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Global and regional abatement costs of INDCs and of enhanced action to levels well below 2 °C and 1.5 °C

Note

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Findings

In this study, we estimated the abatement costs of achieving the Intended Nationally Determined Contributions (INDCs), outlining the post-2020 climate action plans submitted by countries to the UNFCCC, as well as more ambitious scenarios. These more ambitious scenarios aim at meeting the Paris climate targets (to keep global warming well below 2 °C and to 'pursue efforts' towards 1.5 °C), and distribute emission reductions cost-optimally among regions (least-cost pathways). The annual abatement costs were calculated relative to various baselines, all harmonised to historical greenhouse gas emissions data. The most important findings are:

1. Several non-OECD countries have provided both conditional and unconditional targets, the conditions often being related to international finance. Global abatement costs for implementing the unconditional INDCs are projected at USD 58 to 135 billion by 2030, depending on baseline assumptions. For achieving the conditional INDCs, costs are estimated at USD 97 to 191 billion by 2030. For the unconditional INDCs, about 70% of these costs are projected to take place in OECD90 countries (countries that were a member of the OECD in 1990: United States, Canada, Europe, Japan, Australia and New Zealand (not including Turkey); together responsible for about 30% of global emissions in 2012). For the conditional INDCs, between 50% and 60% of the costs are projected to take place in those countries.

2. The difference in abatement costs between achieving the unconditional and conditional INDCs for non-OECD countries is estimated at USD 33 to 46 billion by 2030, which can be regarded as the part of the INDCs that is subject to international financing.

3. Abatement cost could be decreased substantially by allowing for flexible mechanisms to achieve the INDCs. For example, full emission trading could decrease the abatement costs related to unconditional INDCs by about 55% globally, and for non-OECD90 countries by as much as 85%.

4. Finally, although the conditional INDCs already would half the difference in global emission levels between baseline and least-cost pathways to 2 °C by 2030, the difference remains large in terms of abatement costs. Globally, the costs of achieving 2030 emission levels that are consistent with least-cost pathways to 2 °C are projected to be 3 to 3.5 times higher than the costs of achieving the conditional INDCs. For the least-cost pathways to 1.5 °C, costs would be even 5 to 6 times higher.

Background and objectives

In December 2015, in Paris, parties to the United Nations Framework Convention on Climate Change (UNFCCC) adopted the Paris Agreement (UNFCCC, 2015a). Parties agreed to keep the increase in global average temperature to well below 2 °C above pre-industrial levels, and to pursue efforts to stay below 1.5 °C. The agreement officially entered into force on 4 November 2016.

In this context, by 15 January 2016, 161 Parties had formulated and submitted INDCs[1] that outline the post-2020 climate action plans they intend to implement under the Paris Agreement (UNFCCC, 2015b). Assessments of the aggregated impact of the INDCs have shown that the resulting global emission reductions by 2030 will fall short of those necessary to be consistent with the 2 °C climate target (Rogelj et al., 2016), and therefore also with the 1.5 °C target.

This report presents projections of the global direct abatement costs and those of 10 major emitting world regions, by 2030, resulting from full implementation of the measures to achieve the INDC reduction targets. Furthermore, it provides the additional costs if countries would implement measures to achieve enhanced reduction targets, in line with limiting temperature increases to 2 °C and 1.5 °C. Our analysis is based on a country-level assessment of INDCs.

The integrated modelling framework FAIR was used for calculating emission targets and annual abatement costs (Den Elzen et al., 2013; Den Elzen et al., 2014; Hof et al., 2016). This model uses information on the (no-policy) IMAGE SSP1, SSP2 and SSP3 baselines (Van Vuuren et al., 2016), on marginal abatement costs (MAC) of reducing energy-related emissions based on the TIMER energy model (Van Vuuren et al., 2014), and on MACs of reducing non-CO_2 greenhouse gas emissions from a variety of sources (see Hof et al. (2016) for more details).

The SSP baselines cover a range of projections for the future (O'Neill et al., 2014): SSP1 is a scenario with relatively low challenges for mitigation, as sustainable development is proceeding at a reasonably fast pace and inequalities are being reduced. SSP3, on the other hand, involves steep challenges for mitigation, as emission levels are high due to a rapidly growing population, high inequality, and slow technological change in the energy sector. SSP2 is an intermediate scenario, between SSP1 and SSP3. The baselines were harmonised to match historical emission data.

