# Learning about urban mitigation solutions

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**Climate change assessments by the IPCC and others put increasing emphasis on cities as key actors in mitigation and early policy adoption. While a coherent understanding of barriers and opportunities for urban climate solutions remains fragmented, there is already a large body of case study literature to learn from and translate into different urban contexts** 1**. But a number of practical and conceptual challenges hinder systematic learning. First, the literature tends to focus on cases in mega-cities or those in wealthy urban areas. By contrast, the majority of the global population resides in much smaller agglomerations, and most of the upcoming urban growth will occur in the Global South where infrastructures are only partially developed. Second, the researched solution space focuses on demand-side measures, but tends to overlook issues of urban form and infrastructure development in growing cities, even as carbon intensive consumption patterns are being locked into place. Third, comparative analysis of cases is sparse and systematic reviews of the literature are virtually non-existent. Given the large scope for learning between cities, but the challenges of generalising from individual studies, we propose a systematic blend of quantitative typologies with qualitative knowledge derived from cases to inform urban climate solutions.**

When it comes to urban mitigation solutions, the key questions are: what works, for whom, under what conditions, and why? Little progress has been made so far. With no consistent epistemology, enormous variety in boundaries of analysis, and a lack of formal research synthesis, urban mitigation solutions remain diffuse and under-exploited 2–4.

Systematic learning hinges on aggregating information about individual cities. Recent work emphasises a quantitative direction to this work, using ‘big data’ and typologies to identify structural similarities and path dependencies of development 5. Similar cities in this sense might draw from the same pool of solutions, or learn from early pioneers in climate policy. To make this strategy actionable, however, it will be critical to complement quantitative typologies with an understanding of how underlying social and political conditions can shape or hinder urban transformations 6.

To this end, a sizable body of case study research exists for individual cities, as well as comparative studies across multiple urban settings 1. These cases often include a rich variety of contextual information on urban-scale projects and reforms, yet are not well represented in the scope of assessment literature on cities. The typical presentation of such evidence in assessment studies is of an anecdotal rather than analytical nature – in dedicated boxed sections, as examples of particular phenomena, or within curated libraries of initiatives. Above all, a lack of rigorous literature selection procedures in assessments (and in reviews generally) means that potentially relevant cases remain undiscovered – a hidden treasure that is increasingly buried under the exponential growth of publications 4.

Urban case studies can add to our understanding of climate mitigation solutions, but an overview of the field is urgently needed. Which cities do we know about? What topics do we know about? What comparative and secondary analysis is there of cases? And how can generalizable knowledge be derived from urban cases? In this perspective we address these questions, with a view to developing a more systematic agenda for aggregating knowledge on urban solutions. Overall we identify a rich and varied case study literature, albeit one with regional and topic biases, and a distinct lack of learning on these studies. We then propose an approach that blends quantitative and qualitative knowledge to inform urban climate solutions.

As a starting point to our analysis, we obtain a sample of urban mitigation articles using a search query that combines synonyms for “urban” and “mitigation” in the Web of Science and Scopus literature databases (see methods). Our interpretation of case study research is straightforward: if an article mentions a city name in the abstract or title, we assume it is a case study located in the city (or cities) mentioned. Our dataset for the proceeding analysis therefore consists of 3,440 publications, with meta-data on the cities they are situated in, the topics they investigate, their balance of review studies, and other information.

## Urban case studies are biased towards large cities and the global North

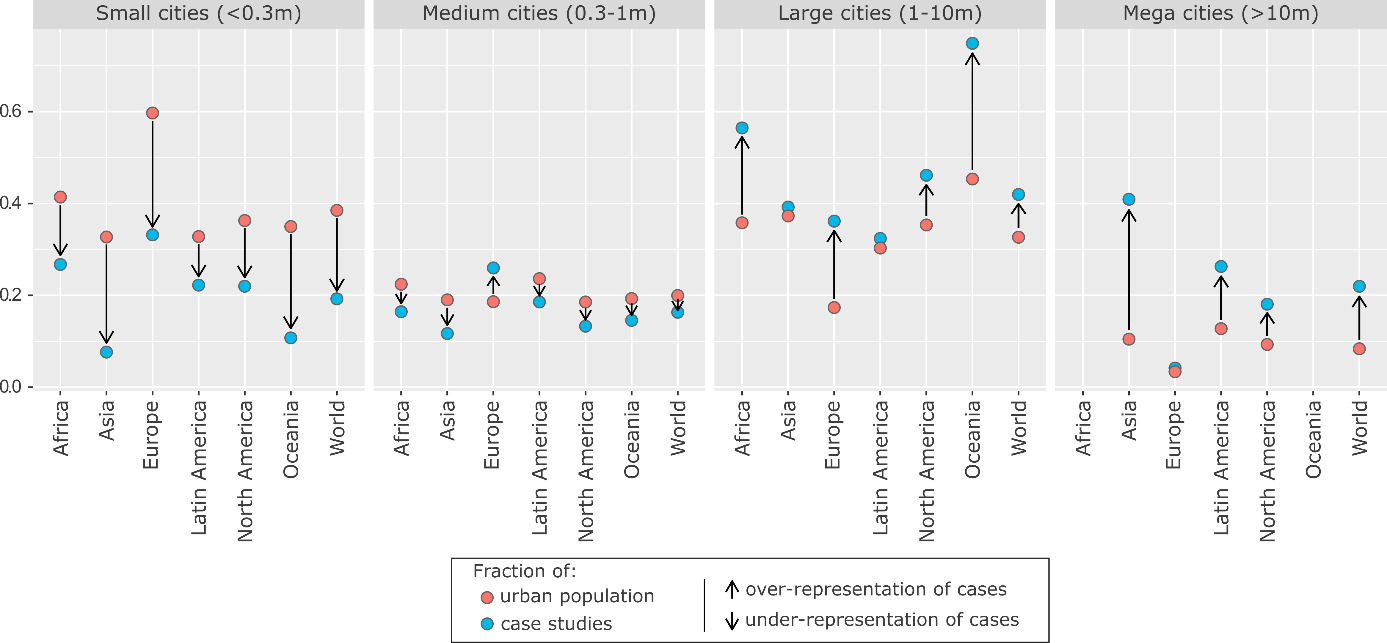
Cities vary in many dimensions, including size, wealth and infrastructure development. As different types of cities face different challenges, learning about solutions depends on a balanced coverage of case study research. An obvious question therefore arises: which cities do we actually know about?

Figure 1 shows the spread of case study research across different city sizes, from a small number of familiar ‘mega-cities’ (over 10m inhabitants), to dozens of smaller national and regional capital cities (1-10m), and hundreds of yet smaller metropoles. The majority of research so far has focused on larger cities, with a small number of mega-cities receiving particular attention: Beijing (284 articles), New York (146), Shanghai (140) and London (117). Other cities are mentioned in fewer than 100 articles each.



