Global climate action from cities, regions, and businesses

Technical annex II: Methodology for quantifying the potential impact of individual region, city, and business commitments

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Disclaimer

This publication is part of a collaborative series of reports by over 30 organizations released in concert with the 2018 Global Climate Action Summit, which showcase the extraordinary action of states, regions, cities, businesses and investors – and assess the opportunity for even greater impact.

In this specific publication we focus on the contribution of regions, cities and businesses and of cooperative initiatives that include regions, cities, businesses along with national governments and civil society partners, in order to understand their contributions to national and global efforts to reduce greenhouse gas emissions, and prevent the most damaging impacts of climate change.

The views and assumptions expressed in this report represent the views of the authors.

Notes (July 2019)
The document has been updated to correct for non-substantive errors.

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1 Introduction

The *Global climate action from cities, regions, and businesses* report determines the global impact of both individual and international cooperative initiatives (ICIs) on national and global greenhouse gas emissions by 2030. It also shows to what extent individual and ICI climate commitments exceed current national policies' emission reductions, and how this relates to the “well below 2°C” temperature limit goal that was secured in the Paris Agreement. The mitigation impact of individual commitments from cities, regions and companies, and the mitigation impact of ICIs were calculated separately are not meant to be aggregated or combined. A separate technical annex describes the methodology used to calculate the mitigation impact of ICIs. This technical annex describes the methodology used to determine the mitigation impact of individual commitments from cities, regions, and companies.

Nine countries and regions were covered in the assessment: Brazil, China, the European Union (EU28), India, Indonesia, Japan, Mexico, South Africa and the United States of America (USA). Russia was considered in the assessment, but we found no commitments from subnational actors and no quantifiable company commitments.

As a starting point, we use a **“Current national policies” (CP)** scenario, which considers only currently implemented national and federal policies. To cover the uncertainty of future projections, two current national policy scenario projections are taken into account, one that is conducted by NewClimate Institute and one produced by PBL Netherlands Environmental Assessment Agency (Kuramochi *et al.*, 2017). Both are supplemented with LULUCF and agricultural sector projections from the International Institute for Applied Systems Analysis (IIASA) (Kuramochi *et al.*, 2017). The CP scenario projections considered main energy and climate policies implemented as of July 2017.

The **“Current national policies plus individual actors’ commitments” (CP+NSA)** scenario is the main scenario in this analysis and builds upon the CP scenario. In addition to national policies, it considers the recorded and quantifiable commitments made by individual sub-national and non-state actors (e.g., regions, cities and companies). This scenario assumes full implementation, meaning we do not discount certain reductions based on an assessment of their likelihood of implementation. We do not further analyze specific policies, actions or implementation barriers to meeting these targets. This scenario considers and quantifies the overlaps across commitments, the methodology of which are explained in detail in section 3.

As part of the sensitivity analysis, we also investigated the **“NDCs plus individual actors’ commitments” (NDC+NSA)** scenario. This scenario builds upon the unconditional NDC scenarios also taken from (Kuramochi *et al.*, 2017), and assumes full implementation of conditional and unconditional NDCs by 2030. We add the impact of recorded and quantifiable commitments from individual sub-national and non-state actors, assuming their full implementation. This scenario also considers and quantifies the overlaps across commitments, the methodology of which are explained in detail in section3.5.

All scenario projections developed in this analysis include emissions from land use, land-use change and forestry (LULUCF). The NDC target emission levels for the EU are adapted from Kuramochi et al. (2017) to account for the LULUCF emissions because the referenced study assumed that the EU’s NDC excludes LULUCF.

All scenarios are calibrated to the historical emissions of 2015 and span until 2030. All GHG emission values are expressed using the global warming potential (GWP) values from the second assessment report (SAR) of the Intergovernmental Panel on Climate Change (IPCC, 1995). SAR GWPs were used in Kuramochi et al. (2017), from which the current policies scenario projections were taken.

The analysis covers commitments from individual actors that have set quantitative emission reduction or renewable energy targets, and for which historical emissions data is available. The emissions trajectories for non-state and subnational actors with commitments are developed based on the data provided by CDP for companies and by Data-Driven Yale, with data from the EU Covenant of Mayors, Global Covenant of Mayors, Compact of States and Regions, CDP Cities, carbon*n* Climate Registry, C40 Cities, Under 2 Coalition, and United States Climate Alliance, for sub-national actors. Our analysis covers quantifiable emissions reduction commitments from 5,910 cities, 75 regions and 2,175 companies globally as of end-May 2018.

Direct emissions (Scope 1) and indirect emissions from electricity generation (Scope 2) are included in the analysis for individual actors. Commitments' impact on supply chain emissions (Scope 3) are excluded from the analysis if they make up the entirety of the commitment. While Scope 3 emissions are significant for most companies, 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 availability. We include commitments with a combination of Scope 1 and 2 emissions and Scope 3 emissions, although the impact of this assumption on the obtained results are likely limited since there are only 118 companies with this type of commitment in our dataset. For cities, very few report Scope 3 emissions in their inventories, which prevented us from assessing them in this study.

2 Datasets used in the analysis

2.1 Overview of data

Our analysis considered approximately quantifiable emissions reduction commitments from 5,910 cities and 75 states and regions. We also considered 21,562 commitments from companies. 44% of the company targets were intensity targets (e.g., emissions reductions denominated on a per unit basis). 14% of the company and 77% of the city targets were renewable energy targets. The emissions inventory totals used for the calculations were mostly self-reported by entities through one of the above-mentioned reporting platforms.

Data for quantifiable climate commitments came from the following sources (Table 1):

Table 1: Data sources for individual subnational and non-state actor commitments

Climate Action Platform	Data Source
C40 Cities for Climate Leadership	www.data.cdp.net: 2017 Cities Emissions Reduction Targets; 2017_Cities Community-wide Emissions Map; 2017 Cities Renewable Energy Targets Map.csv; City-wide Electricity_Mix. March 2018.
ICLEI Local Governments for Sustainability carbon*n* Climate Registry	www.carbonn.org; individual targets, action plans, and progress data collected for all reporting members. March 2018.
CDP Cities	www.data.cdp.net: 2017 Cities Emissions Reduction Targets; 2017_Cities Community-wide Emissions Map; 2017 Cities Renewable Energy Targets Map.csv; City-wide Electricity_Mix. March 2018.
CDP 2017 Disclosure Survey	CDP (2018) *GHG emissions and action data for companies based on the 2017 responses*.
Compact of States and Regions	www.data.cdp.net: 2017 States and Regions Climate Actions; 2017 States and Regions GHG Emissions Reduction Targets Map; 2017- States and Regions GHG Emissions
EU Covenant of Mayors	www.globalcovenantofmayors.org: individual targets, action plans, and progress data collected for all reporting members. March 2018.
Under2 Coalition	www.under2mou.org: membership and action data collected from annual reports.
Global Covenant of Mayors.	www.globalcovenantofmayors.org and limited baseline and target data provided directly from Global Covenant of Mayors, May 2018.
US Climate Alliance	www.usclimatealliance.org: target information collected from Kuramochi et al., 2017.
US Climate Mayors	www.climatemayors.org; limited commitment information collected from Climate Action Compendium (http://climatemayors.org/actions/climate-action-compendium/), others supplemented through desk research of member climate action plans.

