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Beyond national climate action: the impact of region, city, and business commitments on global greenhouse gas emissions

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ABSTRACT

This article quantifies the net aggregate impact in 2030 of commitments by individual non-state and subnational actors (e.g. regions, cities and businesses, collectively referred to as 'NSAs') to reduce greenhouse gas (GHG) emissions. The analysis was conducted for NSAs operating within ten major emitting economies that together accounted for roughly two-thirds of global GHG emissions in 2016. Our assessment includes 79 regions (e.g. subnational states and provinces), approximately 6,000 cities, and nearly 1,600 companies with a net emissions coverage of 8.1 GtCO₂e/year, or a quarter of the ten economies' total GHG emissions in 2016. The analysis reflects a proposed methodology to aggregate commitments from different subnational (i.e. regional and city government) and non-state (i.e. business) actors, accounting for overlaps.

If individual commitments by NSAs in the ten high-emitting economies studied are fully implemented and do not change the pace of action elsewhere, projected GHG emissions in 2030 for the ten economies would be 1.2–2.0 GtCO₂e/year or 3.8%–5.5% lower compared to scenario projections for current national policies (31.6–36.8 GtCO₂e/year). On a country level, we find that the full implementation of these individual commitments alone could result in the European Union and Japan overachieving their nationally determined contributions (NDCs), while India could further overachieve its unconditional NDC target. In the United States, where the national government has rolled back climate policies, NSAs could become a potential driving force for climate action.

Key policy insights



- Full implementation of reported and quantifiable individual commitments by regions, cities and businesses (NSAs) in ten major economies could reduce emissions by 3.8%–5.5% in 2030 below current national policies scenario projections.
- National governments' mitigation targets could be more ambitious if they would take NSA commitments into account. With full implementation of such action, the European Union and Japan would overachieve their NDC targets. For the United States such action could help meeting its original 2025 NDC target in spite of rollbacks in national climate policies.
- The full universe of NSA climate action expands far beyond the subset of commitments analysed in this study; NSAs could become a strong driving force for enhanced action towards the Paris climate goals.


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1. Introduction

The role of non-state and subnational actors (hereinafter referred to as 'NSAs'), such as regions, cities and businesses, in climate change mitigation has become critical to achieving global climate goals. With the inadequacy of current national government policies to keep global emissions in line with 1.5°C/2°C pathways (UNEP, 2018), the Intergovernmental Panel on Climate Change (IPCC) has emphasized the need for all actors to reduce greenhouse gas (GHG) emissions in a strengthened and timely manner, while cooperating with national governments, in order to limit global warming to 1.5°C (IPCC, 2018).

Climate action by NSAs, however, is not a substitute for national government climate action; rather, it is largely complementary to national policies (Andonova et al., 2017; Roger et al., 2017). Nevertheless, understanding NSA climate action alongside national governments is critical because the mitigation potential of such action can be significant. NSAs are also increasingly responding to calls for deeper and more ambitious climate action; for example, the 2018 Global Climate Action Summit triggered over 500 new NSA commitments to strengthen global action (UNFCCC, 2018), some made by actors in countries where national governments are rolling back climate policies.

These NSA climate commitments will become even more crucial within the Paris Agreement's 'ratchet' mechanism, where countries are requested to update their nationally determined contributions (NDCs) with more ambitious targets by 2020 and every five years afterwards. Although NSAs could become key ambition drivers in these review cycles of country-level climate action, national governments overall have yet to leverage NSAs' potential in the first round of NDCs, with many failing to mention these actors' contributions altogether (Hsu et al., 2019a). Providing national governments with evidence of NSA climate action's potential impact is necessary to support more ambitious NDC revisions in the future.

Only limited assessments of NSA climate action's net aggregate impact on GHG emissions exist, however. Most analyses have focused on international initiatives, which represent coalitions of actors in diverse constellations, sometimes involving national governments. Blok et al. (2012) formulated the concept of aggregating large-scale initiatives of NSAs, finding that 21 of these initiatives could lower global emissions by 10 GtCO₂e/year in 2020 with approximated estimates on overlaps between initiatives; Wouters (2013) conducted a more detailed assessment of overlaps for the 10 initiatives covered in Blok et al. (2012). Hsu et al. (2015) found that the 29 commitments pledged at the 2014 UN Summit would result in 2.5 GtCO₂e/year emission reductions by 2020, taking into account geographical and sectoral overlap between initiatives. Höhne et al. (2015), UNEP (2015) and Graichen et al. (2017) aggregated the potential GHG impact of selected international cooperative initiatives; these applied a more systematic approach to quantifying overlaps by developing a sector-based overlap matrix across initiatives and considering different types of intra- and inter-sectoral overlaps. Roelfsema et al. (Roelfsema et al., 2018) used an integrated assessment model and estimated that 11 selected transnational emission reduction initiatives could –if fully implemented– deliver annual GHG emission reductions of 5.0 GtCO₂e/year by 2030; overlaps across initiatives were based on literature estimates.

Hsu, Höhne, Kuramochi *et al.* (2019b) presented a research roadmap for quantifying individual-scale non-state and subnational climate mitigation action. Methods to quantify overlaps across commitments applied in the literature differ from those applied for the aggregation of international cooperative initiatives because of the differences in the types and levels of data available. Kuramochi et al. (2017) provided a first estimate for the United States (US); a step-wise approach addressing, in order, regions, cities, energy end-use companies and then electricity-generating companies, was taken to quantify overlaps between commitments. America's Pledge's report (2018) explored three different policy scenarios for the US, using an integrated assessment model combined with bottom-up analyses on the impact of NSA climate action in the US. Kona et al. (2018) examined the aggregated effort of the European Covenant of Mayors signatories in terms of geographical distribution, mitigation ambition and achievements, as well as whether projected emissions reductions are consistent with limiting warming to 2°C or 1.5°C. To the authors' knowledge, however, there is no peer-reviewed publication to date that has quantified the GHG mitigation potential of existing individual city, region and company climate commitments for a range of major emitting economies.

