). It describes residential
441 buildings across 46 countries in the seismically active areas of the world. In the context of the present work it is
442 used to derive wall and roof cover materials based on the report's descriptions and window share based on the
443 report's pictures. However this database does not provide parameters on building thermal properties, such as the
444 envelope insulation characteristics.

445
446 The analysis focused on three variables available in all datasets: exterior wall material, roof cover material, and
447 window share. For each building typology, the value of these variables was compared between the survey and the
448 external database. This required compiling relevant information from representative Tabula and WHE reports into
449 a comparative table, which was then evaluated against the survey data.

450 WHE reports often provide comprehensive information on materials but may lack clear specifications regarding
451 representativeness. Furthermore, the database's emphasis on earthquake-vulnerable buildings may not align with a
452 country's most representative building typologies. To address this, selection criteria consistent with those used for
453 the survey responses were applied. Reports explicitly indicated as common to the entire country or those not
454 designated as at subnational scale or in rural areas were prioritised. In cases where multiple rural or subnational
455 reports presented consistent values (e.g., in accompanying charts), all such reports were retained. Any reports not
456 meeting these criteria were excluded. Following this selection, materials specified for walls and roofs were
457 examined. If multiple options were presented, all were included in the comparison. In instances where only
458 "masonry" was specified for walls without further detail, "brick" was assumed as the material. Window share was
459 deduced from the provided report photographs.

460 For Tabula, no filtering of reports was required, as their typologies are already considered representative. Given
461 Tabula's objective of estimating energy consumption, it provides information on insulation (e.g., U-value,
462 insulation thickness) and heating systems. While material information is often indicated, it is not consistently
463 present. For walls, if the material was not explicitly stated, attempts were made to identify exposed brick from
464 accompanying photographs. If information remained unavailable or indiscernible from images, that variable was
465 then excluded from the comparison. For roofs, since the database mainly provides structural rather than covering
466 materials, images were used to identify roof coverings based on color, form, and texture. For flat roofs, "gravel"
467 and "concrete" were assumed as potential materials. For sloped roofs, color and texture guided identification: red



468 roofs were associated with tiles, while darker roofs, depending on texture, were categorised as asphalt, slate, or
469 metal. If identification was not possible through this examination, the roof cover material variable was excluded
470 from the analysis.

471 The results of the comparisons with both external databases are presented in Table 5. All the compared variables
472 showed an agreement of at least 50% with most of them ranging above 70%. The degree of agreement is
473 satisfactory, especially given the differing purposes of the external databases and the present database. However,
474 these results should be interpreted with caution, as the external databases were developed for other objectives and
475 likely contain non-exhaustive building lists focused on typologies relevant to their original contexts. Despite these
476 limitations, the methodology intended to maximize the use of the available information.

477 *Table 5 - Agreement levels between external databases and the survey data.*

Building form	External database	Exterior wall material agreement	Roof cover material agreement	Window share agreement
LR	Tabula	73 %	75 %	67 %
	WHE	67 %	50 %	71 %
MR	Tabula	67 %	73 %	100 %
	WHE	77 %	85 %	92 %

478
479 To assess data coverage, the availability of Tabula and WHE data alongside the survey data is presented in the
480 Appendix B. Locations where both the external database and the survey data were available were used in the above
481 comparison. For locations where external database data were available but survey data were missing, the external
482 data were used to fill the gaps. The following section outlines the methodology used to complete the missing data.

483 **5.4 Filling missing data**

484 To avoid overgeneralization based on too-sparse survey responses, some variables are not included in the
485 database. For example, variables describing insulation details, such as the position of the insulation and the
486 evolution of wall and roof insulation thickness over time, exhibit response rates below 10%.

487 Other variables are excluded because it is assumed that the survey questions may have been misunderstood or that
488 the responses are not consistent. For example, survey responses related to air infiltration are difficult to analyse, as
489 they likely reflect respondents' perceptions rather than objective measurements. Another example concerns the
490 reported presence of mechanical ventilation systems, defined here as central systems designed to regulate air
491 exchange with the external environment, did not follow expected patterns and may have been misinterpreted by
492 respondents. In several countries where air tightness is not a regulatory priority, the formulation of the question
493 and the respondents' prior knowledge may have led to confusion between mechanical ventilation systems and
494 simpler devices such as individual fans. As a result, responses related to air tightness and mechanical ventilation
495 were excluded from the analysis.



496 All descriptive variables, excluding those previously mentioned, are retained in the final data, with missing data
497 completed as described in this section. Different actions were taken to complete the data based on their nature and
498 the availability of information. Preserving the original survey data was a priority; however, modifications were
499 made when the original data appeared clearly implausible.

500 Variables are classified by nature—structural, lighting, or thermal—to tailor missing data completion strategies to
501 relevant data sources. Structural variables include the main wall material, its exterior color (which may be inherent
502 to the material if no paint is applied), the roof slope and cover material. Lighting variables comprise the window
503 share and the types of solar shading used. Thermal variables encompass the presence of insulation, the thickness of
504 wall and roof insulation, the temperature control system and the window glazing type.

505 The Tabula and WHE data sources provide country-level information and are used to fill in missing values. Tabula
506 often provides information on all variable categories, either through building descriptions or accompanying
507 images. For insulation characteristics derived from Tabula, buildings constructed in the 1990s are used as the
508 reference. WHE data is primarily used to obtain structural variables from report descriptions and lighting variables
509 from report images, as thermal variables are generally not covered in WHE reports.

510 For variables with low variability in survey responses, a default-value imputation method was applied. This was
511 particularly the case for HR buildings, which exhibited less diversity in structural variables across the survey
512 responses. Consequently, a default combination, concrete walls in light tones and a flat concrete roof, was defined
513 for all HR buildings. For lighting variables, both HR and MR buildings are assumed by default to have "many
514 windows," as this was by far the most frequently selected category in the survey responses.

515 In general, thermal variables are linked to a building's location and a country's thermal regulations. For this reason,
516 if information for a thermal variable was available for one building form (e.g., LR) within a country but missing for
517 another (e.g., MR or HR), the available data was imputed to the missing forms.

518 A key step in defining the thermal variables was completing the "presence of insulation" variable, which guided
519 the assignment of other variables. In this endeavor, the World Map of Köppen-Geiger Climate zones (Peel,
520 Finlayson, and McMahon, 2007) is used as a reference for climate zones. The 'BWk', 'Dfa', 'Dfb', 'Dfc', 'Dfd', 'Dsa',
521 'Dsb', 'Dsc', 'Dsd', 'Dwa', 'Dwb', 'Dwc', 'Dwd', 'EF', and 'ET' zones are assumed to represent cold climates, whereas
522 the 'Af', 'Am', 'As', and 'Aw' are assumed to represent hot climates. It was then assumed that buildings without any
523 data in cold climate countries are insulated, while those in hot climate countries are not. Following the delineation
524 of insulation zones, buildings in insulated areas are assumed to have heating systems and double-glazed windows,
525 whereas those in non-insulated zones are presumed to have single-glazed windows and no heating system.

526 Regarding insulation characteristics, two additional variables, representing the evolution of insulation thickness
527 over time (insulation period) for walls and roofs, are not included in the final dataset but were used to complete
528 missing data. For records lacking wall or roof insulation thickness, values were imputed based on available data for
529 insulation periods, with priority given to insulation levels from the 1990s, followed by the 2000s, and then the
530 1970s–1980s. This approach is grounded in survey observations showing that general wall insulation thickness



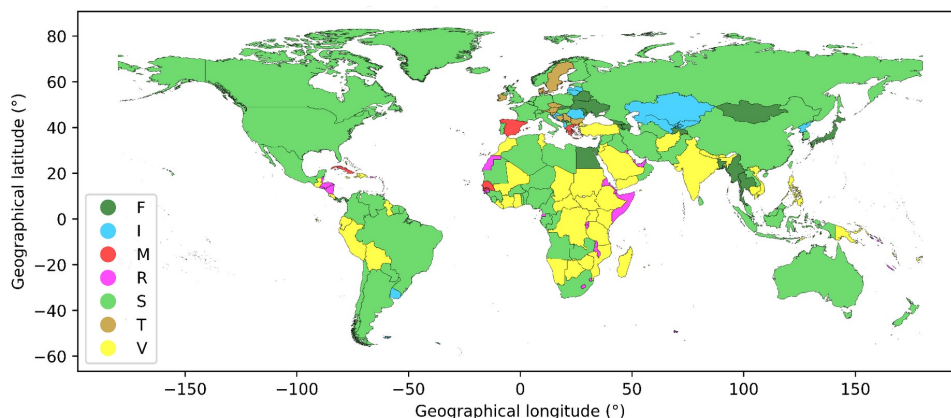
531 and its temporal evolution correspond most closely to values from the 1990s, making these values a reasonable
532 approximation for overall wall insulation levels.

533 A last step of missing data completion was to attribute values from another country in the same region. This
534 involves two main aspects: defining the region limits and choosing an appropriate neighboring country with
535 available data. Initially, the regions considered are based on the GDUBP database regions, which were defined to
536 describe similar building typologies and practices. In case no data is available within the region, other neighboring
537 countries are considered, this could be especially important for large countries that are the only country in a
538 GDUBP database region.