The emission pathway in the "Current national policies plus individual actors' commitments" (CP+NSA) scenario for each actor is derived from emission levels in target year. We assume a linear interpolation of emission levels between the starting year (2015) and the short- to mid-term target year (between 2015 and 2030), as well as between the short- to mid-term target year and the long-term target year. After the last target year, we have assumed that the emission levels follow CP scenario emission projections until 2030 (see Section 2.4).

2.2 Subnational actions

Subnational climate action data was collected from a variety of climate action registries and platforms, including the EU Covenant of Mayors, Global Covenant of Mayors for Climate and Energy, Compact of States and Regions, CDP Cities, carbon*n* Climate Registry, C40 Cities, Under 2 Coalition, Climate Mayors and United States Climate Alliance.[1] We collected participation information additionally from the We Are Still In initiative, a pledge platform that as of August 2018 includes 276 cities and counties and 10 states in the United States[2]. But, this platform does not report individual actor climate commitments, so therefore we could not quantify these actors' mitigation efforts unless they were also member of another network that includes quantified emissions reduction target information.

Different platforms report participants' climate actions in different formats and to different levels of detail: CDP Cities report the breakdown of Scope 1 and Scope 2 emissions of subnational actors, whereas platforms like carbon*n* Climate Registry and the EU Covenant do not include information on emissions scopes if inventory information is reported by an actor. Climate action platforms also capture different types of targets that span energy efficiency targets, renewable energy, as well as intensity-based targets.

To overcome the inconsistencies in each platform's method of categorizing targets and to include as many subnational actors' targets as possible, we chose the most common targets across platforms. We included city- or region-wide absolute emission reduction targets and quantified each target's emissions reduction using the following variables: actor's base year Scope 1 and Scope 2 emissions, the target percent reduction, the target base year, the target year, and the actor's most recent GHG inventory year and the 2015 inventory Scope 1 and Scope 2 emissions.

In the preliminary analysis presented in this paper, sector-level and government-operations targets for cities and regions were excluded if city- or region-wide emissions reduction targets existed. Renewable energy targets were included if cities and regions did not have an absolute emissions reduction target.

In sum, the hierarchy was applied as follows:

1) City- or region-wide absolute emission reduction targets, in terms of:
    - Absolute emissions reduction
    - Reduction relative to base year emissions
2) Government (e.g., direct and indirect emissions from buildings and other government-owned sources)
3) Renewable energy commitments

We supplemented data on subnational actors from a range of external sources for key countries in our analysis. Chinese subnational commitments were derived from the 20 Chinese cities and 2 provinces are part of the Alliance of Pioneer Peaking Cities (2016) plus Hong Kong. China's 2012 emissions inventory data (including both Scopes 1 and 2) of these cities in 2012 were taken from Liu & Cai (2018). For U.S. subnational actors, we gap-filled some missing information on baseline emissions and climate action commitments through internet desk research of city climate action plans and progress reports.

In other cases when city-level greenhouse gas emissions data is missing, cities' emission values were calculated by multiplying per-capita provincial-level emissions by the cities' population. An example of such a case is Semarang in Indonesia. The city's most recent emissions inventory value was calculated by multiplying per capita emissions of Central Java Province (where Semarang is located), as reported in the World Resources Institute (WRI)'s CAIT Indonesia Climate Data Explorer (PINDAI) (WRI, 2016), by Semarang's population.

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[1] Several of these networks are included as data sources for both the analysis of individual commitments by cities, states, and regions and the analysis of ICIs. In this analysis, we assess the specific commitments already made by each city, state, and region, while the ICIs analysis assess the aspirational goals of included initiatives.

[2] We Are Still In. https://www.wearestillin.com/signatories. Accessed August 1, 2018.

We also made several corrections to the reported data based on additional desk research and expert judgment. When we could not verify questionable data, we removed these commitments from our analysis. In total we quantified commitments from 5,985 subnational actors from 36 countries in our key 10 regions and a further 77 renewable targets.

There were only a few subnational actors with no GHG emissions reduction targets but with renewable energy targets, which were considered but resulted in very small total reductions.

The emissions data for the subnational commitments was carefully examined and corrected or excluded erroneous data points whenever identified. Most commonly observed errors were emissions reported in wrong orders of magnitude in the original source from which we collected data. At the same time, it was not possible to verify the orders of magnitude for all commitments, which add up to more than 6,000. Therefore, we applied filters to exclude commitments with per capita GHG emissions lower than 0.2 tCO_2e/capita and higher than 40 tCO_2e/capita, with a few exceptions for which were able to verify the correctness of the data.

Overall, we included emission reduction targets for subnational actors from 36 different countries, and a further 77 renewable targets.

2.3 Companies' actions

The dataset of companies' actions was provided by CDP. It is based on the 2017 responses to CDP's investor climate and supply chain program (CDP, 2018). The CDP dataset on company-level action provides information necessary for the analysis, such as the amount of GHG emissions generated in each country's jurisdiction, by a company operating worldwide. While CDP is not necessarily comprehensive of all corporate global climate action, they report that over 6,300 companies representing a combined purchasing power of over $3 trillion responded to their climate change questionnaire (CDP, 2018). In 2016, 1,073 companies who disclosed to CDP represented 12 percent of global direct GHG emissions.

The CDP questionnaire for companies encourages the use of GWPs from the IPCC's Fifth Assessment Report (AR5) (IPCC, 2014) for reporting emissions. We consider these data to be comparable with that reported in terms of SAR GWPs as most companies are categorized to be emitting predominantly CO_2, with only a minimal amount of tracked emissions (<1%) coming from non-CO2 emissions from the waste sector.

For the quantification of absolute emission levels under the commitments, values provided by CDP are used. In turn, CDP either received emissions reduction levels directly, or calculated levels based on another indirect measure of climate mitigation (i.e. a commitment to increase renewable energy generation). Starting year (inventory) emission values were calculated as the sum of total Scope 1 and 2 emissions in the country of operation, while target year emission values were calculated using the company's target percentage in emissions reduction for absolute targets, anticipated emissions reduction for emission intensity targets, and added renewable energy generation for renewable targets. Targets aiming at exclusively reducing Scope 3 emissions were removed from the dataset since we were unable to quantify probable overlaps, while targets that also include Scope 3 emissions alongside Scope 1 and/or Scope 2 emissions were included due to their low group size (~1% of the number of total company commitments).

Not all necessary information was available in the CDP dataset to quantify the target emission levels for about 20% of all company commitments. For those companies with targets, but without emissions data at starting year, the GHG emissions were estimated with linear scaling factors and assuming company revenue as the main driver of emissions. The revenue of these companies was scaled with those companies in the same industry group with both available emissions and revenue data. Furthermore, for companies who did not report how much of the overall company emissions is covered by the target, it was assumed that their target covers 100% of their emissions.