This article responds to this gap in the peer-reviewed literature by quantifying the potential aggregate impact of quantifiable climate change mitigation commitments by individual regions, cities, and companies

on global GHG emissions in 2030. The analysis was conducted for ten major emitting economies: Brazil, Canada, China, the European Union (EU28), India, Indonesia, Japan, Mexico, South Africa, and the US. These ten economies together accounted for 67% of global GHG emissions (excluding land use, land-use change and forestry) in 2016 (Olivier & Peters, 2018).

The world of climate action is vast and heterogenous. This study uses the best available current data, looking at NSA climate action that is reported to selected global databases and networks. Therefore, the scale and scope of climate commitments presented in this study is likely to systematically underrepresent smaller scale actions, such as those that are not formally institutionalized or those not described or presented in English or other major languages. In a similar context, this study also does not quantify the potentially significant synergistic or catalytic impacts that NSA climate action may generate. Notwithstanding these limitations, this study is one of the first in the academic literature that attempts to quantify the potential aggregate contributions of global NSA climate action towards the achievement of the Paris Agreement climate goals.

2. Definitions, data and methods

The assessment presented in this paper consists of:

- (1) a methodology to aggregate cities' commitments to the country and global levels;
- (2) projections of GHG emissions reductions that would result from the implementation of these commitments, including estimating the overlap between different NSAs; and
- (3) a quantification of reductions additional to national government policies.

For the purposes of this study, cities are local governments that are administrative units of a specific geographical territory, and include towns, urban communities, districts, and counties. Regions are subnational administrative units that are generally broader in population and in scope, and often are the first administrative level below the national government.

All GHG emissions figures presented in this article are presented in terms of aggregated 100-year global warming potential (GWP) values of the IPCC Fourth Assessment Report (AR4). Global and national GHG emissions totals include LULUCF emissions, unless otherwise noted. Businesses are defined as private or publicly-traded for-profit entities that operate within or have emissions impact in one or more of the 10 countries we analyse in this study. We distinguish between energy-end use companies that consume energy and electricity and electric utilities that generate electricity for other actors' consumption.

2.1. Scenarios investigated

We use the following scenarios showing emissions pathways for different actors' climate policy implementation:

- (1) The '**Current national policies' (CNP) scenario** considers the likely path of emissions under currently implemented national policies. This scenario assumes that no additional mitigation action is taken beyond climate policies implemented as of mid-2018. Whenever possible, current policy trajectories reflect all adopted and implemented policies, which are defined here as legislative decisions, executive orders, and their equivalent. This scenario excludes announced plans and future strategies, yet policy instruments to implement such plans or strategies would qualify. We do not assume that policy targets will be achieved even when they are codified in a law or a strategy document. These classifications of policy type are often subject to interpretation and sometimes require informed judgement calls. These current national policies scenario criteria are consistent with those applied in den Elzen et al. (2019). For our analysis we took two current national policies scenario projections based on distinct modelling approaches: the PBL IMAGE model (Stehfest et al., 2014) bottom-up policy impact analysis using existing external baseline scenario projections, and land-use sector modelling by IIASA using the global land-use model GLOBIOM (Havlík et al., 2014) global forest model G4M (Fricko et al., 2017), presented in Kuramochi et al. (Kuramochi et al., 2018).

- (2) The **‘Current national policies plus individual actors’ commitments’ (CNP + NSA) scenario** models the potential impact of both currently implemented national policies as well as recorded and individual, quantifiable city, region, and company commitments. This approach accounts for overlaps between and within the jurisdictions of NSAs to avoid double-counting of potential emission reductions. The main assumptions are that all commitments are fully implemented and that the pace of action elsewhere is not impacted. At this moment, we believe the latter is a valid assumption, as there is limited coordination on policy implementation between national governments and other actors (Chan et al., 2018a). Therefore, we did not quantify the coordination effects between national governments and other actors, nor the interaction between policy instruments at different scales. Instead, we assume that additional reductions take place for each actor group (e.g. regions, cities, companies), if their aggregated reductions (relative to 2016) are larger than those that would result from the (geographically evenly distributed) implementation of national policies. We also assume that both national governments and other actors do not change (i.e. roll back or increase) existing climate policies and actions in response to these NSA efforts.

This study uses the current national policies scenario as the baseline, rather than an NDC achievement scenario that considers national-level Paris Agreement climate change mitigation commitments (i.e. NDCs), for several reasons. For all countries analysed in this article, it is useful to inform policymakers of the extent to which NSAs could potentially help national governments to achieve their NDC targets. For countries that are projected to (over)achieve their NDC targets with existing national policies, such as China, EU28, India, Japan and Mexico (den Elzen et al., 2019; Kuramochi et al., 2018), it is useful to inform policymakers of the extent to which they could raise their mitigation ambition by considering NSA commitments within their territory. For countries where national governments are rolling back climate policies, such as Brazil and the US, it is useful to inform stakeholders of the extent to which NSA commitments could collectively make up for regressive policies at the national level.

2.2. Dataset preparation

We first collected the available current data on individual commitments, drawing from NSA climate action that is reported to global databases and networks, and selected those appropriate for our analysis.

For each commitment by regions, cities and companies (per country location), we developed GHG emissions time series for the period 2016–2030. When an actor had multiple targets, we always prioritized the use of absolute economy-wide (for cities) or operations-wide (for companies) GHG emissions reduction targets over intensity-based targets or targets that covered limited sectors or scopes. For companies, we analysed absolute targets and intensity targets. We did not include renewable energy targets in our analysis due to inconsistencies in how these targets were reported and limited available information on underlying energy mixes.

GHG emissions are categorized into scopes that indicate where emissions are physically emitted (Greenhouse Gas Protocol, 2004, 2014). This analysis considered scope 1 emissions –GHG emissions emitted directly by the actors– and scope 2 emissions, which result from the actors’ electricity consumption. The impacts of commitments on supply chain emissions (scope 3 emissions) are excluded from the analysis, even though they are significant for some companies, because it was not possible to quantify the overlaps between scope 1 and 2 emissions and scope 3 emissions across actors, nor to localize these emissions to specific geographies given current data gaps.

