

## Contribution of the G20 economies to the global impact of the Paris agreement climate proposals

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Received: 26 January 2016 / Accepted: 18 May 2016 / Published online: 30 May 2016  
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**Abstract** By 15 December 2015, 187 countries had submitted their Intended Nationally Determined Contributions (INDCs) summarising their climate actions after 2020 in the context of the Paris Agreement. We used a unified framework to assess the mitigation components of INDCs covering 105 countries (representing approximately 91 % of global greenhouse gas emissions in 2012) with a special focus on the G20 economies. We estimated the required reduction effort by comparing the greenhouse gas emission targets implied by the INDCs with the projected levels resulting from current mitigation policies. The resulting projected global reduction effort amounts to approximately 4–6 GtCO<sub>2</sub>eq by 2030, of which the G20 economies are responsible for the largest share, in particular Brazil, China, the EU, and the United States. Despite these reductions, the global and G20 emission level is still projected to be higher in 2030 than it was in 2010. We compared the ambition levels of individual INDCs by analysing various indicators. Our analysis shows, for instance, that INDCs imply that greenhouse gas emissions of Brazil, Indonesia, Mexico, and South Korea peak before 2025, and of China, India and South Africa by 2030 or later.

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**Electronic supplementary material** The online version of this article (doi:10.1007/s10584-016-1700-7) contains supplementary material, which is available to authorized users.

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## 1 Introduction

On December 12, 2015 in Paris, countries adopted a historic international agreement to address climate change, under the umbrella of the United Nations Framework Convention on Climate Change (UNFCCC 2015a). Governments agreed to a long-term target of keeping the increase in global average temperature to well below 2 °C above pre-industrial levels and to pursuing efforts to limit temperature increase to 1.5 °C. The agreement calls for global greenhouse gas (GHG) emissions to peak as soon as possible, recognizing that this will take longer for developing countries, and for rapid emission reductions thereafter. Before and during the Paris conference, countries submitted Intended Nationally Determined Contributions (INDCs) to the UNFCCC. These INDCs outline the intended post-2020 climate action plans (UNFCCC 2015b).

Several studies have assessed the aggregated effect of the INDCs on global emissions in 2030 (Boyd et al. 2015; CAT 2015; Climate Interactive 2015; Fawcett et al. 2015; IEA 2015; Kitous and Keramidas 2015; Meinshausen 2015; UNFCCC 2015c), as summarized in Rogelj et al. (2016). In addition, some studies have projected global mean temperature increase over the twenty-first century resulting from the INDCs (CAT 2015; Fawcett et al. 2015; Rogelj et al. 2016). Only very few studies have analysed and reported results for individual INDCs with a transparent method and clear assumptions. To our knowledge, only the website CAT (2015) has analysed the assumptions and emission projections of individual INDCs. A further three studies report emission implications of individual economies, but all in grey literature with very limited documentation on the methods and assumptions (Supplementary Table 1). The remainder of the above studies only consider aggregated world regions or even provide only a global estimate.

This study goes beyond existing literature by assessing in detail the implications of the INDCs for GHG emissions for the individual G20 economies in a unified framework, and by comparing the results to projected emission levels from current domestic mitigation policies. The comparison with current domestic mitigation policies allows an assessment of the additional emission reductions needed to achieve the INDCs reduction targets. Moreover, we provide an assessment of the relative ambition level of the INDCs of the G20 economies based on a few selected key emission indicators.