2.4 Emission projections for cities and companies from the IMAGE model

Our assessment makes use of business-as-usual and current policy projections for non-state actors derived from the Targets IMage Energy Regional (TIMER) model developed by PBL. These projections were done for the following cases (see Section 3).

- Emission projections for regions, cities and companies without commitments (partial effect method);
- Current policies scenarios representing emission pathways as the results of national climate- and energy policies.

The TIMER model forms part of the integrated assessment model IMAGE 3.0 (Stehfest *et al.*, 2014). It describes future energy demand and supply for 26 global regions, of which some are large countries (e.g., US, China), and is able to assess the implications of energy system trends for all major greenhouse gases and air pollutants. This model simulates long-term energy baseline and mitigation scenarios (Van Vuuren et al., 2014) on the global and regional levels. The investments into different energy technologies are calculated by a multinomial logit function that accounts for relative differences in costs and preferences (e.g., technologies with lower costs gain larger market shares). The model is built up from different modules, including energy demand modules for transport, industry, buildings and modules for energy supply, industrial processes and emissions.

The TIMER model does not represent specific actors, but instead a carefully chosen subset of CO_2 emission projections was used from the TIMER Shared Socio-Economic Pathway 2 (SSP2) scenario from van Vuuren et al. (2017). Based on the emission projections from the SSP2 and current policies scenario calculated using the TIMER model, projections have been made for the aggregated regions, cities and companies of a country. This has been done for Brazil, China, EU (based on Western and Central Europe), India, Indonesia, Japan, Russia and USA. The emission projections for regions were assumed to be the same as the country projections. For cities and companies the selection of sub-sectors and weights is shown in Table 2 and Table 3. The current policies scenario from Kuramochi et al. (2017) was derived to represent aggregated region, city and company emission growth.

Table 2 Weight applied to total sub-sector CO_2 emissions from TIMER Model to construct (per country) aggregated CO_2 emission projections for companies (for scope 1 and scope 2)

Sector	**Sub-sector**	**Weight scope 1**	**Weight scope 2**
Industry	Cement	100%	100%
	Steel	100%	100%
	Other	100%	100%
	Total industry		
Transport	Bus	0%	
	Train	0%	
	Car	5%	25%
	High speed train	0%	
	Air	0%	
	Trucks	0%	
	Other freight	0%	
	Total transport	0%	
Residential	Urban	0%	0%
Services		100%	100%
Other		100%	100%
Losses/leakages		100%	100%
Bunkers		0%	0%

Table 3 Weight (as percentage of total emissions coming from urban areas) applied to total sub-sector CO_2 emissions from TIMER Model to construct (per country) aggregated CO2 emission projections for cities (for scope 1 and scope 2)

Sector	Sub-sector	Weight scope 1	Weight scope 2
Industry	Cement	0%	0%
	Steel	0%	0%
	Other	75%	75%
	total industry		
Transport	Bus	75%	
	Train	50%	
	Car	Share of urban population	75%
	High speed train	50%	
	Air	0%	
	Trucks	50%	
	Tther freight	0%	
	total transport	0%	
Residential	Urban	100%	100%
Services		100%	100%
Other		75%	75%
Losses/leakages		0%	0%
Bunkers		0%	0%

3 Quantification of GHG emissions reductions at national level

The quantification of national level aggregate impact includes two steps (Figure 1):

- First, the share of current national emissions that is covered by regions, cities and companies with targets is determined. The share of current emissions that is not covered by regions,' cities' and companies' targets follows the right-hand trajectory of the "current policies scenario."
- Second, for the share of emissions covered by targets, the combined effect of all individual actors' targets is determined. Here the share of emissions only follows an actor's path if that actor's path is unambiguously more ambitious than the other individual actors'.

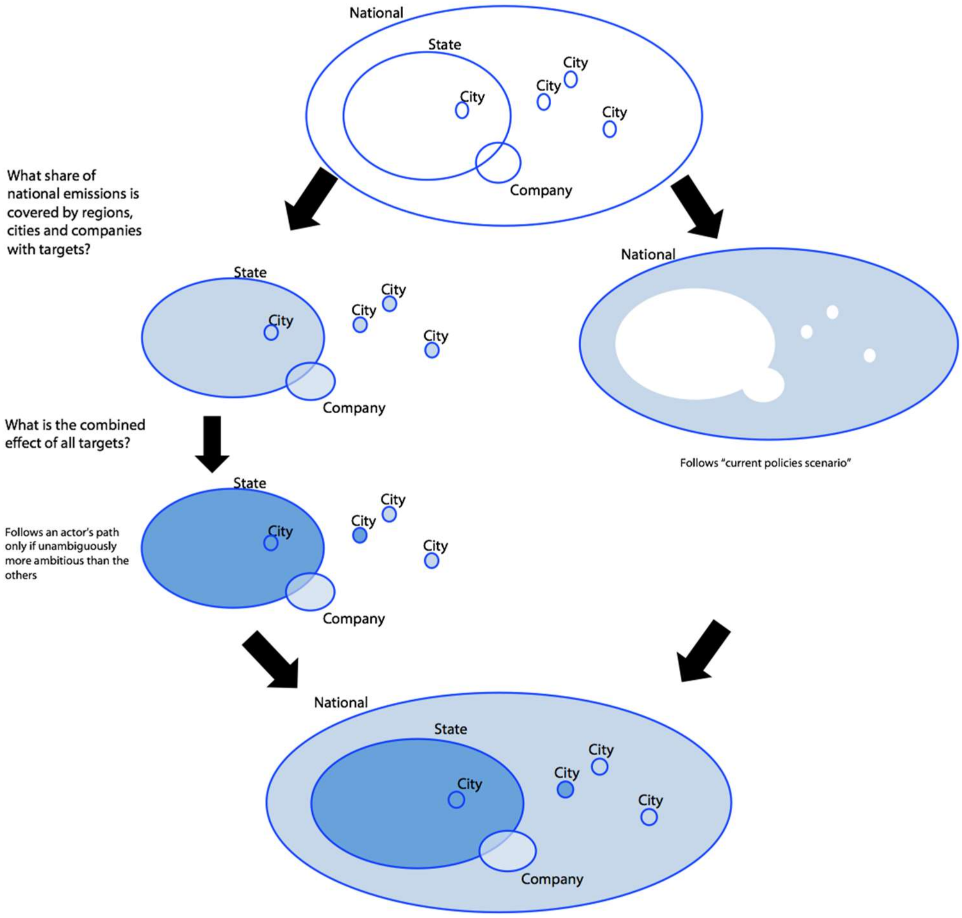

Figure 1. Process employed to account for overlaps and quantify the overall impact of all targets.

