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City–company collaboration towards aligned science-based target setting

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Cities and companies have great potential to reduce pressures on Earth system boundaries. Science-based target setting has emerged as a powerful tool to help achieve the potential, but its uptake has been limited. Moreover, cities and companies usually develop their targets separately, even though many are co-located. Focusing on the top 200 cities and 500 companies by greenhouse gas emissions, we analyse the current state and potential of adopting science-based targets for climate. Of these key actors, 110 cities with existing net-zero targets and 22 companies with existing science-based targets could together eliminate up to 3.41 $GtCO_2e$ of annual emissions. We argue that this reduction potential could increase by as much as 67% (to 5.70 $GtCO_2e$) if the cities and companies that already have targets bring their co-located counterparts on board to keep abreast of their ambitions. Using freshwater as another example, we discuss entry points for addressing interrelated Earth system boundaries through city–company collaborations. Our findings elucidate previously untapped potentials that could accelerate transformations for operating within Earth system boundaries.

Seven of the eight Earth system boundaries (ESBs) are recently assessed as having been transgressed[1]. Cities and companies are key actors responsible for anthropogenic impacts at local, regional and global scales[2–5]. Concurrently, they have considerable potential to take actions that can transform trajectories for the better, and they are influential actors in supporting sustainability transitions[6–10]. Collaborative and coordinated actions, such as sharing information between cities and companies to reduce anthropogenic impacts, could stimulate positive feedback loops[11], especially if cities and companies share and work towards the same goal of safeguarding the global commons[12]. Cities and companies have the collective power to make and influence structural decisions[6] and can be nimbler and more willing to act than national governments[13,14]. They can also be vibrant hubs for experimentation[15] for low-carbon transitions[16,17]. Front-runner cities and companies—actors that take the lead—could serve as good examples and could have a positive influence on others[18]. Co-learning between these actors could further fast-track action[19]. City–company collaborations can, thus, be one of the leverage points[20] for reducing human pressures on ESBs.

Companies with science-based targets for the climate have more ambitious aims for greenhouse gas (GHG) emission reductions than companies with other climate targets and that these aims are much higher than national pledges to the Paris Agreement[21]. Similarly,

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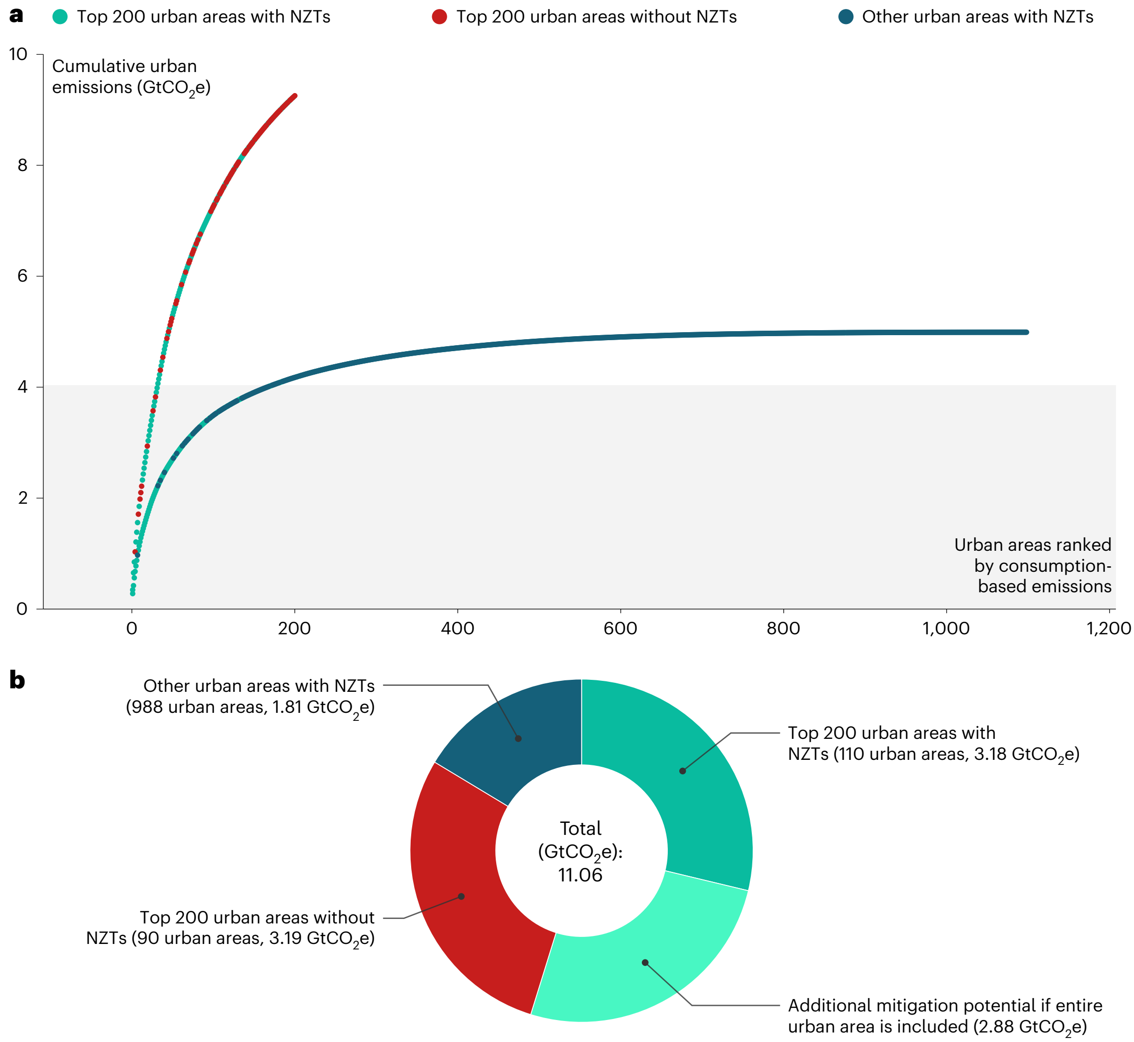

Fig. 1 | Urban emissions when urban areas are ordered by their consumption-based CO_2e emissions in 2020 and their distribution with a focus on the top 200 urban areas with and without NZTs. a, The ordering in the lower curve represents the first 1,098 cities and towns with NZTs. Beyond 200 urban areas, each urban area starts contributing relatively less to the cumulative total. The ordering of the top curve represents the mitigation potential that could be possible if the 200 urban areas with the highest consumption-based CO_2e emissions adopt NZTs. **b**, The colourings in the data points in both curves (**a**) and the pie chart (**b**) represent the distribution of the top 200 urban areas with and without NZTs, the extra mitigation potential if the target covers the entire urban area, and other urban areas with NZTs. The red dots represent the 90 urban areas among the top 200 emitters without any NZTs.

many cities are adopting ambitious targets to reach net-zero emissions. It has been estimated that various mitigation commitments by subnational and non-state actors in ten major economies will reduce national emissions by about 3.8–5.5% in 2030[22]. Although this demonstrates the potential, there is a need to boost the effort in both scale and breadth[23,24], particularly through setting science-based targets, if we are to stay within safe and just ESBs and achieve the Sustainable Development Goals[25].

Moreover, cities and companies have largely been setting and implementing targets separately, leading to inconsistencies. Thus, companies with a higher ambition may be in a city with a lower ambition or vice versa. Such co-location and inconsistency could be a promising leverage point for cities and companies to extend the sphere of 'proactive influencing'[18] beyond their peers and enhance collaboration. Pertinent questions remain about the opportunities for increasing collaboration and setting sustainability targets among key cities and companies and how best to catalyse science-based collaborations between these types of actors and across ESBs.

We first show the potential for two-way proactive influencing between cities and companies, focusing on GHG emission reductions as an example. By analysing the top 200 urban areas with the largest GHG emissions (the key cities, referred to hereafter as the top 200 cities) and the top 500 companies by emissions (the key companies, referred to hereafter as the top 500 companies), we quantify and compare the impacts of science-based climate targets with the potential that could be realized if co-located cities and companies align with and keep abreast of more ambitious targets. Moreover, we use freshwater to illustrate opportunities for these co-located cities and companies to work together across other ESBs. Finally, we analyse the current state of city–company collaborations and discuss possible entry points for more strategic collaborations across ESBs. Our analysis elucidates an untapped potential to accelerate operating within ESBs.

