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ORIGINAL ARTICLE

Dynamism and stasis in the climate policies of German cities between 2018 and 2022

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Abstract

As climate change progresses, significant mitigation and adaptation efforts are needed, including at the local level, and there is a growing literature analysing whether and how cities are taking action. However, few studies have assessed the progress and dynamics of urban climate policies over time. We examine the development of climate mitigation and adaptation at the institutional level in 104 German cities between 2018 and 2022, based on their membership of city networks, the awards and prizes they have received, and the existence, publication year, number of updates, and goals or contents of their climate strategies. We complement these findings with insights from interviews and document analyses in 15 cities. On this basis, we trace general trends in municipal mitigation and adaptation policies, as well as specific changes, dynamics and constants for selected cities and city clusters. We find that both fields of policy are highly dynamic and that there is a general trend towards more comprehensive mitigation and adaptation activities. However, adaptation is still lagging behind mitigation, and some less active cities have not developed during this period, leading to further polarisation between leaders and laggards. We discuss several reasons for these divergent developments, including differences in capacity, city size, location in federal states, and the issue of symbolic politics. We also reflect on the limitations of our approach and consider potential steps for improvement.

Keywords Climate mitigation · Climate adaptation · Urban planning · Adaptation tracking · City ranking

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1 Introduction

As climate change progresses, the need for mitigation and adaptation increases. While governments at all levels have introduced policies to reduce greenhouse gas emissions for more than three decades, most only started much later to adapt to current and expected future climate conditions, such as extreme weather events and sea level rise (IPCC 2022). In response to these developments, studies have begun to assess where we are in terms of mitigating climate change and adapting to its impacts, and also to assess whether targets – particularly those set by the 2015 Paris Agreement – are being met (Azevedo and Leal 2017; Reckien et al. 2018). Recent insights show that previous and existing mitigation and adaptation efforts at the global and international level are far from sufficient (IPCC 2022; UN 2023); research could help to inform possible improvements in structures, processes and the focus of future policy.

Urban areas are crucial sites for mitigation and adaptation (Aboagye and Sharifi 2024; Amundsen et al. 2018; Rosenzweig et al. 2010). They are major emitters of greenhouse gases and home to more than half the global population, and their assets and infrastructure tend to be more vulnerable to frequent and intense heat waves, floods and other extreme weather events (IPCC 2022). In addition, cities are partly seen as being more committed to climate change action than nation states (Rosenzweig et al. 2010). They are closer to the different stakeholders that need to be motivated to take action and are able to shape local developments.

Despite these dynamics, few studies focusing on many cities go beyond describing and explaining the current state of climate mitigation or adaptation, and instead track developments over time (Biesbroek et al. 2018; for exceptions see: Canosa et al. 2020; Reckien et al. 2023). Such analyses are hampered by the availability of data and the fact that data collection is often part of projects with a fixed duration (Biesbroek et al. 2018). To assess the progress and dynamics of cities' climate policies, we need to compare conditions and outcomes at different points in time. In this article, we address this issue by highlighting progress in the local institutionalisation of climate mitigation and adaptation over recent years.

As a baseline, we use the results of Otto et al. (2021a), who ranked the climate activities of 104 German cities at the end of 2018, based on their memberships of city networks, the awards and prizes they achieved, and the existence, publishing year, updating and goals or contents of their climate strategies. In this paper, we examine how climate mitigation and adaptation have evolved until 2022 in the same 104 cities using the same assessment approach. We also complement these findings with qualitative insights from 15 of the cities, which provide more detailed knowledge of how and why policies may have changed over this period, and thereby go beyond assessing developments at the strategic level of plans. The main research questions of this article are:

1. What are the general trends in municipal mitigation and adaptation policy in 104 German cities between 2018 and 2022?
2. What are the specific trends, dynamics and constants for selected cities or clusters of cities?

By answering these questions, this article provides detailed knowledge about the state and process of urban mitigation and adaptation in Germany. More generally, it can also add to our knowledge of the factors that may contribute towards municipalities accelerating or

decelerating their climate activities. We also discuss whether the approach to rank cities on their mitigation and adaptation activities, which was developed five years ago by Otto et al. (2021a) and is reused for this article, is still valid or what changes are needed to respond to policy and societal developments.

2 Background

2.1 Drivers and dynamics of local mitigation and adaptation policies

A growing literature investigates the activities of large numbers of cities in mitigation (Salvia et al. 2021; Wang et al. 2020; Vanhuyse et al. 2023), adaptation (Araos et al. 2016; Otto et al. 2021a; Kalbarczyk and Kalbarczyk 2022; Reckien et al. 2023) or both fields at the same time (Aboagye and Sharifi 2023; Debbage et al. 2025; Grafakos et al. 2020; Otto et al. 2021a; Pietrapertosa et al. 2019; Reckien et al. 2018). A growing number of cities are developing strategic plans and implementing measures, although progress in adaptation is still lagging behind mitigation, and adaptation is found to be less (but increasingly) represented in joint climate action plans (Aboagye and Sharifi 2023; Pimenta and Kamruzzaman 2024; Debbage et al. 2025; Reckien et al. 2023).

A long-running theme in studies of local climate policy relates to the factors that contribute to action (van der Heijden 2019). Where national or regional governments require municipalities to produce plans or implement certain policies, there is a clear legal driver for local governments to act. Unsurprisingly, studies have found that cities are much more likely to produce mitigation and/or adaptation plans in countries that have introduced such mandates, such as France, Denmark, Ireland and the UK (Buzási et al. 2024; Heidrich et al. 2016). Where no such legal obligations exist, local political drivers for action need to be strong – and municipalities also need to possess the expertise and financial capacities to develop and implement policies. This means that, in general, larger cities are more likely to be active in both climate policy fields (Araos et al. 2016; Otto et al. 2021a, b; Reckien et al. 2015; Salvia et al. 2021), and cities with younger and wealthier populations, universities or research institutes, stronger green parties, civil society actors and greater reliance on the service economy tend to introduce more ambitious mitigation policies (Haupt et al. 2023a).

Although these factors are important, broader societal or economic developments can sometimes change the political agenda very quickly and lead to policymakers focusing on different priorities. Similarly, some studies show that adaptation can be motivated by the experience of extreme weather events as, among other things, the sense of urgency or the call to adapt increases (Aguiar et al. 2018; Braunschweiger and Ingold 2023; Nohrstedt et al. 2022; Schoenefeld et al. 2023; Shi et al. 2015). In addition, national or regional funding schemes for climate action can also trigger local climate policies (Kern et al. 2023).

These internal and external factors mean that local climate policies are dynamic, and the same municipalities are unlikely to remain as 'leaders' or 'laggards' indefinitely. In Germany, as in many other countries, large and medium-sized cities such as Freiburg, Heidelberg, Hanover, Munich, and Frankfurt am Main took the lead in climate mitigation as early as the late 1980s and early 1990s. Although it is often possible to detect a visible cohort of forerunners and identify a group of municipalities that have not started specific initiatives in the past and do not plan to do so in the future, there are also municipalities that cannot be classified as leaders or laggards. For example, a study of all 311 Finnish

municipalities revealed that more than 80 municipalities did not belong to either of these two groups (Kern 2020).

As such, Kern (2020, 2023) identifies six types of municipalities. On the one hand, we often have (1) a relatively small number of forerunner cities which stay ahead, (2) a group of followers that want to catch up with the forerunners, and (3) mostly smaller, latecoming municipalities, which only started local climate actions quite recently. On the other hand, however, urban climate policy is not always characterised by progress, because internal or external barriers, such as a lack of resources or support, can lead to stagnation or regression. Thus, Kern (2023) also points out (4) a group of formerly quite active cities which are straggling and falling behind, (5) followers which started climate initiatives but are stepping out and (6) a group of often smaller municipalities with low capacities and little sense of urgency which stay behind. Applying this typology to the Finnish case by analysing sustainability and climate policy initiatives since the 1990s, Kern (2020) identified 7 cities as *forerunners staying ahead* (group 1); 29 municipalities as *followers catching up* with the forerunners (2), 23 as *latecomers stepping in* (3); 9 as *forerunners falling behind* (4); 22 as *followers stepping out* (5); and 221 as *laggards staying behind* (6). Given that the situation in Finnish local government has been so dynamic over 30 years, we might expect similar changes to be in play in other countries, too.

2.2 Urban mitigation and adaptation in the German context

Despite national support for mitigation and adaptation, e.g. through research programmes and funding schemes, up until 2024 they were both only voluntary tasks for local authorities in Germany (Bulkeley and Kern 2006; Kern et al. 2023).[1] Nevertheless, the first German cities began to take strategic action on mitigation in the late 1980s, although they did not begin to introduce adaptation policies until the end of the 2000s (Otto et al. 2021a). Recent studies show that mitigation is still given higher priority than adaptation, and both areas tend to be less prioritised than other municipal functions (Koerth et al. 2019; Otto et al. 2021a). While all but one of the 104 large and medium-sized German cities had published a climate change mitigation plan by the end of 2018 (Otto et al. 2021a), only 59% of these municipalities had already developed an adaptation plan or a mitigation plan with comprehensive adaptation content, and just 13% were working on one (Otto et al. 2021b).