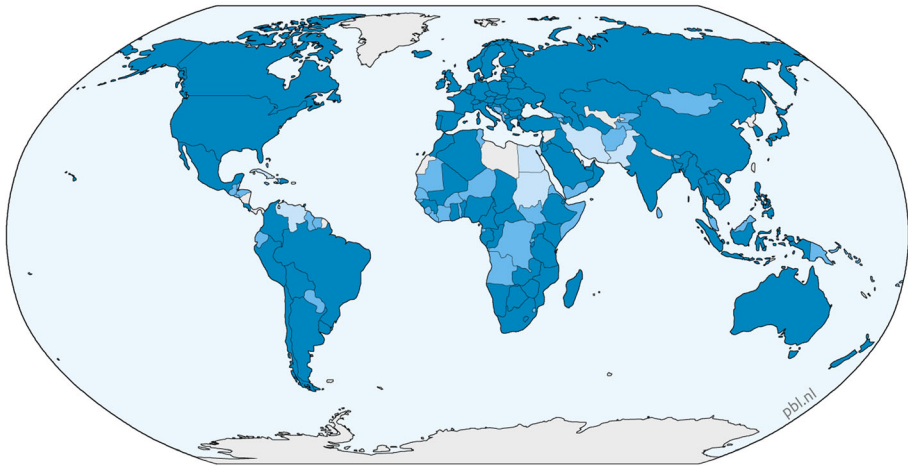
## 2 Methods

While the focus is on G20 economies, we assessed all INDCs of countries with a 2012 global emission share higher than 0.1 % and which included specific quantifiable goals. For 72 countries, together representing 1.5 % of global emissions in 2012, the emission share was less than 0.1 %, while for ten INDCs, representing about 6 % of global emissions, specific goals were not mentioned (Fig. 1). This implies that we assessed 78 of the 160 INDCs (187 countries,<sup>1</sup> as the EU28 submitted one INDC for the whole region) submitted by 15 December 2015. These 78 INDCs cover 105 countries, which together account for 91 % of global GHG emissions (Supplementary Text and Table 2).<sup>2</sup>

<sup>1</sup> The 187 countries represent 97 % of global emissions in 2012. The remaining emissions come from international aviation and shipping and from countries that have not submitted an INDC.

<sup>2</sup> An interactive tool showing total emissions per country, emissions per capita, and emissions per unit of income, resulting from the current policies and INDCs, is available at: [www.pbl.nl/indc](http://www.pbl.nl/indc).

Countries that have submitted INDCs to the UNFCCC



Situation 15 December 2015

	Share of global 2012 emissions (%)
■ INDC submitted, analysed	90.63
■ INDC submitted, not analysed (2012 emissions share <0.1%)	1.51
■ INDC submitted, not-analysed (non-GHG target and actions, and cannot be quantified)	4.82
■ No INDC submitted	3.05

**Fig. 1** Countries that have submitted INDCs

The INDC emission target levels by 2025 and 2030 for the G20 economies were based on the INDC submission if provided by the submitting Party. This was the case for Argentina, Brazil, Indonesia, Mexico, South Korea, and Turkey, as these countries have provided baseline emissions projections in their INDC. For all other G20 economies except Saudi Arabia, the emission target level could not directly be derived from the INDC, as the target was given relative to a base year in the past without specification of the corresponding emission level. For these economies, we used UNFCCC national inventories to determine the base year emission levels used for calculation of the emission target levels. Saudi Arabia, finally, has indicated by how much it aims to reduce emissions without specifying a baseline. For projecting the INDC emission level, we assumed a baseline based on recent national CO<sub>2</sub> emissions projections (King Abdullah University of Science and Technology 2014). More detail on the calculation of the emission target levels can be found in Supplementary Table 3.

China and India are the only G20 economies that have proposed a combination of targets. These include non-fossil energy targets, forest targets, and emission intensity targets (i.e., improvements of the ratio of emissions to GDP). Their combined effect was calculated using the PBL TIMER energy model (Van Vuuren et al. 2014) for energy- and industry-related emissions and the IIASA GLOBIOM/G4M land use model (Havlik et al. 2014) for the land use, land-use change and forestry (LULUCF) emissions (see Supplementary Text and for further details for China den Elzen et al. 2016).

The reported emission target levels of Australia, Brazil, China, India, Indonesia, Mexico, Turkey, and the United States include emissions and removals from activities related to LULUCF. Although there are uncertainties concerning how these countries intend to account

for LULUCF related net emissions, we assume in the INDC target calculations that these countries will apply the net-net accounting approach.<sup>3</sup> For the other G20 economies, emissions from the land use sector are excluded from the calculation of their emissions targets, as this was explicitly mentioned in the INDC. These emissions were included into the remaining LULUCF emissions (see end of this Section). For these countries we also do not account for credits or debits from LULUCF accounting, because there is too much uncertainty on which rules will be applied, and specific LULUCF emission projections are often lacking. This method for quantifying the contribution of the LULUCF sector within the INDCs is consistent with the methodology of Grassi and Dentener (2015). For Canada, the EU28, Japan, the Russian Federation, and South Korea, the LULUCF emission projections from national communications were used, and for the other countries, IIASA BAU projections from 2010 through 2030 were used, based on FAOSTAT data for the historical trend.