Results

Existing uptake and potential of science-based targets

Mitigation efforts to prevent 1.5 °C of global warming, which is a vital physical limit for averting serious tipping points that interact with several domains in the Earth system, are present in public- and private-sector science-based targets. Over 1,000 cities and towns have set targets for net-zero emissions by 2050 or earlier under the Race to Zero initiative of the United Nations Framework Convention on Climate Change, which is supported by the Science Based Targets initiative.

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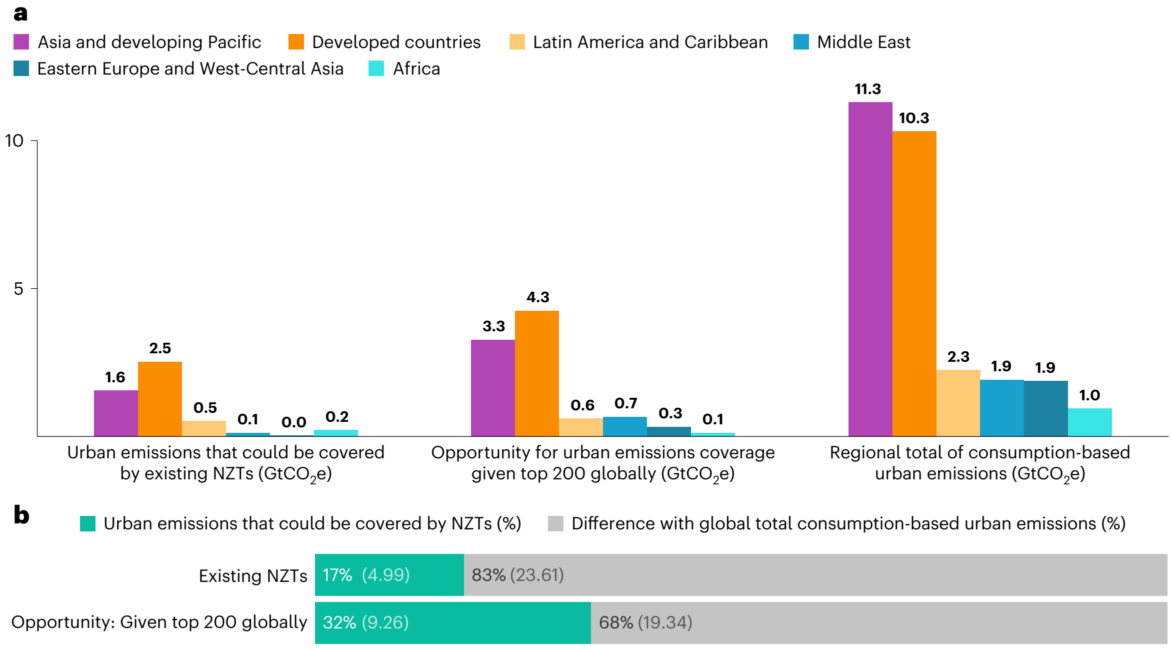

Fig. 2 | Consumption-based urban GHG emissions that could be covered by existing NZTs for the first 1,098 cities and towns and the opportunity space for mitigation given the engagement of the highest-emitting urban areas globally (top 200). a, Left and middle: vertical bar charts show the results of the analysis by region. Right: the total regional consumption-based urban emissions are shown for comparison. The colouring of the bars represents six main regions as indicated in the legend. **b**, Horizontal bars depict the share that existing NZTs (from the 1,098 cities and towns emitting 4.99 $GtCO_2e$ as marked) and the opportunity of NZTs of the top 200 urban areas (representing 9.26 $GtCO_2e$) can have in the total consumption-based urban emissions of 28.60 $GtCO_2e$. Each horizontal bar represents the share of the total.

We estimated that the first 1,098 cities and towns that have set net-zero targets (hereafter urban areas with net-zero targets (NZT)) could potentially reduce their total annual emissions by 4.99 $GtCO_2e$ if such targets are extended to cover urban-consumption-based GHG emissions. Of these urban areas, the 200 with the highest urban-consumption-based emissions comprised the lion's share in 2020, exceeding 80% of the total and representing 4.00 $GtCO_2e$ of mitigation potential (Fig. 1a).

By contrast, the top 200 urban areas globally (with and without NZTs) were estimated to be responsible for about 9.26 $GtCO_2e$ of consumption-based emissions in 2020. Only 110 of these top 200 urban areas have set NZTs, and some of the targets cover only a part of the entire urban area. Having the remaining 90 major cities adopt NZTs would mean a further commitment of 3.19 $GtCO_2e$ of emission reduction, representing a substantial further reduction potential (Fig. 1b). Compared with the total urban-consumption-based GHG emissions of 28.60 $GtCO_2e$ in 2020, existing NZTs by the first 1,098 cities and towns represent about 17%. If all the top 200 urban emitters achieved their NZTs, that would represent almost a doubling of this share (Fig. 2a,b). There are regional variations in existing NZTs and uptake among the top 200 urban areas. The greatest potential for increasing current mitigation commitments by city is in Asia and the developing Pacific, where NZTs are not as widespread. By contrast, the greatest potential for a further absolute emission reduction is in the top 200 cities by emissions in developed countries, which could reach 4.3 $GtCO_2e$.

Science-based targets for GHG emission reductions aligned with limiting global warming to 1.5 °C are also diffusing among companies[26]. However, only 22 of the top 500 companies (with estimated total scope 1 emissions of 9.15 $GtCO_2e$) had a science-based target for climate by 2022, whereas 138 companies had adopted less ambitious reduction targets that are not aligned with limiting global warming to 1.5 °C. An overwhelming majority (68% or 340 companies) of the top 500 companies had not set any targets, representing 6.38 $GtCO_2e$ of direct (scope 1) emissions (Fig. 3a–c). This indicates that there is a large gap in mitigation efforts. The sectoral profile of the top 500 companies involves 62% energy and utilities, 27% materials and chemicals and 11% other sectors.

Co-location of key cities and companies and the potential

A vast majority of companies and their consumers are within or near the administrative boundaries of cities. Figure 4a,b compares the co-location and target status of the top 200 cities and 500 companies. There are four main combinations: (1) companies with science-based targets in cities with NZTs, (2) companies with other targets in cities with NZTs, (3) companies with no targets in cities with NZTs and (4) companies with no targets in cities with no targets. Figure 4c maps the co-location of cities and companies. Of these key actors, 110 cities with existing NZTs (3.18 $GtCO_2e$) and 22 companies with existing science-based targets (0.23 $GtCO_2e$) represent up to 3.41 $GtCO_2e$ of annual emission reduction between the starting point and when net-zero emissions are achieved.

There are 326 top 500 companies headquartered in urban areas with NZTs (among the top 200 or other urban areas). Among these companies, only 13 have science-based targets; 101 have less ambitious targets, and 212 have no targets. If the cities with NZTs can somehow urge all the top 500 companies with headquarters in their jurisdiction to adopt science-based targets, this could reduce scope 1 emissions by 4.72 $GtCO_2e$. The impact of this alignment would be about 21 times more compared with the current level of 0.23 $GtCO_2e$ for companies with science-based targets. Moreover, nine other companies with science-based targets out of the 500 top companies are presently headquartered in an urban area without NZTs. If these companies can persuade their hosting cities to follow suit by adopting NZTs, emissions could be reduced by another 0.07 $GtCO_2e$. Overall, if all 18 cities hosting the 22 companies with science-based targets for climate adopted NZTs, this could reduce emissions by 0.98 $GtCO_2e$.

