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A research roadmap for quantifying non-state and subnational climate mitigation action

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Non-state and subnational climate actors have become central to global climate change governance. Quantitatively assessing climate mitigation undertaken by these entities is critical to understand the credibility of this trend. In this Perspective, we make recommendations regarding five main areas of research and methodological development related to evaluating non-state and subnational climate actions: defining clear boundaries and terminology; use of common methodologies to aggregate and assess non-state and subnational contributions; systematically dealing with issues of overlap; estimating the likelihood of implementation; and addressing data gaps.

As major international bodies such as the United Nations and the IPCC work to produce scientific assessments of the efforts needed to increase the likelihood of achieving 1.5 or 2 °C emissions pathways[1–3], the contributions from non-state (that is, business, investors and civil society organizations) and subnational (local (city, state) and regional government) actors remain uncertain. There have been several studies[4–9] assessing these actors' potential contributions to global climate change mitigation efforts, yet these assessments utilize differing assumptions, methodologies and data sources, which does not allow for accurate comparison or global aggregation[10].

Non-state and subnational actors can help national governments to reach existing climate policy goals and set higher targets[11–13]. While the literature suggests that non-state and subnational climate action are, on average, complementary to national policies[13,14], such actions can also help fill gaps. The 'We Are Still In' and America's Pledge campaigns emerged following President Trump's announcement of national climate policy rollbacks and so far include more than 3,500 mayors, governors, business leaders and higher learning institutions pledging to uphold the Paris Agreement[15]. This initiative, along with others such as the 2014 New York Climate Summit or the ongoing Marrakech Partnership for Global Climate Action, demonstrate subnational and non-state actors' roles as contributors to national and international climate, development and sustainability efforts.

As climate governance is evolving into what some scholars term polycentric[16,17], researchers are now conducting studies that seek to quantify the contributions of non-state and subnational climate actions to global climate mitigation in terms of tonnes of GHG emissions reductions (that is, aggregation analyses). These aggregation studies are critically important to the international climate governance regime for several reasons. Non-state and subnational actors are undertaking climate mitigation efforts (many of them independent of national policy) that are leading to measurable emissions reductions. These actors could also drive additional climate policy action in a number of ways. Non-state and subnational climate actions help identify, scale up and pilot innovative approaches to climate action for national governments[18]. Global analyses of these actors' efforts could demonstrate and communicate the collective capacity of non-state and subnational actors in periodic stocktakes for the Paris Agreement, and the results may inform periodic revisions of national climate action plans (Nationally Determined Contributions; NDCs)[19].

Existing global aggregation studies, however, are fragmented and incomplete. The field suffers from a lack of terminological consistency, varying methodological approaches and difficulty measuring whether non-state and subnational actions achieve their goals. It is vital for sound global climate governance to develop a clear and accurate accounting of non-state and subnational actors' climate efforts, without which it is impossible to estimate with any accuracy whether global emissions are in line with trajectories to avoid catastrophic warming.

While there are many aspects of non-state and subnational climate actions that could be evaluated, such as their political impact on national governments and intergovernmental processes[12,20,21], here we focus on non-state and subnational actors' actions to reduce GHG emissions. We draw on studies that seek to quantify and aggregate non-state and subnational actors' contributions to global climate mitigation as of September 2017 (see Supplementary Table 1). Applying a consistent framework of analysis to determine

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key methodological divergences between the reports, we identify five major areas of research and development: (1) defining consistent taxonomies for defining the diverse landscape of non-state and subnational actions; (2) developing methodologies to quantify aggregate impact of their contributions, (3) factoring in overlaps with national efforts and initiatives; (4) assessing the likelihood that these actors achieve their goals and intended effects; and (5) addressing data gaps.

Defining consistent taxonomies

Clarity and consistency of definitions are critical for delineating boundaries to assess climate actions. Non-state or subnational action generally refers to "a diverse set of governance activities taking place beyond strictly governmental and intergovernmental (or multilateral) settings"[22]; these entities are often referred to as non-Party actors to distinguish them from the UN Framework Convention on Climate Change (UNFCCC) Parties. When non-state or subnational actors from at least two different countries "adhere to rules and practices that seek to steer behaviour towards shared, public goals"[13] across borders, this relationship has been referred to as transnational climate governance[23]. Hybrid coalitions of these actors that often involve national governments are commonly termed cooperative initiatives[4]; and when they transverse national borders they become 'international cooperative initiatives' (ICIs)[24]. The UN Environment's Climate Initiatives Platform catalogues more than 200 of these instances[25]. With collective initiatives that can involve diverse actors, however, the criteria for inclusion are often unclear, meaning each study quantifying non-state actors' climate contributions cannot be compared and must be considered in isolation.