**Figure 1: Number of urban climate mitigation articles, grouped according to city size.** Where available, urban agglomeration data is used. The 15 most frequently studied cities are labelled.

Considering the global distribution of population, the current focus on larger cities does not seem to be justified. Just 10% of the world’s urban population lives in mega-cities, compared to 40% in small cities – yet both groups are treated equally in research, each receiving approximately 20% of the case studies we find (Figure 2). A particularly stark divide can be seen in Asia, where the low proportion of mega-city inhabitants (10%) is served by over 40% of the urban case study literature in this region. Although mega-cities are fast-growing in most regions (SI Text Figure 2), this unbalanced focus leaves smaller urban centres consistently under-represented. This pattern is repeated for literature citations, with progressively larger cities receiving, on average, more citations (SI Text Figure 3).



**Figure 2: Size bias in urban mitigation case study research.** Fractions of population and case studies are relative to regions.

Regionally, we also observe a clear bias towards Europe, North America and Oceania, which receive an outsized share of articles relative to their small proportion of the global urban population (SI Text Figure 4). Looking forward to urbanisation trends in 2030, the least well represented region, Africa, has the fastest growing cities (SI Text Figure 2). And the least well represented segment, small Asian cities, will have the largest share of the global urban population (SI Text Figure 1). Hence, the world regions and city scales with most future relevance in terms of total urban population and growth dynamics are systematically underrepresented in the literature.

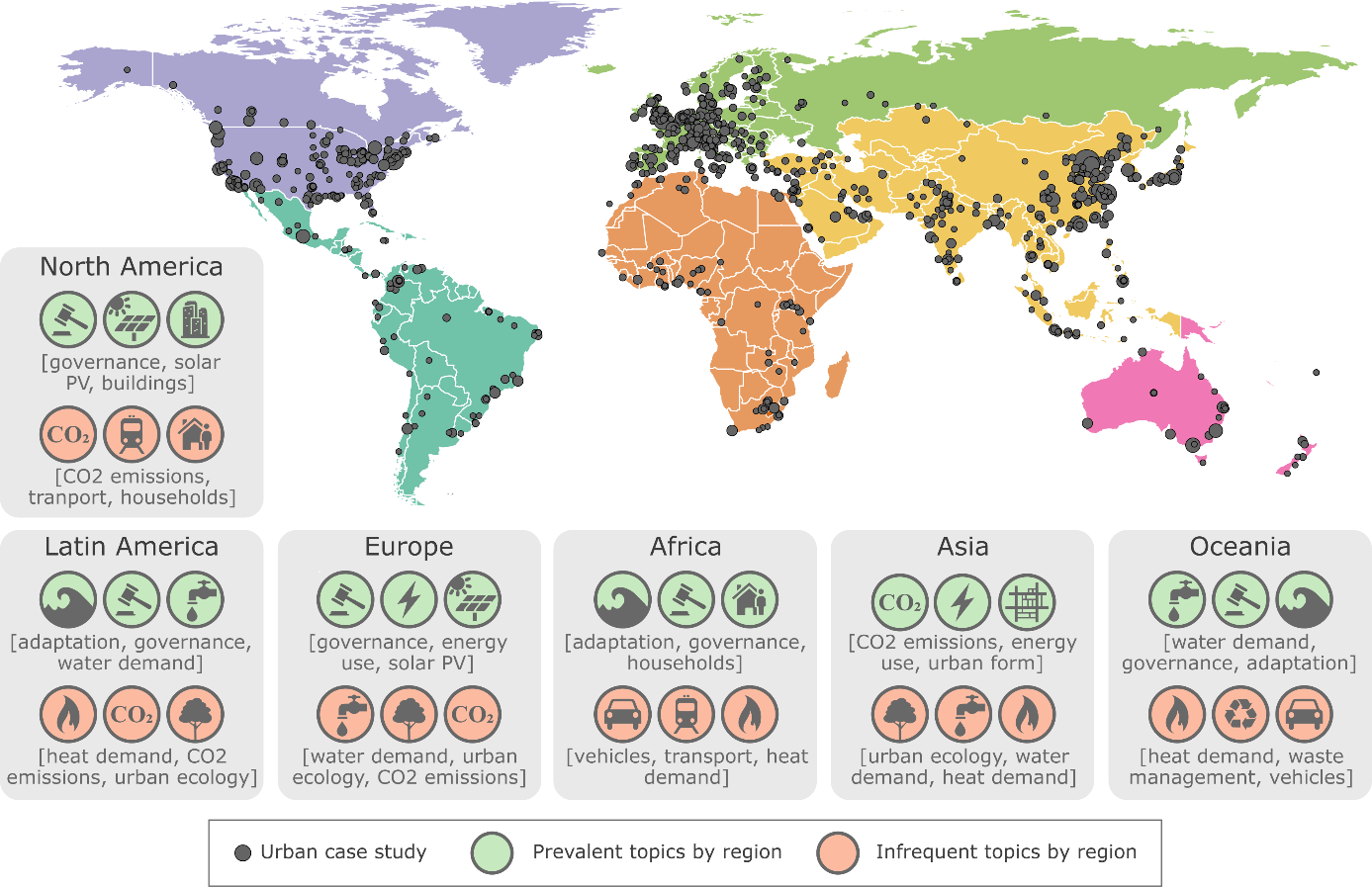
With the window on the 1.5°C and 2°C goals rapidly closing it is essential to immediately initiate infrastructure transformations wealthier Northern cities. The current focus of case study research on these cities is congruous with current debates in climate ethics, where responsibility for drastic mitigation action rests on the shoulders of high-emitters 7. Nonetheless, the majority of future urban emissions will originate from Asian and African cities, where ongoing processes of urbanization and infrastructure development provide a window of opportunity for establishing urban designs consistent with low-carbon mode choices and building use 8. Guiding these growing cities towards compact, low-carbon urban forms requires a major shift in research focus.

Redressing the lack of focus on smaller cities emerges as a second priority. Yet herein lies a more fundamental problem: whereas large cities are few in number and can be reasonably sure of dedicated case studies that address specific policy needs, smaller cities are far more numerous, rendering direct coverage of all such cities near impossible. In our dataset almost 60% of global mega-cities (17/29) are directly researched in the case study literature. This figure declines to less than 25% (281/1228) for medium-sized cities (SI Text Figure x). Learning about solutions across a variety of contexts and scales thereby requires major innovations in knowledge synthesis.

## Demand-side topics dominate urban case studies

Urban climate mitigation is a broad church, encompassing research on a variety of sectors (buildings, transport, waste), policies (infrastructure provisioning, behavioural incentives) and overarching concerns (human well-being, sustainability). The relevance of a particular research stream depends on the cities and context at hand. Some urban issues are known to be ubiquitous – car-centric transportation infrastructures often result in a variety of harms to human health, civic life and equal access to services – while others are far more location specific, such as high heating demands in northern latitudes, or climate adaptation needs in low-lying coastal cities. Understanding the scope of mitigation research carried out on cities is an entry point to structured learning on solutions.