Hence, target alignment and two-way proactive influencing between cities and companies could potentially reduce emissions by up to 5.70 $GtCO_2e$. This could deliver about 25 times more impact than the existing science-based targets among the top 500 companies. Considering the

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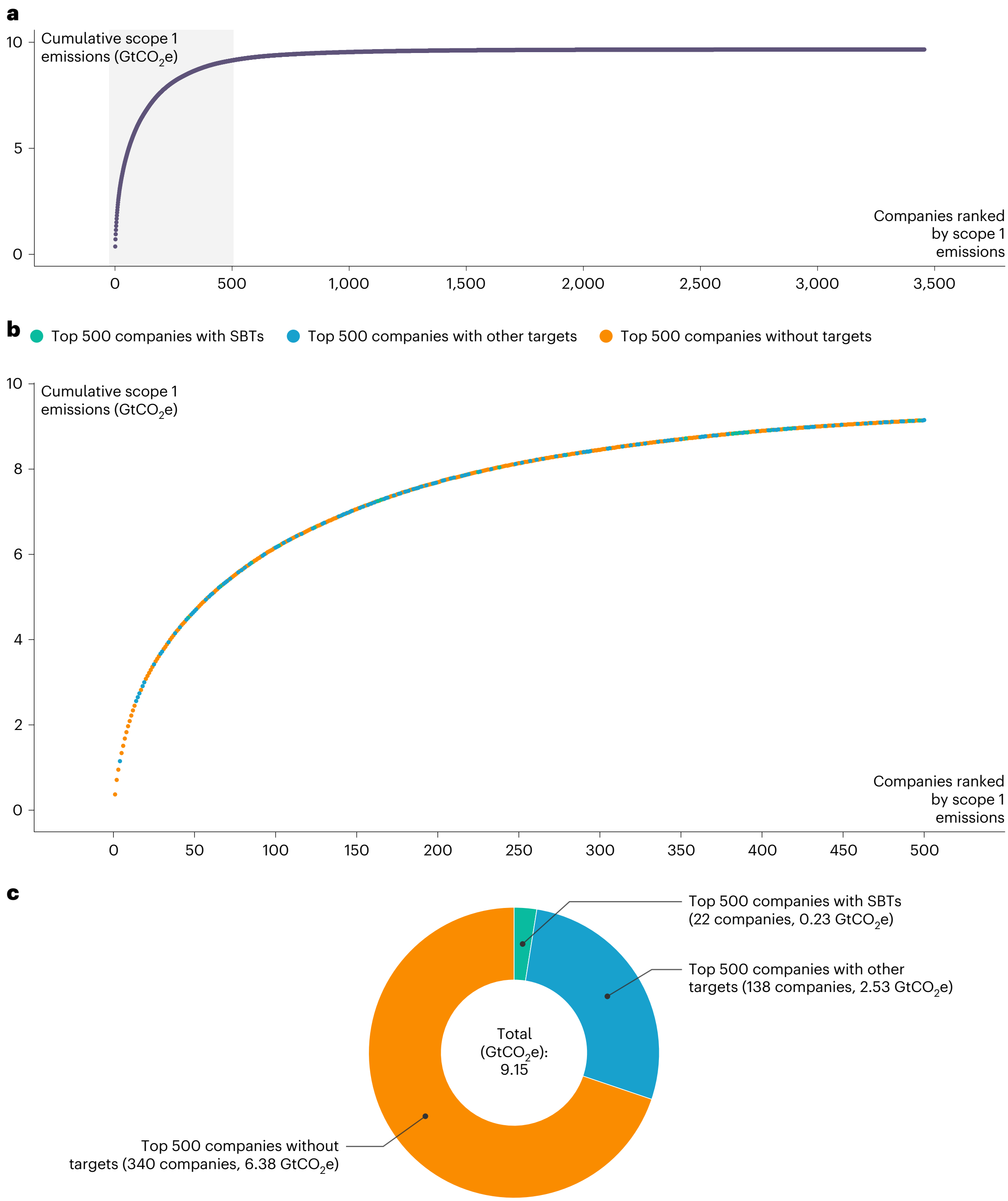

Fig. 3 | Company scope 1 emissions ordered from highest to lowest and their distribution with a focus on the top 500 companies with and without mitigation targets. a, The curve represents 3,456 companies ranked by direct emissions (scope 1) with a turning point at the first 500 companies having the greatest mitigation potential (shaded area). **b**, Top 500 companies with SBTs (green), with other targets (blue) and without any targets (orange). **c**, Pie chart for the same companies in panel **b** with the same colour scheme. SBTs, science-based targets.

total reduction potentials with collaboration (5.70 $GtCO_2e$) and without collaboration (3.41 $GtCO_2e$), there could be a multiplier of 1.7 times difference, which represents the potential for co-located cities and companies to jointly adopt science-based targets. Matching ambition levels across cities and companies is crucial for attaining this potential. If existing city and company actions are to be catalysed towards higher impact, new mechanisms are urgently needed to mobilize the two-way proactive influencing of co-located cities and companies. The pace of action impacts cumulative emissions and the remaining carbon budget[27].

Our analysis also reveals hotspots for opportunities and urgent action. For instance, in a top 200 urban area with a NZT that hosts the largest number of 500 top companies—Tokyo with 27 top emitters co-located in the city—less than half of the firms had adopted any kind of target and only two had science-based targets. Such cities should explore ways to better engage with these companies, to enhance awareness and to develop incentive or regulatory structures. Among the top 200 urban areas, some are already engaging with companies to promote carbon neutrality (for example, Cape Town), analyse the emissions of domiciled companies (Vancouver), provide recognition for sustainable businesses (for example, Phoenix) or build capacity to address climate risks (Hong Kong)[28]. It is notable that 64 of the top 500 companies lack targets and are headquartered in 21 of the other top