Networks and actor platforms also vary with respect to how they refer to climate mitigation activities. Some initiatives only require a political statement (a commitment rather than a specific action), whereas others require specific target setting, monitoring and evaluation. The Under 2 Coalition, for example, sets as a collective goal for its members to commit to a specific emissions reduction target of 80–95% below 1990 levels by 2050 or 2 tCO_2 per capita. Actions can be as diverse as an individual company setting specific targeted emissions reductions versus a broad coalition of actors expressing support for climate policy objectives. These definitions matter for determining impact — initiatives that aggregate several actors could lead to greater impact than individual actions alone, and the systemic impact (sector- or economy-wide effects) of initiatives can be larger still[26].

What are the criteria for including certain actors in an analysis, and how are those actors' efforts defined? We recommend that:

- Researchers undertaking analysis be clear about which actors and initiatives are included in studies. They should indicate whether they traverse national boundaries or involve national governments.
- Research on ICIs, particularly those that include complex constellations of actors and initiatives, should set clear definitional boundaries that specify whether the analysis includes individual actions, initiatives combining several actors, or both. It is also critical to specify how climate actions are defined, including details such as whether targets are absolute or intensity-based reduction targets, for example.
- Researchers should clearly note any specific criteria used to include or exclude actors in the study. Graichen and colleagues[7], for instance, outline nine criteria in their review of 180 ICIs' contributions to global climate mitigation, assessing only those that have 'high mitigation impact' potential and 'innovativeness of approach'.

Clearly defining the scope and criteria for what an aggregation study includes is essential for transparently communicating to policymakers and other audiences what an analysis evaluates, which is crucial for synthesis or comparison across studies.

Quantifying aggregate mitigation

A central aim in many aggregation analyses is to determine the combined mitigation (tonnes of GHG emissions) of non-state and subnational actors' pledges compared to a scenario of national governments' pledges alone. There is no agreed-on approach or single standard to quantitatively assess these contributions, however. Existing analyses are inconsistent with respect to multiple domains: the scope of emissions covered by different actors (direct or Scope 1 emissions versus indirect or Scope 2 or 3 emissions, per the Greenhouse Gas Protocol/ISO 14064:1 classification[27]), target and base years, and counterfactuals or scenarios used to evaluate additional impact (hereinafter referred to as baselines). Such scope distinctions are critical, as for many actors' efforts, impacts are considerably greater for indirect (Scope 2 and 3) than for direct (Scope 1) emissions. The emissions picture is further complicated by the often transboundary nature of operations and initiatives, which are not limited to territorially defined jurisdictions and operate across a range of standards and systems[28], making attribution of emissions and resulting reductions complicated.

Studies that assess non-state and subnational actor reductions in national and global scenarios compare additional reductions against different kinds of baselines:

- Counterfactual or 'no policy' scenarios that specify no additional action from a noted base year or set of policies (for example, the baselines of the IPCC Fifth Assessment Report or a separate baseline assessment).
- 'Current policy scenarios' that are based on national policy implementation (such as the IEA World Energy Outlook's Current Policies Scenario). Some include sub-national policies, whereas others do not. They usually do not explicitly include non-state actor commitments.
- A scenario based on NDCs to the Paris Agreement. These contributions are pledges made at the international level that may not yet have been translated into national policies, and therefore lead to a different emissions outcome than the current policy scenario.
- Some studies use the term business as usual (BAU), which could refer to one or more of the above scenarios.

Existing scenarios are largely a function of the types of policies modelled — from no policy to national or global policies — and inherently assume that policy is the main driver of mitigation. Instead, what is needed is a 'current national policies plus non-state and subnational action' scenario that simultaneously represents the impacts of national policies as well as the voluntary actions of non-state and subnational actors. To develop these scenarios, realistic representation of actors, institutions and climate change decision-making are needed[29]. Such improved scenarios can be accomplished by adjusting existing models or building new models that include more detailed representation through integrated assessment models (IAMs), modelling agents specifically, or through simplified bottom-up models.