539 A flag is defined to highlight the sources used to complete the database information:

- 540 ● **S: Survey** - The data was obtained from the corrected and aggregated survey responses.
- 541 ● **V: Inferred from another variable** - Data completed using other related variables from the same survey
542 response. This strategy was applied to temperature systems and insulation thickness.
- 543 ● **T: Tabula** - Data sourced from the Tabula database. This imputation strategy was applied uniformly
544 across all variables.
- 545 ● **W: WHE** - Data sourced from the World Housing Encyclopedia. This imputation strategy was applied to
546 structural and lighting variables, as no thermal variables were provided.
- 547 ● **D: Default** - The data has been completed using default values. This strategy was applied to window
548 share in MR buildings and to structural and lighting variables in HR buildings.
- 549 ● **F: Urban Form** - The data has been derived from buildings with other forms (LR, MR, HR) within the
550 same country where survey data was available. This strategy has been applied to complete missing
551 thermal variables across all building forms and window share only in HR buildings.
- 552 ● **C: Climate** - The data has been completed using assumptions based on the climate zone. This strategy
553 has been applied specifically for the variable presence of insulation.
- 554 ● **I: Insulated** - Thermal variables have been completed with default values according to the building's
555 final insulation status.
- 556 ● **R: Region** - Missing data was filled using values from a neighboring country within the same region
557 (GDUBP or climatic). This approach was applied to most variables.
- 558 ● **M: Manual corrections** - In cases where gaps remained after all previous treatments, or when a value
559 required adjustment, manual corrections were applied punctually.

560 The specific treatment given to each group of variables is documented in the *Detailed methodology for completing*
561 *data*, included in the intermediate data of the data repository (de Carvalho Araujo et al., 2025). Figure 8 illustrates
562 the diverse data sources and methodologies used to complete information on temperature systems, with each color
563 representing a different strategy for handling missing data.



564
565

Figure 8 - Flag of data sources for temperature control systems in low-rise residential buildings.

566 In some countries across all continents, survey data (S) is available. Much of Africa, India, Southeast Asia, and
567 parts of South America rely on inferred values estimated from the presence of other related variables (V).
568 Specifically for the temperature control system, it was noted that no respondent selected the 'None' category.
569 However, many answered preceding questions on air tightness and mechanical ventilation, indicating they were
570 engaged with the survey but likely did not consider the temperature system relevant, as it is uncommon in their
571 region. In these cases, the temperature system was assumed to be 'None' despite the missing response.

572 In some countries across Europe, Asia, and Africa, temperature control system data is derived through form-based
573 extrapolations (F), using information from similar building types within the same country. Some European
574 countries benefit from localised data sourced from the Tabula building database (T). In areas like Central Asia and
575 scattered regions elsewhere, default values are assigned based on insulation presence (I). Small regions apply
576 regional estimates (R) by borrowing data from neighboring countries with similar climates, this extrapolation may
577 be less reliable given the potential differences between countries even within similar climate zones. Finally, only a
578 few countries required manual corrections (M). This reflects disparities in data source, which can influence the
579 reliability of the provided information. The maps of data source flags for all variables are available in the data
580 repository (de Carvalho Araujo et al., 2025).

581

582 **6 Building typologies**

583 Following the completion of all variables for residential building typologies, a geographical analysis has been
584 conducted to study their spatial distribution across the globe. These analyses for all residential building forms,
585 variables are provided in the Appendix C and in the data repository (de Carvalho Araujo et al., 2025), where the
586 corresponding tabular and GIS data can also be found. Selected geographical maps of residential buildings
587 variables are presented in Sect. 5.1 and Sect. 5.2. Section 5.3 shows the global typologies for non-residential
588 buildings. The proposed relationships between certain variable categories and physical parameters are presented in
589 Appendix D.

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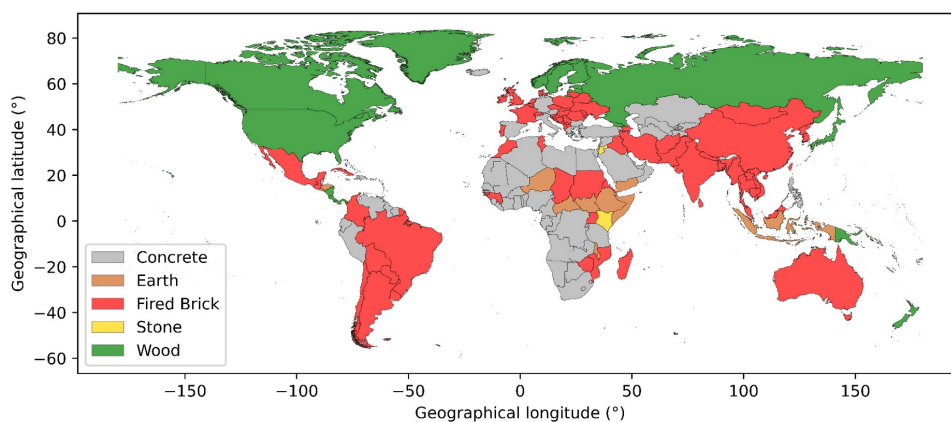
590 **6.1 Structural variables in residential buildings**

591 Figures 9 to 12 display the global distribution of principal wall and roof materials for LR and MR buildings. The
592 results for HR buildings are not displayed since their construction materials are considered homogeneous.

593 Figure 9 illustrates the global distribution of exterior wall materials in LR buildings. Fired brick and concrete are
594 the most common materials, accounting for 52% and 32% of all countries, respectively. Fired brick is widely
595 distributed worldwide, while concrete is notably prevalent in North Africa, parts of Sub-Saharan Africa, Central
596 Asia, and various European countries. Wood predominates in forested, colder regions, accounting for 8% of
597 countries. Earth construction is concentrated in arid or traditionally built environments, representing 7% of
598 countries. Conversely, metal and stone are rarely identified as the primary wall material in any country.

599 Figure 10 shows the geographical distribution of roof cover materials. It appears to be significantly influenced by
600 local climate, material availability, traditional construction practices, and Gross Domestic Product (GDP). Metal,
601 concrete, and clay tiles emerge as the most widespread roof cover materials globally, accounting for 31%, 27%,
602 and 23% of countries, respectively.

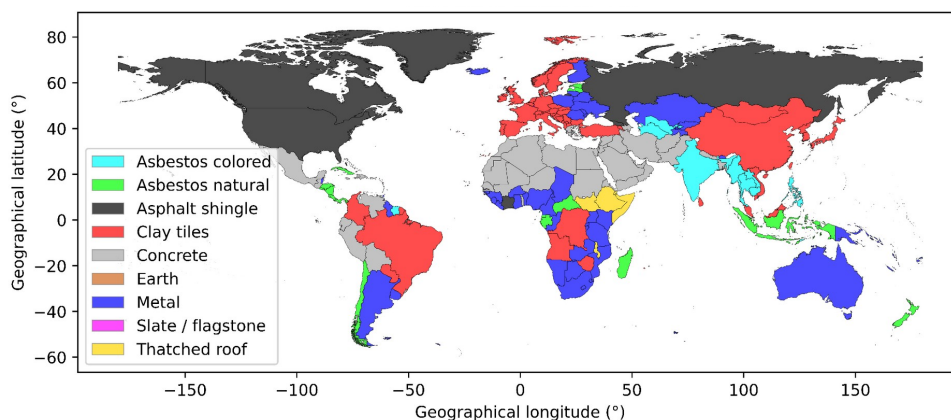
603 A high prevalence of concrete is particularly noticeable in North Africa and the Middle East. Asbestos, in both its
604 natural and colored forms, remains a common building material in several countries, primarily in Southeast Asia,
605 Central America, and isolated areas of West Africa, collectively representing 13% of all countries. Asphalt
606 shingles are predominantly found in colder climate countries, constituting 4% of the total. Thatched roofs,
607 accounting for 2% of countries, are prevalent in regions with traditional building practices or where rural
608 typologies are considered dominant, specifically in certain African nations. Earth and slate were not frequently
609 identified as the majority roof cover material in surveyed countries.



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Figure 9 - Wall material in low-rise residential buildings.

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613

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Figure 10 - Roof cover material in low-rise residential buildings.