The emission pathway for the "Current national policies plus individual actors' commitments" (CP+NSA) scenario is defined as the total GHG emissions in a country in year *t* under (E_{tot}(t)), and is given by:

$$E_{\mathrm{tot,CP+NSA}}(\mathrm{t}) = E_{\mathrm{tot,CP}}(\mathrm{t}) * \frac{E_{\mathrm{tot}}(2015) - E_{\mathrm{NSA}}(2015)}{E_{\mathrm{tot}}(2015)} + E_{\mathrm{NSA}}(\mathrm{t}) \qquad (1)$$

where

$E_{tot,CP+NSA}$(t): total GHG emissions under "Current national policies plus individual actors' commitments" scenario in year *t*,

$E_{tot,CP}$(t): total GHG emissions under the current national policies scenario in year *t*,

E_{NSA}(t): total GHG emissions from non-state and subnational actors in year 2015 as a result of achieving pledged commitments, accounting for overlap between non-state and subnational actors.

We assume in Eq. (1) that the GHG emissions not covered by existing subnational and non-state actor commitments, determined by the 2015 emissions data, will grow proportionally to the current policies scenario projections.

In the following sections the details of the four calculation steps are described: (1) quantify the target emission levels for individual commitments and then aggregate for each actor group (e.g. regions, cities, and companies) (section 3.1), (2) quantify the geographical and supply chain overlaps between commitments (section 3.2), (3) compare ambition for emission sources for which targets are overlapping (section 3.3), and (4) determine the combined effect of all targets in cases of overlap (section 3.4).

3.1 Quantification of target emission levels under individual commitments and their aggregation by actor group

Regions, cities and companies are assumed to fully implement their target reductions in the target year, following a linear emissions reduction pathway from the starting year. The time period analyzed in this study (2015-2030) extends past the target years of many regions, cities and companies. For those non-state and subnational actors, whose target years end before 2030, it is assumed that they follow the average of the two current policies pathways from Kuramochi et al. (2017). For regions, cities and companies with multiple GHG emission reduction targets in the same operating country, the most ambitious absolute emission reduction targets were prioritized in the analysis to avoid double counting of commitments.

3.1.1 Subnational actors

To calculate the individual subnational emissions reductions, we used three tiers of interpolation for the quantifiable emissions reduction targets, depending on data reported by individual actors.

- Tier 1: if inventory year and inventory emissions are both available, we interpolate between the latest inventory emissions reported and the target year emissions, assuming a constant rate of decrease.
- Tier 2: if inventory emissions are known but not inventory year, we assume that inventory year is 2010, and apply the same interpolation as Tier 1 (the average year of last inventories was 2013; we assumed an earlier year of 2010 in order to not overestimate the emissions reductions for 2015 and consequently the emissions reductions between 2015 and 2030).
- Tier 3: for cases with no inventory emissions or inventory year, we base our interpolations on base year emissions and base year.

For cities that only report one target year, we assume a constant rate of reduction until the target year, after which we assume emissions have the same trend as the current policies scenario. For cities that have multiple targets, we interpolate from either the inventory or baseline emissions, whichever is available, up to the first target year (i.e., 2030). If a longer-term target (i.e., 2050) is available, we interpolate from the first target year (i.e., 2030) to the second target year (i.e., 2050) by assuming different rates of reduction between the target years.

Because of the nature of China’s Alliance of Pioneer Peaking Cities' peak emissions year targets, we had to calculate the emissions reductions differently. We extrapolated emissions from 2012 until 2030, assuming the rate of change in emissions is identical to the rate of change in population. The population projection time series data is obtained from UN Populations Division, World Urbanization Prospects: The 2014 Revision (UNDESA, 2014). For two Chinese cities (Nanping and Jinchang) and two provinces (Sichuan and Hainan) that did not have population projections available, we used national level emissions growth rates based on the TIMER BAU model to extrapolate future emissions pathway.

For subnational actors that report inventory-year emissions that are lower than the estimated target-year emissions, we assume that these actors have achieved their target emissions reductions in the inventory year and then assume a constant emissions level after the inventory year (i.e., no additional reductions are assumed).

3.1.2 Companies

The analysis differentiated the companies' actions into three groups based on the target type and the data availability in the CDP dataset:

1) Energy end-use companies with GHG targets;
2) Electricity-generating companies with commitments;
   2a) Utilities with absolute or intensity-based GHG targets
   2b) Utilities and energy end-use companies with renewable electricity generation targets
3) Energy end-use companies with renewable electricity consumption targets.

In the net aggregate impact quantification, we included renewable energy targets (types 2b and 3) set by energy end-use companies only when these companies did not have GHG emissions reduction targets.

For each company, absolute emissions reduction targets were prioritized over emission intensity and renewable targets if multiple targets from the same company report identical baseline emissions within the same operating country, as this suggests overlapping targets from the same branch. For companies that have both renewable energy targets and absolute emission reduction targets, we assumed that renewable energy targets do not deliver additional emission reduction impact beyond the absolute emission reduction targets.

When companies report multiple near-identical targets in the same operating country branch, we consider only the most ambitious target. We also applied the split between direct emissions (Scope 1) and emissions from electricity generation (Scope 2) of the last reported year (2015 in the current dataset) to the target year emissions since our data does not report this for both base and target year.

For renewable electricity production targets (target type 2b), to calculate the additional renewable electricity generation compared to the current national policies scenario we assumed that the total power generation of a company remains at 2015 levels up to 2030, unless otherwise specified. To calculate the GHG emissions reductions we assumed that the additional renewable electricity generation replaces fossil fuel-fired electricity; the country- or region-average CO_2 intensity values of which for 2030 was taken from the current policies scenario projections in the IEA World Energy Outlook 2017 (IEA, 2017c).

For companies with renewable electricity generation targets (type 2b), we considered not only the companies' electricity generation-related emissions but also the total GHG emissions as reported by CDP to estimate the overlaps between commitments.

For renewable electricity consumption targets (type 3), we did not estimate company-wide GHG emissions because the data needed to estimate future GHG emissions (e.g. base year and historical GHG emissions) were often not available for these targets. We calculated the GHG emissions reductions resulting from the additional renewable electricity consumption compared to 2015 levels.

Regarding the CDP dataset, company totals are reported for both base year and target year renewable energy data. To estimate the country-specific figures, we divided the company total figures based on the country-specific base year emissions covered by the renewable energy targets.

3.2 Quantification of geographic overlaps between actor commitments

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

The determination of the overlap was conducted in three steps (see Figure 2).

First, **the geographic overlap between regions with GHG targets and cities with GHG targets** was quantified in terms of GHG emissions. This overlap is calculated based on whether a city with a target is located within a region with a target or not. After identifying such cities, the net coverage of GHG emissions of sub-national actors (i.e. regions and cities) with commitments (overlap (a-b) in the top panel of Figure 2) was calculated. We have assumed that all electricity consumed by cities is generated in regions in which the cities are located.