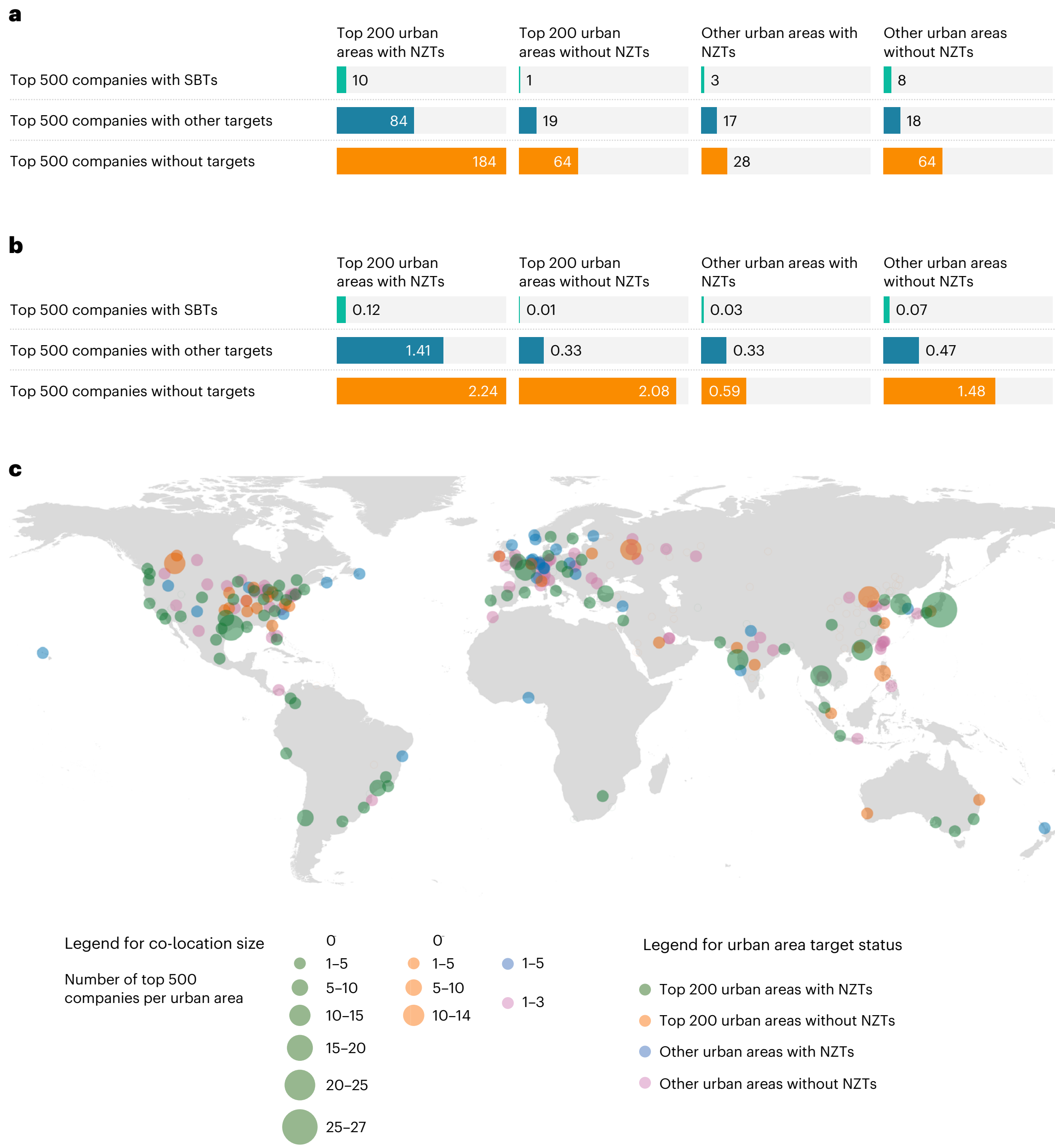

Fig. 4 | Co-location of the top 200 urban areas with the largest GHG emissions and top 500 companies in comparison with the status of their NZTs. a,**b**, The number (**a**) and scope 1 emissions in $GtCO_2e$ (**b**) of the top 500 companies with and without science-based or other targets. Co-location was assessed based on the city of domicile of the company. The companies are grouped across the top 200 urban areas or other urban areas with and without NZTs. **c**, Geographical position of the headquarters of the top 500 companies in the top 200 or other urban areas by target status. The size of each circle represents the number of companies in the urban area. The colouring indicates the status of the NZTs of the city of domicile. The 200 top urban areas are marked in green (with NZTs) or orange (without NZTs). Other urban areas that are the city domicile of a top 500 company are marked in blue (with NZTs) or pink (without NZTs).

200 urban areas without NZTs. On average, each of these firms emits 0.033 $GtCO_2e$ of scope 1 emissions, nearly twice that of the 184 companies without targets but in a top 200 urban area with a NZT. These 64 firms tend to be more carbon-intensive (33 are in the energy and utilities sector, including fossil fuel and renewable electricity producers, 17 are in the materials and chemicals sector, including metals and mining, and 14 are in other sectors), which may explain the reluctance by both the city and company to adopt science-based targets, but there are ways ahead[29]. Mobilizing these 64 companies (representing 2.08 $GtCO_2e$) and their co-located 21 of the top 200 urban areas (representing 1.01 $GtCO_2e$) to adopt science-based targets from both directions of influence (cities to companies and companies to cities) could further increase the mitigation potential by up to 3.09 $GtCO_2e$. This could bring the total reduction potential to 8.79 $GtCO_2e$, representing a multiplier of 2.6 compared with the current level, which clearly indicates the importance of engaging co-located 'laggard' actors as well.

Current state of collaboration across cities and companies

Cities and companies have close linkages. Foremost, cities have a disproportionate concentration of economic activities, generating more than 80% of global gross domestic product[30]. City governments are less constrained by geopolitical and ideological factors than their national counterparts, and some have policies and regulations that companies need to follow. In turn, companies provide critical services, for example, energy, food, buildings, infrastructure, mobility and communications,

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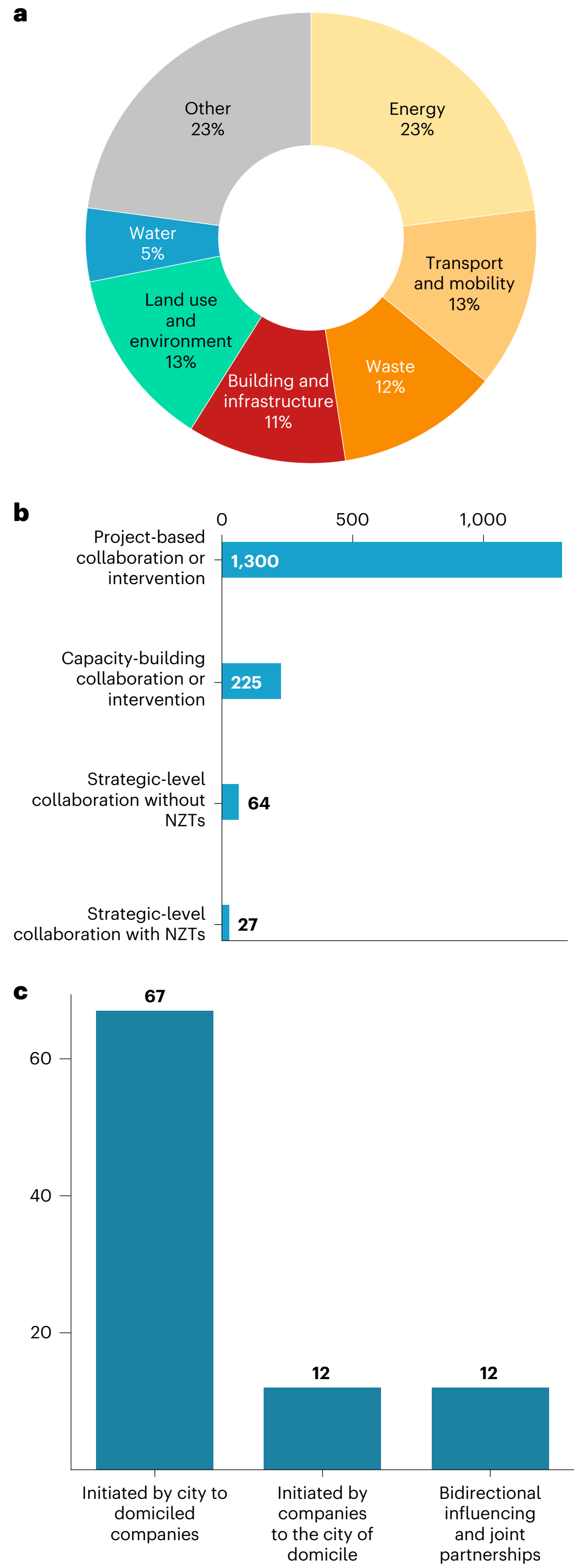

Fig. 5 | Analysis of the scope of existing collaborations between cities and companies and contrasted with the collaborations needed to address ESBs holistically. a, Pie chart representing the share of existing collaborations across sectors in the relevant dataset of the CDP[28]. In total, 59% of collaborations are related to energy, transport and mobility, waste, or building and infrastructure. By contrast, about 13% of collaborations are related to land use and the environment (aggregated from the agriculture, forestry, other land use and fisheries category, natural environment category, and spatial planning category). Water has critical interactions with several ESBs, including climate change, biosphere integrity and biogeochemical flows but is presently represented in only 5% of collaborations. Other initiatives, such as for public health, safety, social services, financial services, education, industry and technology, comprise about 23% of the collaborations. **b**,**c**, We code city–company collaborations based on the type of collaboration (**b**) and by the direction of influence (**c**) among cities and companies in strategic-level collaborations as possible pathways for change (Methods). The type of collaboration is coded for all entries with descriptions ($n = 1{,}617$), and the direction of influence is coded for strategic-level collaborations only ($n = 91$). Overall, collaborations tend to be fragmented and siloed, and there is no framework for leveraging the co-location of cities and companies to lessen impacts across ESBs. The possible pathways of change can involve different opportunities and barriers that warrant synthesis with further multi-disciplinary discourse.

generate tax revenues, and may shape the overall environmental performance of cities[31]. The proximity and mutual complementarity of these linkages and hotspots of both impacts and policy learning prioritize city–company collaborations. Many cities are already collaborating with companies, although not necessarily in the context of ESBs. The need to establish NZTs while jointly tackling other pressures on the Earth system, such as water consumption, is only starting to be touched upon. Our analysis of CDP data[28] shows that collaboration mainly occurs in the energy, transport and mobility, waste, and building and infrastructure sectors, comprising 59% of all collaborations (Fig. 5).