As it is increasingly difficult to track the development of rapidly growing scientific fields, we turn to natural language processing methods to explore the thematic content of urban case studies. Using the identified corpus of 3,440 case studies we construct a matrix of documents and the words contained in their abstracts, factorising to obtain the ‘topics’ that describe commonly co-occurring words across the document set (we subsequently refer to this as “topic modelling”; see methods). In essence, machine reading software discovers the latent topics that permeate the document set and categorises each document accordingly, substituting for the laborious task of reading and tagging each article by hand. The unsupervised ‘learning’ in this method also reduces subjectivity in one’s overall assessment of a body of literature.



**Figure 3: Urban case study cities and topics by region**

Isolating 17 overarching themes in the set of case studies (SI Text Table 1), we observe a prevalence of demand-side topics, including transportation, waste management, and energy and heat demand in buildings – alongside issues of urban governance, urban form and CO2 emissions accounting. A single supply-side topic emerges, on solar PV. Topic modelling typically ascribes multiple topics to each document, allowing combinations of issues to be found, hence we see a wider set of sustainability concerns represented in the urban mitigation cases such as air pollution, water demand, urban ecology and climate adaptation.

Topics are not evenly distributed across different urban regions. Scaling up the analysis from individual documents to groups of documents, we observe that emissions accounting and urban form are frequent subjects of case study research situated in Asia (**Figure 3**), perhaps reflecting strong investments into engineering disciplines and education in China and South Korea (44% of all students in China graduate in science & engineering, compared with 16% in the US). This contrasts with the ubiquity of urban governance research, which captures research on policies and policy-making, in all other regions. And despite specifying no climate adaptation keywords in our search query, it emerges as the most prominent topic in the cities of Africa, Latin America and Oceania, reflecting a continued failure to place climate mitigation on the urban agenda in these regions.

Individual cities are hotspots for particular mitigation topics. Transportation case studies are well developed for London, but scarcely researched in New York City and Chicago (Table 1). Again, emissions accounting dominates the case study work on top-tier cities in China (Beijing, Shanghai and Tianjin), while topics around urban ecology, water demand and waste management are overlooked here – at least in the mitigation focused literature we identify. Table 2 in the SI text lists the articles we identify for the largest urban centre in Africa, Cairo, showing not just the scarcity of studies on this city, but the potential of topic modelling to rapidly expose the main research to date, in this case a narrow focus on building design and technologies.

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| --- | --- | --- | --- | --- |
| **City** | **N. studies** | | **Frequent topics** | **Infrequent topics** |
| Beijing | | 284 | CO2 emissions; Energy consumption; Air pollution | Urban ecology; Water demand; Waste management |
| New York City | | 146 | Urban governance; Buildings; Climate adaptation | Waste management; Transportation; CO2 emissions |
| Shanghai | | 140 | CO2 emissions; Energy consumption; Urban form | Urban ecology; Water demand; Waste management |
| London | | 117 | Urban governance; Transportation; Climate adaptation | Water demand; Waste management; Green roofs |
| Tianjin | | 66 | CO2 emissions; GHG emissions; Energy consumption | Water demand; Urban ecology; Vehicles |
| Los Angeles | | 59 | Green roofs; Water demand; Air pollution | Waste management; Heat demand; CO2 emissions |
| Tokyo | | 59 | Solar PV; Urban form; Climate adaptation | Urban ecology; Water demand; Households |
| Chicago | | 49 | Urban governance; Urban ecology; Climate adaptation | Waste management; Households; Transportation |
| Melbourne | | 49 | Climate adaptation; Water demand; Urban governance | Urban ecology; Vehicles; Heat demand |
| Paris | | 47 | Urban governance; Air pollution; Climate adaptation | Water demand; Urban ecology; Green roofs |

**Table 1: Frequent and infrequent topics in the 10 most studied cities**

Urban form describes the spatial characteristics of a city, including density and the configuration of land-use. It is a key bottleneck in reaching very low levels of energy demand 9,10. Yet while urban form is one of the most prevalent topics in the set of case studies, after governance and energy use (SI Text Table 1), an important question in the context of learning is whether future urbanisation challenges (or opportunities) are being anticipated, rather than responded to after the fact. Searching abstracts directly for keywords that might indicate such “forward looking” studies (e.g. “scenario” or “2050”; see methods for more detail), we find 333 documents that mainly emphasise CO2 emissions accounting, transportation and air pollution (SI Text Table 3). Notably, urban form is less prominent, and the fastest urbanising region, Africa, is particularly under-represented in this subset of documents. Just 2% of the case study literature in Africa takes a forward looking orientation (3 studies), contrasting with an average of 10% in other regions (SI Text Table 4).

Topic modelling can rapidly uncover the content of existing research streams, providing an overview and entry point for structured assessments of the literature. In this sample of urban mitigation case studies we identify several knowledge gaps, such as the lack of topic diversity in case studies on large Chinese cities, the absence of mitigation cases in African and Latin American cities, and the limited extent of forward looking studies on urban form. Topic modelling also highlights opportunities for consolidating well-developed literatures. For instance, there is scope for consolidating the very large number of life cycle and emissions inventory case studies. Indeed this would directly support efforts to establish an urban data science 11. More broadly, the overall focus of urban case studies on demand-side issues suggests this will be an important evidence base for the upcoming demand chapter of the IPCC 6th Assessment Report – one that requires dedicated attempts in knowledge synthesis 12.

## Limited efforts to learn from case study evidence

A learning agenda requires understanding variability. How do solutions differ across contexts? What drives variations in outcomes? Such questions can only be answered by moving beyond single case studies to examine and compare a wider set of contexts. In this regard, comparative studies that contrast two or more cases simultaneously offer one route to generalizable knowledge. Systematic literature reviews that review or perform secondary analysis on published cases offer another route. Both approaches have been extensively discussed in the methodological literature 13–15.

Comparative research is considered a strength of urban studies, albeit a locus of on-going debate. The epistemological value of North-South urban comparisons is widely discussed, for instance, as is the generalisability of individual cases 16. Our sample of documents suggests the urban mitigation community does not shy away from comparative research, but remains conservative in the number of cases compared. We identify 699 studies that refer to more than one city in the abstract (of 3,440 in the sample – approximately 20%). The majority of these studies (409) mention only two cities, with a steep decline to a few dozen studies on 5 or more cities (SI Text Figure 6).

Inter-regional comparisons are relatively rare. Figure 5 in the SI text visualises the pairwise correlations of cities within abstracts, aggregating by region. Asian cities tend to be compared to other Asian cities, European cities to European cities, and likewise in North America. Comparative literatures based in Latin America, Africa and Oceania, on the other hand, are far less cautious and have higher fractions of international comparisons, although fewer total studies. Considering the total scope of the urban case study literature (3,440 studies), the subset that is comparative (699), and internationally comparative (202), is small.