Integrated assessment models and agent-based models (ABMs) provide modelling approaches to designing such scenarios and evaluating ex-post emissions after subnational and non-state initiatives are implemented in a unified manner[8,30,31]. Although IAMs provide a consistent emissions scenario to evaluate the impacts of these actors on global emissions levels, they only explicitly represent large countries or regions and fail to represent interactions between different actors; this makes it difficult to resolve overlaps and estimate impacts resulting from interactions. Agent-based models, on the other hand, provide more explicit representation of different actors and their interactions on the basis of prescribed behavioural rules, but up until now have mostly focused on small regions or parts of the energy system[29]. Hovi et al.[31] apply ABMs to evaluate the impact of clubs of climate actors to global mitigation, simulating their motivations and behaviour. The main challenge with ABMs is to make transparent and reasonable assumptions that fit non-state and subnational commitments to the parameters available in the modelled scenarios.

The accuracy attainable using these approaches is also highly dependent on the availability of information about non-state and subnational actors' baseline emissions, targets and growth assumptions. These data are often scarce and non-transparent, complicated by the diverse reporting requirements and multiple accounting methodologies used by reporting platforms. In some studies, particularly those that include subnational actors, baseline emissions data are estimated using population and gross domestic product as proxies[32]. If actions over different actors are aggregated, varying approaches can be used to calculate baselines:

(1) Individual baselines for specific actors can be determined, independent of the baseline of the country. This method could be challenging if many actors are involved and varying assumptions are adopted (for example, the assumptions for a city's baseline may be different to those from other jurisdictions' baselines within the same country). (2) Generic baselines for specific actor groups can be chosen, utilizing industry sector projections from the IEA World Energy Outlook for companies operating in the same sector[26,33,34]. (3) Emissions of individual actors are assumed to grow at the same rate as the total economy or region[7,35,36]. (4) A constant emissions level is used in projections[37] or base-year emissions are used as a baseline[38–41].

We recommend the research community adopt the following: (1) describe the model's level of granularity and assumptions made to assess the impact of different actors; (2) explicitly specify a current national policies plus subnational and non-state action scenario when non-state and subnational actions are evaluated as a separate group of actors; (3) clearly state the baseline that is used for the countries as a whole and for the actors within the country, in terms of the above mentioned approaches. Avoid the term BAU in reference to a baseline scenario given its ambiguity.

Precisely stating which baselines and counterfactuals are being employed to compare additional GHG emissions reductions and impacts is critical if comparisons between studies are to be made. Adopting consistent terminologies facilitates understanding of different analyses and allows for comparison.

Disentangling overlaps and comparing ambition

Determining the degree of overlap to compare the ambition of different actors is a critical issue that modelling frameworks should be capable of addressing. Two critical methodological issues are of concern: how to quantify the degree of overlap between actors' impacts and how to attribute emissions reduction impacts to individual actors. The unambiguous attribution of individual actors' impacts on global GHG mitigation may not be possible and may also not be necessary for global assessments. Instead, climate action assessments can focus on the aggregated effect of actions from many different actor types. For this purpose, we suggest that analyses separate the treatment of overlap into three elements:

- Determine whether there is any overlap in emissions; geographic overlap occurs where actors take action in the same country and sector and cover the same GHGs (such as the influence on local electricity supply by a federal government, a state, a city and a company); supply chain overlap occurs when targeting the same emission source either from a supply perspective (car manufacturers, for example) or use perspective (initiatives to change company vehicle fleets).
- If overlap exists, compare the ambition of overlapping actors' GHG reductions, assuming that one actor adds to the effect of another if its ambition is higher.
- Determine any amplification effects due to overlapping actions: are the impacts of actions larger due to complementary mitigation actions that intensify impacts or due to other catalytic actions (such as capacity building) that are not strictly mitigation-focused?

Geographic overlap is defined as the percentage of GHG emissions that is common between two actors because they are situated in the same geographical location, and both commitments could be associated with the same reductions. The existing literature adopts a variety of approaches to determining this degree of overlap. A sectoral approach discounts the overall mitigation impact if two initiatives are targeted at the same sector[8]. The estimate of overlap, however, varies widely. For example, UNEP[6] estimated a small 2% overlap between cities and businesses, whereas Roelfsema et al.[8] estimated a high degree of overlap (80%) overlap between national pledges and international initiatives.