For several G20 economies, a range in the emission projection was calculated. For Australia, the Russian Federation, South Africa, and the United States, this range reflects the range in targets mentioned in the INDCs themselves. Several countries have made a distinction between an unconditional and a conditional target in their INDC. The former target holds irrespective of actions of other countries, whereas for the latter, more ambitious, target, certain conditions regarding the actions of other countries (which mostly refer to international finance or international cooperation mechanisms) have to be met. To show the effect of conditionality, we have distinguished two scenarios: the unconditional INDC scenario, in which only the unconditional targets are implemented, and the conditional INDC scenario, in which both unconditional and conditional targets are implemented. For countries whose INDC included unconditional targets only, we assumed that their emission level would be the same in both the unconditional and conditional scenarios. For countries whose INDC included only conditional targets, we assumed that emissions follow the current policies emission levels for the unconditional INDC scenario.

The current policies scenario for the G20 economies was taken from model calculations by Den Elzen et al. (2015) and Roelfsema et al. (2014) (Supplementary Table 4). This scenario includes the impact of the most effective current policies in several subsectors, and was developed using the PBL TIMER energy model (Van Vuuren et al. 2014) for energy- and industry-related emissions, and the IIASA GLOBIOM/G4M model (Havlík et al. 2014) for the LULUCF CO<sub>2</sub> emissions.

For determining global emissions, the following emissions were added to the G20 INDC and current policies emission levels: emissions of the non-G20 economies (see Supplementary Text 3); international aviation emissions (ICAO 2013); international shipping emissions (IMO 2014); and remaining LULUCF emissions based on various sources (including FAOSTAT, national communications and model projections) for those countries whose INDC did not address LULUCF.

### 3 Required reduction effort

We compared current policies emissions trajectories with the trajectories associated with the achievement of the INDCs of G20 economies. Such a comparison provides insight into the

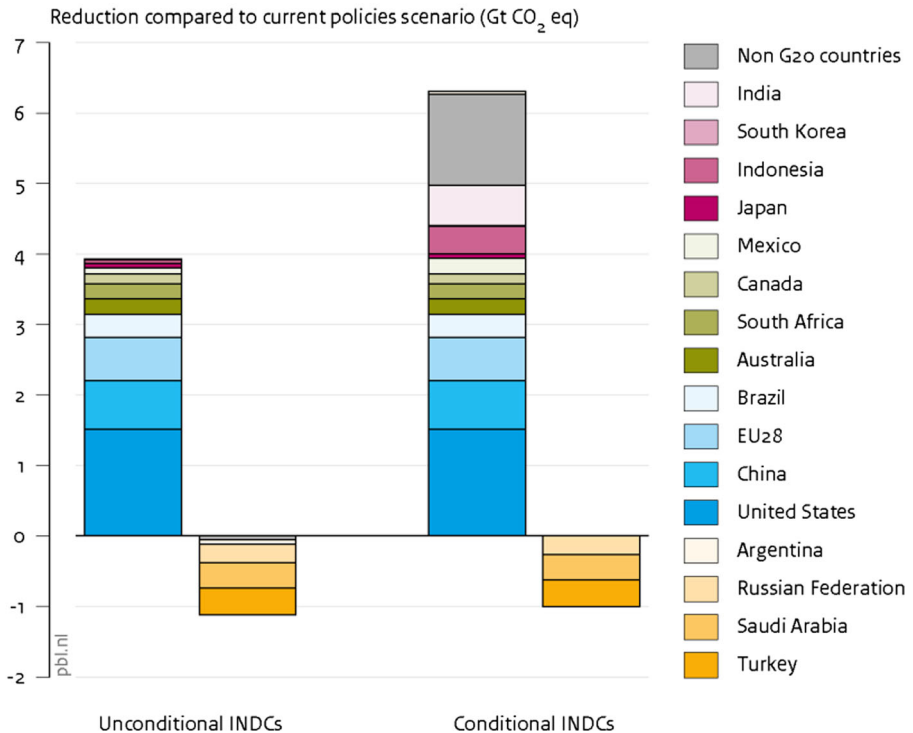
<sup>3</sup> The net-net LULUCF accounting method implies that credits and debits from the LULUCF sector are treated in the same way as any other GHG inventory sector.

required additional reduction effort compared to already existing policies to achieve the INDCs, or, alternatively, it can be interpreted as the progress G20 members have already made. The required reduction effort cannot be directly linked to ambition levels, as countries differ with regard to the policies already in place. In Section 4, we look in more detail at indicators that could be used to compare ambition levels.