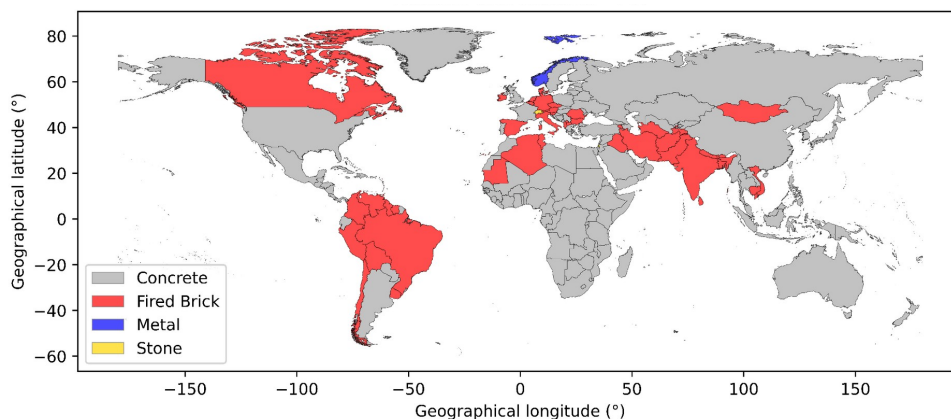
615

616 Figure 11 indicates that MR buildings exhibit less variability in wall materials than LR buildings, primarily
617 utilising concrete (71%) and fired brick (28%). This is likely because MR buildings require stronger, more uniform
618 materials to support greater loads and meet stricter codes. Figure 12 shows a similar pattern for roof materials, with
619 MR buildings presenting less variability than LR buildings. Concrete is the predominant roof cover material for
620 MR buildings globally, accounting for 78% of countries. It is distantly followed by metal at 9% and clay tiles at
621 8%.

622

623 Colored asbestos is primarily observed in African countries, a pattern potentially influenced by the regional data
624 completion methodology and the lower abundance of MR building data compared to LR buildings in those
625 regions. Additionally, it appears sporadically in other areas, with all forms of asbestos combined representing only
626 4% of countries. Other roof cover materials are present in negligible amounts on a global scale for MR buildings.

627



628

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Figure 11 - Wall material in mid-rise residential buildings.

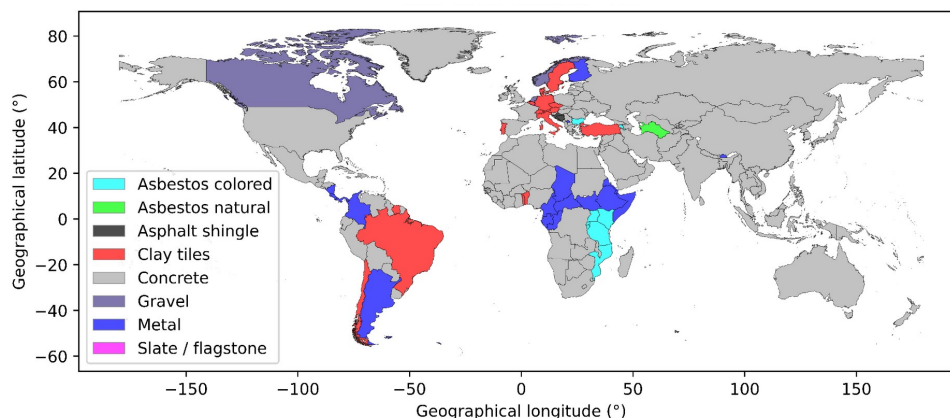
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Figure 12 - Roof cover material in mid-rise residential buildings.

635 A specific verification in Tunisia, using data from Mhedhbi (2019), confirmed the findings of this research; both
636 LR and MR buildings in Tunisia are predominantly constructed with fired brick for their walls. Regarding exterior
637 wall color, Mhedhbi (2019) reports that both LR and MR buildings are white, whereas in the present data, LR
638 buildings are also white, but MR buildings are described as having light tones.

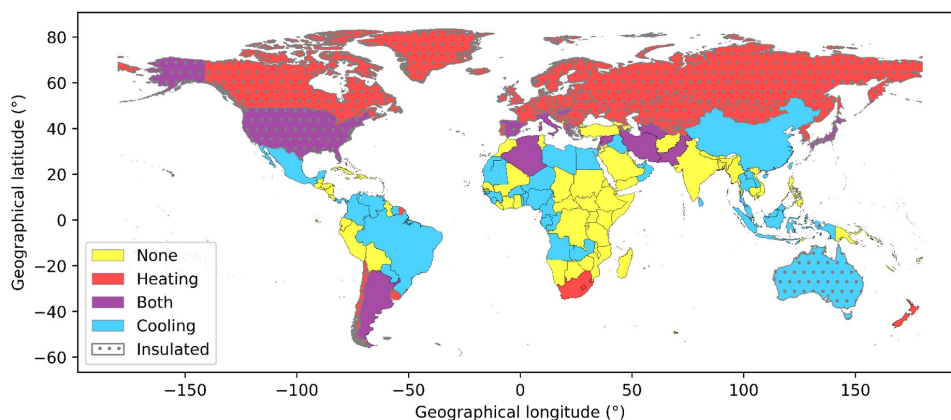
639 6.2 Thermal and lighting variables in residential buildings

640 Figures 13 to 16 display the global distribution of selected thermal and lighting variables in LR buildings.

641

642 Figure 13 illustrates the global distribution of temperature control systems in LR residential buildings, along with
643 the presence of insulation, revealing clear climate-driven patterns. As expected, heating systems dominate in
644 colder regions, while cooling systems are prevalent in warmer tropical and subtropical areas, patterns that partly
645 reflect the assumptions made in the data completion strategies.

646 Temperate climate zones are frequently characterised by the presence of both heating and cooling, reflecting
647 seasonal temperature variability. Similarly, some partially tropical countries with mountainous regions exhibit
648 heating or mixed systems due to local cooler climates. Regions without any formal temperature control systems are
649 found in parts of Africa, Asia, and Central and South America, likely reflecting either mild climates or limited
650 technological access. It is important to recognise that the presence or absence of temperature control systems goes
651 beyond building typology, reflecting a complex interplay of climate conditions, cultural norms, and economic
652 factors. While this figure offers a useful general overview, significant variation may also occur within a single
653 country, particularly where altitude or regional climates diverge from national averages.



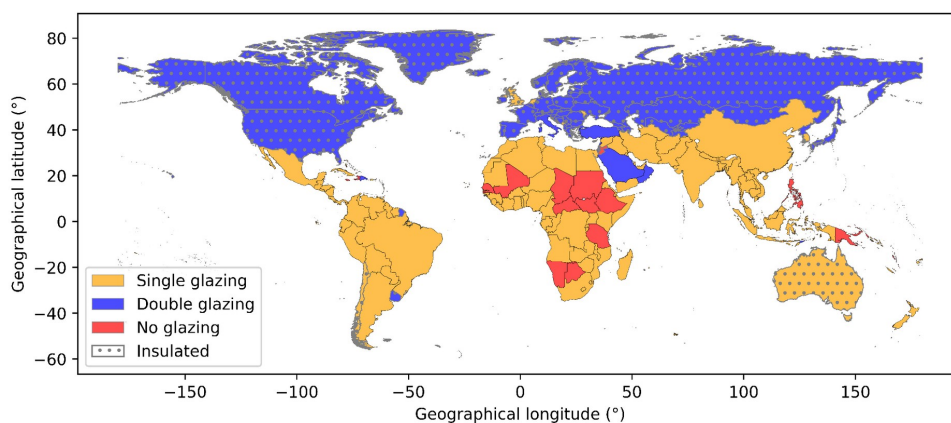
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Figure 13 - Temperature control systems and insulation presence in low-rise residential buildings.

656

657 Figure 14 shows the global distribution of window glazing types in LR residential buildings. Double glazing
658 dominates colder regions, while single glazing is more common in moderate and warm climates. In hot, arid parts
659 of central Africa, areas without glazing appear, likely for ventilation purposes. The observed alignment between
660 insulated buildings and double-glazed windows is partly influenced by the data completion methodology: where
661 glazing data was missing, double glazing was assigned to insulated countries and single glazing to non-insulated
662 ones, based on typical patterns from surveyed regions. While this approach supports existing climate-based
663 patterns, it also means that part of the observed distribution reflects the imputation strategy itself.



664

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Figure 14 - Window glazing type and insulation presence in low-rise residential buildings.

666

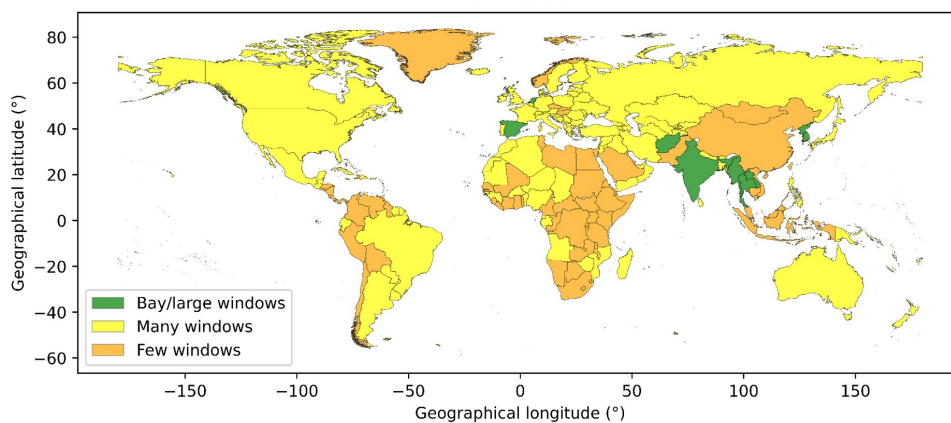
667 Figure 15 shows window share in LR buildings globally, with "many windows" dominating Global North
668 countries, while "few windows" is common across much of Africa and parts of Asia. "Bay/large windows" appear
669 in specific regions like parts of India and the Middle East. It is generally observed that building design patterns,
670 particularly concerning the amount of glazing, are influenced by a combination of economic development, climate

48

49



671 considerations, and prevailing architectural traditions. For instance, there's a tendency for more extensive glazing
672 to be favored in wealthier, temperate regions, often to maximize natural light. Conversely, in hotter climates or
673 developing areas, fewer windows may be preferred, likely due to concerns for thermal comfort and cost-
674 effectiveness.