Our qualitative analysis of 1,617 textual responses from 482 cities to the CDP survey revealed a set of emergent themes surrounding existing city–company collaborations. City–business activities on sustainability topics are diverse and fragmented, often targeting small and medium-sized enterprises. Some cities invite companies into alliances, pacts or charters for climate-neutrality but mostly without engaging large companies. Other examples include the London Business Climate Leaders initiative, where the city works with 11 companies to develop a strategic plan for clean transport, energy, waste and the circular economy, and energy-efficient businesses. However, few of the participating companies are from our target group of top companies with science-based targets headquartered in the city. Most efforts focus on single issues, mainly climate and energy. Project-based (80.4%) and capacity-building collaborations (13.9%) dominate. Strategic-level collaborations (long-term partnerships beyond the project level) comprise at most 5.6% or only 91 out of the total. The integration of the financial sector in mobilizing green innovation[32] is lacking, and reporting on actual impacts is rare. Only a few responses explicitly mention science-based targets, the Task Force on Climate-Related Financial Disclosures or the Sustainable Development Goals. Among the few examples, climate-related disclosures that are aligned with the recommendations of the Task Force on Climate-Related Financial Disclosures will be mandatory across sectors in Hong Kong at the start of 2025[28]. Some Global South cities are working on connecting sustainability and climate policies, for example, Kuala Lumpur, to overcome the fragmented policy-making. Beyond certain links with national business organizations and chambers of commerce, the City–Business Climate Alliance is mentioned for climate partnerships. Of the 91 cases with strategic-level collaborations, 73.6% were initiated by cities and 13.2% by companies. Making strategic-level collaborations among cities and companies more widespread would require an intentional effort. Understanding the potential such collaborations could bring is a good step forward.

Need for collaboration across ESBs

Cities and companies must collaborate across ESBs and address their interactions, such as between climate and water stress. Based on the World Resource Institute's Aqueduct Water Risk Atlas (Methods), we estimated that 102 (51%) of the top 200 urban areas with the largest GHG emissions are in basins with high levels of water stress (Extended Data Fig. 1). Water stress is projected to increase due to climate change. Only 21 of these urban areas have NZTs for climate, although 43 already face extremely high water stress. In 107 other urban areas with a top

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500 company, 48 (45%) are in basins with high water stress. Among these companies, 285 (57%) are in high-water-stress basins according to their city of domicile and 276 lack science-based targets for the climate. This includes companies in water-intensive industries (for example, energy, materials and chemicals). There remains potential for dual commitments to science-based targets for climate and freshwater quantity. Companies can work with cities to address water-stress areas, not only in the cities in which they are based but also in the locations of their broader operations and value chains. This could initiate a process that reduces water use in other basins[33] and also reduce water use for goods and services consumed in urban areas spanning water footprints globally.

Discussion

Despite having separate target-setting practices due to having different constituencies, stakeholders and rules of governance, reporting and accountability[21], there are strong reasons why cities and companies should work together more closely. First, target setting and implementation cannot happen entirely in isolation as they require collaboration that considers social[34] and ecological proximity and embeddedness[35]. For example, co-located cities and companies draw on the same pool of local resources and environmental capacity for pollution assimilation. Second, for climate mitigation, expanding targets from scope 1 or 2 to scope 3 is widely called for, with some front runners moving towards doing so. This requires cities and companies to increasingly work together to cover broader impacts. Third, large companies and cities are more likely to face common environmental stresses (for example, climate change and water stress). Aligning targets and actions on the ground could maximize synergistic value, as more value could be co-created through a collaborative approach rather than separate approaches[36]. A paradigm shift towards considering coupled impacts and systems thinking may be necessary for recognizing responsibilities for physical flows and environmental effects nearby and far away[37]. Understanding metacoupling is crucial. Metacoupling includes energy trade-offs during water transfer from water-abundant to water-scarce areas[38] and impacts on ecosystem services.

Current social and governance systems do not offer clear pathways for cities and companies to collaborate closely. However, there are incentives and mechanisms that may encourage such an approach. For example, an actor that has already adopted ambitious plans has an incentive to actively lobby and encourage its less ambitious counterparts to do the same. Unless many actors are involved, their actions alone may be insufficient to reach the overall target, which may thereby be futile. For companies with NZTs, having other companies adopt similar NZTs reduces the risk of incurring unfavourable circumstances or competitive disadvantages. Our analysis highlights potential gains for cities and companies in matching high ambitions, which may necessitate increased collaboration. From either a city's or a company's perspective, influencing a co-located actor may add more value than acting alone. As stated, there is empirical evidence of proactive influencing among cities[18]. There is no reason why such behaviour cannot be extended across sectors to businesses that are bold enough to go against mainstream modes of operation. Other empirical evidence from an early-mover city where companies signed commitments with the mayor indicated the challenges in keeping businesses engaged, motivated and active[39]. Offering greater rewards to, imposing regulations on and putting pressure on actors that do or do not sufficiently support ambitious targets (for example, carbon neutrality in Helsinki) are among the lessons-learned[39]. Institutional pressure from the government, such as legal frameworks and low-carbon city policies, was also found to be effective in influencing corporate behaviour towards reducing emissions[40]. Moreover, cities of domicile do have some influence over industries within their administrative boundaries because they can introduce policies that induce industrial structural change[41], including through strategic planning and regulation, and also influence the company's headquarters to align with NZTs. Business headquarters hosted in cities represent strategic nodes or brains in a network. They have the power to make key decisions that can reduce emissions within and across their production bases and supply chains. Emerging examples of such influence include regulations on public procurement and supply chains and mandating companies to disclose their environmental impact or to adopt science-based targets by law.

Thus, cities and companies should expand their horizons and amplify the impacts of their targets and actions from a systems perspective. Specifically, cities with NZTs should urge companies to reduce emissions within and beyond their jurisdictions. Similarly, companies with science-based targets but in cities without NZTs should urge their hosting cities to align. Broader public awareness of these potentials and imperatives may help to bring these key actors closer. Although at present cities have more catalysing potential (Fig. 5), the dynamics may shift as more companies adopt science-based targets. The top cities and companies can apply different levers. For example, cities could persuade the peers within their networks to influence domiciled companies. City–company collaborations are gaining attention, including through the City–Business Climate Alliance, a solution-oriented platform that aims to reach 100 cities collaborating with businesses by 2025. At present, 19 cities are piloting initiatives to scale up efforts on climate action by collaborating with businesses, of which 13 are from our target group of the top 200 urban areas by emissions and nine of those host 39 of the top 500 companies. However, only three out of these 39 companies have a science-based target and 15 have other targets. Target alignment and joint implementation across cities and companies should be explicitly emphasized, while also broadening the scope to include other ESBs.

Companies in some sectors have set science-based targets relating to broader Earth system impacts. Targets based on the Net-Zero Standard, which is under revision, would cover scope 3 to minimize emissions embedded in the company's value chain[42]. With the release of the first methodologies for science-based targets for nature, companies can set targets beyond climate to address environmental impacts (https://sciencebasedtargets.org/resources/). The 17 pilot companies setting science-based targets for nature are seeking to act across their value chains. They are engaging with their suppliers to reduce impacts on freshwater, land systems and biogeochemical flows and to address scope 3 emissions and environmental impacts beyond direct operations. By adopting a spatially explicit approach, companies could identify footprint hotspots across their value chains and set priority targets, which may deliver co-benefits across ESBs. Four of the pilot companies are top emitters, hosted equally in cities with and without NZTs.

Interconnections among ESBs, including the biodiversity crisis[43], further heighten the urgency of tackling intertwined challenges jointly. Guiding principles include common procedures for translating ESBs[44], focusing on interactions, acknowledging dynamics, allocating for justice and equity, and designing incentives[21]. Catalysing collaborations may also involve researching solutions, brokering power, navigating differences and reframing agency[45]. Moreover, complex contexts require solutions that are tailored to context sensitivity[46]. Leadership by both cities and companies is needed to disrupt existing silos between these key actors and to facilitate joint target setting, action, financing, reporting and accountability on progress. Expanding public–private partnerships may be one possible avenue, especially when configured and allied around shared goals, including those for zero-deforestation initiatives[47]. Supplementary Table 1 presents other possible entry points for catalysing city–company collaborations with examples from our analysis. Greater mobilization is needed to avert impacts and tipping points[48], including those for biosphere integrity[49] and freshwater use[50,51], and to gain a view of interactions across domains[52,53]. Possible entry points in this illustrative roadmap could be used to explore the design of new incentives, policies and measures[54] through a more integrated framework.