As a starting point for our costs analysis, we used the countries' expected national emission levels by 2025 and 2030 that would result from the full implementation of the conditional and unconditional INDCs, based on Den Elzen et al. (2016). That study assessed the mitigation components of 79 of the 161 INDCs (note that the EU-28 submitted a single INDC for the whole region). Together, the countries that submitted these 79 INDCs were responsible for about 91% of global greenhouse gas emissions in 2012.

[1] INDCs were submitted before the Paris summit; under the Paris Agreement, future mitigation contributions will be referred to as NDCs, without the 'intended'.

Our analysis focused on the following two policy questions:

1. What would be the abatement costs and financial flows for reaching the 2030 INDC reduction targets? What would be the impact of emission trading?
2. What would be the abatement costs if countries would take measures to achieve enhanced reduction targets in line with keeping global temperature increase to below 2 °C or 1.5 °C, assuming that the measures are taken wherever it is cheapest to do so?

INDC emission levels

Some countries included a reduction target range in their INDCs and attached conditions to the achievement of the higher end of the range

Several countries have submitted an INDC with a certain reduction target range. In some cases, the less ambitious end of that range has been defined as an unconditional target, and the more ambitious end to be contingent on ambitious efforts by other countries, realisation of financial and technical support and/or other factors. For this reason, we defined an unconditional and a conditional INDC scenario.

For countries whose INDCs included unconditional targets only, we assumed the same emission level in the unconditional and conditional scenarios. For countries whose INDCs included only conditional targets, we assumed the SSP baseline emissions for the unconditional INDC scenario. Of the 10 largest emitters, the Russian Federation and the United States have indicated an emission reduction target range without specifying the reason for this range; the ranges are specified separately (see Figure 1). The following sections assume the lower end of the range to be the unconditional INDC scenario and the higher end the conditional INDC scenario.

INDCs lead to a 10% to 17% greenhouse gas emission reduction, relative to the three baseline scenarios

The harmonised SSP2 baseline will lead to a global emission level of 58.0 $GtCO_2$ eq by 2030 (SSP1–3 range 53.2–60.2 $GtCO_2$ eq), excluding emissions from international aviation and shipping and land use, land-use change and forestry (LULUCF; **Error! Reference source not found.**). This is 36% (25%–41%) above the 2010 emission level of 42.7 $GtCO_2$ eq. Full implementation of the less ambitious end of the unconditional INDCs will lead to a global emission level of 50.8 (48.1-51.7) $GtCO_2$ eq, and for the conditional INDCs to 48.9 (46.5–49.7) $GtCO_2$ eq, both excluding emissions from LULUCF and international shipping and aviation. This implies that the INDCs are projected to lead to a reduction in emissions of 10% (under the unconditional SSP1 scenario) to 17% (conditional SSP3 scenario) below the baseline, by 2030.

Table 1. Emissions under the scenarios ($GtCO_2$ eq)

	2010	2030 Baseline	2030 Unconditional INDCs	2030 Conditional INDCs
Global emissions (excl. LULUCF and international aviation and shipping)	42.7	53.2–60.2	48.1–51.7	46.5–49.7
International aviation and shipping emissions	1.1	1.8	1.8	1.8
LULUCF emissions	2.9	1.1	1.1	1.1
Global emissions	46.8	56.1–63.1	51.0–54.6	49.4–52.6

Ranges represent the differences between the baseline scenarios considered (SSP1, SSP2, SSP3)