Figure 2 shows that the G20 economies will likely need to implement additional policies to further reduce GHG emissions by 4 GtCO<sub>2</sub>eq by 2030 to achieve the unconditional INDCs, and by 5 GtCO<sub>2</sub>eq to achieve the conditional INDCs. Only four economies are responsible for the largest share (about 80 % for the unconditional INDCs and about half for the conditional INDCs) of the required reductions, namely the United States, China, the EU28 and Brazil. The emission target levels of several INDCs (among which Argentina, Russia, Saudi Arabia, Turkey, and several non-G20 members) are projected to be *above* the estimated current policies scenario levels. These countries are thus expected to overachieve their INDC targets with current policies. In our assessment, we assumed that these countries will follow their current policies emissions trajectory.

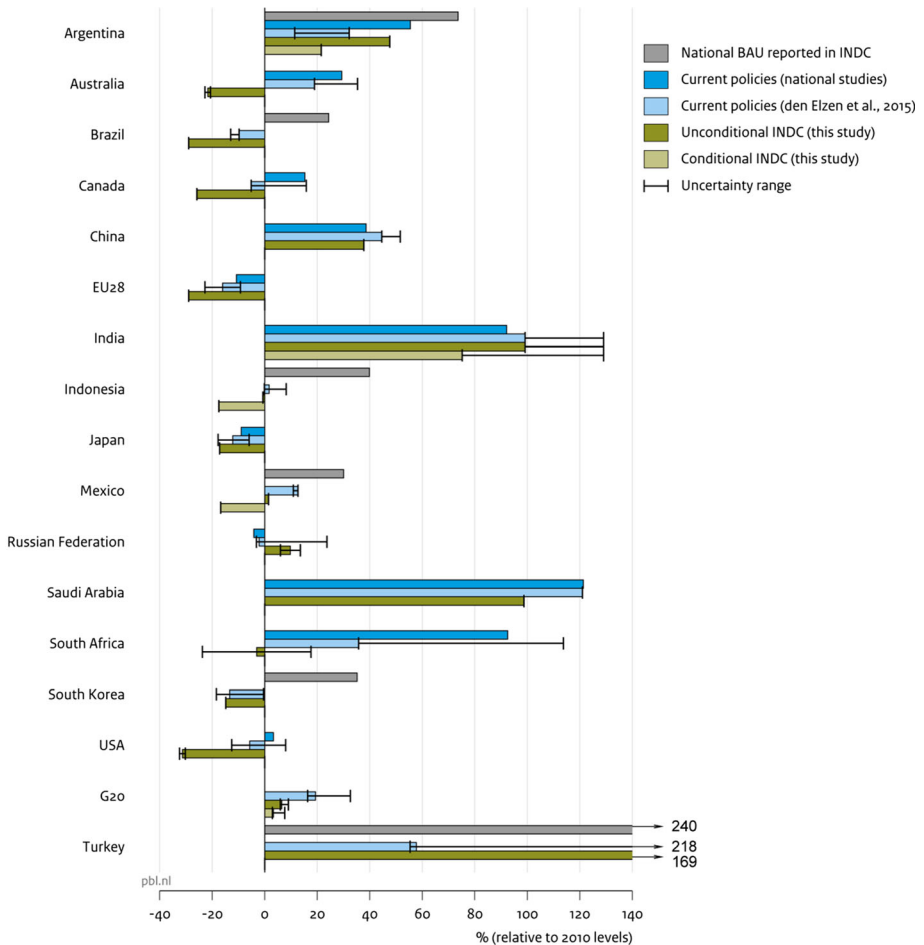
As shown in Fig. 3, the emission projections from current policies are surrounded with uncertainties. For Fig. 2, the model calculation projections by den Elzen et al. (2015) and Roelfsema et al. (2014) were used, as these calculations were done using a consistent

### National emission reductions in countries based on their INDCs, 2030



**Fig. 2** Projected emission reductions relative to the current policies scenario in 2030 in the individual G20 economies and non-G20 economies as a group, based on their INDCs. For countries with a reduction target range, projected reductions were based on the average of the range