Comparison of ambition evaluates the additional mitigation impact that different overlapping actors contribute[42]. Studies vary, estimating a very small additional impact (that is, no additional effect) to large additional impacts (full effect). Figure 1 and the following sections evaluate these different approaches to comparing ambition, using the example of a state's target and a city within that state's target.

No additional effect. Roelfsema et al.[8] assume that subnational or non-state action, regardless of ambition, yields no additional effect if the scope of the action is within the scope of national targets, resulting in full overlap (Fig. 1a).

Partial conservative effect. Roelfsema[43] calculates an average trajectory for all cities. The cities with targets follow this path, whereas those without targets follow a no-policy baseline emissions growth and fail to implement the national target (Fig. 1b). The additional effect is the aggregated action of all cities.

Partial effect. Kuramochi et al.[35] only account for the additional effect of a city if its action is unambiguously more ambitious than the region it is located in. A city's pledge will have an additional effect if its annual reduction rate is more ambitious than a linear reduction towards the long-term regional reduction target (by 2050) (Fig. 1c). This approach only assesses cities with targets and implicitly assumes that some cities without commitments may not follow the state/regional reduction target.

Full effect. This approach accounts for all reductions of cities with targets that go beyond the state-level target (Fig. 1d), implicitly assuming that all other cities reach the state-level target.

The above methods do not account for possible leakage and double counting. Leakage occurs if GHG emissions are relocated to remote geographical locations or non-state actors due to other actors setting targets. Commitments could also be double counted by different actors — in the case of emissions trading, for example.

The amplification effect accounts for synergistic or catalytic action impacts that may be overlooked or that are often hard to quantify. Alignment between national governments and non-state actor networks could harness additional action by building catalytic linkages[44,45]. These alignments or linkages can generate what scholars refer to as interaction effects[46–48]. Although some of these interactions can lead to negative or disruptive events, others reinforce and support activities upheld by another actor[47], and therefore increase the likelihood of implementation or spur more ambitious actions. For instance, although a city's energy efficiency target may

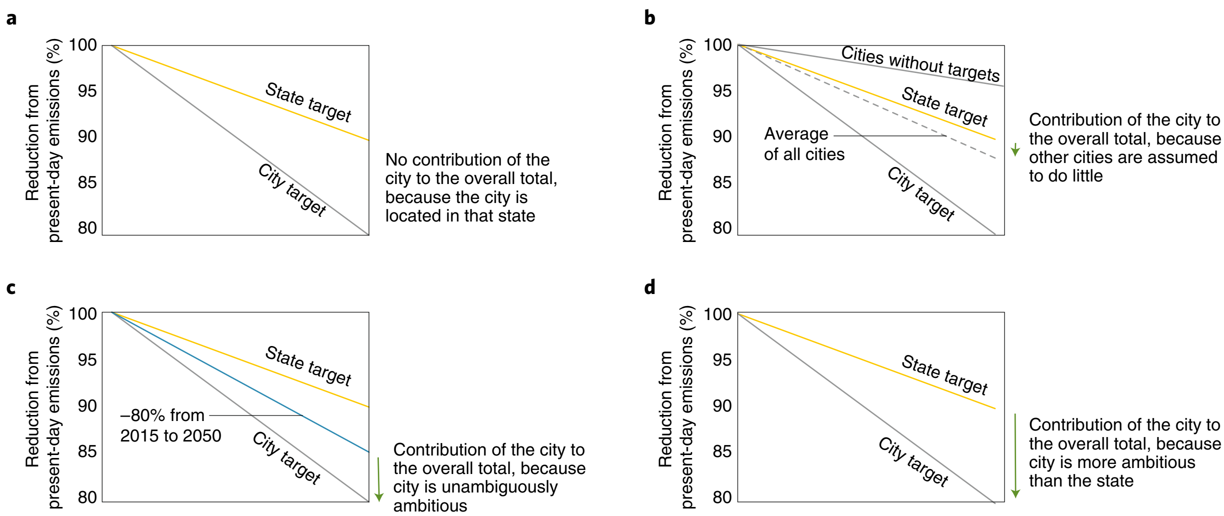

Fig. 1 | Different ways of comparing city non-state climate action with state targets. a, No additional reductions in a case with 100% geographical overlap. **b**, Additional action compared to the average of all cities (with and without targets) in the state. **c**, Additional action compared to an average long-term target for all cities with targets in the state. **d**, Full effect (assuming 100% attribution). Panel **a** adapted from ref. [35], NewClimate Institute, 2013.

not be more ambitious than its overarching state target, it may support implementation and increase the likelihood of achieving this regional goal. But methodologies to assess and account for these interactions are scarce. Some empirical evidence of these interactions producing climate benefits exists[49], however, revealing them is challenging due to the lack of common frameworks and methodologies for evaluating these aspects of climate action.