Second, **the geographic overlaps between energy end-use companies with GHG targets and sub-national actors with GHG targets** were quantified (overlap (c-ab) in the middle panel of Figure 2). Energy end-use companies are companies that are not electric utilities. We assumed the same percentage of GHG emissions for the overlap between energy end-use companies with GHG targets and sub-nationals with targets as that between sub-nationals and the national target. Therefore, if the net coverage of national total GHG emissions by sub-national actors with commitments in a country is *xx*% of national total GHG emissions, we assumed that the same *xx*% of emissions under end-use companies' commitments are overlapping with subnational actors' commitments. This simplified approach was taken because there was no data available on which subnational jurisdictions the companies' emissions were generated (the CDP dataset provides country-specific emissions data per company).

Third, **the overlaps between electricity-generating companies with commitments and all other sub-national and non-state actors with commitments** (overlap (d-abc) in the bottom panel of Figure 2) 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 the overlap rate for electricity-generating companies is 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 the data available (Table 4). Country-level total GHG emissions from electricity generation in 2015 were estimated based on IEA (2017a, 2017b).

Table 4: Share of Scope 2 emissions in total Scope 1 plus Scope 2 emissions from cities by region.

Country	Value	Source
Brazil	12%	Median of 14 cities data from CDP (2017)
China	45%	Authors' estimate from Liu (2016) on four major cities (Beijing, Shanghai, Tiangjin, Chongqing) in 2009
EU	34%	Median of 53 cities data from CDP (2017)
India	20%	Authors' estimate from Ramachandra et al. (2015) on seven cities (Delhi, Mumbai, Hyderabad, Chennai, Kolkata, Bangalore, Ahmedabad) in 2009-2010
Indonesia	57%	Median of 2 cities data from CDP (2017)
Japan	50%	Median of 2 cities data from CDP (2017)
Mexico	26%	Median of 5 cities data from CDP (2017)
South Africa	63%	Median of 5 cities data from CDP (2017)
USA	43%	Median of 81 cities data from CDP (2017)

The overlaps between companies with renewable electricity consumption targets (but without GHG emissions reduction targets) and all other actors are considered differently from the actor groups described above. Here we defined two extreme cases to fully account for the uncertainty of their additionality. The maximum overlap case assumes that these consumption targets result in no additional renewable electricity generation—this considers cases where consumption targets are met by purchase agreements with electric utilities, which are selling renewable electricity that would have been generated anyway. The other case assumes that these consumption targets are entirely met by additional renewable electricity generation and replacing fossil fuel-fired power generation.

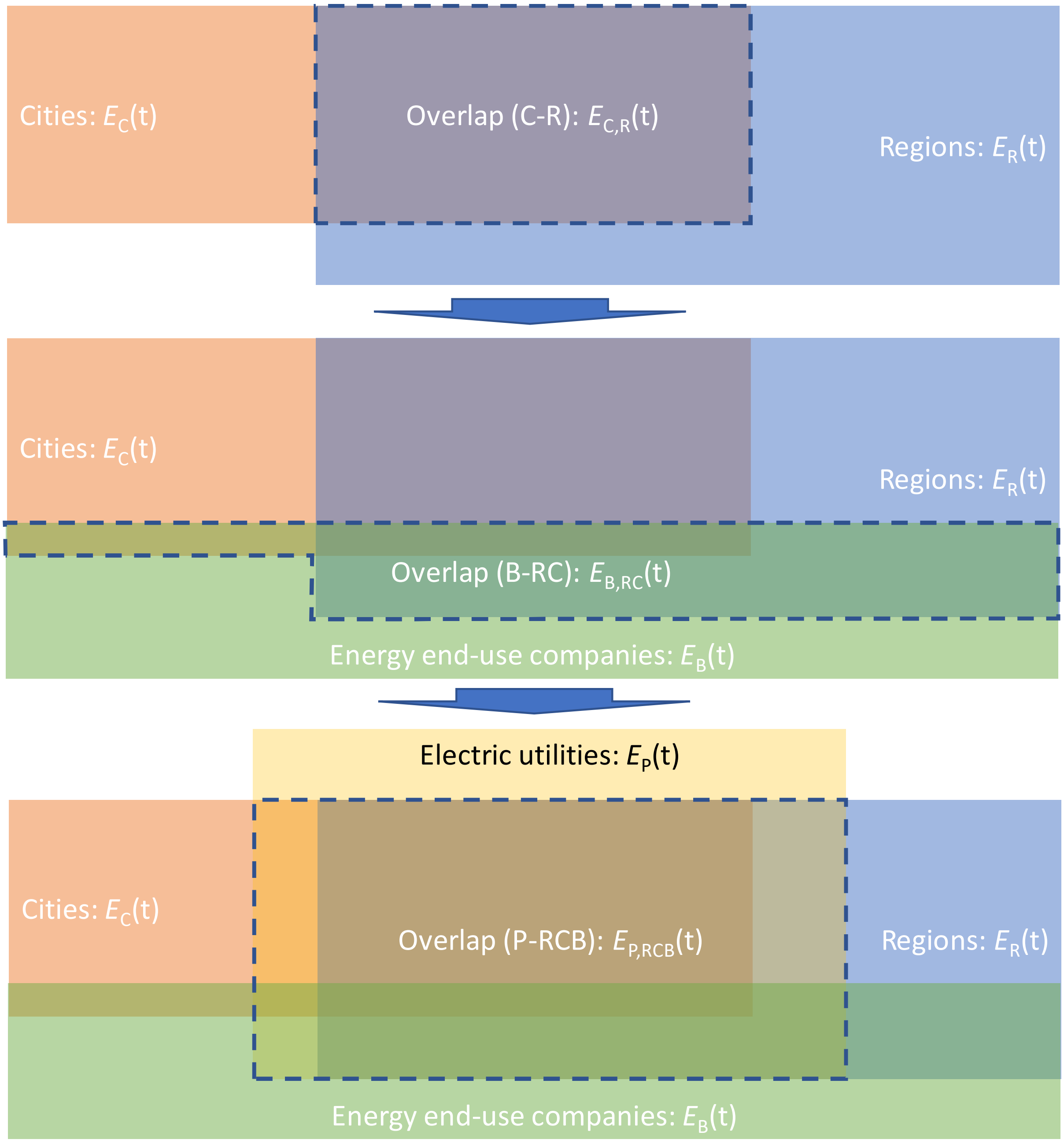

Figure 2: Step-by-step quantification of overlaps between actor groups.

The quantification of overlaps was done in the following order: regions, cities, and companies. This order implies starting from the largest emissions scope to the 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 in any possible way the relative importance of different actor groups.

3.3 Comparison of ambition when targets are overlapping

In the previous section we identified emissions that overlap for multiple actor groups, i.e. overlap areas (C-R), (B-RC) and (P-RCB) from Figure 2. For these emissions, we assessed which of the actor group's targets is more ambitious compared to the others.

Two extreme approaches 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.

We here took two different approaches that present the middle ground between those described above: the **"partial effect" method** and the **"partial conservative effect" method**. Both methods are treated equally and contribute to the uncertainty range presented with the results. The below sections describe instances of comparing the ambition of city-level targets against region-level targets.