In line with literature from other countries (Kern 2019; Reckien et al. 2018; Salvia et al. 2021), city size is an important predictor of climate ambition in Germany. For example, larger German cities are more likely to have a mitigation and an adaptation plan than smaller municipalities, and more likely to have set ambitious greenhouse gas reduction targets (Otto et al. 2021a). Conversely, studies into smaller cities have found that a much smaller share have developed adaptation strategies (18% (Hasse et al. 2019) and 33% (Reckien et al. 2018)).

Notably, however, various factors may have contributed to greater dynamism in German cities' climate policy in recent years, which could have led to some smaller cities catching up with their larger counterparts. For example, the rapid emergence of

[1] Both the Heat Planning Act and the Climate Adaptation Act came into force in 2024. For the first time, these laws lay down binding nationwide requirements for municipalities to develop local heat plans and adaptation strategies.

Fridays for Future played a decisive role in contributing to many German municipalities declaring 'climate emergencies' and introducing more ambitious policies in 2019 and 2020 (Haupt et al. 2023b; Eckersley et al. 2025). Although new issues brought much of this momentum to a halt in 2021 (Haßler et al. 2023), the development or updating of municipal mitigation plans, and sometimes adaptation plans, that began during the period of high attention to climate issues, has generally continued. Additionally, several extreme weather events, such as heatwaves and intense rainfall events leading to flooding, affected Germany from 2019 to 2022 (Ballester et al. 2023; Thieken et al. 2023). Another issue that may have influenced adaptation is a change in the funding available to produce local strategies. While the so-called *Kommunalrichtlinie* supported the development of municipal strategies in both policy areas until 2019, adaptation funding was stopped. Only at the end of 2021 were municipalities again eligible to apply for funding for an adaptation strategy under a different funding programme (*Deutsche Anpassungsstrategie*). Furthermore, the support provided to municipalities within the 16 federal states varied over time, with the states of North Rhine-Westphalia and Thuringia, for example, pursuing adaptation in a more coordinated and direct manner than many other parts of Germany (Eckersley et al. 2023; King 2022).

This changing external context, alongside any internal political or personnel changes within municipalities, is likely to significantly impact local climate policy. However, there has been little research into whether and how cities might become more (or less) ambitious over time. Such studies are important from a policy perspective because they help us ascertain the extent to which humanity might be on track to achieve climate objectives, and they can also help academics to understand the factors that contribute towards cities changing (or not) their approaches. With this in mind, we now highlight how individual cities and groups of cities (clusters), may have changed their positions in terms of climate mitigation and adaptation efforts over recent years.

3 Methods

Figure 1 shows our methodological approach, which included research and document analysis of 104 cities' mitigation and adaptation policies, ranking and cluster analyses, and semi-structured interviews in 15 selected cities.

3.1 City sample and ranking approach

To enable a comparison of two points in time (31/12/2018 and 31/12/2022), we investigate the same 104 German cities that were examined in Otto et al. (2021a) and apply the same assessment criteria. All these municipalities have at least 50,000 inhabitants, accounting for 34% of the total German population (see supplementary information SI 1 for the location of all 104 cities). We assessed each city's climate activity along three dimensions for both mitigation and adaptation, and cities could potentially achieve a total of 100 points for each area (details are given in Otto et al. (2021a)):

- Commitment (33 points), divided into the indicators a) membership of relevant city networks (16.5 points) and b) participation in relevant certification programmes and awards in competitions (16.5 points);

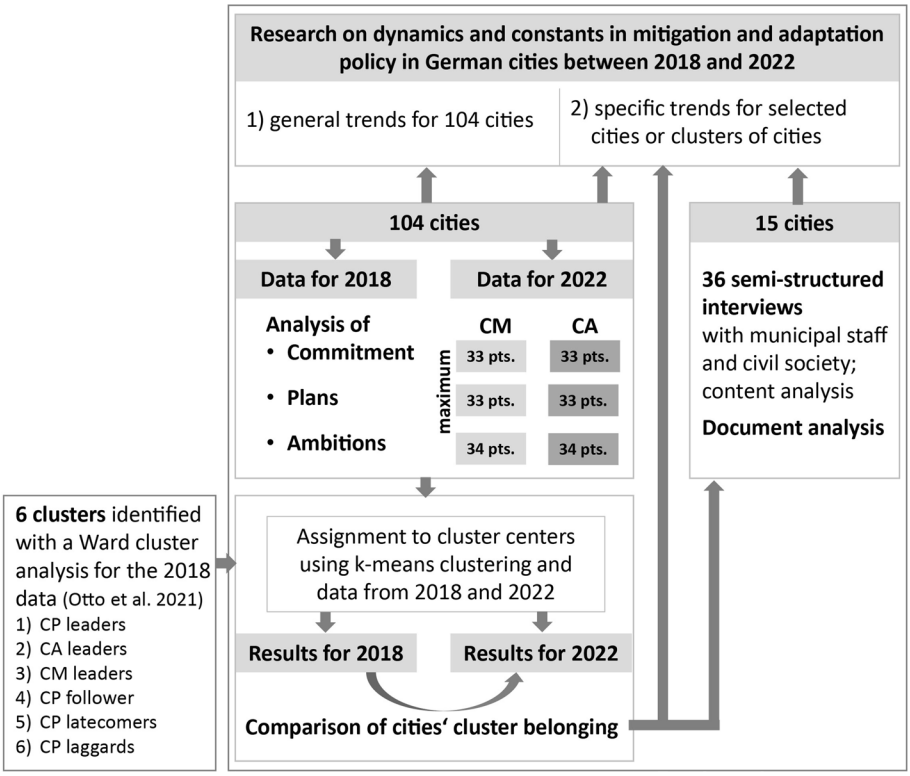

Fig. 1 Overview of methodological approach (CM: climate mitigation, CA: climate adaptation, CP: climate policy)

- Plans (33 points), including a) existence of plans (9 points), b) year of publication of the first plan (15 points)[2] and c) updates of plans (9 points);
- Ambitions (34 points), which for mitigation refer to the overall target for CO_2 or greenhouse gas (GHG) emissions reduction (17 points) and the proposed CO_2/GHG reduction per year (17 points), and for adaptation relates to the extent of measures foreseen in adaptation plans (34 points).

The assessments for mitigation and adaptation were coded, analysed and ranked separately.

[2] Originally, cities received 4 points for adaptation plans published in 2018 and 3 points for adaptation plans in progress. In the updated assessment 2022, cities with plans published in 2019 or 2020 receive 3 points, and 2 points for plans from 2021 or 2022. Cities that are preparing plans receive 1 point. Such adjustments are not necessary for mitigation, as all but one city had a mitigation plan in place by 2018.

Table 1 Comparison of scores 2018 and 2022 for mitigation and adaptation

	Climate mitigation		Climate adaptation	
	2018	2022	2018	2022
Selection of activities on which dimension A-C are based				
Share of cities that are members of at least one relevant city network (dimension A)	81.7%	88.4%	34.6%	36.5%
Share of cities that participate in competitions or certification programmes (dimension A)	61.5%	67.3%	14.4%	30.8%
Share of cities that have published mitigation/adaptation plans (dimension B & C)	99.0%	100%	58.7%	76.9%
Scores for the three dimensions				
A Commitment (max. 33)—Mean value	6.8	7.7	5.1	6.7
B Plans (max. 33)—Mean value	22.8	23.7	10.8	13.2
C Ambitions (max. 34)—Mean value	17.3	22.8	11.8	17.9
Total scores (maximum of 100)				
Lowest score	0	15	0	0
Highest score	76	84	80.5	80.5
Mean value	46.9	54.1	27.7	37.8
Coefficient of variation	32%	28%	87%	63%

3.2 Cluster analysis

In Otto et al. (2021a), the 104 cities were grouped into six clusters based on a hierarchical Ward-clustering. The six assessment criteria (i.e., three for each policy field as shown in Table 1) were used as input variables and the distances between cities were calculated by Squared Euclidean Distances. Six different groups of cities (clusters) were identified: cluster 1 was termed "climate policy leaders", cluster 2 "climate adaptation leaders", cluster 3 "climate mitigation leaders", cluster 4 "climate policy followers", cluster 5 "climate policy latecomers" and cluster 6 "climate policy laggards". For this study, we undertook another cluster analysis: Each city was assigned to one of these six clusters based on our assessment of the 2022 data (see Fig. 1). This was done with IBM SPSS Statistics Version 29.0.1.1 by a k-means clustering (classification only) using the mean values of the six clusters presented in Otto et al. (2021a) as centres. Since the k-means algorithm works differently from the Ward-algorithm, this classification was also done with the assessment points as of 2018 to enable a fair comparison between the results from 2018 and 2022. In comparison to the clusters for 2018 originally reported by Otto et al. (2021a), the k-means algorithm reclassified eleven cities, leading to small changes in all clusters but preserved the overall picture and distribution of cities. In particular, there were no transitions between the group of active cities (clusters 1 to 4) and the rather inactive cities (clusters 5 and 6). Hence, the differences were judged as being minor.