Greenhouse gas emissions in the BAU scenario and under the current policies and INDC scenarios in 2030



**Fig. 3** GHG emission projections of the G20 economies and G20 as a whole by 2030, relative to 2010 levels, for the BAU emissions projection from the INDC submission (*first bar*), for the current policies scenario from official and national studies (*second bar*), from global model studies used for our analysis (*third bar*), for the unconditional INDC scenario (*fourth bar*), and for the conditional INDC scenario (*fifth bar*). The estimates and sources for official and national studies are based on UNEP (2015) (Supplementary Table 5). The uncertainty ranges are explained in the main text. For reporting reasons, the emissions projections are shown relative to 2010 levels, and Turkey is shown at the bottom

framework. Alternatively, bottom-up calculations based on existing scenarios from international studies (e.g. IEA’s World Energy Outlook 2014) could be used. Figure 3 shows that the differences in projected emission levels between official and national studies (as used in UNEP 2015) and the model calculations we used can be large. Based on the minimum and maximum estimates of the different current policies projections, the required additional effort of G20 economies ranges from 3 to 8 GtCO<sub>2</sub>eq by 2030 for the unconditional INDCs and from 4 to 9 GtCO<sub>2</sub>eq for the conditional INDCs, if we assume that Argentina, Russia, Saudi Arabia and

Turkey follow their current policies trajectory. The total G20 emission level of the unconditional INDCs would then amount to 37–38 GtCO<sub>2</sub>eq, which is 6 % to 9 % above 2010 levels (Fig. 3). For the conditional INDCs, the G20 emission level would be 1 GtCO<sub>2</sub>eq lower, but still 3 % to 8 % above 2010 levels.

It should be noted that the above uncertainty ranges only account for the range in targets mentioned in the INDCs. A much larger uncertainty is related to the intensity targets of India and China. A very simple sensitivity analysis shows that the effect of a 1 %-point lower or higher annual average GDP growth of both countries<sup>4</sup> increases the ranges in G20 emissions projections to 36–41 GtCO<sub>2</sub>eq (2 %–17 % above 2010 levels) for the unconditional INDCs, and again 1 GtCO<sub>2</sub>eq lower (0 %–16 % above 2010 levels) for the conditional INDCs.

The non-G20 members are responsible for 1 GtCO<sub>2</sub>eq additional reduction in the conditional INDC scenario compared to current policies. As almost all the INDCs of the non-G20 members are conditional, non-G20 economies hardly add to the emission reductions in the unconditional INDC scenario. The projected global emission reduction requirement is, therefore, 4 GtCO<sub>2</sub>eq (unconditional) to 6 GtCO<sub>2</sub>eq (conditional) by 2030. The corresponding projected global emission level in 2030 is approximately 54.5 (53–58) GtCO<sub>2</sub>eq if all unconditional INDCs are implemented, and approximately 52 (51–56) GtCO<sub>2</sub>eq if the conditional INDCs are implemented as well (Supplementary Figure 1, Tables 3 and 4). These numbers are in line with those of UNEP (2015) and UNFCCC (2015c), but are 1–1.5 GtCO<sub>2</sub>eq lower, as we assumed that countries that are expected to overachieve their INDC targets will follow current policies trajectories.

The above numbers mean that global emissions are projected to be higher in 2030 than they were in 2010, even if all INDCs are fully implemented, although the increase in these 20 years is well below the increase in the decade 2000–2010. As already concluded by several earlier studies, we find that the current INDCs do not put the world on a least-cost path towards keeping global temperature change well below 2 °C and “to pursue efforts” to limit it to 1.5 °C. As noted in the Decision text (II.17) accompanying the Paris Agreement, a global emission level of not more than 40 GtCO<sub>2</sub>eq by 2030 will be required for that least-cost path, which is 12–14.5 GtCO<sub>2</sub>eq lower than the INDCs imply.

## 4 Comparing indicators

In this section, we present the impact of the INDCs of the G20 economies on emission peak years and levels, emission intensities, and emissions per capita.<sup>5</sup>

### 4.1 Timing and level of emission peaks

Full implementation of INDCs is projected to lead to emission trajectories with different emission peak years and peak emission levels across countries (Table 1). Among the G20 members, the EU was the first region where emissions peaked (around 1980). At that time, EU emission levels were about 13 tCO<sub>2</sub>eq per capita and the per capita GDP was 17.4 thousand

<sup>4</sup> We analysed the effects of an average annual GDP growth rate between 5 % and 7 % for China and between 6 % and 8 % for India (Supplementary text).