3.3.1 Partial effect method

The partial effect method only counts the additional reductions of cities to regions if they are unambiguously more ambitious. Ideally, we would compare a city's commitment to the emissions reductions of that city expected under the region-level commitment, but such information does not exist. Therefore, we implement this approach by considering only reductions if a city's target is more ambitious than a long-term emission trajectory consistent with the 2 °C goal (Figure 3). Country-specific long-term trajectories are estimated from Höhne, den Elzen and Escalante (2014) by taking roughly the central estimates of all effort-sharing approaches; the values for 2030 used in the analysis are presented in Table 5.

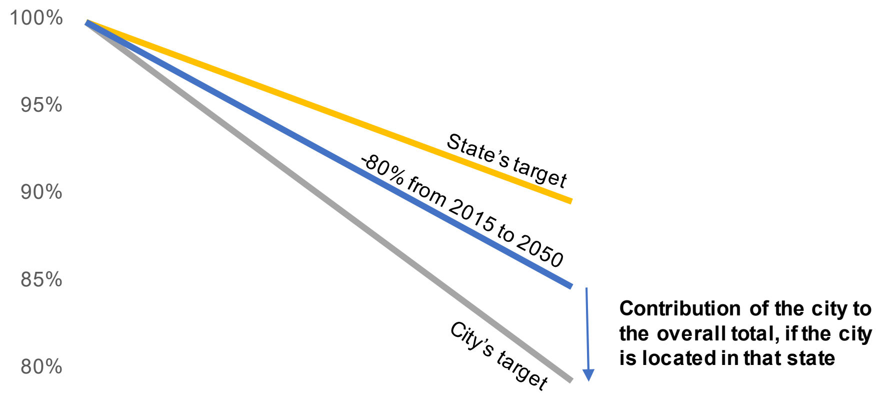

Figure 3: Illustrative example of contribution to the overall total of a city located in a state with a target in the case of the United States (Kuramochi et al. 2017).

Table 5: 2030 emission levels implied by 2 °C-consistent emission trajectories under a range of effort sharing approaches used as a threshold for quantifying net additional impact. Source: authors' estimate based on Höhne et al. (2014).

Country	Emissions in 2030 relative to 2015 levels
Brazil	-40%
China	-20%
EU	-50%
India	+50%
Japan	-50%
Mexico	-40%
USA	-50%
Indonesia	-30%
South Africa	0%

3.3.2 Partial conservative effect method

The partial conservative effect method assumes that there is always a group with "laggard" sub-national actors and companies that do not implement any climate action. We assume that this groups accounts for the same amount of 2015 GHG emissions as the actors with commitments ("forerunners"). So, there is a group of frontrunners, laggards and a group of followers in between. Implicitly, the group of followers implement climate action in line with the national current policies scenario (or NDCs). The assumption on size of the groups is not based on statistical data, as such data on progress is not available. These assumptions on size can be improved when this comes available. Therefore, we have assumed that the group of laggards have the same size, in terms of emissions, as the group of frontrunners. This 'laggard' group is assumed to follow a business-as-usual scenario, which is derived from the TIMER model (see Section 2.4).

For illustration purposes, we show an example of calculating aggregated additional city impact relative to the region (see top panel in Figure 2). Suppose the "forerunner" cities in area (C-R) cover 120 $MtCO_2e$/yr in 2015, and this group has committed to an annual 2.8% emission reduction rate below 2015 by 2030; the "laggard" cities group which by definition also covers 120 $MtCO_2e$/yr in 2015, follows a lower 0.2% business-as-usual emission reduction rate below 2015 by 2030. Further suppose the group of regions (area (C-R)) have on average committed to a 1.4% emission reduction rate below 2015 by 2030. This method assumes that the "forerunner" cities in area (C-R) would deliver emissions reductions additional to those of the regions only when the average emissions reduction rate of "forerunner" cities in area (C-R) and the "laggard" cities, i.e. 1.5% (*2.8%+0.2%*)/2), is larger the regions' 1.4%. In this case the additional mitigation impact is 0.12 $MtCO_2e$/yr (0.1%*120).

3.4 Emissions from subnational actors and companies with commitments after accounting for overlaps

Summarizing the above calculation steps, the total GHG emissions from individual actors' commitments are calculated as:

$$E_{NSA}(\mathrm{t}) = E_R(\mathrm{t}) + \left(E_C(t) - E_{C,R}(\mathrm{t}) - E^*_{C,R}(t)\right) + \left(E_B(\mathrm{t}) - E_{B,RC}(\mathrm{t}) - E^*_{B,RC}(t)\right) + \left(E_P(\mathrm{t}) - E_{P,RCB}(\mathrm{t}) - E^*_{P,RCB}(t)\right) \quad (2)$$

where

E_{NSA}(t): total GHG emissions from non-state actors with commitments in year *t*.

E_R(t): total GHG emissions from regions with commitments in year *t*;

E_C(t): total GHG emissions from cities with commitments in year *t*;

$E_{C,R}$(t): total GHG emissions from cities with commitments overlapping with E_R(t) in year *t*;

$E^*_{C,R}$(t): additional GHG emissions reductions from cities with commitments overlapping with E_R(t) in year *t*, after comparing the level of ambition;

E_B(t): total GHG emissions from energy end-use companies with commitments (excluding electricity-generating companies) in year *t*;

$E_{B,RC}$(t): total GHG emissions from energy end-use companies with commitments overlapping with E_R(t) and E_C(t) in year *t*;

$E^*_{B,RC}$(t): additional GHG emissions reductions from energy end-use companies with commitments overlapping with E_R(t) and E_C(t) in year *t*, after comparing the level of ambition;

E_P(t): total GHG emissions from electricity-generating companies with commitments in year *t*;

$E_{P,RCB}$(t): total GHG emissions from electricity-generating companies with commitments, overlapping with E_R(t), E_C(t) and E_B(t) in year *t*; and

$E^*_{P,RCB}$(t): additional GHG emissions reductions from electricity-generating companies with commitments overlapping with E_R(t), E_C(t) and E_B(t) in year *t*, after comparing the level of ambition.

3.5 Overlap quantification in the "NDCs plus individual actors' commitments" (NDC+NSA) scenario

For the **"NDCs plus individual actors' commitments" scenario** analyzed as part of the sensitivity analysis, cities' and companies' commitments that are not in the aforementioned overlap areas are also examined for additional reductions relative to NDCs. The areas in orange (top panel) for cities, gold (middle panel) energy end-use companies, and light green (bottom panel) electricity-generating companies in Figure 2 would be considered as overlapping with NDC targets—the additional mitigation impact from these cities is calculated similarly for the overlap areas (C-B), (B-RC) and (P-RCB) in Figure 2 as described above.

4 Quantification of GHG emissions at global level

We added the impact of the analyzed countries to derive the global total. We did not quantify the mitigation potential outside the nine countries, due to the relatively small scale of commitments outside the nine countries. Among more than 6,000 quantifiable subnational actors' commitments we have identified, there were only about 250 from the countries outside the nine we analyzed. We assume that same holds for companies.