Operating within ESBs will often require nexus approaches[55,56] that exploit synergies among interconnected domains[57]. For example, phasing out fossil fuels[58], saving water resources[59], switching to more sustainable energy resources[60] and reducing biodiversity impacts[61] are intertwined with city and company supply chains. Socio-economic and environmental drivers and effects within and across geographical boundaries are also interwoven[62]. Joint actions across actors, scales and domains require cities and companies to work collaboratively across ESBs to amplify the effort. Although largely remaining at project level, there are some early signs of promising city–company collaborations. Major cities like London, Paris, Helsinki and Boston have established city–company partnerships, primarily for climate. These efforts have resulted in joint strategy development, higher public transparency and concrete mitigation gains. There are also city–company collaborations in the water sector. For example, Cape Town, Hong Kong, Atlanta and Edinburgh have established initiatives to deliver improved water management, reduced fertilizer use and gains in water-use efficiency[28]. These voluntary collaborations could kick-start broader initiatives, including joint target setting. Proactive influencing between cities and companies in the adoption of science-based targets could be an important mechanism for transcending existing paradigms and mindsets[11]. Such shifts may be effective for countering climate delay discourses (for example, redirecting responsibility and insisting that someone else should take action first)[63] and siloed approaches[64].

Realizing targeted action can be challenging. Policy learning could accelerate the diffusion of new experiences to make such collaborations work. Yokohama in the Greater Tokyo Area, for example, has chosen to engage with the private sector in upscaling decarbonizing solutions, and the city is just starting to amplify the voices of hosted companies with science-based targets to positively influence others. Through an intercity collaboration programme, the city is also providing advice on establishing similar platforms in other cities, including Bangkok, which has 11 of the top companies, all without science-based targets. Domino effects across cities[65] and companies may prove the value of joined-up targets as key opportunities, especially when top emitters are involved. Databases of business partners that support city NZTs (for example, Adelaide, which presently headquarters none of the top firms) could enhance transparency and pressure businesses without science-based targets into action. Emerging dynamics in the policy sphere are also being coupled with analyses of favourable conditions and barriers towards climate-neutrality in European cities, including operational capacity, stakeholder collaboration, visionary co-implementation[66] and resource mobilization[67]. Similar studies are needed to explore barriers hindering city–company collaborations and ways of overcoming these barriers worldwide.

Research could focus on specific tools and mechanisms for forming and implementing partnerships and consider the role of collaborative decision-making in partnership dynamics and capacity[68]. For example, financial incentives, tax benefits and recognition (such as, sustainable business certification programmes) could even out asymmetrical incentive structures across actors during the process of setting and meeting science-based targets. In addition, gaining an understanding of the institutional logics of cross-sector partnerships is crucial, including temporal issues and tensions[69]. Uncertainties may involve technical obstacles, institutional inertia[70,71], established power structures, diverging interests and cultural norms[72]. Size, impacts and context also matter. Collaboration examples outside the top cities (for example, Birmingham, Mannheim and Turku[28]) may not involve the same challenges or opportunities. Change barriers can intensify with increasing ambition and complexity[72] whereas problem urgency[73]—such as climate change and water stress—could diminish conflicts in striving to reach common goals. Synthesizing insights from organizational change[74], planned change[75], power relations[76] and other fields are needed to enhance the realization of the potentials.

Ultimately, realizing an alignment with ESBs requires a concerted effort and the engagement of key actors[21]. Many more city–company collaborations that keep abreast of ambitious targets and join forces to operate within ESBs are urgently needed. Our analyses emphasize the engagement of co-located cities and companies—whether front runners or laggards—based on their potential for leveraging action to safeguard the planet's life-support systems. Of the key actors with science-based targets for climate, persuading co-located cities and companies to adopt a more ambitious target level would increase the reduction potential from 3.41 up to 5.70 $GtCO_2e$, a multiplier of 1.7. Further engaging with co-located laggards could raise the potential to 8.79 $GtCO_2e$ with a multiplier of 2.6. City–company collaborations also affect mitigation pace and the mechanisms used by the best-enabling co-located actors to operate within ESBs. Interconnections, including those for climate and water, require the targeting of collaborative action across ESBs and an extension beyond climate to natural ecosystems, biosphere integrity, freshwater flows, land, nutrient cycles and aerosol loading.

In a time that requires accelerated system transformations, city–company collaborations through aligned science-based target setting hold untapped catalytic potential. Decision-makers, managers, practitioners, scientists, researchers and civil society in key cities and companies must work together systematically so that 'all hands are on deck' to mobilize the required responses. This will involve setting new rules so that the system can operate within ESBs, enhancing alliances and coalitions at all levels, and reducing the stark gaps in the alleviation of environmental impacts. We expect that upscaled efforts regarding proactive influencing and collaboration among key cities and companies will motivate greater action across many others with positive cascading effects at the national and international levels globally. Key cities and companies could lead transformative change across ESBs and initiate long-awaited changes towards global sustainability.

Methods

A cumulative distribution function in the form of a Lorenz curve was used to determine the cumulative impact of cities and companies when ordered based on emissions to support the identification of key actors. We then analysed the co-location of these key actors, as geographical proximity can provide an important basis for collaboration. Our analyses focused on the targets set by these key cities and companies and their co-location. We completed comparative analyses for water stress and the current status of city–company collaborations. We then produced an illustrative roadmap related to several ESBs (Supplementary Table 1). There were five main steps in our methods, as detailed below. Finally, we provide statistics on the analysed cities and companies.

Urban areas with and without targets

The status of cities adopting NZTs under the Race to Zero was collated from the United Nations Framework Convention on Climate Change in mid-2022. Details of participants were downloaded from the initiative website for the selected cities (https://climateaction.unfccc.int/Initiatives?id=Race_to_Zero). The data include the populations of urban areas that have joined the initiative. The scope 1 emissions were provided in limited cases. The population data were merged with data on consumption-based emissions per capita for each of the cities and towns that have joined the Race to Zero (n = 1,098). Thus, we analysed the first 1,098 cities with NZTs out of the 1,143 local governments that were members as of June 2024. The data points were ordered according to urban-consumption-based emissions, which showed that the first 200 cities and towns offer the greatest mitigation potential. This result was compared with the top 200 urban areas with the largest urban-consumption-based emissions in 2020[77,78]. The urban areas with and without NZTs were then determined. The Global Human Settlement

Layer (GHSL) was the main basis of these analyses and was accessed through the Urban Centre Database (https://data.jrc.ec.europa.eu/collection/ghsl). More information about the database can be found in the documentation for the GHSL data package (https://publications.jrc.ec.europa.eu/repository/handle/JRC117104). We quantified the difference between the urban population in each administrative unit that has adopted NZTs under the Race to Zero with the population of its entire urban area based on contiguous areas. We compared the regional distribution of the estimated urban-consumption-based emissions relevant to existing NZTs with the opportunities for reduction for the 200 urban areas with the largest GHG emissions. We used the six regions defined in Annex II of the Sixth Assessment Report of Working Group III of the Intergovernmental Panel on Climate Change, which is available from https://www.ipcc.ch/report/ar6/wg3/. We provided the total regional urban-consumption-based GHG emissions[79,80] for comparison.