Based on a random selection and review of documents, we find little justification for why particular cities are bundled together, beyond claims of contextual diversity. Although this decision may often be driven by pragmatic concerns (such as funding and research partners), scientific learning in the field presupposes a transparent discussion of comparative logics 17. For instance, comparisons might proceed from the observation that common structural (political, economic, or geographic) characteristics drive urban phenomena, leading to differing path dependencies in energy consumption, and hence a role for typologies in structuring learning between similar types of cities 5. Alternatively, ubiquitous urban problems have been observed across many types of systems, such as the nexus of health, transportation and pollution externalities arising from agglomeration 18. Where individual cities demonstrate progress on solutions, for example through land-use policies and active travel provisioning, the resulting ‘proof of concept’ can prove highly relevant indeed across the urban landscape 8.

Another key route towards learning is through literature reviews and urban assessments. Formal review methods – those that deploy transparent and systematic procedures for literature selection, quality assessment and synthesis – are the gold standard for generating a robust evidence base for policy 19,20. These consist of a wide spread of quantitative, qualitative and mixed formal review approaches that are well-documented in the health sciences literature 21. Again, however, we find limited progress on this front.

We search the original set of documents identified in our urban mitigation query (12,918 articles) for review articles, and identify just 10 studies that apply formal review methods (see methods). The majority of these studies are narrative reviews (Table 2): akin to a normal literature review, but proceeding from a transparent search and selection of literature. Quantitative synthesis methods are sparse, comprising a single meta-analysis of residential demand-response programs (ref) and two studies that extract and analyse quantitative information from literatures on urban ecosystem services (refs). We do not find a single study referring to formal *case study* review methods, such as qualitative comparative analysis, case study meta-analysis, or case surveys 22 – although there are examples of these methods being applied directly to urban data (but not to the existing literature) 23.

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| --- | --- | --- |
| **Authors & year** | **Title** | **Method** |
| Li & Babcock 2014 | Green roofs against pollution and climate change. A review | Narrative review |
| Lwasa et al. 2014 | Urban and peri-urban agriculture and forestry: Transcending poverty alleviation to climate change mitigation and adaptation | Narrative review |
| Brands 2014 | Prospects and challenges for sustainable sanitation in developed nations: a critical review | Narrative review |
| Lwasa et al. 2015 | A meta-analysis of urban and peri-urban agriculture and forestry in mediating climate change | Narrative review |
| Kwan & Hashim 2016 | A review on co-benefits of mass public transportation in climate change mitigation | Narrative review |
| Garcez 2017 | What do we know about the study of distributed generation policies and regulations in the Americas? A systematic review of literature | Bibliometrics |
| Deng et al. 2017 | Co-benefits of greenhouse gas mitigation: a review and classification by type, mitigation sector, and geography | Bibliometrics and narrative review |
| Francis & Jensen 2017 | Benefits of green roofs: A systematic review of the evidence for three ecosystem services | Quantitative synthesis |
| Srivastava, Passel & Laes 2018 | Assessing the success of electricity demand response programs: A meta-analysis | Meta-analysis |
| Song et al. 2018 | The economic benefits and costs of trees in urban forest stewardship: A systematic review | Bibliometrics, quantitative synthesis, narrative review |

**Table 2: Formal reviews of urban climate change mitigation.** The minimum criteria for a ‘formal review’ is the systematic selection of literature via a database search. Some reviews (7,8,9) focus on non-urban issues, but derive important conclusions for scientific learning at urban scale, and thus should be included in the relevant literature base on urban-scale climate change mitigation. See methods for our identification procedure.

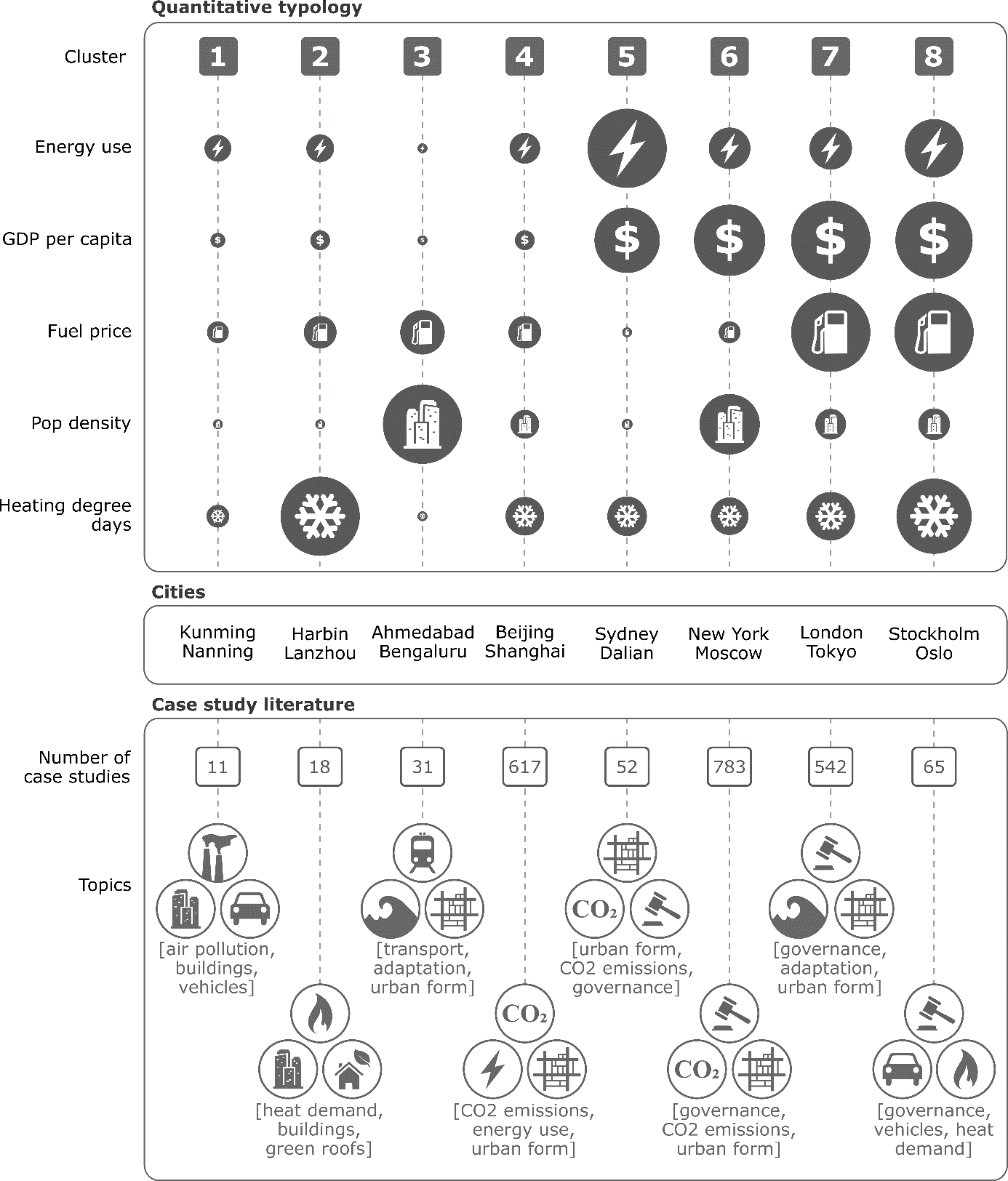
The dearth of formal reviews on urban case studies is consistent with the wider field of energy studies and climate change mitigation 4,20 – and unsurprising given the challenge of varied case study methods, locations and scales. Yet, at the very least, a greater focus on transparent literature selection is needed to avoid overlooking research, particularly the minority of studies on smaller cities and less comprehensively covered regions. As with the narrow scope of comparative urban mitigation research, limited progress on this front suggests major innovations are needed to stimulate learning on urban solutions.