Our dataset on NSA commitments is primarily based on those that are reported by the actors themselves to international networks and/or data providers. This analysis therefore excludes a large portion of actions that are (i) not (self-)identified as climate change mitigation-related, (ii) not linked to international networks with English as working language, although we estimate that these exclusions are likely minimal.

2.2.1. Regions and cities

Data for subnational climate actions was collected from a variety of climate action registries and platforms, including the Alliance of Pioneer Peaking Cities, Global Covenant of Mayors for Climate and Energy, Global Covenant of Mayors for Climate and Energy (EU Secretariat), Compact of States and Regions, CDP Cities, ICLEI

carbonⁿ® Climate Registry, C40 Cities Climate Leadership Group, Under2 Coalition, United States Climate Mayors, United States Climate Alliance and We Are Still In. We supplemented data on subnational actors from a range of external sources for the ten analysed countries.

In some cases when city-level GHG emissions data was missing, cities' emission values were estimated by multiplying per capita provincial-level emissions by the cities' population. For example, the emissions inventory value of Semarang, a city in Indonesia, was calculated by multiplying per capita emissions of Central Java Province, where Semarang is located (WRI, 2016), by Semarang's population.

Further details on the preparation of the subnational actors' dataset can be found in section S1 of the supplemental online material (SOM).

2.2.2. Companies

The country-specific corporate GHG emissions and climate action dataset used in this analysis was based on responses to CDP's 2018 climate change questionnaire (CDP, 2019). Dataset preparation involved data cleaning and processing of the raw response data provided about company and supply chain (scope 3) emissions and climate actions, including statistical examination of the internal consistency of companies' responses and additional consistency checks using responses in previous years. Our analysis specifically draws on the relationship between companies' actions and the reported amount of GHG emissions generated in each country's jurisdiction per emissions scope, by a company operating worldwide (CDP, 2018). Detailed description of the dataset preparation can be found in section S2 of the SOM.

The analysis divided the companies' actions into two groups based on the target type and the data availability in the CDP dataset: (1) energy end-use companies with GHG targets, and (2) electricity-generating companies with commitments. Targets aiming at exclusively reducing scope 3 emissions were removed from the dataset since we were unable to quantify probable overlaps. For targets that include scope 3 emissions together with scope 1 and/or scope 2 emissions, we excluded the scope 3 part, and assumed the same scope 3 emissions share in the target year as the target base year (or most recent data year); such targets comprised about 1% of the number of total company commitments and 13% of total GHG emissions in the companies' commitments dataset.

Only one target was selected for each company branch, and the aggregated emission pathway for companies per country was calculated by summing up interpolated individual historical and target year emissions for each year, assuming emissions growth at the CNP scenario rate after the target year.

2.3. Calculation of net aggregate GHG impact of commitments

2.3.1. General approach

Quantifying subnational non-state actor commitment impact in the context of national-level policies included three steps:

- First, aggregated emission pathways per actor group (regions, cities, and companies) were calculated based on the assumption that NSAs fully achieve their commitments in the target year.
- Second, the emissions pathways from the CNP scenario were divided into two separate parts. The first part begins from the share of current national emissions covered by regions, cities and companies that have targets. We then calculated the aggregated reductions per actor group by comparing their emission growth between 2016 and 2030 with the growth from the CNP scenario. The second part originates from the share of current emissions that are not covered by city, region and company targets and follows the CNP scenario.
- Third, for the share of emissions covered by targets, geographical and supply chain (only scope 2) overlaps of GHG emissions between actor groups were determined. Then, for overlapping targets, only the additional reductions compared to other actor groups were calculated. Finally, the combined mitigation reductions of all actor groups were determined.

Total GHG emissions under the CNP + NSA scenario in a country in year t under ($E_{\text{tot}}(t)$) and is given by (Equations (1) and (2)):

$$E_{\text{tot,CNP+NSA}}(t) = E_{\text{tot,CNP}}(t) * \frac{E_{\text{tot}}(2016) - E_{\text{NSA}}(2016)}{E_{\text{tot}}(2016)} + E_{\text{NSA}}(t) \quad (1)$$

where $E_{\text{tot,CNP+NSA}}(t)$: total GHG emissions under CNP + NSA scenario in year t ; $E_{\text{tot,CNP}}(t)$: total GHG emissions under the CNP scenario in year t ; $E_{\text{NSA}}(t)$: total GHG emissions from non-state and subnational actors in year t as a result of achieving pledged commitments, accounting for overlap between non-state and subnational actors. 2016 is the base year for the scenario analysis.

We assume that those GHG emissions in Equation (1) not covered by existing NSA commitments, based on the 2016 emissions data, will grow proportionally to the current policies scenario projections. The quantification of GHG mitigation impact overlaps between commitments is based on Hsu et al. (2019b). Details are described in the following sections and the derivation of $E_{\text{NSA}}(t)$ is elaborated in section S3.1 of the SOM.

2.3.2. Quantification of emissions overlaps between actor commitments

Multiple actors have commitments that target the same geographic area or the same subset of emissions. To avoid the double counting of emission reductions, we first determined to what extent the commitments target the same set of emissions (i.e. overlap, as described in this section) and then, in cases of overlap, we compared the stringency of various actions.

The determination of the overlap was conducted in three steps (see Figure 1).

First, **geographic overlap between region and city commitments** was quantified based on whether or not a city with a target is located within a region with a target. After identifying these cities, the net GHG emissions coverage of subnational actors with commitments (overlap (C-R) in the top panel of Figure 1) was calculated. We have assumed that all electricity consumed by cities is generated in regions where the cities are located.