5 Summary of results

5.1 Global results

Total GHG emissions and reductions for all actor groups and at the country level can be found in Table 6. The results on the country level account for overlap between different actors.

Table 6 Total GHG emissions and reductions on the global level for regions, cities, companies and at the country level

World	Regions	Cities	Energy end-use companies	Electricity companies	Total Country Accounting for overlap
Total GHG emissions (current policies scenario)					[56,050; 59,300]
Total GHG emissions (current policies + NSA scenario)	2,750	2,465	2,405	1,030	[54,540; 57,130]
Additional GHG reductions to national policies	[675; 965]	[385; 660]	[485; 755]	[75; 180]	[1,505; 2,170]

5.2 Results for individual commitments of regions, cities and companies

In the tables below, you can find the total GHG emissions for the current policies and current policies+NSA scenarios, and reductions relative to the current policies scenario for regions, cities, companies. It also includes the results on the country level, where overlap between actors is accounted for.

Table 7 Split up of 2030 emissions and reductions (accounting for overlap) for China ($MtCO_2e$/year)

China	Regions	Cities	Energy end-use companies	Electricity companies	Total Country Accounting for overlap
Total GHG emissions (current policies scenario)					[12,385; 14,915]
Total GHG emissions (current policies + NSA scenario)	360	920	330	25	[12,385; 14,760]
Additional GHG reductions to national policies	[-20; 25]	[-45; 80]	[20; 70]	[5; 5]	[0; 155]

Table 8 Split up of 2030 emissions and reductions (accounting for overlap) for EU ($MtCO_2e$/year)

EU	Regions	Cities	Energy end-use companies	Electricity companies	Total Country Accounting for overlap
Total GHG emissions (current policies scenario)					[3,175;3,580]
Total GHG emissions (current policies + NSA scenario)	695	625	555	495	[2,950;3,135]
Additional GHG reductions to national policies	[185; 285]	[40; 115]	[60; 130]	[-20;35]	[230;445]

Table 9 Split up of 2030 emissions and reductions (accounting for overlap) for USA ($MtCO_2e$/year)

USA	Regions	Cities	Energy end-use companies	Electricity companies	Total Country Accounting for overlap
Total GHG emissions (current policies scenario)					[5,275;5,590]
Total GHG emissions (current policies + NSA scenario)	1330	310	810	310	[4,610;4,785]
Additional GHG reductions to national policies	[490; 585]	[105; 125]	[175; 225]	[40; 60]	[670;810]

Table 10 Split up of 2030 emissions and reductions (accounting for overlap) for Brazil ($MtCO_2e$/year)

Brazil	Regions	Cities	Energy end-use companies	Electricity companies	Total Country Accounting for overlap
Total GHG emissions (current policies scenario)					[12,385;14,915]
Total GHG emissions (current policies + NSA scenario)	360	920	330	25	[12.4-5; 14,760]
Additional GHG reductions to national policies	[-20,25]	[-45;80]	[20;70]	[5;5]	[0;155]

Table 11 Split up of 2030 emissions and reductions (accounting for overlap) for India ($MtCO_2e$/year)

India	Regions	Cities	Energy end-use companies	Electricity companies	Total Country Accounting for overlap
Total GHG emissions (current policies scenario)					[4.020;5,125]
Total GHG emissions (current policies + NSA scenario)	0	5	170	20	[3,795;4,875]
Additional GHG reductions to national policies	[0; 0]	[5; 5]	[205; 235]	[20; 25]	[225;255]

Table 12 Split up of 2030 emissions and reductions (accounting for overlap) for Indonesia ($MtCO_2e$/year)

Indonesia	Regions	Cities	Energy end-use companies	Electricity companies	Total Country Accounting for overlap
Total GHG emissions (current policies scenario)					[2065;2140]
Total GHG emissions (current policies + NSA scenario)	0	205	15	5	[1865;1935]
Additional GHG reductions to national policies	[0; 0]	[200; 205]	[10; 10]	[5; 5]	[205;210]

Table 13 emissions and reductions (accounting for overlap) for Japan ($MtCO_2e$/year)

Japan	Regions	Cities	Energy end-use companies	Electricity companies	Total Country Accounting for overlap
Total GHG emissions (current policies scenario)					[960;1045]
Total GHG emissions (current policies + NSA scenario)	255	255	175	60	[935;990]
Additional GHG reductions to national policies	[-5;15]	[20; 40]	[5; 20]	[5; 10]	[25;55]

Table 14 Split up of 2030 emissions and reductions (accounting for overlap) for Mexico ($MtCO_2e$/year)

Mexico	Regions	Cities	Energy end-use companies	Electricity companies	Total Country Accounting for overlap
Total GHG emissions (current policies scenario)					[745;770]
Total GHG emissions (current policies + NSA scenario)	25	45	25	45	[705;745]
Additional GHG reductions to national policies	[15; 15]	[20; 20]	[5; 10]	[15; 20]	[30; 40]

Table 15 Split up of 2030 emissions and reductions (accounting for overlap) for South Africa ($MtCO_2e$/year)

South_Africa	Regions	Cities	Energy end-use companies	Electricity companies	Total Country Accounting for overlap
Total GHG emissions (current policies scenario)					[645;745]
Total GHG emissions (current policies + NSA scenario)	30	85	200	35	[585; 665]
Additional GHG reductions to national policies	[5; 10]	[30; 40]	[25; 45]	[10; 10]	[65;80]

6 Policies considered in the "Current national policy" scenario emissions projections in selected countries

The current policy and NDC scenarios are taken from a NewClimate Institute and PBL analysis (Kuramochi *et al.*, 2017). In that work, we describe which policies are included in the current policy scenario, an excerpt of which is provided here for reference. Tables that provide an overview of the key mitigation policies for China, the EU and USA follow below.

6.1.1 China

Table 16: Overview of key climate change mitigation policies in China, Source: (The People's Republic of China 2012, The People's Republic of China 2014a, The People's Republic of China 2014b, State Council 2015). Note: Policy targets may change significantly under the 13th Five Year Plan (2016-2020) currently in action.