## Towards learning about urban mitigation solutions

- Learning about cities is hampered by the diversity of contexts. This is also a common critique of the field (know any references?) To this problem we can add three others: a bias in case study coverage, uneven progress on urban mitigation topics, and limited efforts to synthesize the literature.

- Cities need to be categorised in order to make progress on learning. How else will smaller cities gain the needed evidence base? We see a lot of efforts on the quantitative front, using big data and crowdsourcing. This is promising, but needs to be matched with similar efforts along quantitative lines: what are the relevant urban peer groups in terms of prevailing social practices, or the political economy?

- Above all, an integrated and synthetic framework is required for learning about cities. We propose matching typologies with bottom-up assessments of the literature base…

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## Conclusion

In this perspective we survey the landscape of case studies on urban climate mitigation. We focus on the geographic and topic distribution of research to date, and assess progress on comparative studies and systematic reviews. 5 issues appear to stand in the way of learning in this literature domain. (1) A substantial and unwarranted bias exists towards studies on large cities, and studies situated in the global North. (2) Only a handful of studies exist on African cities. These tends to emphasise adaptation over mitigation, and fail to address future urbanisation challenges. (3) The literature on Asian cities is strongly focused on emissions accounting, and is not yet balanced by a focus on policies and sustainability issues. (4) The existing comparative research lacks international scope and tends to be under-justified on conceptual grounds. (5) Only minor attempts have been made at systematically aggregating urban case study research through formal review methods.

Our sample of studies captures some non-English language articles (180 in total), most likely ignoring many others; nor does it capture grey literature such as NGO reports. Nonetheless, these results resonate with calls to develop global urban solutions and ‘leave no city behind’ in scientific assessments 2,3,24. The use of bibliometric techniques and topic modelling show that it is possible to judge progress on these goals with reduced subjectivity, even as the quantity of studies rapidly grows. Scaling the analysis to individual cities, groups of cities, or regions provides a flexible means to track and review literatures in advance of AR6 and future urban assessments. These methods are also applicable to other areas of case study literature, including urban adaptation research 25 and land-use science 26.

Our systematic review and topic modelling reveals that case studies are dominated by demand-side issues, such as demand for heating, transport, and water, but much less on supply-oriented solutions. This contrasts with the majority of climate mitigation scenarios that focus on supply-side technologies in the energy and also transport sector. The higher spatial resolution of city-level analysis appears to coincide with higher resolution on end-users and their concerns, but less investigation of the role of supply-side technologies to realize city-level climate mitigation. This insight has inversely relevant implications for the study of demand-side climate solutions that will have their own chapter in the IPCC’s AR6 report 16. A comprehensive understanding of demand-side solutions will need to build extensively on urban case studies.

Nonetheless, several pre-conditions need to be met to make progress on urban solutions. There are clear research gaps on African cities and smaller cities in Asia. Locating research efforts, as well as stakeholder engagement and policy advocacy in these regions will be instrumental to avoiding lock-in and realising compact, low-carbon urban forms that can tackle the coming mitigation challenge 10,27. Where large bodies of research already exist for other locales, the literature scoping methods shown here could support the consolidation of existing work into systematic reviews, allowing for a shift in focus towards less studied topics and locations.

Above all, a culture of learning is needed in the field. From making individual case studies available for meta-analyses, to increased ambition in comparative research, to large scale reviews of the case study literature that apply formal methods. (…)

**Methods**

*Literature scoping*

A search query combining ‘urban’ and ‘mitigation’ synonyms was used in the Web of Science and Scopus to identify relevant documents (Table 3). As of March 2018 this search returned 12,918 documents (unconstrained by language or document type).

|  |  |
| --- | --- |
| Urban synonyms | Mitigation synonyms |
| ("urban\*" OR "municipal" OR "city" OR "cities" OR "metropolitan") | (“Paris Agreement” OR “low carbon” OR "decarboni\*ation" OR (“energy” OR “carbon” OR “CO2” OR “GHG” OR “greenhouse gas” OR “climat\*”) NEAR/3 ("mitigation" OR "reduc\*" OR "polic\*" OR "governance")) |

**Table 3: Search query for urban climate mitigation literature.** The two strings are combined with an ‘AND’ operator and entered as a topic search in the Web of Science, and a title-abstract-keyword search in Scopus.

*Identifying cases*

To identify urban case studies we searched the abstracts of the queried documents for city names. We use the Geonames database of geographic locations, which aggregates national survey data, travel destinations and open sourced contributions. Cities with a population greater than 15,000 were considered. This narrows the document set to 3,440 studies that directly refer to a city in the abstract or title. Double counting where an article mentions multiple city names, we obtain 4,730 case studies on individual cities. We excluded the text “Paris Agreement” and “Kyoto Protocol” from abstracts to avoid false hits.

*Topic modelling*

We use the sklearn library in python 28 to process and produce a topic model from the 3,440 studies mentioning a city in the abstract. Weighting terms in each document by the inverse of the number of times they appear across the corpus (tf-idf), we apply non-negative matrix factorisation 29 to a matrix of documents × terms, to identify 17 topics. The resulting matrices, whose product approximates the document-term matrix, are used to label documents by topic and topics by term. Each topic is given a name manually, according to the words and documents associated with it.

*Future-looking case studies*

To identify case studies with a future-looking orientation (including for example, mitigation scenarios, or projections of urbanisation, land-use, or energy demand), we manually search for the following keywords within abstracts: “scenario” OR “2020” OR “2025” OR “2030” OR “2040” OR “2045” OR “2050”. A random selection and screening of these documents showed they were broadly in line with our expectations.