Second, **geographic overlaps between energy end-use companies and subnational actor commitments** were quantified (overlap (B-RC) in the middle panel of Figure 1). Energy end-use companies are companies that are not electric utilities. We assumed that energy end-use companies with commitments are geographically evenly spread over subnational actors with and without commitments. We therefore applied the same GHG emissions percentage for the overlap between energy end-use companies with commitments and subnational actors with commitments as the share of sub-national actors with commitments in national total GHG emissions. This simplified approach was taken because there was no data available on which subnational jurisdictions the companies' emissions were generated, as the CDP dataset provides only country-specific emissions data per company. As companies within a geographical area with an ambitious commitment might be more likely to adopt commitments themselves, stringent thresholds were applied to estimate the impact of companies that is unambiguously additional to the impact of the commitments of the regions or cities in which the companies (or company operations) are located (see section 2.3.3 for details).

Third, **overlaps between electricity-generating companies and all other NSA commitments** (overlap (P-RCB) in the bottom panel of Figure 1) was quantified. This overlap is calculated to avoid double counting of emissions from electricity production by electric and gas utilities (scope 1), and the use of electricity by other sectors (scope 2).

We assumed that electricity-generating companies with commitments are geographically evenly spread over regions/cities. The overlap rate for electricity-generating companies is therefore equal to the net coverage rate of electricity-related GHG emissions by subnational actors and energy end-use companies. For the calculations, the share of electricity-related GHG emissions in total emissions of a region is assumed to equal the national average. The shares of scope 2 emissions in energy end-use companies' total scope 1 plus scope 2 emissions were often not available, so we mainly used the median values for companies with available data (Table S-2 in S3.2 of the SOM). Country-level total GHG emissions from electricity generation in 2016 were estimated based on IEA statistics (2018a, 2018b).

The quantification of overlaps was done in the following order: regions, cities, energy end-use companies then electricity-generating companies. This order implies starting from the largest emissions scope to the

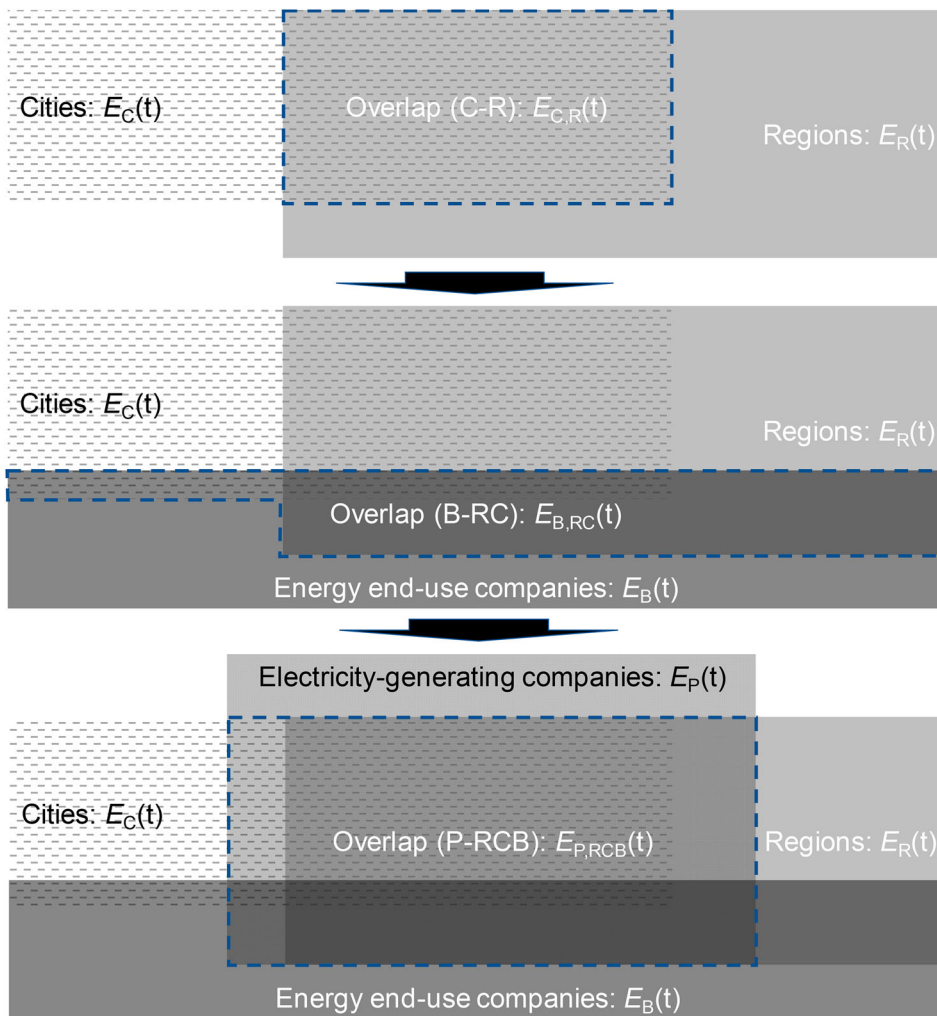


Figure 1. Step-by-step quantification of overlaps between actor groups.

smallest, but it is important to note that this order was taken only to maximize the transparency of the calculation methods and does not imply the relative importance of different actor groups.

2.3.3. Comparing ambition when targets are overlapping

In the previous section, we identified emissions that overlap between regions, cities and companies, i.e. overlap areas (C-R), (B-RC) and (P-RCB) from Figure 1. For these emissions, we assessed which of the actor group's targets is more ambitious compared to others.

To determine additional reductions, two extreme assumptions could be taken: (1) emission reductions by actors with commitments are fully counterbalanced by actors that do not act on climate change; and (2) action by actors with commitments is fully additional to other actor's commitments. In the first case, the additional emissions reduction impact of city A's commitment compared to the commitment of region B, in which the city is located, could possibly be zero, even if city A's emissions are reducing at a faster rate than region B's. In the second case, city A's action would lead to significant emission reductions, as the reduction effort is not reversed by inaction elsewhere within region B.