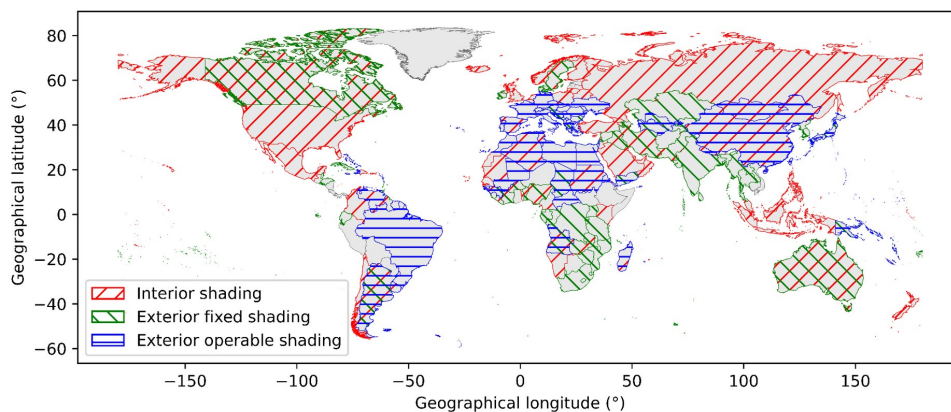


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676

Figure 15 - Window share in low-rise residential buildings.

677

678 Figure 16 illustrates the types of shading device utilized across the globe, reflecting strategies to manage solar
679 radiation for thermal comfort and daylighting. While some nuanced regional variations exist, a general tendency
680 can be observed, with exterior shading appearing somewhat more prevalent in hotter climates, and interior shading
681 showing a higher presence in cooler, higher latitude regions. This distribution aligns with the inherent thermal
682 performance of each shading type. Exterior shading devices intercept solar radiation before it reaches the glazing
683 surface, preventing it from entering the building. In contrast, interior shading allows solar radiation to penetrate the
684 glass and convert into heat inside the space before it can be blocked, making it less efficient for thermal control.
685 Therefore, the greater efficiency of exterior devices makes their use in global areas where controlling solar heat
686 gains is crucial a logical architectural response.



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Figure 16 - Shading devices in low-rise residential buildings.



689

690 6.3 Structural variables in non-residential buildings

691 For non-residential buildings, global typologies are defined by grouping responses according to building use and
692 form combinations. Structural variables are then assigned based on the most frequently reported values within
693 each group. This approach resulted in one to three representative typologies per combination. To ensure global
694 applicability, thermal and lighting variables are excluded, as they are climate-dependent and thus considered
695 country-specific. The resulting non-residential building typologies are presented in Table 6.

696

Table 6 - Wall and roof characteristics of global typologies.

Form	Use	Wall material	Wall color	Roof slope	Roof material
HR	Commercial	Concrete	White tones	Flat	Concrete
HR	Commercial	Glass	N/A	Flat	Concrete
LLR	Commercial	Concrete	Light tones	Flat	Concrete
LLR	Commercial	Fired Brick	Light tones	Flat	Concrete
LLR	Commercial	Metal	Medium tones	Flat	Metal
MR	Commercial	Concrete	Medium tones	Flat	Concrete
MR	Commercial	Glass	N/A	Flat	Concrete
LLR	Industrial	Concrete	Medium tones	Flat	Concrete
LLR	Industrial	Metal	Dark tones	Moderately sloped	Metal
HR	Offices	Concrete	Medium tones	Flat	Concrete
HR	Offices	Glass	N/A	Flat	Concrete
LLR	Offices	Concrete	Light tones	Flat	Concrete
MR	Offices	Concrete	Light tones	Flat	Concrete
MR	Offices	Fired Brick	Light tones	Flat	Concrete
MR	Offices	Glass	N/A	Flat	Concrete
HR	Residential	Concrete	Light tones	Flat	Concrete

697

698 6.4 Discussion

699 This study led to the development of a global architectural database at the country scale, specifically tailored to
700 urban climate contexts. While this represents a significant advancement, the methodological framework inevitably
701 involves certain compromises and limitations must be acknowledged. One key constraint lies in the simplified
702 typological approach adopted, which, while necessary for global-scale analysis, does not fully capture the
703 diversity and variability of national building stocks. This may limit the applicability of the findings, particularly in
704 regions with highly heterogeneous architectural characteristics.

52

53



705

706 Another important limitation concerns the granularity of the data. Initially, the objective was to provide more
707 detailed typological information by considering all typological variables. However, due to the uneven availability
708 of survey results across these variables, only the main typological variables (*country*, *use* and *form*) were
709 prioritised over the auxiliary ones (Fig. 1).

710

711 Distinguishing between urban and rural LR building forms would be important, as settlement type significantly
712 influences construction materials and practices. Ideally, both would be included, but due to the lack of
713 comprehensive data covering both contexts, providing separate datasets was not feasible. When both urban and
714 rural survey responses existed, urban typologies were generally prioritised, reflecting the study's focus on urban
715 climate modeling and phenomena like the UHI effect. However, in countries where rural buildings constitute a
716 large share of LR structures, rural typologies were considered more representative. This was the case of some
717 African nations. As a result, the final dataset does not explicitly differentiate urban and rural contexts, representing
718 a practical compromise within the study's objectives and constraints.

719

720 Still within the set of main typological variables retained for defining building types, the level of available
721 information varied considerably. A substantial amount of data was available for LR buildings, and to a lesser
722 extent for MR buildings, allowing for geographically robust results for these categories. In contrast, data on HR
723 and non-residential buildings were more limited. Due to the scarcity of survey responses for these typologies, a
724 simplified approach was necessary, leading to the adoption of less detailed global categories (table 6), even if it
725 was possible to derive country-specific information for thermal and lighting variables for HR residential buildings.

726

727

728 Despite these limitations, a relatively high level of information was available for LR and MR buildings, which
729 enabled good global coverage for these categories. The amount of available survey data was also sufficient to
730 analyse major trends within the reported variable categories, allowing for cross-analysis with other factors such as
731 climate, region, and the interactions between typological characteristics. This supported a satisfactory approach to
732 filling missing data, relying on logical assumptions based on the nature and behavior of the variables. For the
733 remaining data gaps, a regional extrapolation approach was applied, an assumption with higher uncertainty, but
734 still reasonable, based on the hypothesis that neighboring countries are more likely to share similar construction
735 practices. Together, these strategies make the country-level geographical granularity particularly robust for LR
736 and MR typologies, offering a solid foundation for large-scale applications.

737

738 In terms of application, this database represents a significant advancement for urban climate modeling at multiple
739 scales, from city to continental and global scale. This data expands the analytical capabilities of urban research
740 teams worldwide. It enables comparisons of UHI across cities and countries and supports simulations in contexts
741 where researchers have limited data. At the regional and global scales, it facilitates simulations that account for the
742 distinct architectural characteristics of each country. For instance, it complements the European (Demuzere et al.,
743 2019) and global (Demuzere et al., 2022) LCZ maps that provide information on urban form and function with
744 information on construction materials and systems. This can enhance the realism of urban climate model

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745 simulations. Beyond its application in urban climate modeling, this resource can also contribute to assessments of
746 building energy consumption, offering valuable insights to inform building-scale climate mitigation and
747 adaptation strategies in the face of climate change.

748 **6 Conclusion and outlook**

749 This study presents a first step towards a global architectural database at the country level tailored for urban
750 climate modeling. This database should address a crucial data gap in the materials description needed by urban
751 canopy models and should further help in the understanding, the quantification and the mitigation possibilities of
752 UHI. By leveraging a collaborative expert based survey rooted in a typological framework, the project collected
753 detailed information on building form, use, materials, thermal systems, and shading.

754

755 The survey yielded 521 responses across 141 countries, with strong coverage of residential buildings which
756 compose the majority of the building stock. Due to limited data for non-residential typologies, global typologies
757 are defined based on predominant wall materials and other shared characteristics, while omitting climate-sensitive
758 variables to maintain broader applicability.

759

760 To ensure data reliability, several verification steps were undertaken: statistical assessments of response
761 agreement (Cohen's and Fleiss' Kappa), plausibility checks across variables, and literature reviews where survey
762 responses appeared unrepresentative. A methodology was implemented to select one representative building per
763 typology, prioritising descriptions marked as "common" and balancing socio-economic, temporal, and spatial
764 representativeness. Cross-checks with external sources such as Tabula and the World Housing Encyclopedia
765 showed good alignment for key variables, increasing the confidence of the database.