<sup>5</sup> Population and GDP (in purchasing power parity, PPP) data are based on the SSP2 scenario database SSP database (2015). The SSP database uses the population and GDP history until 2008 from The World Bank (2015), with SSP growth projections from 2008 onwards.



**Table 1** Emission peak years of the G20 economies, and per capita emissions, GDP per capita and emission intensities in these peak years\* for the unconditional INDC scenario. The projection for the conditional INDC scenario is given in brackets

Country	Peak year	Per capita emissions (tCO <sub>2</sub> eq/cap)	GDP (PPP) per capita (thousand USD <sub>2005</sub> /cap)	Emission intensity (tCO <sub>2</sub> eq/ million USD <sub>2005</sub> , PPP)
Argentina	2030	12.4 (10.9)	26.0	475 (391)
Australia	2005	29.4	33.8	869
Brazil	2020	7.2	13.5	530
Canada	2005	23.7	35.1	662
China	2030	9.6	23.1	416
EU28	1980	13.3	17.4	759
India	2030	2.8	8.2	341
Indonesia	2025 (2020)	8.0 (7.4)	8.8 (6.7)	680 (1170)
Japan	2005	10.7	30.4	351
Mexico	2025	6.6 (6.4)	18.3	360 (350)
Russian Federation	1990	22.7	12.6	1797
Saudi Arabia	>2030	32.8	37.3	878
South Africa	2030	7.3–11.3	18.8	389–599
South Korea	2010	13.1	27.4	446
Turkey	2030	10.5	22.4	470
United States	2005	21.7	42.6	510

USD<sub>2005</sub>. Ten years later, emissions in the Russian Federation (then Soviet Union) peaked, with higher per capita emissions, lower income levels and over twice the emission intensity in the EU during its peak year. Emissions in Australia, Canada and the United States peaked around 2005 at similar per capita income levels as the EU, but with per capita emissions that were a factor two higher.

Emissions in Brazil, Indonesia, and Mexico are projected to peak before 2025, while emissions in South Korea already peaked in 2010. Emission levels of China, India and South Africa are projected to peak by 2030 or later. Based on China's INDC, CO<sub>2</sub> emissions in this country are projected to peak by 2030 at the latest, but its *total* GHG emissions are projected to peak after 2030. The Russian Federation is a special case, as after the peak year of 1990, GHG emissions have been increasing again since 2000. Based on its INDC, emissions in this country are expected to stabilise by 2030 at 25–30 % below 1990 levels.

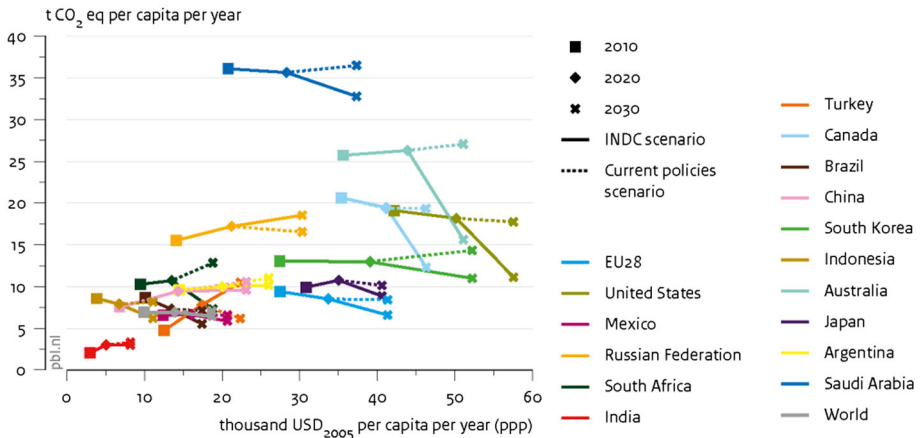
#### 4.2 Per capita emissions and emission intensities

Both emissions per unit of GDP (emission intensities) and emissions per capita are useful indicators to see whether INDCs lead to a convergence in emission intensity among countries and to a decoupling of economic growth and emissions.