Our analysis makes use of the average result of two different approaches that present the middle ground between those described above:

- The first is the **'partial effect' method**, which uses 2°C-consistent emission levels based on a range of effort-sharing approaches calculated by Höhne et al. (2014) as threshold values to quantify the additional emissions reductions. Compared to current ambition and effort levels observed in most countries as well as NSAs, stringent threshold values were applied to identify and quantify only the commitments that are unambiguously more ambitious than the overlapping commitments compared (in the above example, city A compared to region B).
- The second is the **'partial conservative effect' method**, which assumes that the NSAs' actions are partially offset by a group with 'laggard' sub-national actors and companies that do not implement any climate action (Hsu et al., 2019b). This 'laggard' group is assumed to follow a no policy, business-as-usual scenario projection, which is derived from the TIMER model (for details, see S3.3 in the SOM).

3. Results

3.2. GHG emissions coverage

Our assessment included 79 regions accountable for at least 3.7 GtCO₂e/year in 2016, approximately 6,000 cities accountable for at least 4.4 GtCO₂e/year, and nearly 1,600 companies accountable for 2.6 GtCO₂e/year (Table 1). Altogether, individual commitments from the ten economies cover 8.1 GtCO₂e/year in 2016 after subtracting the overlaps, a total larger than the US' 2016 emissions and accounting for 25% to 26% of total GHG emissions including LULUCF from the ten economies in the same year. The combined revenue of the companies with commitments assessed here totals over 21 trillion US Dollars (USD), roughly the size of US GDP (World Bank, 2019). China, EU28 and the US together accounted for more than 80% of the total GHG emissions covered by the dataset used for the assessment. The emissions coverage rates were close to 40% in Canada, whereas they were generally in the order of 10% to 20% for emerging countries. S4 of the SOM presents the population coverage of city and region commitments, the number of commitments by target year, and the number of company commitments per sector.

3.2. GHG emission reductions in 2030

This analysis estimates significant emission reductions from city, region, and business climate commitments. Total GHG emissions in 2030 for the ten major-emitting economies would be 1.2–2.0 GtCO₂e/year or 3.8%–

Table 1. 2016 greenhouse gas (GHG) emissions covered by quantifiable non-state and subnational actor commitments.

Country	2016 GHG emissions coverage by subnational and non-state actors (unit: MtCO ₂ e/year)			
	Regions	Cities	Companies	Net total (share in national total emissions including LULUCF)
Brazil	127 (n = 1)	35.5 (n = 7)	60.3 (n = 361)	199 (12%)
Canada	147 (n = 5)	112 (n = 24)	114 (n = 371)	256 (38%)
China	313 (n = 2)	2,170 (n = 27)	129 (n = 607)	2,510 (20%)*
European Union (EU28)	801 (n = 33)	808 (n = 5,707)	729 (n = 4,572)	1,500 (38%)
India	15.6 (n = 1)	3.54 (n = 3)	218 (n = 392)	235 (9%)*
Indonesia	0	234 (n = 7)	22 (n = 183)	244 (12%)*
Japan	283 (n = 15)	265 (n = 56)	347 (n = 445)	559 (45%)
Mexico	46.6 (n = 2)	50.9 (n = 9)	37.6 (n = 323)	93.1 (14%)*
South Africa	0	85.3 (n = 7)	98.9 (n = 194)	118 (21%)*
United States	1,940 (n = 20)	657 (n = 156)	884 (n = 837)	2,610 (45%)
Total of ten economies	3,670 (n = 79)	4,430 (n = 6003)	2,640 (n = 8285)	8,080 (26%)

*For national total GHG emissions in 2016, the average values of high and low estimates were used.

5.5% lower than the CNP scenario projections (31.6–36.8 GtCO₂e/year), if recorded and quantified commitments by individual regions, cities and companies are fully implemented (Table 2). The range for the quantified projected emissions reductions is nearly entirely attributable to the uncertainty in the CNP scenario projections; the difference in results due to the methodological choice to compare ambition in case of overlapping commitments (i.e. partial effect method versus the partial conservative effect method) is very small.

The highest global reductions relative to the CNP scenario are estimated to be contributed by regions, while the lowest contribution is from electric utilities (Figure 2(a)). Individual commitments from regions, cities and energy end-use companies could result in 0% (China) to 14.3% (US) lower GHG emission levels below CNP scenario projections in the ten major emitting economies (see Table 2). Only electricity-producing companies have not made sizeable commitments that go beyond current national policies; a possible explanation is that national climate policies in the economies concerned have so far focused on the power sector.

3.2.1. Summary of country findings

The extent to which sub-national and non-state actors are found to contribute to or exceed current national policies varies by country and is certainly dependent on data availability, as our analysis only includes actions that are recorded through voluntary climate action reporting initiatives and platforms. In the US and Brazil, where national governments have retreated from their Paris pledges (Friedman, 2019), sub-national and non-state climate action, if fully implemented, could recover a significant portion of the emission reductions potentially lost. For the US, a surge of sub-national and non-state actors representing almost half (45%) of 2016 national emissions could yield 21% to 24% below 2005 levels in 2025, nearly constituting the country's original NDC of 26% to 28%. The largest impact is expected from 20 US states, including California and New York (Figure 2(g)). The impact in Brazil, however, is not as substantial, as the scope of NSAs recording climate actions is still limited (12% of total national emissions including LULUCF) (Figure 2(b)).

Table 2. Projected greenhouse gas (GHG) emissions in 2030 for non-state and subnational climate commitments in ten major-emitting economies under the current national policies (CNP) scenario and CNP plus individual actors' commitments scenario. Emissions projections for unconditional NDC scenario are also presented for comparison. The CNP scenario projections do not account for subnational and non-state climate action.