Sector	Policies (marked with "(+)" when mentioned in the NDC document)	Description
Economy-wide	National Action Plan on Climate Change (2014)	Emission trading program to be expanded to nationwide scale by 2017
	13th Five Year Plan (2016-2020)	Cap on total primary energy use in 2020 at 5.0 billion tce Decrease CO_2 intensity by 18% between 2015 and 2020
	The Thirteenth Five Year Energy Development Plan	Limit share of coal to 58% of total energy consumption
Energy supply	Energy Development Strategy Action Plan 2014-2020	Cap on coal consumption in 2020 at 4.2 billion tce A 10% target share of gas in primary energy supply in 2020 15% non-fossil share in TPES in 2020 Renewable electricity: 350 GW hydropower excl. pumped storage, 200 GW wind, 100 GW solar, 30 GW biomass, 0.1 GW tidal[4)] 800 million m^2 collector area 10 million tonnes ethanol, 2 million tonnes biodiesel 58 GW nuclear power (150 GW by 2030)
	Action Plan for Upgrading of Coal Power Energy Conservation and Emission Reduction Released (2014)	Reduce average net coal consumption rate of new coal-fired power plants to 300 g of standard coal per kWh (implemented as a power plant standard of 889 gCO_2/kWh by 2020)
Transport	Vehicle fuel economy standards (2005)	Fuel efficiency of new light duty vehicles: 1.5 MJ/pkm by 2015, 1.1 MJ/pkm by 2020 Fuel efficiency of new medium duty trucks: 0.19 MJ/tkm to 0.29 MJ/tkm and 0.08 to 0.13 MJ/tkm since 2015
	Biofuel targets	Ethanol blending mandates 10% in selected provinces
Industry	"Made in China 2025" CO_2 intensity target (2013)	Manufacturing industries reduce their CO_2 emissions per unit of added value by 22% by 2020 and 40% by 2025 from 2015 levels[1),2)]
	Green industry development plan (2016-2020) China 2016	Decrease energy consumption per value added by 18% between 2015 and 2020.
Buildings	Appliance standards and labelling programme	Supplemented with subsidies and awareness-raising campaigns*

Sector	Policies (marked with "(+)" when mentioned in the NDC document)	Description
	National Building Energy Standard	30% of newly constructed to meet standards by 2020[5)]
F-gases	N/A	N/A
Forestry	Promotion of afforestation and sustainable forest management	Increasing the forest area by 40 million hectares and the forest stock volume by 1.3 billion m^3 from 2005 levels by 2020.
	Program Plan of Fast Growing and High Yielding Timber Plantations (2001)	Establishment of at least 15 million hectares of fast-growing, high-yield plantations, of which 5.8 million hectares of fast-growing pulpwood plantations
	Mid and Long-Term Plan for National Forest Management (2011)	Building young and mid-aged forest tending areas and transformation of low-yield forest area in the range of 35 million hectares [3)]

[1)] *Not quantified in PBL TIMER model*

[2)] *Not quantified by NewClimate Institute calculations*

[3)] *Policy not quantified in the IIASA LULUCF projections*

[4)] *NewClimate used capacity targets from 13th FYP: 340 GW hydro, 210 GW wind, 110 GW solar, 15 GW biomass, 58 GW nuclear*

[5)] *Implemented by PBL via assuming standard means 439 MJ/m²*

6.1.2 The European Union (EU28)

Table 17: Overview of key climate change mitigation policies in the EU. Source: (European Parliament 2009b, European Parliament 2009d, European Parliament 2009c, European Parliament 2009a, European Parliament 2012, European Commission 2015, EEA 2016, European Commission 2016)

Sector	Policies (marked with "(+)" when mentioned in the NDC document)	Description
Economy/ state wide	EU ETS Directive (2003/87/EC revised by Directive 2009/29/EC)	• Emission cap on emissions from electricity/heat and industry of 21% below 2005 levels, by 2020
Energy supply	Renewable Energy Roadmap/ Directive (2009/28/EC)	• Target of 20% renewable energy by 2020
	Energy Efficiency Directive (2012/27/EC)	• Target of 20% energy efficiency improvement by 2020
Buildings	Eco-design Framework Directive (Directive 2009/125/EC)	• Specific standards for a wide range of appliances
	Building Energy Efficiency Directive (2012)	• Near zero energy buildings by 2020 (residential) and by 2018 (public)[1)]
Transport	Regulation of CO_2 emissions from passenger vehicles (443/2009)	• Emission standard of 95 gCO_2/km, phasing in for 95% of vehicles by 2020 with 100% compliance by 2021 • Light commercial vehicle standards of 147 gCO_2/km by 2020
	Directive 2009/28/EC Biofuel target	• 10% quota for RE in transport fuels (also electricity)

1) NewClimate only quantified the policy for residential buildings

6.1.3 The United States

Table 18: Main climate change mitigation policies considered under the Climate Action Tracker's current policies projections for the United States. Source: Climate Action Tracker (Climate Action Tracker, 2017), based on: (Executive Office of the President, 2013; U.S. Department of State, 2014; United States of America, 2015; N.C. Clean Energy Technology Center, 2016)

Sector	Policy	Description
Economy-wide	Clean Air Act (1963)	Act governed by the EPA that is implemented through actions such as the Clean Power Plan (CPP)
Energy supply	Reduce CH_4 emissions from oil and gas production	40 – 45% from 2012 levels by 2025 Specific standards for oil and gas production
Transport	Efficiency standards light commercial vehicles (CAFE)	34.1 mpg (14.9 km/l) by 2016, 55 mpg (23.2 km/l) by 2025
	Efficiency standards heavy-duty trucks	Differentiated standards per truck type
	Renewable fuel standard (2015)	Volume of renewable fuel required to be blended into transportation fuel from 9 billion gallons in 2008 to 36 billion gallons by 2022
Buildings	ENERGY STAR Tax credits for buildings	Tax credits for energy efficiency products and solar energy systems
	Building Energy Codes Program	Efficiency codes are adopted at a state level
	Federal Appliance standards	Appliance standards for a large number of appliances
Industry	Curbing emissions of hydrofluorocarbons (HFCs)	Mix of actions to reduce HFCs use and encouraging the use of alternatives

Glossary

Cities: Administrative units that pledge commitments to a climate action platform, and which include municipalities, towns, urban communities, districts, and counties defined by the actors themselves.

Climate action by subnational and non-state actors: Any kind of activity that is directly or indirectly aimed at reducing GHG emissions or driving adaptation and resilience and that is led by non-state and sub-national actors. Actions can be put forward and pursued individually (by *one* sub-national or non-state actor) or cooperatively in the form of initiatives (by a *group* of actors, including non-state and/or sub-national actors).

Commitments by subnational and non-state actors: Planned climate action as well as action currently under implementation, which has been publicly announced. Commitments can be put forward and pursued individually (by one sub-national or non-state actor) or cooperatively in the form of initiatives (by a group of actors, including non-state and/or sub-national actors).

International Cooperative Initiative (ICI): Collaborative efforts to address climate change among countries, NGOs, academia, international organizations, states, regions, cities, businesses and investors.

Non-state actor: Any actor other than a national and sub-national government. This includes private actors, such as companies and investors, civil society and international organizations, among others.

Scope 1 emissions: Direct emissions resulting from owned or controlled sources. See www.ghgprotocol.org for further details.

Scope 2 emissions: Indirect emissions resulting from purchased electricity, heat or steam. See www.ghgprotocol.org for further details.

Scope 3 emissions: Other indirect emissions not included in Scope 2 that are in the value chain of a reporting actor, including both upstream and downstream sources. See www.ghgprotocol.org for further details.

States and regions: Larger administrative units that are generally broader in population and in scope than cities. They usually have separate governing bodies from national and city governments but encompass lower administrative levels of government; often, they are the first administrative level below the national government. Regions can also include councils of subnational governments acting together.

Sub-national actor: Any form of government which is not a national government, such as cities, states, provinces and regions.

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