3.3 Interviews and document analysis in 15 cities

The quantitative cluster analyses were complemented by qualitative case studies in 15 selected cities that represent all six clusters and include examples of cities that moved between different clusters: Aachen, Bergisch-Gladbach, Cottbus, Emden, Erlangen, Gera, Kempten, Krefeld, Potsdam, Regensburg, Remscheid, Rostock, Worms, Wuppertal and Würzburg (see Section 4 and supplementary information SI 1).

We conducted 36 semi-structured expert interviews, 19 with municipal staff (e.g. employees of climate coordination units or the environmental department) and 17 with civil society actors (*Fridays for Future* or other local civil society groups) on the development of climate mitigation and adaptation in their city. Interviewees were identified through desk research and following recommendations of other people we spoke to (snowball sampling). The interviews were recorded, transcribed and analysed. The first step of the analysis included sequencing according to thematic units and codes, and the second stage involved categorizing and comparing text units from the different interviews. The interviews were complemented by in-depth analyses of various policy documents, including key climate-related publications such as mitigation and adaptation plans, energy or climate reports, further related municipal reports and plans (e.g. urban development or sustainability plans), media reports and protocols of city council meetings.

4 Results

Comparing the 2018 and 2022 data, the scores for both mitigation and adaptation generally increased: the total average score for mitigation grew by 7.2 points and for adaptation by 10.1 points (note that adaptation began from a lower base than mitigation). For both policy

fields, this increase is mostly based on higher scores in dimension C. In the area of mitigation, this refers to GHG reduction targets and proposed reductions per year. For adaptation, dimension C relates to the diversity of planned measures, and the increase is mainly due to the greater number of municipalities with a plan, although also partly because newer plans are more comprehensive. Of the 76.9% of cities with an adaptation plan, four-fifths are stand-alone adaptation plans. The variation between the mean score in mitigation and adaptation decreased, suggesting that cities are becoming more similar in their engagement (see Table 1). For adaptation, the number of cities receiving no points at all fell from 26 in 2018 to 12 in 2022 (out of 104). Overall, mitigation remained at a higher level than adaptation (see Table 1 and Fig. 2).

Between 2018 and 2022, the mitigation score changed for 69.2% and the adaptation score changed for 61.5% of the 104 cities (see Fig. 2). However, these numbers include very moderate changes – e.g. just 40.4% and 44.2% of cities increased their scores by more than 5 points between 2018 and 2022 for mitigation and adaptation, respectively. Thus, some cities show considerable changes between 2018 and 2022 while others do not. This is also evident in the results of the cluster analysis (see detailed information in the supplementary information SI 2, SI 3 and SI 4).

As outlined in the method section, cities were assigned to the original clusters reported by Otto et al. (2021a) by a k-means classification. This was done for the assessments of 2018 and 2022 to guarantee a fair comparison over time. Our findings are summarized in Fig. 3 and reveal significant changes in the membership of those clusters that Otto et al. (2021a) identified in their previous study: The number of cities in cluster 1 (climate policy leaders) almost doubled from 16 in 2018 to 30 in 2022. In addition, cluster 4 (climate policy followers) grew slightly, while cluster 2 (climate adaptation leaders) was stable regarding the number of cities. In contrast, cluster 3 (climate mitigation leaders) and 5 (climate policy latecomers) shrunk a little, while cluster 6 (climate policy laggards) lost almost two thirds of its members. To illustrate the dynamics in municipal climate policies in recent years, the classification changed for 41 cities (39.4%), while 63 cities (60.6%) were assigned to the same cluster in 2018 and 2022. Hence, Fig. 3 also provides the statistics for the cities that stayed in the same cluster (the "stayers"), in addition to the mean scores for both policy fields and both years (2018 and 2022).

In contrast to Otto et al. (2021a), who ordered the clusters according to their overall climate policy scores, the clusters in Fig. 3 are ranked according to their mean scores for climate mitigation (CM) and climate adaptation (CA) separately. The clusters are drawn in a manner inspired by the Hasse diagram technique (c.f. Carlsen and Bruggemann 2020) as there is no hierarchy between the clusters, but instead different emphases on mitigation or adaptation. In 2018, climate mitigation scores were lowest in cluster 6 (climate policy laggards) and highest in cluster 1 (climate policy leaders). Listing all clusters according to their mitigation score, the resulting order is $6 < 5 < 4 < 2 < 1 < 3$. The mitigation score for cluster 3 (climate mitigation leaders) was almost equal to that of cluster 1 in 2018. In 2022, this order changed slightly to cluster $6 < 5 < 4 < 2 < 3 < 1$, as the score in cluster 1 increased slightly more than in cluster 3. For climate adaptation, cluster 5 (climate policy latecomers) received the lowest scores in 2018 and 2022. However, it should be noted that cluster 6 has only slightly higher scores for adaptation than cluster 5, mainly due to the changes of one city (Wolfsburg) in cluster 6; in general, the cities in cluster 6 lag the others. As with mitigation, the highest scores for adaptation are in cluster 1. For all clusters,

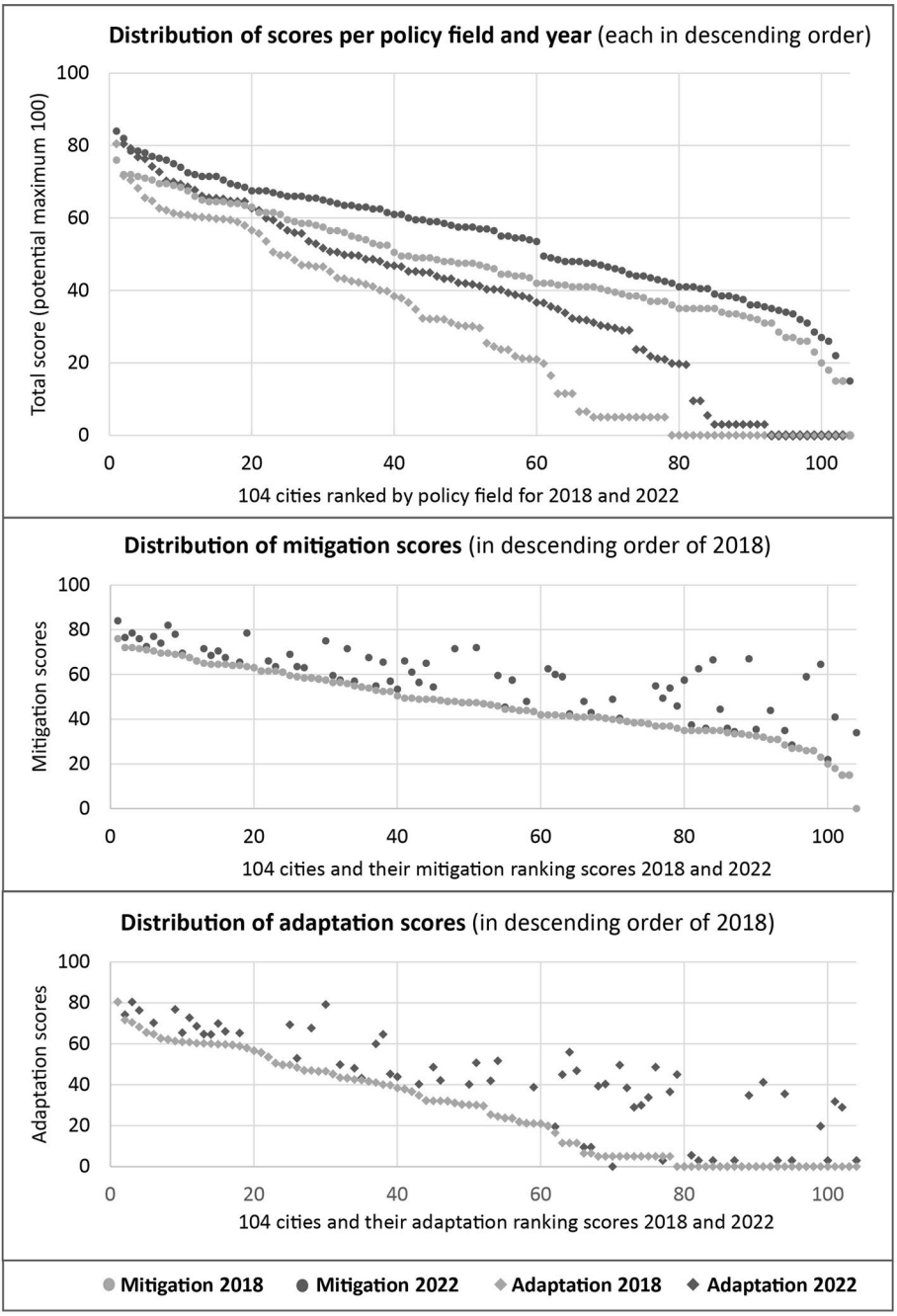

Fig. 2 Distribution of scores per policy field and year in 104 cities ordered in two variants