Country	2016 GHG emissions including LULUCF (MtCO ₂ e/year)	2030 GHG emissions projections including LULUCF (MtCO ₂ e/year)		
		Current national policies (CNP) scenario*	CNP plus individual actors' commitments scenario (%-reduction to CNP scenario)	[For comparison] Unconditional NDC scenario*
Brazil	1,720	1,560–1,800	1,520–1,720 (2.3%–4.5%)	1,180
Canada	676	610–744	558–663 (8.5%–11.0%)	498
China	12,100–12,600	12,200–14,600	12,200–14,500 (0%–0.7%)	13,200–16,200
European Union (EU28)	3,990	2,920–3,540	2,810–3,220 (3.8%–9.2%)	3,100
India	2,510–2,620	4,050–4,450	3,830–4,210 (5.5%)	4,980–6,130
Indonesia	1,990–2,030	2,820–3,170	2,730–2,990 (3.5%–5.5%)	2,100
Japan	1,250	1,040–1,150	953–1,010 (8.2%–11.5%)	1,020
Mexico	640–701	686–834	664–791 (3.2%–5.1%)	750
South Africa	560–574	640–747	622–715 (2.9%–4.3%)	404–623
United States	5,790	5,050–5,760	4,510–4,940 (10.7%–14.3%)	4,740
Total of ten economies	31,200–31,900	31,600–36,800	30,400–34,800 (3.8%–5.5%)	32,000–36,300

*Based on Kuramochi et al. (2018).

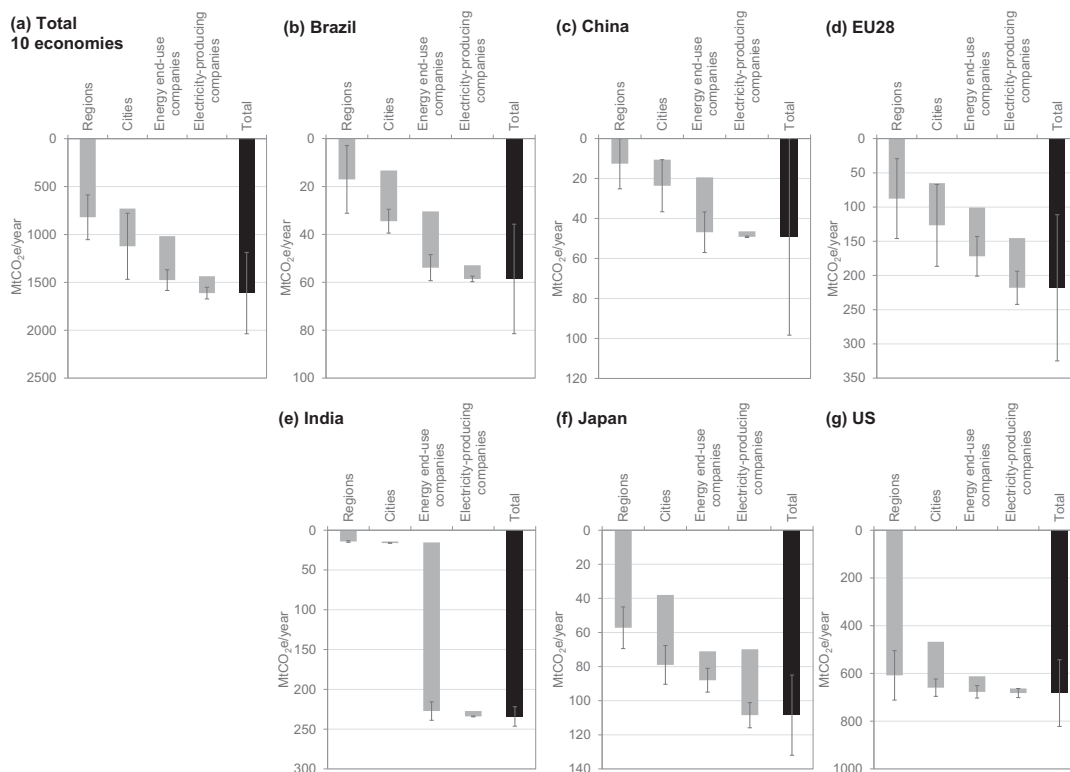


Figure 2. Impact of fully implemented, recorded and quantified region, city and business commitments on global greenhouse gas (GHG) emissions by actor group for the total of ten major-emitting economies and selected individual economies (Brazil, China, EU28, India, Japan and the US).

In a few of the countries analysed, NSAs' commitments allow national governments to even over-achieve their existing NDCs. For instance, in the EU, the full implementation of recorded and quantified individual commitments by regions, cities and companies could lead to an emissions reduction of up to 48% by 2030 from 1990 levels — a 20% increase from the EU's current goal of at least 40% reduction by 2030. In India, commitments would add a 5.5% reduction to the current national policy projections for 2030, which would deepen the ambition of India's current national policy that is expected to exceed its NDC by 1,100–1,900 MtCO₂e/year. A large majority of this expected impact is from companies (Figure 2(e)). Japan also demonstrates significant contributions from city, region and business commitments, which would lower emissions by up to 70 MtCO₂e/year below the country's NDC by 2030. The results for both the EU and Japan show comparatively more balanced contributions from NSAs than in other countries (Figure 2, panel (d) and (f)). Other countries, such as China and Canada, may have a sizeable representation of NSAs taking action, but their marginal additional impact, compared to current national policies, demonstrates the high degree of overlap in their actions. One reason for China's seemingly relatively low impact from cities and provinces could be due to the top-down manner in which national climate policies are set and implemented (Figure 2(c)). In others, such as Indonesia and South Africa, non-state and subnational climate action data are quite limited, a challenge that is further elaborated in the discussion section.

3.3. Sensitivity analysis

We examined the sensitivity of our results to a few key assumptions. The first assumption is the emissions trend under the CNP scenario in 2030 for NSA groups with commitments. In the results presented above, we applied the average national emissions trend compared to a historical base year to all NSAs. For these actors, however,

higher autonomous improvements might already be expected independent of their commitments, as they might foresee declining emissions trends under their jurisdiction even without policies or are frontrunners within their country on climate action with more measures implemented than in regions, cities and companies without commitments.