Discounting of impacts risks ignoring other catalytic functions that are not strictly defined in terms of mitigation. Other output functions, such as awareness raising or capacity building, lobbying, knowledge production and dissemination, may play valuable roles in building a foundation for future reductions. Low- or zero-carbon norm creation, or policy foundations such as voluntary emissions registries, may enhance the prospects for longer-term societal transitions towards decarbonization[21]. In summary, more research is needed to establish empirical evidence of the amplification effects of different climate actions.

We recommend the following as good practice: (1) when assessing different actors' net impacts, use the three categories given above: overlap, comparison of ambition and amplification effect, describing how the study addresses them; (2) for comparison of ambition describe the method used, applying the four categories given above (no additional effect, partial conservative effect, partial effect, and full effect).

Ideally, researchers conducting aggregation analyses could apply each of the four approaches to assessing overlap and provide a range of impact that illustrates the sensitivity of each method. Many studies, if they do quantify overlap, do not clearly specify how overlaps are assessed, rendering their results difficult to compare to other studies.

Assessment of implementation likelihood

Evaluating subnational and non-state actors' contributions hinges on understanding their performance and how their actions interact with those of nation states. One major shortfall exists in available information to appraise implementation of non-state climate actions. Most existing studies[4,5,7,9,42] are ex-ante assessments of potential impacts, which assume complete implementation of non-state actions because scarce ex-post data exist on performance and results. But not all climate commitments produce their intended effects, and being able to differentiate between non-state actions that achieve their goals and those that do not is critical to identifying best practices and accurate global impacts. At worst, non-state and subnational action only suggests potential action, while in reality efforts are not put in place.

The likelihood of implementation can be measured through direct metrics (such as percentage reductions delivered towards a quantified emissions target) or by proxy (money invested, actions implemented to support a goal, institutionalization of the commitment)[50]. Commonly used indicators of the likelihood of a commitment's implementation may include: clear ownership of the goal, the presence of monitoring mechanisms, track record of past achievements, actors' human, financial and technical capacity, a commitment's vulnerability to political considerations and the presence of regulatory support[51]. Michaelowa and Michaelowa[49] propose four necessary prerequisites to successful climate mitigation actions, including a clear mitigation target, financial incentives, a specific baseline, and tracking and verification metrics, although there are others (such as an enabling policy and legal context) that are also critical. Many initiatives, however, fail to require strong financial reporting, monitoring or transparency measures regarding progress and results achieved.

Other scholars point to more qualitative approaches to determine whether implementation of non-state or subnational action has occurred. Van der Ven et al.[21] argue for a broader set of metrics beyond mitigation to evaluate transformational outcomes, such as whether an action has scaled to a broader set of actors or policy domains or has become entrenched or institutionalized. Chan and colleagues[11,45] (see also ref. [52]) apply a function–output–fit framework to assess commitments on the basis of the fulfilment of their stated functions. They evaluated more than 50 initiatives launched at the 2014 New York Climate Summit and found that most actions were well aligned with their intended function, suggesting that these efforts were designed with specific implementation actions. However, data verifying results were difficult to obtain only a year after their announcement[11]. Although this framework does not measure the impacts or results of climate action commitments, it provides an early signal as to whether an initiative is on track to deliver key outcomes that are often necessary to achieving climate impacts.

As a good practice, we recommend that: (1) for subnational and non-state membership networks and reporting platforms,