As Fig. 4 shows, emissions per capita are projected to decline between 2010 and 2030 in all G20 economies except Argentina, China, India, the Russian Federation and Turkey, as a result of the implementation of unconditional INDCs. For several countries (Australia, Mexico, South Africa, and South Korea), the increase in per capita emission levels under current policies is converted into a decline under the INDCs. At the same time, income levels are



**Greenhouse gas emissions per capita versus GDP per capita**



**Fig. 4** GHG emissions per capita as a function of per capita GDP (PPP) in 2010, 2020 and 2030 for the unconditional INDC and current policies scenario

projected to increase in this time period, indicating a decoupling of economic growth and GHG emissions. In total, decoupling is projected for 14 to 16 of the G20 economies, depending on the conditionality of their INDCs. Furthermore, per capita emissions are shown to converge between G20 economies over time, despite the different income levels of these countries. Figure 4 also shows that the INDCs are projected to lead to a (small) decline in global average per capita emissions by 2030.

The decoupling trend is further illustrated by Supplementary Figure 2, which shows a substantive reduction in emission intensity between 2010 and 2030, in tandem with increasing income levels. The reduction in emission intensity is projected for all countries (except for the Russian Federation and Turkey) as a result of national INDCs and is larger than under current climate policies. The largest reductions are projected for countries with the highest emission intensities in 2010, such as Brazil, China, and Indonesia. Furthermore, emission intensities of all G20 economies are projected to converge to levels between 250 and 750 tons CO<sub>2</sub>eq per million USD in 2030, independent of these countries’ emission intensity levels in 2010 and income levels in 2030. This convergence again reflects a decoupling of economic growth and GHG emissions.

**5 Discussion and conclusions**

We assessed the implications of the INDCs for the required GHG emissions reductions for the individual G20 economies. Moreover, we provided an assessment of the relative ambition level of the INDCs of the G20 economies based on a few selected key emission indicators.

Although we considered the most important uncertainties in our analysis, some uncertainties remain. One of those is that we assumed that emissions in sectors not explicitly covered in the INDCs follow the current policies trend, which may have led to an overestimation of the projected emission levels. Another one worth mentioning is that our calculations did not account for credits or debits from LULUCF accounting rules, because there is too

much uncertainty on which rules will be applied, and specific LULUCF emission projections are often lacking. However, the largest uncertainty, as already mentioned in Section 3, is due to China's and India's INDC emission target level being dependent on future GDP growth: a 1 %-point change in China's average annual economic growth alone would result in a target emission level change of approximately 2.5 GtCO<sub>2</sub>eq.

Despite these uncertainties, some important conclusions can be drawn from the analysis. We have found that INDCs do lead to reductions compared to projected current policies trends, and that Brazil, China, the EU28 and the United States, are responsible for about 80 % of these reductions for the unconditional INDCs, and about half for the conditional INDCs. For comparison, these four countries were responsible for about 50 % of total GHG emissions in 2012. The total reduction of all conditional INDCs compared to current policies trends of G20 economies ranges between 4 and 9 GtCO<sub>2</sub>eq, the range being largely dependent on uncertainty in current policies trajectories. However, despite these reductions, the global GHG emission level is still projected to be higher in 2030 than it was in 2010. The projected global emission level ranges from 51 to 58 GtCO<sub>2</sub>eq, depending on the conditionality of the INDCs but more importantly, on the uncertainty on China's and India's INDC emission target level. This compares with a required GHG emission level of 40 GtCO<sub>2</sub>eq in 2030 as stated in the Paris Agreement.

We have showed that some relatively simple indicators provide interesting insights on the ambition levels of INDCs. For instance, the INDCs are projected to lead to a significant reduction in per capita emissions compared to trends under current policies and a further decoupling of GHG emissions from economic growth. Based on national INDCs, GHG emissions of Brazil, Indonesia, Mexico, and South Korea are expected to peak before 2025 while GHG emissions in China, India, and South Africa are expected to peak by 2030 or later. For several countries (Australia, Mexico, South Africa, and South Korea), the increase in per capita emission levels under current policies is converted into a decline under INDCs. This indicates a relative decoupling of economic growth and GHG emissions.

**Acknowledgments** MdE, HvS, MR and NF received funding from the European Commission, Directorate General Climate Action (EC Service contract N°340201/2015/717962/SERJCLIMA.A4).

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