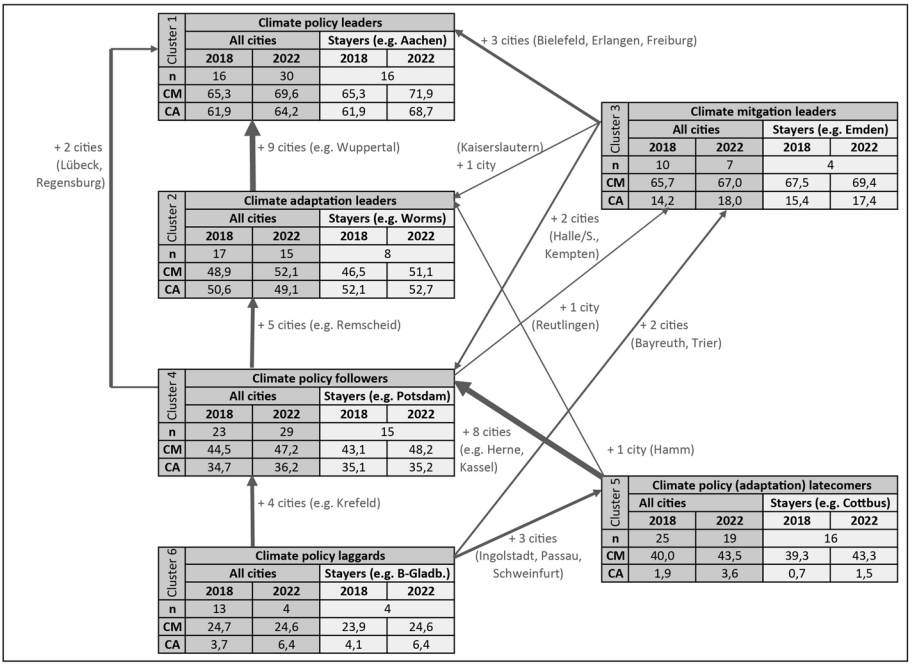

Fig. 3 City classification based on k-means clustering in 2018 and 2022 (CM: climate mitigation, CA: climate adaptation, n: number of cities)

the order of adaptation scores is cluster 5 < 6 < 3 < 4 < 2 < 1 in both years. Thus, cities in clusters 1, 2 and 4 tend to have a climate policy that is more balanced between mitigation and adaptation. In contrast, cities in clusters 3 (climate mitigation leaders) and 5 (climate latecomers) tend to focus more strongly on mitigation. Therefore, it is perhaps more appropriate to describe cities in cluster 5 as climate adaptation latecomers, because their mitigation scores are comparable to those of cluster 4. This should be considered when interpreting the dynamics between 2018 and 2022 (see Fig. 3 and SI 4), which are supplemented below by insights from interviews and document analyses in 15 cities.

By 2022, just four cities remained in *cluster 6* (climate policy laggards). These are Bergisch-Gladbach, Dessau, Wilhelmshaven and Wolfsburg. We highlight *Bergisch-Gladbach* (112,712 inhabitants), located in North Rhine-Westphalia, as an example of a city that was fairly inactive for a long time. One reason is that the municipality belongs to a superordinated administrative district (the county), which had already adopted mitigation and adaptation plans. Despite being located in cluster 6, Bergisch-Gladbach has become more active, for example by declaring a climate emergency in 2019 and announcing that it would develop a mitigation plan shortly afterwards. This plan was published at the end of 2023 with sections on climate mitigation and adaptation and thus was not included in our dataset. As our interviewees reported, the 2020 local elections were dominated by the topic of climate change and Bergisch-Gladbach did take some actions afterwards which are, however, beyond the point of time considered in our analysis.

After 2018, two thirds of the cities in *cluster 6*, i.e. nine municipalities, had increased their mitigation or adaptation scores (and in some cases both) and were hence assigned

to other clusters. Specifically, three cities moved to cluster 5 (climate policy latecomers; Ingolstadt, Passau and Schweinfurt), four cities became climate policy followers (cluster 4), and two cities even moved to cluster 3 (mitigation leaders), i.e., Bayreuth and Trier. One of the four cities that moved from cluster 6 to 4 was *Krefeld* (228,426 inhabitants)**.** This city in North Rhine-Westphalia became active in climate policy very late. As in many other German cities, the protests of Fridays for Future in 2019 were an important initial spark for taking urban climate activities: they contributed towards the city council adopting an integrated climate mitigation plan that addresses mitigation and adaptation. Despite the resolutions, however, Krefeld is struggling with implementation. For example, the municipality is reluctant to undertake potentially controversial projects, e.g. in the mobility sector: the city council developed a parking concept for one city district in 2018, but its implementation was postponed until spring 2024.

Cluster 5, comprising the "climate policy latecomers", shrank slightly from 25 cities in 2018 to 19 in 2022. All nine cities that moved away from cluster 5 remained largely unchanged in mitigation but improved their adaptation scores substantially. As the cities in cluster 5 were already quite active in mitigation in 2018, but not in adaptation, those that are leaving are creating the foundation for a more balanced climate policy. While three cities moved up from cluster 6 (see above), 16 stayed in this cluster, which is quite a large share of stayers. One such example is *Cottbus* (99,515 inhabitants), which is located in a traditional coal mining area in Brandenburg and which interviewees described as still hesitant to address climate change. In contrast to most of the other 14 cities we examined in greater depth, there is little civil society pressure to act on climate change in Cottbus. Instead, influential civil society actors, as well as a strong coal lobby, are explicitly opposed to more ambitious climate action. The situation is similar in *Gera* (93,634 inhabitants) in Thuringia, which also remained in cluster 5. Gera has an older population (an average age close to 50) and went through a process of shrinkage and deindustrialization in recent decades. Unlike in university cities often characterized by an active and younger civil society with strong local climate pressure groups (Haupt et al. 2023b), climate change is not a priority for Gera's residents. Climate-sceptic parties have a strong local presence and were successful in municipal elections. Against this backdrop, our interview partners explained how the city prefers rather low-threshold and less controversial measures to raise climate change awareness and protect the (ageing) population from its impacts. One example is reduced entrance fees to the city's densely forested zoo on hot days.

Notably, cities in *cluster 5* are much more active in climate mitigation than cities in cluster 6, and just a little behind the mean score in cluster 4. Regarding climate adaptation, however, there is a much greater difference between cluster 4 on the one hand, and clusters 5 and 6 on the other (Fig. 3). Eight cities that recently developed climate adaptation plans were assigned to cluster 4 in 2022 instead of cluster 5 as of 2018. One city, i.e. Hamm, even moved from cluster 5 up to cluster 2 (climate adaptation leader; Fig. 3). In addition to establishing its first climate adaptation plan, Hamm also took part in the certification process of the European Climate Adaptation Award, which was funded by its federal state North Rhine-Westphalia.

In terms of the number of cities, *cluster 4* (climate policy followers) grew slightly from 23 to 29 municipalities. Among these cities, 15 barely increased their scores and stayed in the cluster, mainly due to their lower scores in dimension A of adaptation, which relates to awards and certifications that the municipality may have achieved. However, as the two following examples show, staying in this cluster does not imply that cities were inactive between 2018 and 2022. The city of *Würzburg* (127,810 inhabitants) in Bavaria, for example, was grouped in cluster 4 in both 2018 and 2022 as a climate policy follower. However,

during this time a new department for Environment and Climate Change, headed by Bavaria's first Climate Mayor (a deputy mayoral role), was established in 2020 and two years later Würzburg adopted a new mitigation plan. Furthermore, Würzburg prepared a new climate adaptation plan during this period and, in 2023, was one of a very limited number of German cities to publish a heat action plan. Likewise, the city of *Potsdam* (185,750 inhabitants) was considered a climate policy follower in 2018 and 2022. Overall, Potsdam scores very well except in dimension A for adaptation, because the city is not a member of specific adaptation networks and neither does it achieve substantial wider recognition through awards and certifications. Interviews revealed that the city does not have the capacity to engage in further networking and certification processes. Potsdam is a long-time member of the Climate Alliance, regularly attends the annual conferences and considers the exchange through this rather Germany-focused network sufficient.