766

767 To ensure a full world coverage and to provide the widest possible uses of the database, a multi-step imputation
768 strategy has then been applied to fill gaps, using a hierarchy of sources and assumptions based on variable type and
769 climatic logic. Each value is flagged for transparency. The final residential dataset reveals clear global patterns
770 shaped by climate, resource availability, and socio-economic factors.

771

772 This database is known to present some approximations linked to an insufficient amount of data for some countries
773 or typologies. As a consequence, it required the use of simplified typologies, and reduced details for non-
774 residential and HR buildings. But despite these limitations, it represents a major step towards a complete
775 harmonized materials database at the country level.

776

777 Future work should aim to improve data granularity. At first, the database should be completely filled at the
778 country level by additional expert answers. Refining sub-national typologies to enhance reliability at the city level
779 would be a second great aim, especially for countries where the urban form and construction are diverse.
780 Nevertheless, such detailed disaggregation may not be feasible on a global scale due to the complexity of the task.

781



782 To further develop this database an important future direction is to make it evolvable through time. A contribution
783 link is provided in the data repository (de Carvalho Araujo et al., 2025), allowing users and readers to suggest
784 additions or corrections. If significant new data becomes available, future updates could enhance the global
785 database.

786

787 A key outlook for this work is its application in comparative studies and practical urban climate modeling
788 worldwide. This database can already be used in applied research, enabling direct testing of how finer building
789 detail influences simulation outcomes. By incorporating this enhanced dataset into modeling exercises,
790 researchers can better assess the impact of architectural variations on urban climate dynamics, providing valuable
791 insights into the role of building form and materials in shaping local thermal environments. In the meantime, the
792 use and the spreading in the community of this database could benefit to its development by collecting the
793 improvements from the modelers. A positive feedback loop is expected to improve the database and make it more
794 robust.

795 This database was developed through an innovative methodological process, including the selection of targeted
796 variables, collection of specialist knowledge, survey data verification, filtering of representative typologies, multi-
797 step imputation, and transparent flagging of data sources. Despite some limitations, this approach aimed to
798 produce the most precise, reliable and usable database as possible, to fulfill the needs of the urban climate research
799 community.

800 Overall, this work represents a step toward closing the global data gap in urban climate modeling. It delivers an
801 open-source GIS database of representative building typologies worldwide. By providing detailed, globally
802 distributed information on building characteristics, this database UCAD strengthens the capacity to estimate and
803 forecast UHI intensity, energy consumption, and thermal comfort. It offers researchers and policymakers a
804 practical, scalable resource to support the design of more resilient and sustainable cities in the context of climate
805 change and urbanisation. Nevertheless, there is still additional work necessary to make the database more
806 complete and robust and this work opens the way to get these improvements.

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810 **Appendix**

811 **A Survey content**

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Table A1 - Survey questions and options

Element type	Content
Introduction title	Join our Global Effort: Describe Building Types for a Sustainable Future!
Introduction description	We are building a global database to understand how buildings affect our climate. Your knowledge of local building types will greatly improve urban weather and climate models. Why Participate? Climate Impact: Understand how different buildings affect our environment and urban heat. Weather Forecast: Contribute to more accurate weather forecasts in cities. Your Task: Help us by describing various building types from your country. Each submission should focus on one specific building type. You can describe as many building types as you want. Together let's build a more sustainable future!
Page name	Building type
Page description	Think of a type of building that is frequent in your country: homes, shops, offices, industries. Buildings of a same type often share a similar design and materials. Let's describe this type of building by answering some questions! (When several options are possible for a question, focus on the most common feature.)
Question	Country (Required)
Choices	[List of countries]
Question	What is the main use of the building you are going to describe?
Choices	Residential; Commercial; Offices; Industrial
Question hint	In case of mixed use consider the main one. For example a residential building with a commercial ground floor is considered as residential.
Question	What is the shape of this building? (Required)
Choices	Individual houses or low-rise building (1 to 3 storeys); Mid-rise building (4 to 9 storeys); High-rise building (more than 9 storeys); Large low-rise building (1 to 3 storeys)
Question	During which time periods would this type of building typically be constructed? (Select all that apply if this type of building was built in several of these periods.) (Required)
Choices	Before the 20th century; First half of the 20th century; Second half of the 20th century; 21st century; All periods
Question	Is this type of building characteristic of urban or rural areas?
Choices	Both; Urban; Rural
Question	Is this type of building associated with a certain social level?
Choices	No; Low income; Medium income; High income
Question	Where can you find this type of building in your country? (Required)



Choices	In the whole country; In some specific regions
Question	Where is it commonly found? (Many options can be selected)
Choices	[List of the regions]
Question	How common is this type of building?
Choices	Very Common; Somewhat common; Uncommon; I don't know
Page name	Exterior walls and roof
Section header	In the following questions please describe the exterior walls of this building type.
Question	What is the main wall material?
Choices	Fired Brick; Concrete; Stone; Wood; Earth (e.g. Adobe Cob Daub); Metal (e.g. corrugated metal metal panels); Glass (in case of glass buildings)
Question	What is the predominant color tone of the exterior wall surfaces?
Choices	White tones (e.g. pure white off-white); Light tones (e.g. beige cream light yellow); Medium tones (e.g. green red blue other bright colors); Dark tones (e.g. dark brown black dark gray)
Question	Does this building type have thermal insulation?
Choices	Yes; No; I don't know
Question	Where is usually placed the insulation on the wall?
Choices	Inside; Outside; Uniformly distributed throughout the wall; I don't know
Question	Estimate the thickness of the wall insulation:
Choices	< 5 cm (< 2 in); 5 - 15 cm (2 - 6 in); 16 - 25 cm (6 - 10 in); > 25 cm (> 10 in); It depends on the date it was insulated; I don't know
Section header	In the following questions please describe the roof of this building type.
Question	Is the roof usually flat or sloped?
Choices	Flat; Moderately sloped; Steeply sloped (> 45°)
Question	What is usually the roof cover?
Choices	Asphalt shingle; Asbestos cement roofing - coloured; Asbestos cement roofing - natural color; Clay tiles; Concrete; Gravel; Green roofing; Metal (zinc aluminium steel etc); Slate / flagstone; Thatched roof; Wood
Question	Estimate the thickness of the roof insulation:
Choices	< 5 cm (< 2 in); 5 - 15 cm (2 - 6 in); 16 - 25 cm (6 - 10 in); > 25 cm (> 10 in); It depends on the date it was insulated; I don't know
Page name	Window, ventilation, temperature control and shading
Section header	For the following questions focus on the most common building features.



Question	How much of the exterior wall is covered by windows?
Choices	No windows; Few windows; Many windows; Bay windows / Large windows; Glass building
Question	What type of glazing is found in this type of building?
Choices	No glazing (windows without a glass panel); Single glazing; Double glazing; Triple glazing; Other (Please specify)
Question hint	Glazing refers to the number of glass panels in a window.
Question	In this type of building can some windows be opened?
Choices	Yes; No
Question	Assuming all windows and doors are closed can you feel air drafts coming from outside (air infiltration)?
Choices	Not noticeable; Slightly; Strongly; I don't know
Question	Does this type of building usually have a mechanical ventilation system?
Choices	Yes; No; I don't know
Question	Does the building have a heating or a cooling system?
Choices	Heating; Cooling; Both; None
Question	Which types of solar shading are commonly used for this type of building?
Choices	Overhangs: roof overhang balcony overhang arcades etc; Fixed exterior window shading: window overhangs louvers fins egg-crate shading etc.; Operable exterior window shading: shutters rolling shades retractable awnings etc.; Interior window shading: curtains blinds etc.; None of the above; I don't know
Page name	Leave your mark
Question	Would you mind sharing your email?
Choices	[Open field element]
Question	Would you like to share a picture of this building type?
Choices	[upload element]
Question	Have you ever been involved in the field of Architecture or Civil Engineering through study or work?
Choices	Yes; No
Matrix question	Match the wall insulation thickness with the following periods for this type of building: (Please select maximum one choice for each period)
Matrix rows	Before 70's; 70's and 80's; 90's; 2000's; 2010's; 2020's
Matrix columns	I don't know; No insulation; < 5 cm (< 2 in); 5 - 15 cm (2 - 6 in); 16 - 25 cm (6 - 10 in); > 25 cm (> 10 in)
Matrix	Match the roof insulation thickness with the following periods for this type of building:(Please



question	select maximum one choice for each period)
Matrix rows	Before 70's; 70's and 80's; 90's; 2000's; 2010's; 2020's
Matrix columns	I don't know; No insulation; < 5 cm (< 2 in); 5 - 15 cm (2 - 6 in); 16 - 25 cm (6 - 10 in); > 25 cm (> 10 in)
Question	If any, to which architectural style does this building type correspond?
Choices	[Open field element]
Question	Do you have any further comments?
Choices	[Open field element]
Final message	Your responses are incredibly valuable as describing the different types of buildings helps us better understand the urban climate worldwide. Thank you again for submitting this form. We would greatly appreciate it if you could take the time to answer the survey for another type of building in your country.