*Systematic reviews*

To identify systematic reviews of the case study literature we manually search the original document set (12,918 studies) for the following keywords: “ meta-“ OR “systematic review” OR “scoping” OR “narrative review” OR “qualitative comparative analysis” OR “QCA” OR “scientometric” OR “synthesis”. The results are hand filtered to exclude non-urban, non-mitigation and non-review articles.

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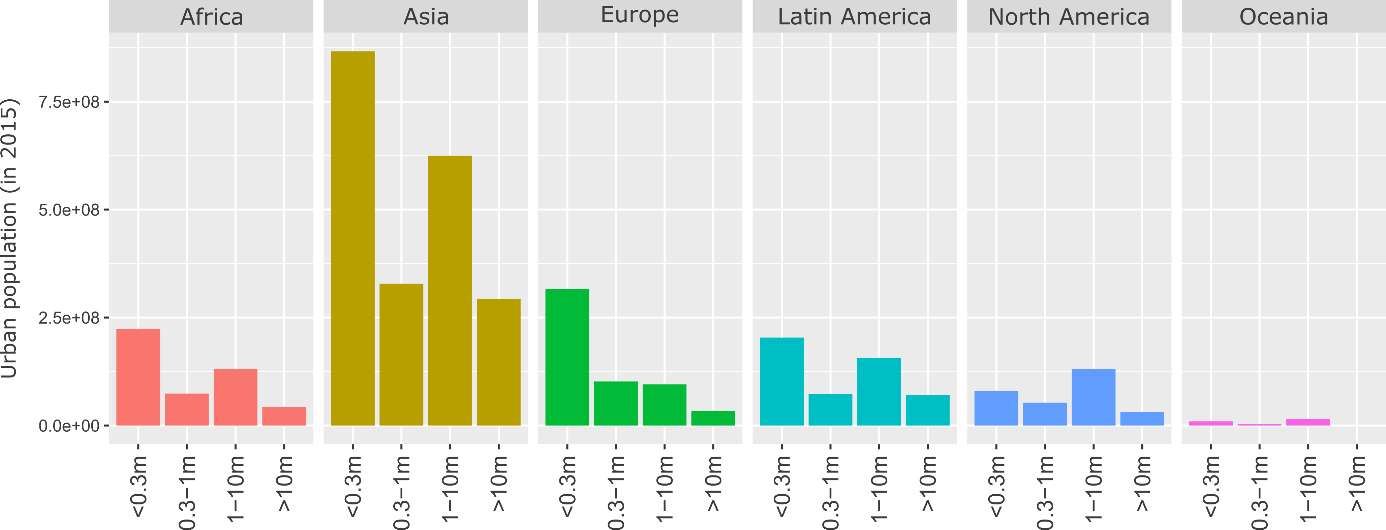
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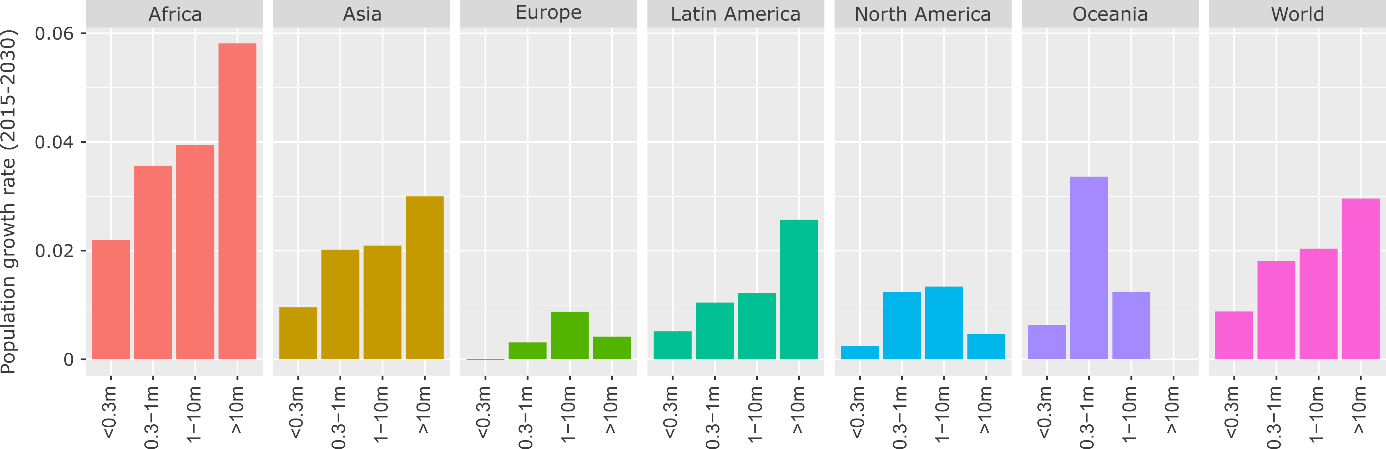
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# Supplementary information