Cluster 4 is very dynamic, with fourteen new cities joining this cluster in 2022: four cities came from cluster 6 (laggards), eight from cluster 5 (latecomers), and two from cluster 3 (mitigation leaders). Conversely, eight cities left this cluster, five of them joined cluster 2 (adaptation leaders), one cluster 3 (mitigation leaders) and two even leaped to cluster 1 (climate policy leaders). Among the five municipalities that moved to cluster 2 is the city of *Remscheid* (112,613 inhabitants) in North Rhine-Westphalia. Similar to Hamm, this city undertook the certification process of the European Climate Adaptation Award. In fact, the other cities that moved 'up' to another cluster also increased their efforts in dimension A of adaptation, i.e. they underwent a certification process or joined a city network. Additionally, Remscheid has regularly participated in applied research projects on adaptation. Two cities jumped up to cluster 1 (climate policy leaders). For example, *Regensburg* in Bavaria (157,443 inhabitants) adopted a new climate mitigation and adaptation plan between 2018 and 2022 and joined the Covenant of Mayors in 2019. Our fieldwork provided additional insights into its efforts to tackle climate change. In particular, the municipality has transformed the centre of Regensburg into a traffic-calming area, by introducing free-of-charge, green electric buses that only operate in the narrow streets of the historic centre. The city has also understood that its UNESCO World Heritage status brings serious challenges and constraints, especially for adaptation measures such as urban greening. As a response, Regensburg established a climate resilience department in 2018.

The number of cities in *cluster 3* dropped slightly in 2022, with six leaving and three joining this group of climate mitigation leaders. The four cities that remained in cluster 3 still focus very much on climate mitigation. For example, the small municipality of *Emden* (50,535 inhabitants) in Lower Saxony, a centre of the wind energy industry, sees manifold synergies between economic development and mitigation but has not yet started to tackle adaptation.

The cities of Kempten and Halle (Saale) further intensified their mitigation activities between 2018 and 2022. Thus, these two cities were assigned to cluster 4 in 2022, after having been in cluster 3 in 2018. However, we should not interpret this change as a decline in their climate activity: both cities have become even more active in mitigation. Instead, because they both adopted their first adaptation plans between 2018 and 2022, they achieved more balanced scores in terms of climate policy and therefore joined cluster 4. In the case of *Kempten* in southern Bavaria (70,056 inhabitants), the city also developed a pluvial flood hazard map in 2020 and a climate analysis map in 2021. Regarding climate mitigation, the city received national funding in 2012 to develop a plan to become climate neutral by 2050. However, our interviewees were critical of its climate efforts in general, and its mitigation plan in particular, which they said was too vague and non-binding. This resulted in adopting a new mitigation plan (2022) that included a more ambitious emissions

reduction goal and more stringent monitoring guidelines. Other cities that left cluster 3 in 2022 made jumps in their adaptation scores and moved to cluster 2 (Kaiserslautern) and even cluster 1 (Bielefeld, Erlangen, Freiburg). For example, *Erlangen* (116,562 inhabitants) was mainly active in mitigation before 2018, but more recently it adopted a climate adaptation plan (2019) and an urban greening plan that includes a catalogue of measures to be implemented by 2030. In the case of mitigation, students and activists from established climate and environmental groups urged the city to declare a climate emergency, and also to adopt a more ambitious mitigation goal (climate neutrality before 2030). A broad coalition of local actors collaborated to propose a list of 41 measures to reach this goal, of which (only) 14 were adopted by the city council in 2022.

Comparing the years 2018 and 2022, the number of cities in *cluster 2* (adaptation leaders) was rather stable, but just eight cities remained in this cluster (Fig. 3), among them the small city of *Worms* (84,646 inhabitants). This city is in one of the hottest and driest regions of the country (the Upper Rhine area) and became active in adaptation comparatively early. In recent years, it has expanded its activities in this field, by participating in a model project on informal participation processes for preventing pluvial flooding (2017–2019) and establishing one of the first municipal heat action plans in Germany (in 2022). Then again, the city's mitigation activities have remained on a comparably low level. In 2021, Worms organised broad public participation and was still working on updating its first mitigation plan dated from 2010 (the plan was not published by January 2025).

Five cities joined *cluster 2* from cluster 4 (climate policy followers), one came from cluster 3 (mitigation leaders) and another one joined from cluster 5 (climate policy laggards). At the same time, nine cities moved from cluster 2 up to cluster 1 due to small gains in mitigation. As an example, the city of *Wuppertal* in North Rhine-Westphalia (358,876 inhabitants) has intensified its activities in mitigation and adaptation in the past years, e.g. by adopting a 14-point mitigation action package and a more ambitious mitigation plan that also integrates adaptation (2020). Moreover, the city has developed a flood risk map and a heat load map (both in 2019).

As said above, *cluster 1* (climate policy leaders) contains 30 cities in 2022. Due to our scoring system, the 16 climate policy leaders from 2018 remained in this cluster in 2022. The statistics in Fig. 3 reveal that the efforts of these 16 on mitigation and adaptation are, on average, still a bit higher than the cluster mean. The city of *Aachen* (252,136 inhabitants) is one such example. Pressured by a strong Fridays for Future movement, Aachen declared climate emergency in 2019, and various actions followed. For example, the city adopted a new mitigation plan and allocated funds for a set of short and mid-term measures to be implemented by 2025 and additional staff and resources. Another example of a city staying in cluster 1 is *Rostock* (209,920 inhabitants). Although this city did not adopt a further mitigation plan (our interviewees felt that the existing plan was challenging enough), Rostock does evaluate and update its adaptation plan regularly.

5 Discussion

In this article, we have used the approach of Otto et al. (2021a) to rank cities according to their mitigation and adaptation activities. We compared the results from 2018 with those from 2022, supplementing the results with information from interviews in 15 municipalities. As such, we added much-needed knowledge on the progress, dynamics and persistence of urban mitigation and adaptation to the literature. For both policy areas, our analysis is

based on memberships of relevant city networks, participation in competitions and certification programmes, the existence of strategic plans, the year of their publication and any subsequent updates, as well as the ambitions expressed in these plans. We find a drop in the number of cities doing little or nothing in climate policy (cluster 6) and in the number of cities focusing only on mitigation (clusters 3 and 5). Overall, we see an increase in scores for both policy areas, indicating that, at the institutional level, both mitigation and adaptation are progressing in Germany. This aligns with findings from other studies focusing on various European countries (Buzási et al. 2024; Reckien et al. 2023).

However, adaptation still lags behind mitigation in all three dimensions and the overall score, with the largest differences in dimension B (existence and updating of strategic plans). While all cities now have a mitigation plan, the share of cities with an adaptation plan increased from less than three fifths (58.7%) to more than three quarters (76.9%). Despite the efforts to improve in adaptation, this policy area cannot quite catch up in our approach as cities score better in mitigation due to more ambitious emission reduction goals (dimension C).

Recent literature has also noted the prevalence of mitigation over adaptation in municipal climate engagement (Aboagye and Sharifi 2023; Pimenta and Kamruzzaman 2024; Debbage et al. 2025; Reckien et al. 2023) and an increase in municipal adaptation plans or adaptation issues in joint mitigation and adaptation plans (Aboagye and Sharifi 2023; Reckien et al. 2023). Our results show that mitigation and adaptation-only plans predominate in Germany over joint mitigation and adaptation plans (e.g. out of 80 adaptation plans considered, 64 are adaptation-only plans). While topic-specific plans are developed in some other countries, such as Sweden (Reckien et al. 2018), joint plans seem to be common in, for example, Australia (Pimenta and Kamruzzaman 2024), the US (Debbage et al. 2025) and various European countries such as Finland, France, and the UK (Reckien et al. 2018). Future studies could examine whether these different approaches lead to different levels of implementation and effectiveness of mitigation and adaptation, and different levels of consideration of potential synergies and trade-offs between the two policies.

The overall increase in mitigation and adaptation scores is quite uneven across cities, with 40.4% of cities for mitigation and 44.2% of cities for adaptation improving their scores by more than five points, but only 20.2% improving by more than five points in both policy areas at the same time. Furthermore, only 39.4% of cities moved to a different cluster between 2018 and 2022. Thus, we can observe a polarisation between cities that have taken action in terms of their commitments and plans during the period under study and those cities—especially the 20 'stayers' in clusters 5 and 6 (latecomers and laggards)—that have not been able to improve their mitigation or adaptation scores considerably and are therefore falling further behind at the institutional level. The interviews show that a generally unfavourable political and socio-economic situation, or the handling of the relevant issues at a higher administrative level (federal states), are reasons for staying in these groups. However, it should also be noted that 9 out of 20 stayers in clusters 5 and 6 were working on an adaptation plan by the end of 2022, indicating that these clusters will continue to shrink in the coming years.

For the two thirds of municipalities that remain in cluster 4, our interviewees suggested that instead of joining (additional) city networks, participating in competitions or updating existing plans, they should build on their existing climate policy base and focus their efforts on e.g. developing knowledge for urban planning or implementing measures. More detailed case studies would be helpful to understand the contexts of these policy followers and whether their activities are mainly beyond the scope of our approach or whether their climate policy progress stagnates due to e.g. a lack of capacity.