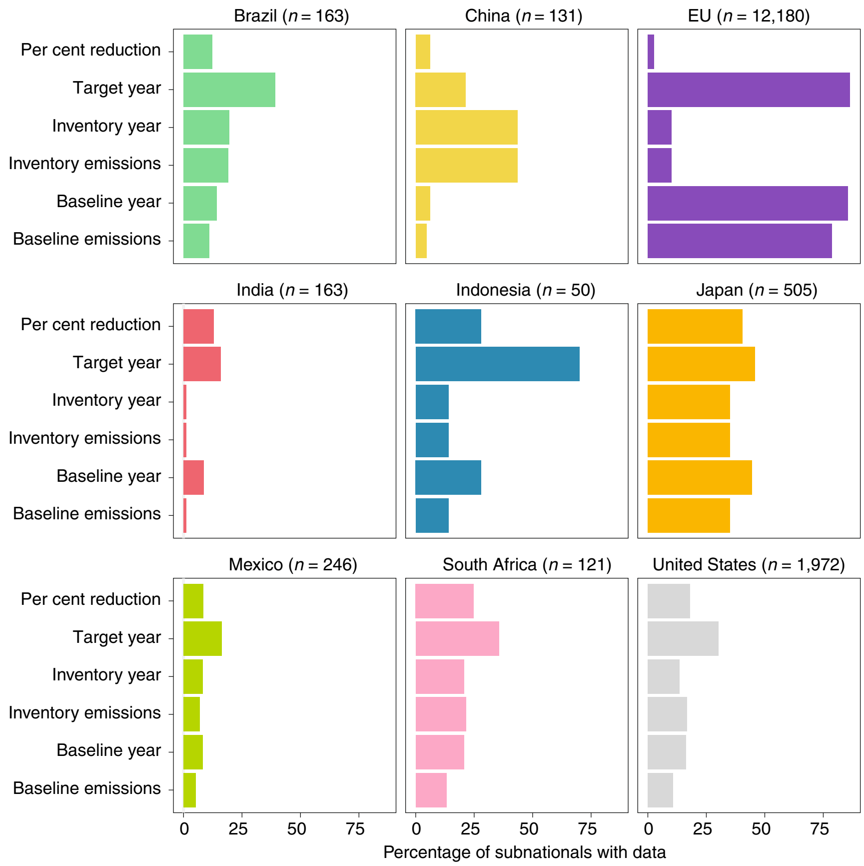

Fig. 2 | Overview of key data missing for selected actors participating in transnational climate initiatives or reporting to city climate action platforms. Percentages refer to climate action commitments for which data have been reported. Data from CDP[61], Global Covenant of Mayors[62], Under 2 Coalition[63], and carbon*n* Climate Registry)[64].

encourage actors to submit information to assess the likelihood of implementation, such as whether an action has sufficient financing, monitoring and reporting mechanisms, or management and workplans in place. These proxies provide critical information to analysts to move beyond assessments of potential impact to actual results. Some networks, including the CDP (formerly known as Carbon Disclosure Project), request that members regularly provide updates on what implementation has been achieved year to year (the percentage of target completion). (2) For researchers conducting an aggregation exercise, clearly describe whether and how the likelihood of implementation was assessed.

Information on whether actions are implemented successfully and to what extent targets and emissions reductions are achieved is critical to developing accurate assessments of mitigation impact and ensuring the credibility of non-state and subnational climate actions. Biermann et al.[53] found that out of more than 300 collaborative non-state partnerships announced at the 2002 World Sustainable Development Summit, nearly 65% were yet to be operationalized. Further, Chan et al.[54] note the relative lack of attention paid to implementation in a broad range of non-state and subnational climate initiatives.

Data gaps and limitations

Data availability is the crucial foundation for any analyses of non-state and subnational climate actions and poses the greatest obstacle to their understanding. Although there are multiple reporting platforms that collect reported information from non-state and subnational climate actors — ranging from the CDP, which has more than 6,000 companies, 500 cities and 100 states and regions reporting data, to the carbon*n* Climate Registry, which has around 1,000 subnational governments — the data included in these platforms is often incomplete. Figure 2 illustrates the distribution of missing information from selected countries' subnational climate commitments required to calculate impact from GHG mitigation actions, revealing data gaps from both developing and developed countries alike.

For actions other than emissions reductions commitments, such as energy efficiency and renewable energy targets, data requirements are even more stringent, particularly if analysts intend to implement the methods proposed here to account for overlaps and assess additional impact. To calculate additional emissions reductions from a city that pledges to increase its share of renewable electricity generation, information about the city's energy mix, baseline share of renewables, intended share of renewables as a result of its action and city-specific emissions factors that can be used to convert megawatts of renewable electricity generation into emissions avoided are among the core information required. Each commitment and action, which could be as diverse as increasing electric vehicle fleets to improving energy efficiency, require data specific to their evaluation; these data are often not reported.