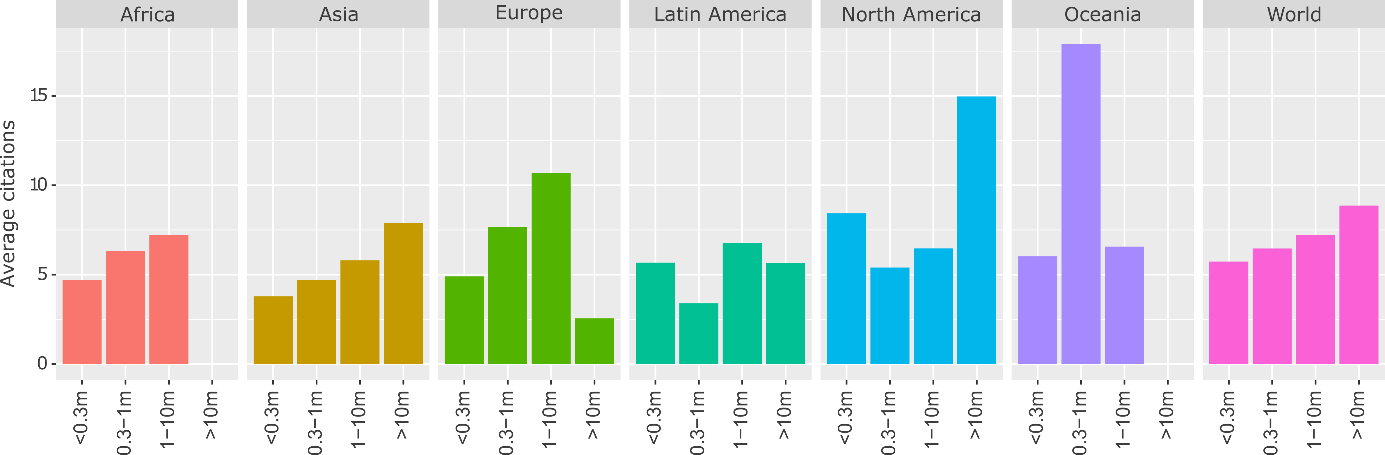
## Additional Figures and Tables

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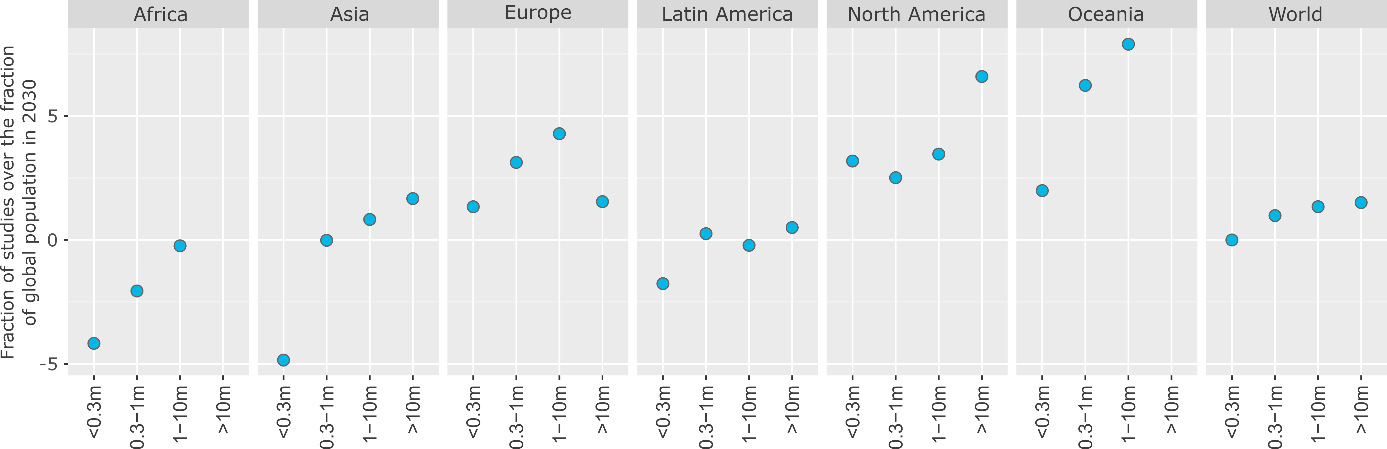
**Figure 1: Total urban population (in 2015) by region and city size**



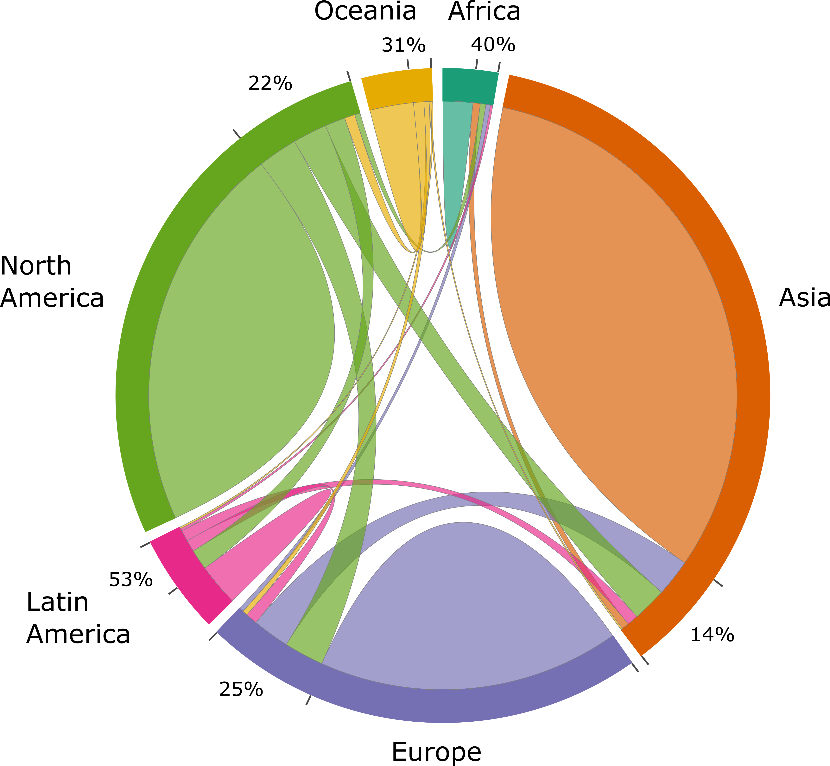
**Figure 2: Projected population growth rate by region and city size, 2015-2030**



**Figure 3: Average citations of urban case studies by region and city size.** Citations are divided equally among cities in double-counted articles.



**Figure 4: The global distribution of urban case studies versus population**. To normalise, where the numerator (% of global population in a region & city size) exceeds the denominator (% of case studies in a region & city size), we subtract the fraction from 2.



**Figure 5: Inter and intra-regional comparative research on urban climate mitigation.** Each link in the chord diagram is based on the pairwise coupling of two cities within a document. Documents where more than one city is mentioned in the abstract are used, totalling 699 studies. The proportion of regional couplings that pair with other regions (i.e. inter-regional urban comparisons) are indicated as percentages.

|  |  |  |  |
| --- | --- | --- | --- |
| **ID** | **Topic Name** | **Stemmed Keywords** | **Marginal Topic Distribution** |
| 1 | Urban governance | citi; polici; govern; local; develop | 9.3 |
| 2 | Energy consumption | energi; consumpt; effici; sector; beij | 7.9 |
| 3 | Urban form | urban; area; land; ecolog; model | 7.2 |
| 4 | Solar PV | system; solar; power; electr; energi | 7.0 |
| 5 | CO2 emissions | carbon; emiss; industri; china; lowcarbon | 6.8 |
| 6 | Buildings | build; design; energi; perform; residenti | 6.8 |
| 7 | Climate adaptation | climat; chang; adapt; risk; govern | 6.5 |
| 8 | Air pollution | air; pollut; health; qualiti; concentr | 6.2 |
| 9 | Transportation | transport; travel; traffic; public; car | 5.7 |
| 10 | GHG emissions | ghg; emiss; greenhous; gas; reduct | 5.4 |
| 11 | Vehicles | vehicl; electr; fuel; drive; emiss | 4.8 |
| 12 | Households | household; incom; electr; survey; hous | 4.7 |
| 13 | Waste management | wast; landfil; solid; manag; msw | 4.6 |
| 14 | Water demand | water; suppli; manag; demand; treatment | 4.6 |
| 15 | Heat demand | heat; district; thermal; demand; network | 4.6 |
| 16 | Green roofs | roof; temperatur; cool; green; surfac | 4.5 |
| 17 | Urban ecology | tree; forest; plant; speci; sequestr | 3.4 |