Due to our reliance on the ranking system from Otto et al. (2021a), which provides limited scope for municipalities to increase their scores substantially at the top of the scale, cities in cluster 1 (climate policy leaders) remain in their cluster and only improve slightly. In terms of the policy cycle, we would expect (and have learned from the interviews) that these cities are already in the process of implementing policies and monitoring how their plans are translated into action.

Otto et al. (2021a) found – in line with other studies on municipal climate policies (Kern 2019; Reckien et al. 2018; Salvia et al. 2021), – that city size influences the extent to which a city is climate active. For mitigation and adaptation in 2018, there was a weak to moderate, though significant correlation (for mitigation 2018: $r = 0.37$; $p < 0.01$; for adaptation 2018: $r = 0.5$; $p < 0.01$). For 2022, this correlation decreased slightly for both policy fields, although adaptation is still more closely linked to city size than mitigation (for mitigation 2022: $r = 0.34$; $p < 0.01$; for adaptation 2022: $r = 0.46$; $p < 0.01$).

In addition to the size of the city, the issue of dynamism and persistence may be influenced by the regional setting. In particular, 16 out of the 17 East German cities (including Berlin) in our sample did not move to another cluster during our analysis period. Interviews in Cottbus, Gera, Potsdam and Rostock suggest that a lack of capacity may be one reason. Evaluations of national funding programmes for mitigation and adaptation also show that municipalities in eastern Germany, and smaller and more rural municipalities in general, are less likely to apply for funding (Scheller and Schlegel 2024; Schumacher et al. 2023). In Lower Saxony, too, the situation is rather static, with only three out of eleven cities moving to another cluster and almost half of the cities remained in clusters 5 or 6. In some other federal states, e.g. Baden-Württemberg and North Rhine-Westphalia at a rather high level, half of the cities changed their cluster between 2018 and 2022. Notably, cities from Bavaria, which on average are rather small and in 2018 were mostly in clusters 5 and 6 (10 out of 16 cities) and two in the group of mitigation leaders (cluster 3), managed to catch up. 11 out of 16 cities moved to a different cluster. 7 of the 19 cities that developed their first adaptation plan between 2018 and 2022 are in Bavaria, and three more Bavarian cities were preparing a plan by the end of 2022. Four of these were funded nationally and three by Bavarian funding programmes that started in 2019 and 2020. For two plans, the funding was unclear from the document and website research, and one was funded by the city's own resources. In general, funding is an important factor in the implementation of urban mitigation and adaptation according to the interviews and recent literature (Kern et al. 2023; Otto et al. 2021a). Building on existing knowledge (Eckersley et al. 2023; King 2022), future studies should explore the consequences at the municipal level of changes in the (non-)availability of funding schemes at the state and national level.

The changes in the funding schemes, i.e. the discontinuation of the funding of adaptation plans with the so-called *Kommunalrichtlinie* in 2019 and the introduction of a new funding scheme at the end of 2021, do not seem to have had an impact in the period under review, as the vast majority of plans published after 2018 were still funded through the *Kommunalrichtlinie*. This is because plans take several years to be developed and grants approved up to 2019 could still be spent. There may be a gap in adopted climate policy plans in subsequent years, as only two plans were published in 2022, compared to five or six per year between 2019 and 2021, but our time period was too short to cover these changes. With the newly enforced federal climate adaptation act (KAnG 2023), local climate adaptation plans need to be prepared. Our analysis suggests that (smaller) municipalities will require external financial support to do so.

Based on the interviews, we can identify further reasons for different levels of engagement in mitigation and adaptation, in addition to funding opportunities and the size of the

city. The most important factor that emerged from the interviews, in particular for more ambitious engagement in mitigation but also for starting to work on climate policy in general, was widespread pressure from civil society and the public, e.g. through the Fridays for the Future protests (see also Eckersley et al. 2025). Interviewees from cities with a rather weak civil society in the field of climate policy and an older population (e.g., Cottbus, Gera) did not report such experiences of pressure to improve climate mitigation and adaptation planning, which may lead to a growing divergence of activities between different cities.

Despite these insights into climate policy institutionalisation at the local level, our approach also has limitations. First, the short time period investigated here cannot capture developments over a longer time which would need further tracking as e.g. Kern (2020) has done for Finnish cities. Furthermore, in a few cases, such as Bergisch-Gladbach, the decision to end data collection at a specific point in time means that the results can become outdated quickly. Second, the results based on the chosen sample of 104 larger and medium-sized cities cannot be generalized for smaller municipalities, as studies show that these are less active (Fünfgeld et al. 2023; Haupt et al. 2024).

Third, our results are based on an analysis of cities in Germany only and thus take place within a specific socio-economic, political, and legal framework. This includes national and state-level funding schemes for municipal climate mitigation and adaptation plans, which may not be present in other countries and regions. The same holds for the rather broad municipal response to protests on climate change action, particularly in 2018 and 2019. Such factors undoubtedly influenced the developments in local climate policy between 2018 and 2022 (Eckersley et al. 2025), and our subsequent findings. Therefore, in addition to the insights that country-specific studies deliver, analyses that take into account several countries or regions are very informative (see e.g. Aguiar et al. 2018; Araos et al. 2016; Reckien et al. 2023; Wannewitz et al. 2024).

Fourth, our approach hardly captures implementation efforts or the impact and outcome of the measures that cities adopt, which is a typical challenge in this area of literature (Biesbroek et al. 2018). Thus, we cannot identify cities that were active prior to 2018 but were falling behind by 2022 (cf. Kern 2023). In the Otto et al. (2021a) ranking system, scores that are related to mitigation or adaptation plans, as well as participation in competitions and certification programmes, are counted as soon as they are adopted or take place and remain counted in perpetuity—unless a city left a network or published a new mitigation or adaptation plan that was less ambitious than the previous one. The data in our ranking approach does not show whether plans have been implemented, which may be insufficient or take a long time (Lee and Kim 2018; Rogers et al. 2023). For the 15 cities where we conducted interviews, we got a much more detailed picture of which and how mitigation and adaptation actions are being taken, and which actions are being supported or challenged. For example, they revealed that some cities focus more on implementation than our quantitative assessment approach might suggest. Others were finding implementation difficult due to local controversies about, e.g. mobility plans, and several municipalities have set targets that will prove extremely challenging to achieve. It would be a huge task, and beyond the scope of this study, to conduct such fine-grained research in all 104 of our cities, but these qualitative insights highlight some of the limitations of a large-n approach to assess such phenomena.

Implementation is a particular issue in the area of mitigation, where many German cities set very ambitious greenhouse gas reduction targets (e.g. climate neutrality by 2030) between 2018 and 2022, comparable to very ambitious cities from, for example, Finland (Huovila et al. 2022) or Sweden (Vanhuyse et al. 2023). However, German cities did not

necessarily set out exactly how they intend to achieve these objectives. Notably, this was not the case for the 15 so-called "*Masterplankommunen*" in our sample, which received funding from the German government in two waves (2012 and 2016) to develop a detailed plan to achieve climate neutrality by 2050. Although these plans often appear to be less ambitious than more recent announcements of carbon neutrality by 2030, they are often much more substantial in their content and feasibility. Our interviewees in Masterplan municipalities, e.g. in Emden, Potsdam and Rostock, suggested that these cities partly did not need new targets because they were busy enough implementing their original measures and some recognised that new targets would be unrealistic (as even introducing the measures to be implemented by 2050 represents a major challenge). Perhaps reflecting the fact that staff in these municipalities may be more aware of the challenges of achieving carbon neutrality than their counterparts elsewhere in Germany, only six of the 15 Masterplan municipalities in our sample adopted more stringent GHG reduction targets in 2022 compared to 2018. As recent studies have pointed out, achieving ambitious targets such as climate neutrality by 2030 is challenging and municipalities need further support to achieve them (Huovila et al. 2022; Vanhuyse et al. 2023). It is therefore a question for future research whether the newer, very ambitious mitigation strategies in some cities (in Germany and elsewhere) can deliver on their promises, or whether these targets will prove to be largely symbolic.

6 Conclusion

This article tracks changes in urban mitigation and adaptation activities, mainly in terms of network membership, participation in competitions and strategic plans, for 104 German cities between 2018 and 2022. While we show that both policy fields are very dynamic and there is a general trend towards more comprehensive mitigation and adaptation activities, some cities have not developed within this period, leading to a further polarisation between leaders and laggards. Thus, further studies that track developments over time are highly relevant within the literature on mitigation and adaptation to identify, for example, if climate adaptation strategies can catch up with mitigation strategies and if certain types of municipalities or regions can catch up or fall further behind. This is important from a scientific point of view, but also has practical implications, as it can help with targeting funding schemes to municipalities that are struggling.

During the period examined in this article (2018–2022), there was a window of opportunity for climate mitigation measures in particular, as street protests in many municipalities led to more ambitious strategies and activities. However, with the emergence of other issues in recent years, attention has shifted away from climate issues. Further research is therefore needed to determine whether ambitious urban mitigation targets will be met and what will happen if they are not. At the institutional level, adaptation in Germany is likely to be quite dynamic in the coming years, as the first federal climate adaptation act will encourage the development of local adaptation plans. In terms of climate mitigation, municipal heat planning also became mandatory. Future studies can show how these processes work, for example, for municipalities of different sizes and in different regions.