Therefore, we conducted a sensitivity calculation by assuming a 10% lower emissions change by 2030 compared to a historical base year. Table 3 shows this assumption equals to approximately 0.7%/year lower emissions growth compared to the national averages between 2016 and 2030, which is more than double the uncertainty assumed for cities in UNEP (2015) (+/−0.3%/year) and is consistent with the range observed across nine US regions for 2030 (90% to 108% of the national average) under the reference scenario in the US Annual Energy Outlook 2019 (U.S. Energy Information Administration, 2019). The estimated GHG emissions reductions for the ten major-emitting economies then reduce by roughly 35% (upper bound) to 45% (lower bound). Similar sensitivity levels were observed also at the individual country levels.

We also assessed the sensitivity of our findings to the threshold values used to determine ambitious city and company commitments (Table S-3 in section S3.3 of the SOM) that were applied to quantify the net additional impact of cities and companies in cases where they are in geographical locations that also have commitments. We found that total GHG emissions reductions changed by 5% when the threshold values were changed by +/−30%.

3.4. Comparison of results with earlier studies

On a global level, there are few studies that have aggregated the GHG mitigation potential of individual NSA commitments. Roelfsema et al. (Roelfsema et al., 2018) projected that the commitments reported to CDP, C40 Cities and Covenant of Mayors (the present Global Covenant of Mayors) would together lead to a reduction of about 1.3 GtCO₂e/year compared to a no-policy baseline by 2030. While Roelfsema et al. (2018) and our analysis used different baselines, we find the calculated GHG mitigation potential values to be comparable to our results (1.2–2.0 GtCO₂e/year by 2030). The Global Covenant of Mayors estimates a 1.4 GtCO₂e/year emissions reduction by 2030, compared to a current policy baseline with a modelling start year of 2010 (GCoM, 2018a).

On country-level assessments, our findings for Japan are consistent with a study by E-konzal and Kiko Network (2016). For the US, our projection range for 2030 is similar to the range indicated by the ‘Climate Action Strategies’ scenario (reflecting 10 high-impact, near-term and readily available opportunities) and ‘Enhanced Engagement’ scenario (broader set of ambitious undertakings by regions, cities and companies) projections in the America’s Pledge (2018) report. Our result is higher than an earlier similar analysis (Kuramochi et al., 2017), as the number of actors and commitments have increased significantly in the US since then.

4. Discussion

4.1. Significance and policy implications of this study

This study represents, to the authors’ knowledge, the most comprehensive analysis to date of the aggregated impact of individual NSA commitments on climate change mitigation. While not comprehensive of

Table 3. Sensitivity of the 2030 greenhouse gas (GHG) emissions reductions to counterfactual emission levels for the non-state and subnational actors with commitments under the current national policies (CNP) scenario. Values are rounded to the nearest five.

Country	GHG emissions reductions in 2030 (MtCO ₂ e/year)	
	2030 counterfactual emissions (relative to 2010 levels) same as the national average under CNP scenario	2030 counterfactual emissions (relative to 2010 levels) 10% lower than the national average under CNP scenario
China	0–100	0
EU28	110–325	0–190
India	220–245	185–205
Japan	85–130	35–80
US	545–820	315–565
Total of ten major emitting economies	1,185–1,985	650–1,325

all actors and climate actions globally, the data evaluated for this study provides a detailed window into bottom-up mitigation efforts, identifying trends, patterns, and gaps in cities, companies and state and regions' responses to climate change. These results have three important implications. First, while many national governments do not seem to fully acknowledge subnational non-state climate action in their NDC formulation (Hsu et al., 2019a), they could help many countries achieve or over-achieve their NDCs. Second, many countries could raise their NDC ambition by considering existing city, region, and company commitments in their national climate policy formulation process. Third, for those countries where national governments withdraw from ambitious climate policy, bottom-up climate action can partly make up for backtracking.

4.2. Limitations of this study

We identify a number of limitations of this study related to: (1) incomplete coverage of existing non-state and subnational climate action, particularly in developing countries and major energy economies, (2) assumptions applied for the preparation of the dataset and for the aggregation of commitments, (3) the assumption that climate action efforts are not displaced elsewhere, (4) the likelihood of commitments being fulfilled. These limitations work in opposite directions (i.e. (1) would lead to an underestimation of the impact, (3) and (4) to an overestimation).

4.2.1. Incomplete coverage of existing sub-national and non-state climate action

Our analysis only included actors from 10 high-emitting countries, while in reality sub-national and non-state climate actions take place globally. Studies have shown that the full extent of climate action often goes unreported, particularly among actors from the Global South (Chan et al., 2018a; Chan & Hale, 2015; Hsu et al., 2016; UNFCCC, 2018; Widerberg & Stripple, 2016) and varies across economic, geographic, and national contexts. For businesses, not all companies are willing to make their climate action commitments public. For example, companies can choose not to allow public access to their survey responses in the CDP questionnaire (CDP, 2019). Actors that do not participate in a voluntary, public reporting platform are also excluded in this analysis. Unquantifiable NSA climate actions can still result in indirect emissions reductions through catalytic effects (Hsu et al., 2019b).

4.2.2. Uncertainties related to the assumptions used for dataset preparation and aggregation

In the process of preparing and validating data used for this analysis, there were certain exclusions and decisions made that may affect the overall assessment, although we deem them to be *de minimis*. For example, we excluded companies' scope 3 emissions by applying their scope 3 share in total emissions covered per target estimated from the most recent historical data throughout the assessment period. This simplified assumption was made due to a lack of information and the complexity of quantifying overlaps with other emissions resulting from the diversity of scope 3 emissions (e.g. upstream, downstream and boundary considerations). While this assumption would not considerably affect our country-level findings because scope 3 emissions accounted for only 13% of total corporate GHG emissions reported to CDP in our dataset, value chain and/or life cycle GHG emissions included in scope 3 are important emissions sources, and future research is needed to understand the net impact of scope 3 emissions-related targets.