814

815 **B Coverage of external databases**

816 Figures B1 and B2 illustrate the geographic coverage of survey data alongside that from the external databases
 817 (Tabula and WHE). Where both data sources were available (countries highlighted in green and marked with
 818 circles), a comparative analysis was conducted. Conversely, in regions where only external database data was
 819 present (countries shown in grey and with circles), this information was utilized to complete missing survey data.
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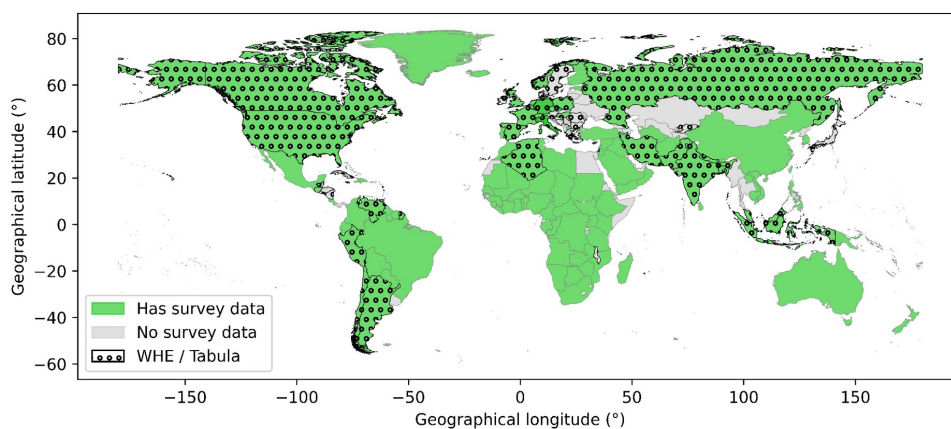
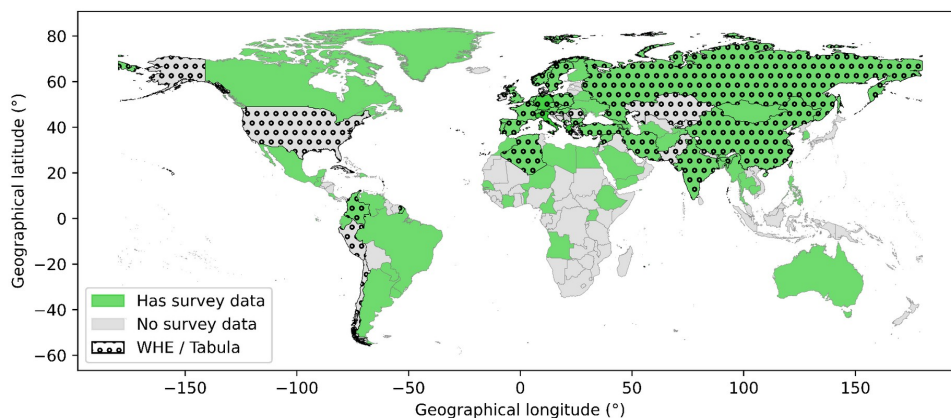


Figure B1: Presence of data in external databases and in the survey for LR buildings

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Figure B2: Presence of data in external databases and in the survey for MR buildings

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826 The following tables present a comparative analysis of building characteristics, specifically focusing on the
 827 agreement regarding wall and roof materials and window share in different global contexts. Tables B1 and B2,
 828 derived from the WHE project, categorise low-rise and mid-rise buildings, respectively, based on whether the
 829 reported characteristics for these elements align with survey data. It should be noted that in some WHE cases, the
 830 absence of clear photographic evidence impeded the precise definition of window share levels. For the WHE data,
 831 every report used is precisely cited for each country. Tables B3 and B4 show the reports used to complete the
 832 missing data with WHE. Table B5, based on the TABULA project, applies this comparison to various European
 833 countries for both low-rise and mid-rise structures. This table additionally indicates instances of data "completion"
 834 where information for one of the building forms was not directly available in the survey data, and also highlights
 835 cases where wall and roof materials were not explicitly described in the TABULA descriptions. All TABULA data
 836 was sourced directly from its website.

837

838 *Table B1: WHE - compared cases with agreement for wall and roof materials and window share for low-rise*
 839 *buildings.*

Country	Agreement			Analysed report number and references
	Wall material	Roof material	Window share	
Algeria	no	yes	yes	#103 (Farsi & Lazzali, 2003).
Argentina	yes	no	no	#1 (Rodriguez et al., 2002a), #2 (Rodriguez et al., 2002c), #70 (Rodriguez et al., 2002b), #89 (Rodriguez et al., 2003), #152 (Graciela & Tornello, 2008).

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Bangladesh	yes	no	yes	#91 (Ansary, 2003), #143 (Das et al., 2007).
Canada	yes	no	yes	# 82 (Ventura & Kharrazi, 2002).
Chile	yes	yes	no	#5 (Moroni et al., 2002c).
Guatemala	no	no	no	#161 (Velasquez Jofre et al., 2011), #144 (Lang et al., 2007), #136 (French, 2007a).
India	yes	yes	no	#18 (Brzev et al., 2002), #20 (Khan & Moin, 2002), #21 (Sinha & Brzev, 2002), #22 (Kumar, 2002a), #23 (Kumar, 2002b), #72 (Choudhary et al., 2002), #80 (Sinha & Ambati, 2002), #116 (Kumar & Pundit, 2005), #146 (Hicyilmaz et al., 2008), #147 (Khan, 2008), #154 (Kaushik, 2009), #170 (Rahul et al., 2013), #171 (Sood et al., 2012), #172 (Sood et al., 2013).
Indonesia	no	yes	yes	#24 (Wijanto, 2002).
Iran	yes	no	yes	#27 (Hashemi et al., 2002) #104 (Mehrain & Naeim, 2004), #114 (Ahari & Azarbakht, 2005), #118 (Bekloo, 2007).
Italy	no	no	yes	#28 (D'Ayala & Speranza, 2002), #29 (D'Ayala et al., 2002), #31 (Goretta et al., 2002).
Jamaica	yes	no	no data	#207 (Webber & Abrahamczyk, 2020).
Malaysia	yes	yes	no	#44 (Adnan et al., 2002).
Nepal	yes	yes	yes	#47 (Parajuli et al., 2002a), #74 (Parajuli et al., 2002b),



				#145 (Bilas Marhatta et al., 2007).
Pakistan	yes	yes	yes	#112 (Ali, 2006), #116 (Kumar & Pundit, 2005), #138 (Ali & Muhammad, 2007), #146 (Hicyilmaz et al., 2008), #166 (Lodi et al., 2012), #173 (Lodi et al., 2013), #174 (Parajuli et al., 2012).
Peru	no	yes	yes	#51 (Loaiza & Blondet, 2002b), #52 (Loaiza et al., 2002), #107(Charleson, 2009)
Russia	yes	no	yes	#56 (Klyachko et al., 2002a), #57(Klyachko et al., 2002b), #53(Klyachko et al., 2002d).
Switzerland	no	no	yes	#108 (Bostenaru, 2004).
United States	yes	yes	yes	#65 (Arnold, 2002).

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844 *Table B2: WHE - compared cases with agreement for wall and roof materials and window share for mid-rise*
 845 *buildings.*
 846

country	Agreement			Analysed report number and references
	Wall material	Roof material	Window share	
Algeria	yes	yes	yes	#75 (Farsi et al., 2002), #103 (Farsi & Lazzali, 2003).
Armenia	no	no	no	#202 (Martin, s. d.a), #203 (Martin, s. d.b), #204 (Martin, s. d.c).
China	no	yes	yes	#9 (Zhou et al., 2002).
Colombia	yes	yes	no data	#11 (Mejia, 2002b), #12 (Mejia, 2002a), #175 (Hackmayer, et al., 2013).
Cyprus	no	yes	yes	#13 (Levtchitch, 2002).
Greece	yes	yes	yes	#15 (Tassios & Symakezis, 2002).
India	yes	yes	yes	#19 (Jaiswal et al., 2002), #150 (Rautela et al., 2008).
Iran	yes	yes	yes	#25 (Alimoradi, 2002), #26 (Hashemi & Ashtiany, 2002), #27 (Hashemi et al., 2002).
Italy	yes	yes	yes	#30 (Leggeri et al., 2002), #113 (Sassu & Cei, 2005), #120 (Vetturini et al., 2007b), #121 (Vetturini et al., 2007a).
Russia	yes	yes	yes	#53 (Klyachko et al., 2002d), #54 (Klyachko et al., 2002c), #55 (Klyachko et al., 2002e).
Switzerland	yes	yes	yes	#108 (Bostenaru, 2004), #119 (Lang & Bachmann, 2007).
Syria	yes	yes	yes	#59 (Awad et al., 2002b), #60 (Awad et al., 2002a).
Turkey	yes	no	yes	#64 (Gulkan et al., 2002), #101 (Yakut & Gulkan, 2003).