Despite the findings of this study, we recognise that our scoring approach needs to be modified as more larger cities adopt mitigation and adaptation plans. Future research could be extended to smaller municipalities and analyse the quality of the plans in more detail (as already done by e.g. Reckien et al. 2023) in a less time-consuming way, e.g. by using

text mining for analysis (as applied by Erős et al. 2022). In general, as more cities adopt mitigation and adaptation plans, research attention needs to be paid to their implementation and effectiveness, and also take equity issues into account. This will require further scientific knowledge and common practical approaches to monitoring and evaluating mitigation and adaptation, and may require different methods. Alongside studying monitoring plans (where they exist and are publicly available) researchers could survey municipal managers to gain additional insights into the barriers and drivers for implementation (e.g. Aylett 2015; Schoenefeld et al. 2023; Shi et al. 2015), and conduct more case studies to provide more in-depth knowledge of specific cities. Such qualitative approaches can then complement quantitative approaches, as we have sought to do in this study.

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Data availability Supplemental 2 provides an overview of the results for all 104 cities. Information on the data research and its sources for clustering can be found in Otto et al. (2021a). In the case of the interviews, participants in this study did not give written consent for their data to be made public, so due to the sensitive nature of the research, supporting data is not available.

Declarations

Conflicts of interest/Competing interests The authors certify that they have no conflicts of interest or competing interests.

References

Aboagye PD, Sharifi A (2023) Post-fifth assessment report urban climate planning: lessons from 278 urban climate action plans released from 2015 to 2022. Urban Clim 49(March):101550. https://doi.org/10.1016/j.uclim.2023.101550

Aboagye PD, Sharifi A (2024) Urban climate adaptation and mitigation action plans: a critical review. Renew Sustain Energy Rev 189:113886. https://doi.org/10.1016/j.rser.2023.113886

Aguiar FC, Bentz J, Silva JMN, Fonseca AL, Swart R, Duarte Santos F, Penha-Lopes G (2018) Adaptation to climate change at local level in Europe: an overview. Environ Sci Policy 86:38–63. https://doi.org/10.1016/j.envsci.2018.04.010

Amundsen H, Hovelsrud GK, Aall C, Karlsson M, Westskog H (2018) Local governments as drivers for societal transformation: towards the 1.5 °C ambition. Curr Opin Environ Sustain 31:23–29. https://doi.org/10.1016/j.cosust.2017.12.004

Araos M, Berrang-ford L, Ford JD, Austin SE, Biesbroek R, Lesnikowski A (2016) Climate change adaptation planning in large cities: a systematic global assessment. Environ Sci Policy 66:375–382. https://doi.org/10.1016/j.envsci.2016.06.009

Aylett A (2015) Institutionalizing the urban governance of climate change adaptation: results of an international survey. Urban Clim 14:4–16. https://doi.org/10.1016/j.uclim.2015.06.005

Azevedo I, Leal VMS (2017) Methodologies for the evaluation of local climate change mitigation actions: a review. Renew Sustain Energy Rev 79(May 2017):681–690. https://doi.org/10.1016/j.rser.2017.05.100

Ballester J, Quijal-Zamorano M, Méndez Turrubiates RF, Pegenaute F, Herrmann FR, Robine JM, Basagaña X, Tonne C, Antó JM, Achebak H (2023) Heat-related mortality in Europe during the summer of 2022. Nat Med 29(7):1857–1866. https://doi.org/10.1038/s41591-023-02419-z

Biesbroek R, Berrang-Ford L, Ford JD, Tanabe A, Austin SE, Lesnikowski A (2018) Data, concepts and methods for large-n comparative climate change adaptation policy research: a systematic literature review. Wires Clim Change 9:e548. https://doi.org/10.1002/wcc.548

Braunschweiger D, Ingold K (2023) What drives local climate change adaptation? A qualitative comparative analysis. Environ Sci Policy 145:40–49. https://doi.org/10.1016/j.envsci.2023.03.013

Bulkeley H, Kern K (2006) Local government and the governing of climate change in Germany and the UK. Urban Stud 43(12):2237–2259. https://doi.org/10.1080/00420980600936491

Buzási A, Simoes SG, Salvia M, Eckersley P, Geneletti D, Pietrapertosa F, Olazabal M, Wejs A, De Gregorio Hurtado S, Spyridaki N-A, Szalmáné Csete M, Torres EF, Rižnar K, Heidrich O, Grafakos S, Reckien D (2024) European patterns of local adaptation planning—a regional analysis. Reg Environ Change 24(2):59. https://doi.org/10.1007/s10113-024-02211-w

Canosa IV, Ford JD, Mcdowell G, Jones J, Pearce T (2020) Progress in climate change adaptation in the Arctic. Environ Res Lett 15:093009. https://doi.org/10.1088/1748-9326/ab9be1

Carlsen L, Bruggemann R (2020) Environmental perception in 33 European countries: an analysis based on partial order. Environ Dev Sustain 22(3):1873–1896. https://doi.org/10.1007/s10668-018-0267-z

Debbage N, Atasoy M, Mitra C, Byahut S (2025) Urban climate action plans in the United States: a textual content analysis and evaluation. Sustain Cities Soc 120:106095. https://doi.org/10.1016/j.scs.2024.106095

Eckersley P, Kern K, Haupt W, Müller H (2023) Climate governance and federalism in Germany. In: Fenna A, Jodoin S, Setzer J (eds) Climate governance and federalism in Germany: a forum of federations comparative policy analysis. Cambridge University Press, pp 150–176

Eckersley P, Haupt W, Kern K (2025) Assessing the impact of fridays for future on climate policy and policymaking in German cities. J Environ Planning Policy Manage. https://doi.org/10.1080/1523908X.2025.2466821

Erős N, Török Z, Hossu CA, Olga Réti K, Maloș C, Kecskés P, Morariu SD, Benedek J, Hartel T (2022) Assessing the sustainability related concepts of urban development plans in Eastern Europe: a case study of Romania. Sustain Cities Soc 85(July):104070. https://doi.org/10.1016/j.scs.2022.104070

Fünfgeld H, Fila D, Dahlmann H (2023) Upscaling climate change adaptation in small- and medium-sized municipalities: current barriers and future potentials. Curr Opin Environ Sustain 61:101263. https://doi.org/10.1016/j.cosust.2023.101263

Grafakos S, Viero G, Reckien D, Trigg K, Viguie V, Sudmant A, Graves C, Foley A, Heidrich O, Mirailles JM, Carter J, Chang LH, Nador C, Liseri M, Chelleri L, Orru H, Orru K, Aelenei R, Bilska A et al (2020) Integration of mitigation and adaptation in urban climate change action plans in Europe: a systematic assessment. Renew Sustain Energy Rev 121:109623. https://doi.org/10.1016/j.rser.2019.109623

Hasse J, Willen L, Baum N, Bongers-Römer S, Pichl J, Völker V (2019) Umfrage. Wirkung der Deutschen Anpassungsstrategie (DAS) für die Kommunen. Umweltbundesamt (ed). https://www.umweltbundesamt.de/publikationen/umfrage-wirkung-der-deutschen-anpassungsstrategie. Accessed 24 Apr 2025