Companies with and without targets

Company targets were obtained from two datasets. Science-based targets for climate were obtained from the Science Based Targets Initiative Progress Report 2021 (https://sciencebasedtargets.org/reports/sbti-progress-report-2021/), and other targets were obtained from the CDP Climate Change 2021 Questionnaire Investor and Supply Chain Version (https://www.cdp.net/en/data/corporate-data). These were compared with a dataset of global companies that disclose emissions based on Bloomberg Greenhouse Gas (GHG) Emissions Sustainability Data (https://www.bloomberg.com/professional/solutions/sustainable-finance/), which allowed us to identify companies with and without targets ($n = 3,456$). The direct emissions (scope 1) of a company are the sum of its direct emissions from all its facilities globally, within or outside its city of domicile. The dataset did not include other facility-level emissions, and these were not available in any other dataset. The companies analysed were ordered based on their direct (scope 1) emissions, which allowed us to determine that the top 500 companies had the largest relative mitigation potential. We used the target status of these top 500 companies to classify them as companies with science-based targets, companies with other targets and companies without targets. The city of domicile of each of the top 500 companies was manually inserted for a cross-comparative analysis with urban areas. By definition, the city of domicile refers to the physical location of the business headquarters for legal purposes. We attempted to gather further online data for companies with science-based targets, including case studies of the Science Based Targets initiative (https://sciencebasedtargets.org/companies-taking-action/case-studies), to determine whether their science-based targets for climate were coupled with targets for other domains, such as regenerative agriculture, but had very limited results. In comparison to our original analysis, a further 28 of the top 500 companies had adopted science-based targets as of June 2024. These companies are domiciled in 27 different cities, and two are domiciled in São Paulo. That at most only two of the top 500 companies have joined the effort from any given city further alludes to the need to catalyse these actors more effectively.

Co-location and harmonization

The GHSL was used to identify the geographical locations of the cities and companies. In certain cases, cities and towns that have adopted NZTs were in the same urban area, such as if different boroughs of a metropolitan area have pledged to reach net zero separately in addition to the main city. Similarly, the city of domicile for a company can be listed as a district within an urban area or even a city in the same urban area when the contiguous urban fabric is considered. Based on the GHSL, these instances were harmonized for our geographical analysis, so that each urban area was counted only once. We also used this approach to harmonize the target status when analysing the geographical overlap between cities and companies. The co-location data were further used to determine the impact of matching ambition levels on the status of targets and the potential of a multiplier based on city–company collaborations. The reduction potential represents the total amount of annual emissions that could be eliminated from the starting point of emission reductions until all actors have achieved their committed NZTs, which should be as early as possible and by mid-century at the latest, regardless of the pace of mitigations that affect cumulative emissions. Our analysis did not consider any increases in levels of emissions, given the aim of reaching net-zero emissions through setting science-based targets. Other facility-level emissions were not available in any publicly accessible dataset. Due to data availability and the distributed nature of facilities, the proportion of companies' scope 1 emissions in cities was not evaluated. The GHSL was also taken as the point of reference when cross-checking references to cities in the other datasets used in our analysis. For example, Culver City, which is listed in the 2021 Cities Collaborating with Businesses dataset[28], is in the Los Angeles–Long Beach–Santa Ana urban area, as noted in Supplementary Table 1.

Current collaborations between cities and companies

We analysed a CDP database with data on collaborations between cities and businesses to determine the current status of collaborative efforts and future opportunities. The 2021 Cities Collaborating with Businesses dataset[28] has 2,606 entries. Entries with a blank collaboration type or domain were removed during data-processing along with entries indicating that the question was irrelevant. The remaining 1,653 valid entries were analysed according to the domain of intervention. A proportion of these entries were for cities in our analysis. Overall, 86 of the top 200 urban areas with the largest GHG emissions were listed among the entries, most with capacity-building measures. Only 20 other urban areas that are the city of domicile of at least one of the top 500 companies were in the dataset. The available descriptions of the collaborations ($n = 1,617$ filled entries) were further coded and analysed in two ways. First, the scope was coded as project-based collaboration, capacity-building collaboration and strategic-level collaboration with or without NZTs. Second, strategic-level collaborations were coded by the direction of influence: collaborations initiated by a city influencing domiciled companies, collaborations initiated by companies influencing the city of domicile and bidirectional influencing. In addition, the evidence base was expanded to cover city-specific reports that were referenced in the dataset and independent online searches for initiatives, technical reports from city–company workshops, and databases of national or regional initiatives for cities that may have involved a collaboration. This process supports a dynamic policy landscape among these actors. Within this process, our comparisons with real-world policies also included decarbonization leading areas in Japan, which is available at www.env.go.jp/en/headline/2604.html. The Web Portal for Zero Carbon Development in Asia was also used (www.env.go.jp/earth/coop/lowcarbon-asia/english/). Moreover, the 91 strategic city–company collaborations identified in the CDP database were used to provide the examples across ESB domains in Supplementary Table 1. A summary of technical guidelines for taking action are given in Supplementary Table 2.

Comparison with levels of water stress

Baseline water stress, or the ratio of total water withdrawals to the available renewable surface and groundwater supplies in a given water basin, is a key indicator of water risk. More information on this global indicator can be found in a technical note (www.wri.org/research/aqueduct-30-updated-decision-relevant-global-water-risk-indicators). The levels of water stress in Extended Data Fig. 1 are based on the geographical coordinates of 307 different urban areas that represent the location of a top 200 urban area with the largest GHG emissions or the city of domicile of a top 500 company. The coordinates were gathered from the World Resource Institute's Aqueduct Water Risk Atlas (www.wri.org/applications/aqueduct/water-risk-atlas/). As well as these raw data, we also downloaded the baseline water stress. The data were based on the PCR-GLOBWB 2 global hydrological model[81]. The spatial resolution was HydroBASINS 6 with monthly temporal resolution (with 12 time series) and an annual baseline. A water-stress index higher than 80% indicates extremely high levels of water stress. High levels of water stress range between 40% and 80%, and medium–high levels of water stress are from 20% to 40%. Low–medium water stress occurs for values of the water-stress index between 10% and 20%. Finally, a water stress index <10% indicates low water stress. The cities and companies were categorized as those suffering from and those not suffering from high levels of water stress.

Statistics for the cities and companies analysed

For the 1,098 cities, the mean value of urban-consumption-based emissions was 4.55 $MtCO_2e$ per year with a median of 0.76 $MtCO_2e$ and interquartile range (IQR) of 2.74 $MtCO_2e$. By contrast, the mean value for the top 200 emitters was larger at 46.27 $MtCO_2e$ per year with a median of 28.98 $MtCO_2e$ and IQR of 35.85 $MtCO_2e$. The mean difference among these two datasets was 41.72 $MtCO_2e$, and the pooled standard deviation was 27.05. Cohen's d as the ratio of these values was 1.54. For the 3,456 companies, the mean value of direct emissions was 2.80 $MtCO_2e$ per year with a median of 0.05 $MtCO_2e$ and IQR of 0.43 $MtCO_2e$. The mean value for the top 500 emitters was larger at 18.29 $MtCO_2e$ per year with a median of 7.53 $MtCO_2e$ and an IQR of 13.86. The mean difference was 15.49 $MtCO_2e$ per year, the pooled standard deviation was 14.65 and Cohen's d was 1.06. Values of Cohen's d above 0.80 indicate a large effect size. We also used the Yuen–Welch test, which is a robust statistical test that considers unequal variance and non-normality. Two-tailed testing based on the Yuen–Welch test gave values of 13.84 for cities and 16.53 for companies. Based on the degrees of freedom of 1,296 for cities and 3,954 for companies, these values are statistically significant at $P < .01$. Our data analyses, including the calculation of descriptive statistics, were conducted in Microsoft Excel v.2.56 and SciPy v.1.10.0.

Inclusion and ethics

Local and regional research relevant to the field of study has been taken into account in the references.

Reporting summary

Further information on research design is available in the Nature Portfolio Reporting Summary linked to this article.

Data availability

All data generated or analysed during this research work are included in this Analysis and its Supplementary Information. As indicated in Methods, data sources used in our analysis include the Race to Zero initiative of the United Nations Framework Convention on Climate Change (https://climateaction.unfccc.int/Initiatives?id=Race_to_Zero), a dataset on urban-consumption-based emissions in 2020 (available via Zenodo at https://doi.org/10.5281/zenodo.5559792)[77], the Science Based Targets Initiative Progress Report 2021 (https://sciencebasedtargets.org/reports/sbti-progress-report-2021/), the GHSL (https://data.jrc.ec.europa.eu/collection/ghsl) and the World Resource Institute's Aqueduct Water Risk Atlas (https://www.wri.org/applications/aqueduct/water-risk-atlas/). Correspondence and requests for materials should be addressed to the co-corresponding authors.