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850 *Table B3: WHE - completed cases for low-rise buildings with detailed used reports.*

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Country	Analysed report number and references
Belize	#164 (Redmond and DesRoches, 2012)
Cuba	#183 (Morejón Blanco et al., 2016a)
El Salvador	#14 (Lopez M. et al., 2002)
Greece	#17 (Koumoussis, 2002)
Honduras	#134 (French, 2007b)
Japan	#86 (Maki and Tanaka, 2002)
Kyrgyzstan	#36 (Begaliev and Uranova, 2002)
Malawi	#45 (Sassu and Ngoma, 2002)
Malawi	#45 (Sassu and Ngoma, 2002a) #46 (Sassu and Ngoma, 2002a)
Nicaragua	#148 (Lang et al., 2008)
Palestine	#49 (Al Dabbeek and Al-Jawhari, 2002b)
Romania	#84 (Bostenaru and Sandu, 2002a) #85 (Bostenaru and Sandu, 2002b)
Serbia	#69 (Muravljev and Dimitrijevic, 2002)
Slovenia	#88 (Lutman and Tomazevic, 2002a)
Trinidad and Tobago	#156 (Clarke and Ramnath, 2009)



881 *Table B4: WHE - completed cases for mid-rise buildings with detailed used reports.*

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Country	Analysed report number and references
Albania	#208 (Charleson, 2020)
Chile	#7 (Moroni et al., 2002b) #8 (Moroni et al., 2002a)
Cuba	#186 (Morejón Blanco et al., 2016b)
Kazakhstan	#32 (Itskov et al., 2002)
Kyrgyzstan	#39 (Uranova and Begaliev, 2002)
Nepal	#145 (Marhatta et al., 2007)
Pakistan	#167 (Lodi et al., 2013)
Palestine	#48 (Al Dabbeek and Al-Jawhari, 2002a)
Peru	#50 (Loaiza F. and Blondet, 2002a)
Romania	#71 (Bostenaru and Sandu, 2002c) #96 (Bostenaru, 2003)
Serbia	#68 (Dimitrijevic, 2002)
Slovenia	#73 (Lutman and Tomazevic, 2002b)
USA	#111 (Faison et al., 2004)



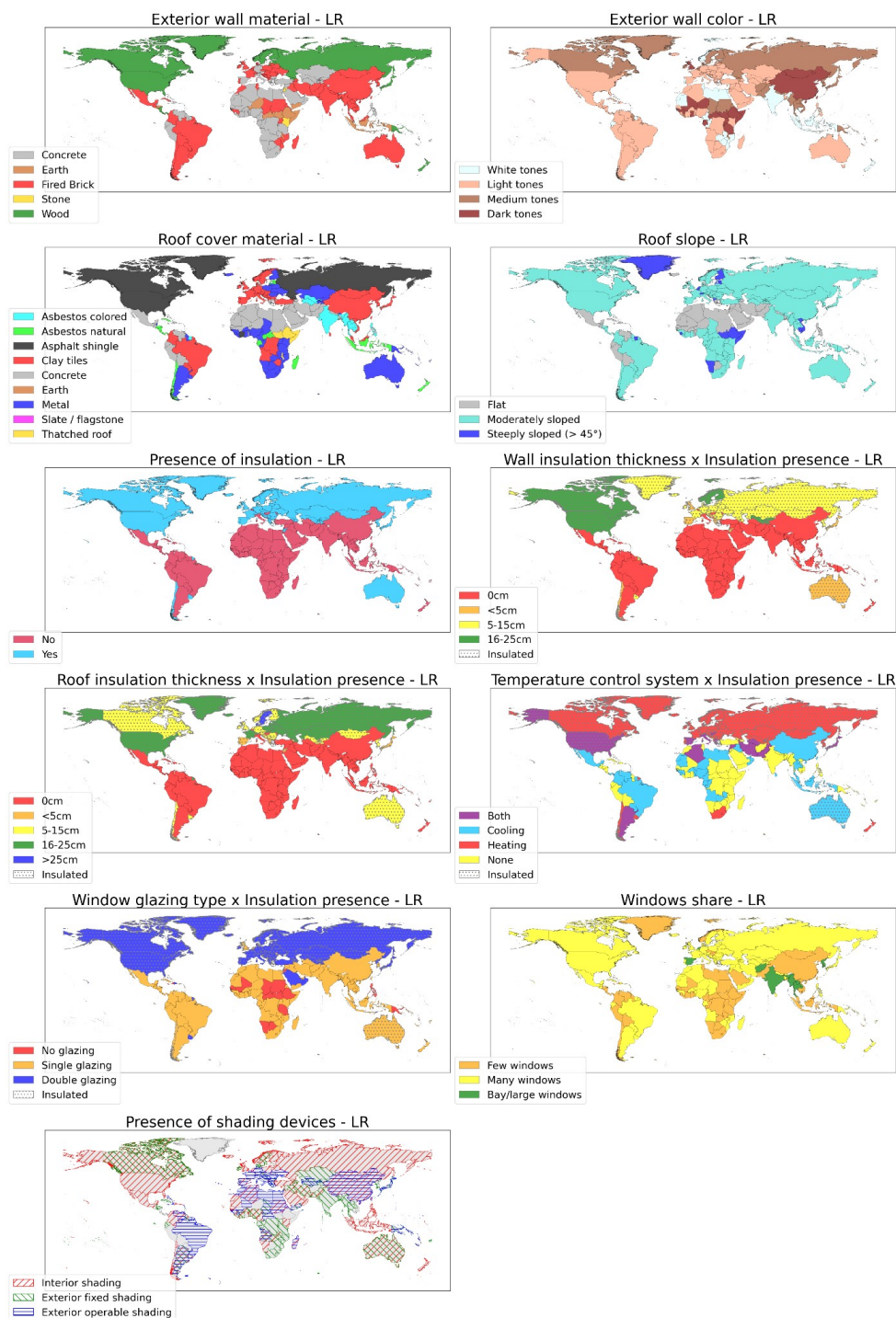
921 *Table B5: Tabula - compared and completed cases with agreement for wall and roof materials and window*
 922 *share for low-rise and mid-rise buildings.*

Country	Agreement					
	MR			LR		
	Wall material	Roof material	Window share	Wall material	Roof material	Window share
Austria	yes	yes	yes	completion	completion	completion
Belgium	yes	no	yes	yes	no	yes
Bulgaria	yes	no	yes	completion	completion	completion
Cyprus	no	yes	yes	no	yes	yes
Czech Republic	yes	yes	yes	yes	yes	no
France	no data	yes	yes	no data	yes	yes
Germany	yes	yes	yes	yes	yes	yes
Greece	yes	yes	yes	completion	completion	completion
Hungary	no	yes	yes	yes	yes	no
Italy	yes	yes	yes	no	no	yes
Netherlands	no data	no	yes	yes	yes	no
Norway	no	no	yes	yes	yes	no
Poland	yes	yes	yes	yes	no	yes
Spain	no data	yes	yes	no	yes	yes
Sweden	no data	no data	yes	completion	completion	completion
United Kingdom	no	yes	yes	yes	yes	yes

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925 **C Maps of all descriptive variables**

926 The three next figures (C1, C2, C3) present all the parameters of the database for the Low-Rise, Mid-Rise and
 927 High-Rise buildings, respectively.