**Table 1: List of topics and their keywords**

|  |  |  |  |
| --- | --- | --- | --- |
| **Title** | **Year** | **Authors** | **Topics** |
| Energy efficiency strategies in urban planning of cites | 2009 | Khalil, H.A.E.E. | Urban governance; Energy consumption; Urban form |
| Active solar retrofit of a residential house, A case study in Egypt | 2010 | Attia, S., De Herde, A. | Buildings; Heat demand; Green roofs; Solar PV |
| Urban form, thermal comfort and building CO2 emissions - a numerical analysis in Cairo | 2011 | Fahmy, M, Sharples, S | Buildings; GHG emissions; Green roofs; Urban form |
| Effect of building form and urban pattern : On energy consumption of residential buildings in different desert climates | 2012 |  | Buildings; Urban form |
| Governing the transition to natural gas in Mediterranean Metropolis: The case of Cairo, Istanbul and Sfax (Tunisia) | 2015 | Verdeil, E, Arik, E, Bolzon, H, Markoum, J | Urban governance; Energy consumption; Heat demand; Urban form |
| Reducing cooling demands in a hot dry climate: A simulation study for non-insulated passive cool roof thermal performance in residential buildings | 2015 | Dabaieh, M, Wanas, O, Hegazy, MA, Johansson, E | Buildings; Green roofs |
| Assessment of building integrated photovoltaics for the residential section in representative Urban areas in Egypt | 2016 |  | Buildings; Energy consumption; Households; Solar PV; Urban form |
| High-rise buildings in context of sustainability; urban metaphors of greater Cairo, Egypt: A case study on sustainability and strategic environmental assessment | 2016 |  | Buildings |

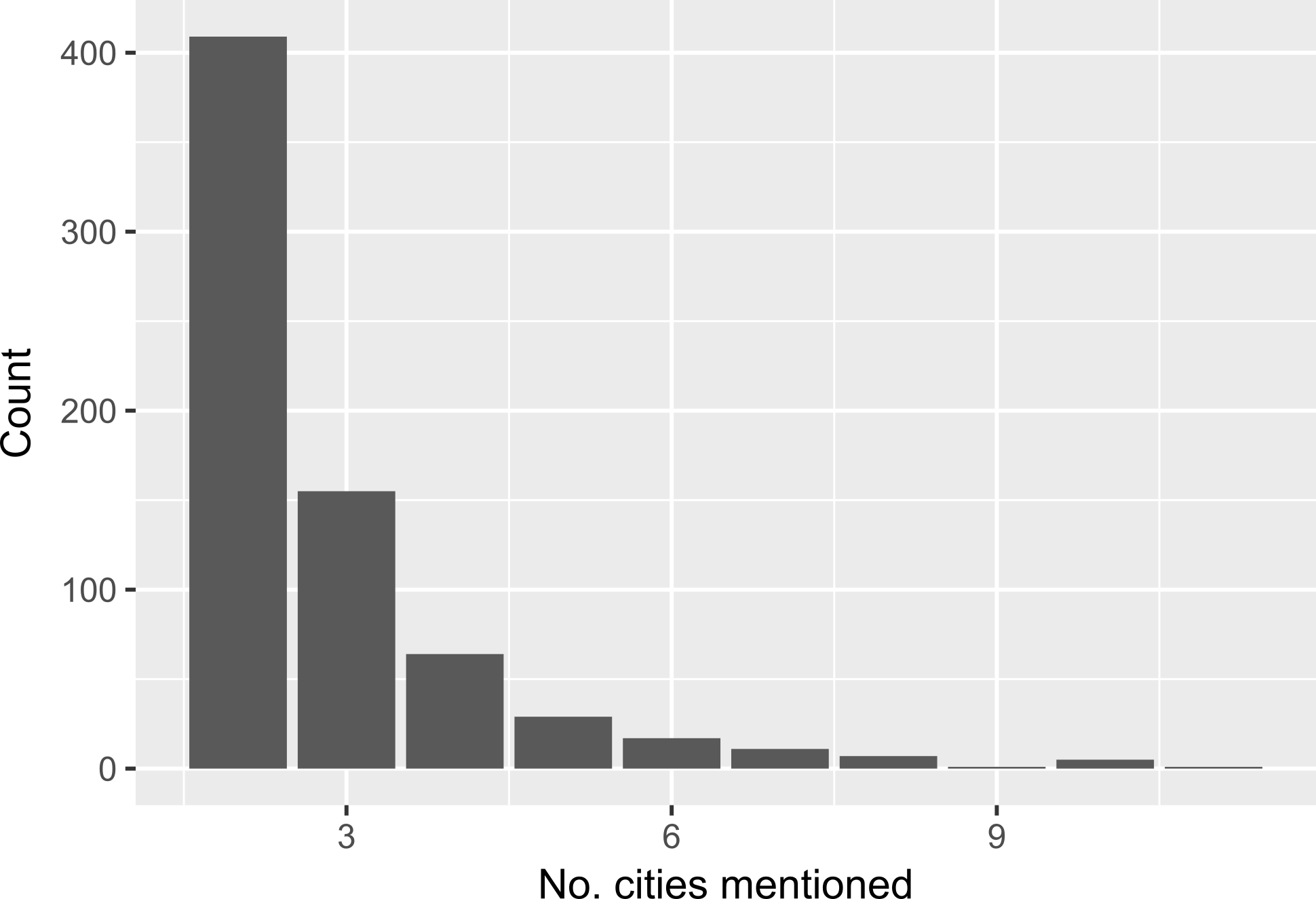
**Table 2: Urban climate mitigation literature on Cairo**

|  |  |  |  |
| --- | --- | --- | --- |
| **Topic** | **Proportion** | **Topic** | **Proportion** |
| GHG emissions | 0.19 | Urban form | 0.08 |
| Transportation | 0.16 | Water demand | 0.08 |
| Air pollution | 0.16 | Waste management | 0.07 |
| CO2 emissions | 0.14 | Solar PV | 0.07 |
| Energy consumption | 0.12 | Households | 0.06 |
| Urban governance | 0.11 | Heat demand | 0.06 |
| Vehicles | 0.10 | Urban ecology | 0.05 |
| Climate adaptation | 0.10 | Green roofs | 0.04 |
| Buildings | 0.10 |  |  |

Table : Topic proportions of 'forward-looking' case studies

|  |  |  |  |
| --- | --- | --- | --- |
| **Region** | **No. case studies** | **No. ‘forward-looking’ studies** | **Fraction** |
| Africa | 175 | 4 | 0.02 |
| Asia | 1761 | 190 | 0.10 |
| Europe | 1207 | 129 | 0.11 |
| Latin America | 246 | 26 | 0.11 |
| North America | 1126 | 84 | 0.07 |
| Oceania | 184 | 19 | 0.10 |

Table : Regional coverage of 'forward-looking' case studies



**Figure 6: Number of cities mentioned in comparative studies**