Haßler J, Wurst A-K, Jungblut M, Schlosser K (2023) Influence of the pandemic lockdown on fridays for future's hashtag activism. New Media Soc 25(8):1991–2013. https://doi.org/10.1177/14614448211026575
Haupt W, Eckersley P, Irmisch J, Kern K (2023a) How do local factors shape transformation pathways towards climate-neutral and resilient cities? Eur Plan Stud 31(9):1903–1925. https://doi.org/10.1080/09654313.2022.2147394
Haupt W, Eckersley P, Irmisch J, Kern K (2023b) Fridays for future auf lokaler Ebene. Aktivität und Stärke der Ortsgruppen in deutschen Städten. In: Pollex J, Soßdorf A (eds) Fridays for future. Einordnung, Rezeption und Wirkung der neuen Klimabewegung. Springer, pp 213–240
Haupt W, Laug L, Eckersley P (2024) Structure, agency and local climate governance: how do individual actors exploit local contexts to shape policymaking in smaller cities and towns? Reg Stud 1–15. https://doi.org/10.1080/00343404.2024.2354384
Heidrich O, Reckien D, Olazabal M, Foley A, Salvia M, Hurtado de Gregorio S, Hamann J, Tiwary A, Feliu E, Dawson R (2016) National climate policies across Europe and their impacts on cities strategies. J Environ Manage 168:36–45. https://doi.org/10.1016/j.jenvman.2015.11.043
Huovila A, Siikavirta H, Antuña Rozado C, Rökman J, Tuominen P, Paiho S, Hedman Å, Ylén P (2022) Carbon-neutral cities: critical review of theory and practice. J Clean Prod 341:130912. https://doi.org/10.1016/j.jclepro.2022.130912
IPCC - Intergovernmental Panel on Climate Change (2022) Impacts, adaptation, and vulnerability. Contribution of working group II to the sixth assessment report of the intergovernmental panel on climate change (Pörtner H-O, Roberts DC, Tignor M, Poloczanska ES, Mintenbeck K, Alegría A, Craig M, Langsdorf S, Löschke S, Möller V, Okem A, Rama B (eds) Cambridge University Press. https://doi.org/10.1017/9781009325844.Front
Kalbarczyk E, Kalbarczyk R (2022) Credibility assessment of municipal climate change adaptation plans using the ex-ante method: a case study of Poland. Sustain Cities Soc 87(September):104242. https://doi.org/10.1016/j.scs.2022.104242
KAnG – Federal Climate Adaptation Act (2023; in force 07–01–2024). https://www.bmuv.de/fileadmin/Daten_BMU/Download_PDF/Gesetze/kang_en_bf.pdf. Accessed 18 July 2024
Kern K (2019) Cities as leaders in EU multilevel climate governance: embedded upscaling of local experiments in Europe. Environ Polit 28(1):125–145. https://doi.org/10.1080/09644016.2019.1521979
Kern K, Eckersley P, Haupt W (2023) Diffusion and upscaling of municipal climate mitigation and adaptation strategies in Germany. Reg Environ Change 23(1). https://doi.org/10.1007/s10113-022-02020-z
Kern K (2020) Von Vorreitern und Nachzüglern: Die Rolle von Städten und Gemeinden in der Klimapolitik. In: Hickmann T, Lederer M (eds) Leidenschaft und Augenmaß. Sozialwissenschatliche Perspektiven auf Entwicklung, Verwaltung, Umwelt und Klima. Nomos, Baden-Baden. pp 195–206
Kern K (2023) Cities and urban transformations in multi-level climate governance. In: Jörgens H, Knill C, Steinebach Y (eds) Routledge handbook of environmental policy. Routledge. https://doi.org/10.4324/9781003043843
King JP (2022) Sixteen ways to adapt: a comparison of state-level climate change adaptation strategies in the federal states of Germany. Reg Environ Change 22(2). https://doi.org/10.1007/s10113-021-01870-3
Koerth J, Massmann F, Dittmann S (2019) Kommunale Klimaanpassung in Schleswig-Holstein Chancen und Herausforderungen. Standort 43(3):177–184. https://doi.org/10.1007/s00548-019-00602-4
Lee JS, Kim JW (2018) Assessing strategies for urban climate change adaptation: the case of six metropolitan cities in South Korea. Sustainability 10(6):1–31. https://doi.org/10.3390/su10062065
Nohrstedt D, Parker CF, Hileman J, Mazzoleni M (2022) Exploring disaster impacts on adaptation actions in 549 cities worldwide. Nat Commun 13(3360):1–10. https://doi.org/10.1038/s41467-022-31059-z
Otto A, Kern K, Haupt W, Eckersley P, Thieken AH (2021a) Ranking local climate policy: assessing the mitigation and adaptation activities of 104 German cities. Clim Change 167(1–2). https://doi.org/10.1007/s10584-021-03142-9
Otto A, Göpfert C, Thieken AH (2021b) Are cities prepared for climate change? An analysis of adaptation readiness in 104 German cities. Mitig Adapt Strateg Glob Chang 26(8). https://doi.org/10.1007/s11027-021-09971-4
Pietrapertosa F, Salvia M, Gregorio SD, Alonzo VD, Marco J, Geneletti D, Musco F, Reckien D, Analysis E, Loja CS, Scalo T (2019) Urban climate change mitigation and adaptation planning: are Italian cities ready? Cities 91(October 2018):93–105. https://doi.org/10.1016/j.cities.2018.11.009
Pimenta A, Kamruzzaman L(Md) (2024) Assessing the comprehensiveness and vertical coherence of climate change action plans: the case of Australia. J Environ Manage 369(June):122419. https://doi.org/10.1016/j.jenvman.2024.122419
Reckien D, Flacke J, Olazabal M, Heidrich O (2015) The influence of drivers and barriers on urban adaptation and mitigation plans — an empirical analysis of European cities. PLoS ONE 10(8):1–21. https://doi.org/10.1371/journal.pone.0135597

Reckien D, Buzasi A, Olazabal M, Spyridaki N, Eckersley P, Simoes G (2023) Quality of urban climate adaptation plans over time. Urban Sustain 3(13):1–14. https://doi.org/10.1038/s42949-023-00085-1

Reckien D, Salvia M, Heidrich O, Marco J, Pietrapertosa F, De Gregorio-hurtado S, Alonzo VD, Orru H, Orru K, Foley A, Simoes G, Flacke J, Olazabal M, Geneletti D, Vasilie S, Nador C, Krookriekkola A, Matosovi M, Fokaides PA, … Dawson R (2018) How are cities planning to respond to climate change? Assessment of local climate plans from 885 cities in the EU-28. J Clean Prod 191(2018):207–219. https://doi.org/10.1016/j.jclepro.2018.03.220

Rogers NJL, Adams VM, Byrne JA (2023) Factors affecting the mainstreaming of climate change adaptation in municipal policy and practice: a systematic review. Clim Policy: 1–18. https://doi.org/10.1080/14693062.2023.2208098

Rosenzweig C, Solecki W, Hammer SA, Mehrotra S (2010) Cities lead the way in climate-change action. Nature 467(7318):909–911. https://doi.org/10.1038/467909a

Salvia M, Olazabal M, Fokaides PA, Simoes SG, Geneletti D, Hurtado SDG, Vigui V, Pietrapertosa F, Ioannou BI, Matosovi M, Flamos A, Heidrich O, Balzan MV, Feliu E, Ri K, Reckien D (2021) Climate mitigation in the Mediterranean Europe: an assessment of regional and city-level plans. J Environ Manage 295:113146. https://doi.org/10.1016/j.jenvman.2021.113146

Scheller O, Schlegel A (2024) Zwischenevaluation der Föderrichtlinie "Maßnahmen zur Anpassung an die Folgen des Klimawandels" 2023. https://www.z-u-g.org/fileadmin/zug/Dateien/Foerderprorgamme/DAS_Anpassung_an_den_Klimawande/2023_Syspons_Zwischenevaluation_DAS_FRL_Endbericht_Kurzzusammenfassung_bf.pdf Accessed 18 July 2024

Schoenefeld JJ, Hildén M, Schulze K, Sorvali J (2023) What motivates and hinders municipal adaptation policy? Exploring vertical and horizontal diffusion in Hessen and Finland. Reg Env Change 23(53). https://doi.org/10.1007/s10113-023-02048-9

Schumacher K, Nissen C, Repenning J, Liste V (2023) Evaluation 2020/2021 der Nationalen Klimaschutzinitiative (NKI) – Gesamtbericht. https://www.klimaschutz.de/sites/default/files/mediathek/dokumente/0_Gesamtbericht%20NKI-Evaluation_2021.pdf. Accessed 18 July 2024

Shi L, Chu E, Debats J (2015) Explaining progress in climate adaptation planning across 156 U.S. municipalities. J Am Plann Assoc 81(3):191–202. https://doi.org/10.1080/01944363.2015.1074526

Thieken AH, Bubeck P, Heidenreich A, Von Keyserlingk J, Dillenardt L, Otto A (2023) Performance of the flood warning system in Germany in July 2021 - insights from affected residents. Nat Hazards Earth Syst Sci 23(2):973–990. https://doi.org/10.5194/nhess-23-973-2023

UN (United Nations) (2023) Technical dialogue of the first global stocktake. https://unfccc.int/documents/631600. Accessed 18 July 2024

van der Heijden J (2019) Studying urban climate governance: Where to begin, what to look for, and how to make a meaningful contribution to scholarship and practice. Earth Syst Govern 1:100005. https://doi.org/10.1016/j.esg.2019.100005

Vanhuyse F, Piseddu T, Jokiaho J (2023) Climate neutral cities in Sweden: true commitment or hollow statements? Cities 137:104267. https://doi.org/10.1016/j.cities.2023.104267

Wang D, Du Z, Wu H (2020) Ranking global cities based on economic performance and climate change mitigation. Sustain Cities Soc 62:102395. https://doi.org/10.1016/j.scs.2020.102395

Wannewitz M, Ajibade I, Mach KJ, Magnan A, Petzold J, Reckien D, Ulibarri N, Agopian A, Chalastani VI, Hawxwell T, Huynh LTM, Kirchhoff CJ, Miller R, Musah-Surugu JI, Nagle Alverio G, Nielsen M, Nunbogu AM, Pentz B, Reimuth A, … Garschagen M (2024) Progress and gaps in climate change adaptation in coastal cities across the globe. Nat Cities 1(9):610–619. https://doi.org/10.1038/s44284-024-00106-9