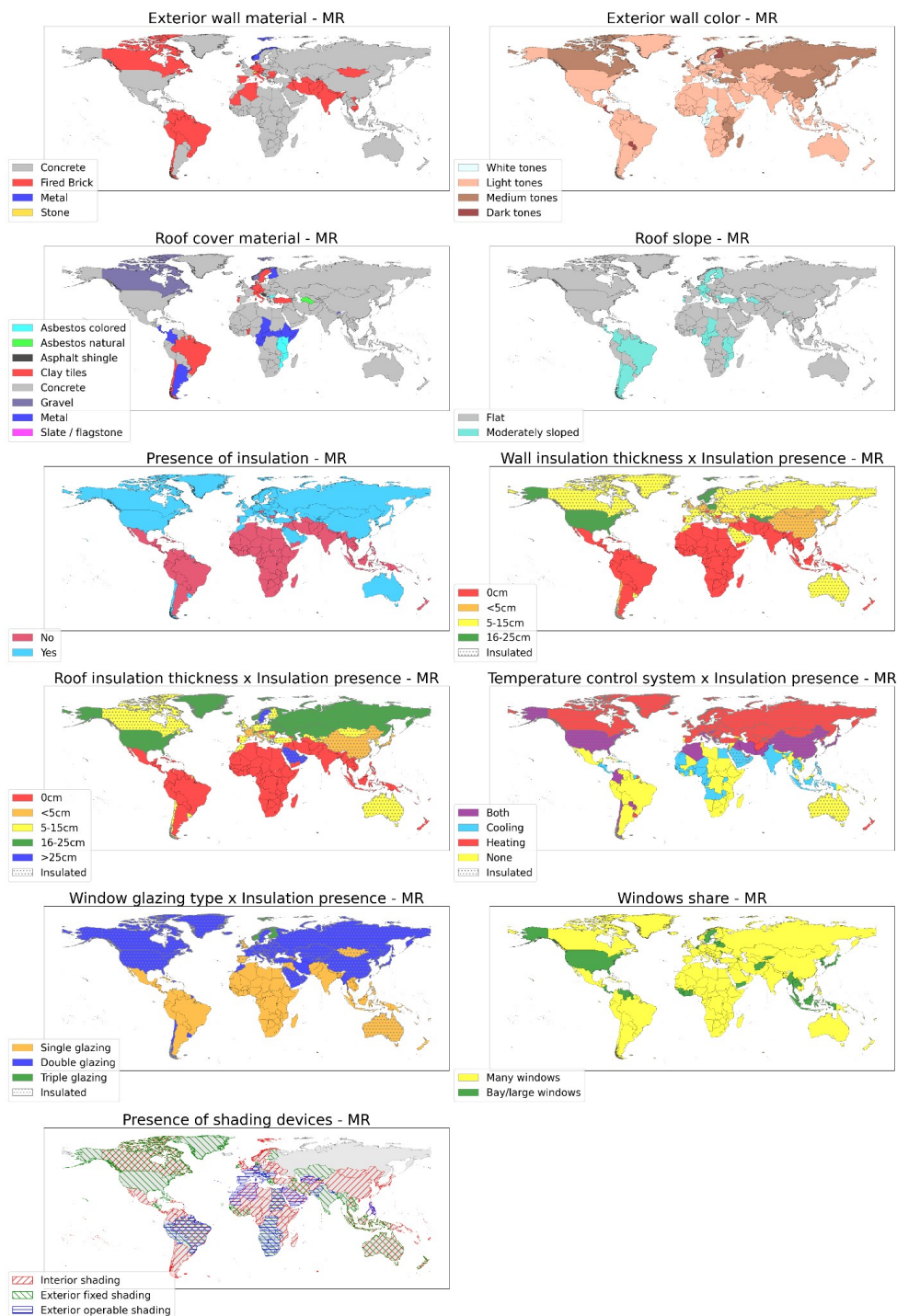


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Figure C1: Descriptive variables for low-rise buildings

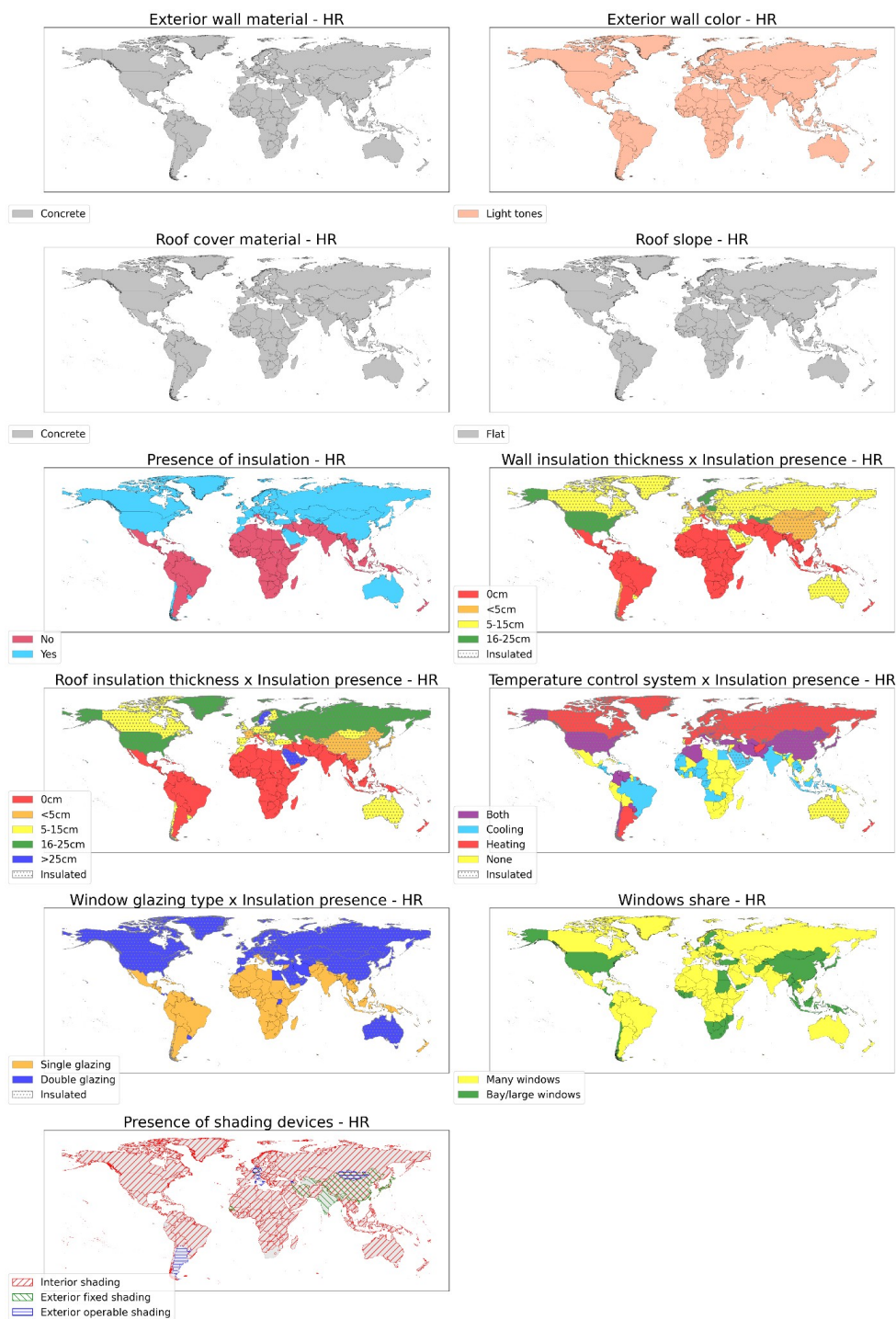


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Figure C2: Descriptive variables for mid-rise buildings



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Figure C3: Descriptive variables for high-rise buildings

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937 **D Look-up tables for physical parameters**

938 This section provides an association between the database categories for each variable and their corresponding
 939 physical parameters, which are to be applied in urban climate modeling. These associations are provided for the
 940 following variables: wall materials (Table D1), roof cover material Table D2), wall color (Table D3), window
 941 glazing type (Table D4), and window share (Table D5). Other descriptive variables do not require conversion.

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Table D1: Associated physical parameters for wall materials.

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Table	Wall material	Thermal conductivity	Specific heat capacity
		[W.m ⁻¹ .K ⁻¹]	[J.kg ⁻¹ .K ⁻¹]
D2:	Concrete	1.8 - 2.5	1000 - 1080
	Earth	0.8 - 1.1	800 - 1000
	Fired Brick	0.7	840
	Glass	1.0	750
	Metal	50	460
	Stone	1.6 - 3.5	1000
	Wood	0.2	1600

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Associated physical parameters for roof cover materials.

Roof cover material	Thermal conductivity	Specific heat capacity	Albedo
	[W.m ⁻¹ .K ⁻¹]	[J.kg ⁻¹ .K ⁻¹]	
Asbestos colored	0.36 - 0.74	816 - 1050	0.10 - 0.40
Asbestos natural color	0.36 - 0.74	816 - 1050	0.20 - 0.40
Asphalt shingle	0.14 - 0.79	900 - 920	0.08
Clay tiles	1.0	837	0.25
Concrete	1.1	920	0.35
Earth	0.8 - 1.1	800 - 1000	0.20 - 0.25
Gravel	2.0	1050	0.20
Metal	110	380 - 1000	0.45
Slate / flagstone	2.2	1000	0.10

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Thatched roof	0.05 - 0.1	1500 - 2000	0.20 - 0.40
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Table D3: Associated albedos for exterior wall color

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Wall color	Albedo
White tones	0.5
Light tones	0.3
Medium tones	0.2
Dark tones	0.15

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Table D4: Associated physical parameters for window glazing types.

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Window glazing type	Thermal transmittance [W.m ⁻² .K ⁻¹]
No glazing	*adapt the model with high ventilation rates
Single glazing	4.8 - 5.8
Double glazing	1.1 - 3.0
Triple glazing	0.5 - 0.8

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Table D5: Associated window facade percentage for window share.

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<i>Window share</i>	<i>Percentage of windows in the facade [%]</i>
<i>No windows</i>	<i>0</i>
<i>Few windows</i>	<i>10</i>
<i>Many windows</i>	<i>20</i>
<i>Bay/large windows</i>	<i>40</i>
<i>Glass building</i>	<i>90</i>



986 **Data availability**

987 The original survey results and the final maps and datasets of building typologies can be downloaded at
988 <https://doi.org/10.5281/zenodo.16096963> (de Carvalho Araujo et al., 2025). The original survey results and the
989 final maps and datasets of building typologies can be downloaded at <https://doi.org/10.5281/zenodo.16096963> (de
990 Carvalho Araujo et al., 2025). The original survey results and the final maps and datasets of building typologies can
991 be downloaded at <https://doi.org/10.5281/zenodo.16096963> (de Carvalho Araujo et al., 2025).

992 **Author contributions**

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