The assumption that all NSAs under the CNP scenario would show future emissions trends equal to the national average may also have affected the obtained results. In the uncertainty analysis, we found that a 10% lower counterfactual baseline emission level would lead to 40% or larger decrease in the potential GHG emissions reductions. We conclude that our results are more robust for economies with comparatively higher coverage of national total GHG emissions by NSA commitments—as the emissions coverage becomes larger, the counterfactual baseline under the CNP scenario would become closer to the national average. For country-specific assessments, subnational region-specific baselines would ideally be used (America's Pledge, 2018).

4.2.3. No displacement of climate action elsewhere

Another major assumption of the mitigation potential achieved is that city, region, and company climate actions do not replace existing climate efforts embedded in the current policy scenario, for example by other sub-national, non-state actors or national governments where the actions take place. This phenomenon, where carbon emissions increase despite actions being taken by some actors, can be compared to carbon leakage (van Asselt & Brewer, 2010) that may occur if a country implements an ambitious climate policy but emissions rise in other countries. For such action displacement to occur, however, actors must have full knowledge of each other's climate actions and legal enforcement of emission reduction policies. Additionally, studies note that almost no coordination between national government and regions, cities and companies on climate action actually occurs (Hsu et al., 2019a). Therefore, we conclude that NSA climate action does not, at this moment, replace efforts elsewhere, although there are open questions that remain as to the future of sub-national and non-state climate action. For instance, if increased coordination with national government occurs, particularly in the context of the Paris Agreement's five-year review cycle, this may subsume sub-national and non-state climate actions into NDCs or national climate policy.

4.2.4. Likelihood of non-state and subnational commitments being fulfilled

This study estimates the GHG emissions reductions of full implementation of NSA commitments, but does not assess the likelihood of this given the current status of progress. Data on progress towards climate action goals is scarce, although a few studies have assessed performance by tracking the production of tangible and attributable outputs by climate initiatives (Chan et al., 2018b; Chan & Amling, 2019). A lack of quality progress data, however, makes it difficult to assess the likelihood of implementation. The challenges of monitoring climate policy implementation have been significant at both national and subnational levels even in the EU, where the bottom-up monitoring system is among the most advanced (Kona et al., 2018; Schoenefeld et al., 2018, 2019). While some climate action networks offer ways for their members to report on their progress, often only a fraction of participating actors share this information (Hsu et al., 2018). Additionally, companies provide information about the percentage of an emissions reduction or renewable energy target that has been achieved to date in their responses to CDP, but there remain challenges to analysing this information from year to year and understanding how it relates to a company's overall emissions inventory. Collection of additional and more streamlined information, including anticipated progress pathways (e.g. linear, exponential, logarithmic, variable, etc.), could improve progress tracking in future datasets.

A better understanding of progress towards meeting goals will be vital for accurately assessing the contributions that NSAs can make towards national and global mitigation goals – and help unlock and direct the support and resources needed to ensure their success. For instance, surveys of cities have flagged shortfalls in funding, technical know-how, or shifts in political priorities or leadership as potential obstacles to progress (C40 Cities, 2016). More detailed implementation data could power expanded analysis that explores drivers and obstacles to climate action in different contexts, insights that would enable the global community to better support these efforts.

Several initiatives to more closely track progress are underway. From 2019 onwards, the Corporate Climate Action Benchmark (CCAB), developed by CDP and the World Benchmarking Alliance, will measure the climate action performance of high emitting companies on a yearly basis, allowing stakeholders to monitor their progress (Hsu et al., 2018). Efforts to streamline the reporting processes could also make it easier to track progress by lowering actors' reporting burden and consolidating existing data. In April 2019, ICLEI's carbonⁿ® Climate Registry and CDP streamlined their data platforms – local and regional governments can report just once, on CDP's platform, and their data will automatically be shared with ICLEI (van Staden & Appleby, 2019). The common reporting framework of the Global Covenant of Mayors for Climate & Energy (GCoM, 2018b), which took effect in January 2019, is designed to enable cities to report data in a standardized way, provide flexibility to meet specific local or regional circumstances, and unambiguously track progress (GCoM). These changes in the reporting pipeline have the potential to make it easier for analysts, policymakers, and the reporting regions, cities and companies to track individual and collective progress towards climate action commitments.

In this context, it is also of critical importance that ex-post assessments of NSA actions be conducted, by both the actors themselves as well as by independent research groups. As there are many NSAs that set targets for 2020, critical assessment of their results is an important area for future research. To date there are limited assessments of NSA climate action implementation, and those that do exist are limited in sample size (e.g. Khan and Sovacool (2016) evaluate 25 cities' emissions reductions reported to Carbonn® Climate Registry) or by sector (e.g. Steffen et al. (2019) evaluate the impact of transnational municipal networks on city investment in utility-scale solar photovoltaics). With the next decade marking a crucial period for the achievement of global climate goals, ex-post evaluation of whether and how NSA climate actions achieve their stated goals will be a critical area for further research.

5. Conclusions

This study quantified the aggregate potential of recorded and quantified city, region, and company GHG mitigation commitments covering 8.1 GtCO₂e/year in 2016 in ten major-emitting economies. We found that these efforts could lower emissions by 1.2–2.0 GtCO₂e/year or 3.8%–5.5% compared to current national policies scenario projections in 2030, if these commitments are fully implemented and if such efforts do not change the pace of action elsewhere. These results may be an overestimation, given a range of assumptions we make in developing our data and models to assess impact of NSA action, but they could also be underestimated as not all NSA action is recorded and/or could be quantified.

On a country level, NSAs are estimated to reduce emissions relative to current national policies from 0% to 14.3%. In some cases, such as the EU, India, and Japan, these actions could help national governments overachieve their NDC targets by extending ambitious actions beyond national policies. In other cases, such as the U.S. and Brazil, sub-national and non-state action could help recover emissions reductions lost through national government rollbacks in climate policies.

To realize the potential quantified in this article, however, efforts for implementation will be required at all levels – from the international community, to national and local governments – to ensure a supportive policy environment that recognizes the valuable contributions of all actors to global climate mitigation. Critical assessment of whether and how NSAs would achieve their stated climate action goals is an important area for future research.

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