Most aggregation analyses apply statistical interpolation techniques to address data gaps. These methods range from developing models to project future emissions pathways on the basis of the estimated population or GDP growth to applying a 'nearest neighbours' approach that estimates baseline emissions by comparing a city to nearby cities that do report emissions data (for example, see ref. [55]). In some cases, studies may also extrapolate commitments to actors that have signed on to a platform but have not specified their own particular emissions target. America's Pledge[56], for example, adapts the United States NDC target to cities that have signed on to the We Are Still In platform in the absence of other detailed emissions reduction pledges for those cities.

As good practice we recommend: (1) where data interpolation techniques are used to estimate missing data points, the methods used and data points that are estimated should be made transparent; (2) a sensitivity analysis that demonstrates the range of uncertainty associated with adopting one data modelling technique over others is made clear.

Next steps

For aggregating subnational and non-state actors' contributions to global climate mitigation, a consistent reporting framework that captures both quantitative and qualitative aspects of their actions is a necessary first step. These accounting challenges should in part be addressed through growing convergence of non-state and subnational climate networks (for example, the Global Covenant of Mayors for Climate and Energy) that are adopting consistent measurement and reporting frameworks (such as the Global Protocol for Community-Scale Greenhouse Gas Emissions[57] and ICAT[51]). These efforts represent progress in the right direction — the need for timely data and information could not be more urgent. But non-state and subnational actors themselves must be held to transparency standards according to these increasingly consistent measurement and reporting frameworks. Without collective reporting platforms and actors' commitment to report to them, the universe of non-state actors will remain dispersed and incoherent, threatening future analyses that seek to aggregate and evaluate their contributions to climate change mitigation.

The aggregation analyses and studies that are the focus of this Perspective only examine one aspect of non-state and subnational climate actions. A rich literature emerging is emerging from scholars who are theorizing and evaluating other aspects of non-state and subnational actors' contributions to climate governance, including experimentation[58], orchestration[59], capacity-building, information sharing and implementation[23]. Although they are difficult (if not impossible) to quantify, they may provide necessary catalytic linkages between actors, including linkages with national governments, to orchestrate and implement a range of climate actions[45]. In moving towards a scientific evidence base for non-state and subnational climate actions to global climate change mitigation, adaptation and governance, these critical functions should not be overlooked in favour of quantifying GHG emissions.

Evaluation of the impacts of non-state and subnational actors requires the research community to develop and use consistent and comparable methodologies to enable meaningful analysis. The ability to ratchet up global climate mitigation relies on all levels of government and various actors[60], but these efforts must now be matched with solid scientific approaches to assess mitigation effort, document progress and highlight the lessons learned over time.

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

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Author contributions

A.H., N.H., T.K., M.R., A.W., Y.X. and K.L. conceived the concept and led the analysis and writing. All other authors substantially contributed suggestions, ideas and writing.

Competing interests

The authors declare no competing interests.

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Software and code

Policy information about availability of computer code

Data collection	Python and R were used to scrape publicly available data from websites to generate a dataset used for Figure 2 - data gaps in commonly reported subnational climate actions.
Data analysis	We used R to calculate the percentage of data type available for each climate action by subnational actors and to produce the bar plot.

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Study description	This article is a commentary that draws from a meta-analysis of studies that attempt to quantify and aggregate the mitigation contributions of subnational and non-state climate actions.
Research sample	We reviewed a total of 24 published reports in gray and academic literature. To produce Figure 2, which provides an overview of data gaps by country, we included data from 7 subnational climate action networks.
Sampling strategy	These reports were identified by the authors and co-authors, many of whom authored these studies, and Internet searches using keywords related to non-state and subnational climate mitigation aggregation analysis.
Data collection	Studies were collected electronically; data to produce Figure 2 were scraped from websites using Python and R.
Timing	Reports ranged from 2014 to 2017; the data were scraped between September 2017 and May 2018.
Data exclusions	None
Non-participation	For Figure 2, we evaluated whether data for a particular data type (e.g., target year, inventory year, inventory emissions) were reported for each climate action recorded.
Randomization	No randomization deemed necessary given the nature of our study.

Reporting for specific materials, systems and methods

Materials & experimental systems

n/a	Involved in the study
☒	☐ Unique biological materials
☒	☐ Antibodies
☒	☐ Eukaryotic cell lines
☒	☐ Palaeontology
☒	☐ Animals and other organisms
☒	☐ Human research participants

Methods

n/a	Involved in the study
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☒	☐ Flow cytometry
☒	☐ MRI-based neuroimaging