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Author contributions

X.B., Ş.K. and A.B. initiated and conceptualized the study. Ş.K. wrote the first version, which was developed collectively with the author team (X.B., A.B., J.L., G.W., B.C., L.S.A., S.H., V.V. and O.S.). Each author wrote at least a paragraph and edited the paper. The analyses for cities and companies were conducted by Ş.K. and A.B., which were visualized as Figs. 1, 2 and 5 and Extended Data Fig. 1 (Ş.K.) and Fig. 3 (A.B.). L.S.A. and Ş.K. conducted the co-location analysis (Ş.K. provided Fig. 4a,b and L.S.A. provided Fig. 4c). G.W. and Ş.K. performed the qualitative analysis of city–company collaboration descriptions, and extended analyses were conducted by Ş.K. Supplementary Tables 1 and 2 were prepared by Ş.K. based on collective discussions. All co-authors read and approved the paper.

Competing interests

The authors declare no competing interests.

Additional information

Extended data is available for this paper at https://doi.org/10.1038/s41893-024-01473-w.

Supplementary information The online version contains supplementary material available at https://doi.org/10.1038/s41893-024-01473-w.

Correspondence and requests for materials should be addressed to Şiir Kılkış or Xuemei Bai.

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Extended Data Fig. 1 | Comparison of the shares and levels of water stress considering the top 200 urban areas with the largest GHG emissions and top 500 companies. Based on the World Resource Institute's Aqueduct Water Risk Atlas, we analyse water stress by coordinate entries (see Methods). **a,** The top panel compares the key cities and companies based on the shares that involve high water stress. These shares are higher in the top 200 urban areas and top-emitting 500 companies as a whole (top left and right graphs in this panel, respectively) than in urban areas that are not a top 200 urban area but where a top-emitting 500 company is located based on the city of domicile (graph in the top middle). **b,** The distribution of water stress categories for the top 200 urban areas with the largest GHG emissions and those urban areas with top-emitting 500 companies is mapped in the bottom panel. Here, each coloured marking represents water stress in a given location. Rather than implying causality or correlation, these shares indicate the importance of taking action across multiple ESBs, including climate and water.

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Software and code

Policy information about availability of computer code

Data collection

Data is collected and compiled for data analysis based on multiple data sources, initially for 1,098 cities and 3,456 companies to identify the key actors. Moreover, data collection related to the locations of the top-emitting 200 cities and the top-emitting 500 companies are based on the city of domicile that are found to represent 307 distinct urban areas. Data collection and data compilation processes are primarily based on the use of spreadsheets in Microsoft Excel version 2.56 that has allowed a common basis for categorizing and labelling collected data. Within the data collection, descriptions that related to the current status of city-company collaborations contained 1,653 valid entries.

Data analysis

Data analyses, including the characterization of the datasets based on descriptive statistics, are conducted in Microsoft Excel version 2.56 and SciPy version 1.10.0, including the SciPy sub-package scipy.stats as described in the SciPy v1.10.0 Manual. The visualization of the colocation based analyses for the top-emitting 200 cities and top-emitting 500 companies are supported using ArcGIS version 10.8.2.

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All data generated or analysed during this research work are included in this analysis article and its supplementary information file, which is accessible based on figure number in the submitted file (Figures 1-5 and Extended Data Figure 1). As indicated in the Methods, data sources of the analysis include the UNFCCC Race to Zero initiative (https://climateaction.unfccc.int/Initiatives?id=Race_to_Zero), a dataset on urban consumption-based emissions in 2020 (https://doi.org/10.5281/zenodo.5559792), the Science Based Targets Initiative Progress Report 2021 (https://sciencebasedtargets.org/reports/sbti-progress-report-2021/), the Global Human Settlement Layer (https://data.jrc.ec.europa.eu/collection/ghsl), and the World Resource Institute's Aqueduct Water Risk Atlas (https://www.wri.org/applications/aqueduct/water-risk-atlas/). Correspondence and requests for materials should be addressed to the co-corresponding authors.

Human research participants

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Study description

Our study focuses on the top emitting 200 cities and 500 companies based on the current state and potential of adopting science-based targets for climate. We distinguish 4 types of combinations among cities and companies with and without science-based targets and quantify potentials for synergy when two-way influencing of these top emitters does take place to match ambitions. We further analyse water stress to elucidate the importance of taking action on multiple domains of the Earth system, such as climate and water. Our analyses provide reasons why cities and companies should work together more closely to capture an untapped potential and an illustrative roadmap for catalysing city-company collaborations to operate within Earth system boundaries.

Research sample

The top-emitting 200 cities and 500 companies are identified as key actors among the first 1,098 cities and towns that have set net-zero targets and the 3,456 companies ranked by direct emissions (scope 1). A cumulative distribution function in the form of a Lorenz curve is used to determine the cumulative impact of cities and companies when ordered based on emissions to support the identification of key actors. The status of cities adopting net-zero targets under the Race to Zero initiative is collated from UNFCCC in mid-2022. The data contains mostly the population that an urban area joined the initiative with scope 1 emissions provided in limited cases. The population data was merged with data on per capita urban consumption-based emissions for each of the cities and towns that joined the Race to Zero (n = 1,098). Companies with targets were obtained from two datasets. Science based targets for climate were obtained from the Science Based Targets Initiative Progress Report 2021 and other targets were obtained from the CDP Climate Change 2021 Questionnaire. These were compared to a dataset of global companies that disclose emissions based on Bloomberg data to identify companies with and without targets (n = 3,456). The Global Human Settlement Layer (GHSL) was taken as the basis of geographical identification across the locations of both cities and companies to provide harmonisation for the colocation analysis. The locations of the top-emitting 200 cities and top-emitting 500 companies are found to involve 307 distinct urban areas.

Sampling strategy

Sampling strategy	The rationale for the sample sizes are based on the objective of identifying key actors for adopting science-based targets for climate. Lorenz curves for both cities and companies are used to identify turning points where each additional actor area starts contributing relatively less to the cumulative total. This approach allowed the identification of the top 200 cities and top 500 companies having the greatest mitigation potential. Figures 1 and 3 provide the curves of emissions when ordered from highest to lowest emissions.
Data collection	Data that is required for the research work is collected, compiled, and analysed based on multiple data sources as described in the Methods: the UNFCCC Race to Zero initiative, a dataset on urban consumption-based emissions in 2020 that is also available in Zenodo, the Science Based Targets Initiative Progress Report 2021, CDP Climate Change 2021 Questionnaire, Bloomberg data, the Global Human Settlement Layer (GHSL), the World Resource Institute's Aqueduct Water Risk Atlas, and the 2021 Cities Collaborating with Businesses dataset. Available descriptions in the latter dataset (n = 1,617 filled entries) were further coded and analysed. ŞK and AB collected and compiled data on cities and companies, respectively. LSA and ŞK conducted the colocation analysis. ŞK also collected and compiled data on water stress and collaboration between cities and companies. GW and ŞK conducted qualitative analyses.
Timing and spatial scale	This analysis is based on collaborations within the Earth Commission's Working Group 5 on Translation and Methods with additional insight from the Science Based Targets Network focusing on cities and companies. Data collection in the scope of the collaboration started February 1, 2022 and ended July 31, 2022 prior to the analyses that are conducted for the study and article preparations.
Data exclusions	No data is excluded from the analyses with the exception of one particular instance. As stated in the Methods, one of the datasets involving 2,606 entries had 953 entries that were blank for the collaboration type and domain or indicated that the question was irrelevant. These entries were removed as part of data processing and the analysis was conducted with the 1,653 valid data entries.
Reproducibility	The reproducibility of the data analysis is ensured through the methods described and the file that is associated with this article containing the data that is generated or analysed during this study based on Figures 1-5 as provided in the Supplementary Data File. This Supplementary Data File also contains the data points that are visualised in the Extended Data Figure 1 of the analysis article.
Randomization	A random allocation process is not relevant for the scope of the present study other than analysing the cities and companies that are involved in science-based target setting and/or have the characteristic of having the largest emissions. In addition, analyses by categories are based on the possible types of combinations, such as cities and companies with and without science-based targets, and the locations of the analysed cities and companies in water basins involving high water stress or other levels of water stress.
Blinding	Blinding is not directly relevant for our study since the physical location of actors are important for geographical identification.

Did the study involve field work? ☐ Yes ☒ No

Reporting for specific materials, systems and methods

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