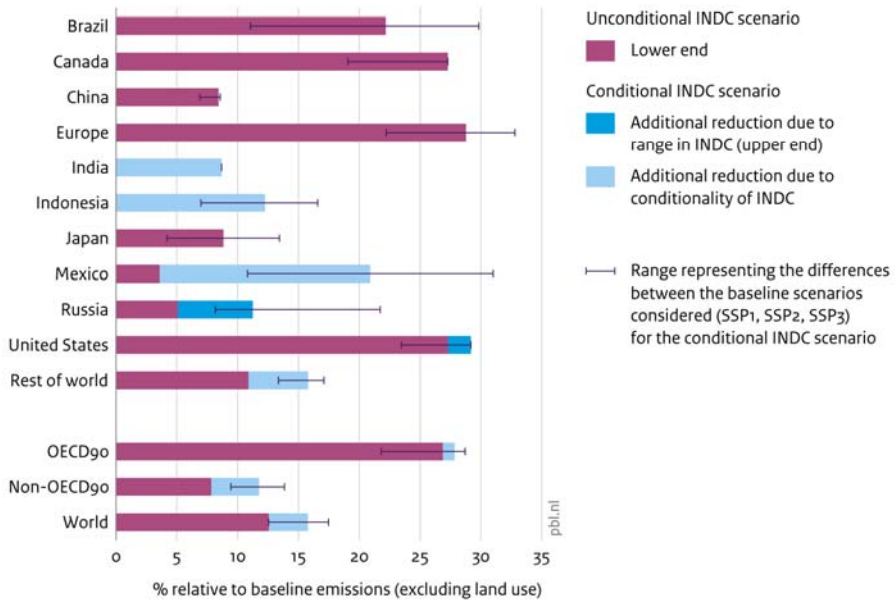
Larger reduction targets projected for OECD90 region

On average, INDCs will lead to higher reduction targets for OECD90 countries (countries which were member of the OECD in 1990: United States, Canada, Europe, Japan, Australia and New Zealand, but excluding Turkey). Figure 1 shows the INDC emission levels relative to the SSP2 baseline, for the 10 largest emitters in 2010, and for the total of OECD90 and non-OECD90 countries. The error bars indicate the minimum–maximum range of reduction targets due to differing baseline assumptions (SSP1, SSP2, and SSP3). Overall, the conditional INDCs will lead to higher reduction targets for OECD90 countries (22% to 29% relative to the three baseline scenarios) than non-OECD90 countries (9% to 14% relative to the three baseline scenarios).

For some non-OECD90 countries, such as Mexico, Indonesia, and India, there are large differences between the unconditional and conditional INDC emission levels. For countries with large differences between SSP1 and SSP3 baseline emissions (such as Brazil, Mexico, Russia, and Japan), the reduction targets relative to the baseline scenarios are very uncertain. Exceptions are China and India, as the absolute emission targets for these countries depend on baseline assumptions (higher baseline emission levels lead to higher absolute emission targets).

Figure 1

Greenhouse gas emission reduction targets for INDCs from SSP2 baseline emission levels, 2030



Source: PBL FAIR/TIMER model

INDC abatement costs

Annual costs of achieving unconditional INDCs projected at USD 58–135 billion by 2030

Table 2 (third column) shows the annual abatement costs by 2030 of full implementation of the unconditional INDCs for the 10 largest emitters in 2010, assuming that all reductions will be achieved domestically. Globally, these are projected at USD 58–135 billion by 2030 (undiscounted values, range dependent on the three baseline scenarios considered). Under SSP3 assumptions, costs are the highest, as baseline emission levels by 2030 – and therefore the reductions required to achieve the INDC targets – are the highest in this scenario. The largest share of these costs (67%–74%) are projected to take place in OECD90 countries, largely as a result of the higher reductions compared to the baseline.

Table 2. Regional and global abatement costs (excluding costs of reducing CO_2 emissions from LULUCF) under the conditional and unconditional INDCs scenarios

	Unconditional INDCs, domestic action only		Conditional INDCs, domestic action only	
	Reduction relative to harmonised SSPs ($MtCO_2$ eq)	*Costs (USD billion)*	*Additional reduction relative to unconditional INDCs ($MtCO_2$ eq)*	*Additional costs (USD billion)*
Brazil	153–522	1–15	0	0
Canada	123–197	2–6	0	0
China	985–1,374	6–10	0	0
Europe	1,010–1,725	14–45	0	0
India	0	0	404–448	2–4
Indonesia	0	0	98–261	1–2
Japan	46–162	0–1	0	0–6
Mexico	0–144	0–1	75–136	2–6
Russia	48–507	0–3	168	1–4
United States	1,367–1,880	20–37	129	5–7
Rest of World	1,330–2,168	14–25	734–881	27–32
OECD90	**2,770–4,064**	**42–90**	**141**	**6–9**
non-OECD90	**2,292–4,436**	**15–45**	**1,468–1,882**	**33–46**
World	**5,062–8,500**	**58–135**	**1,609–2,023**	**39–56**

Ranges are due to different baselines considered (SSP1, SSP2, SSP3)

Additional costs of conditional INDCs will be USD 33–46 billion, annually, by 2030, for non-OECD countries

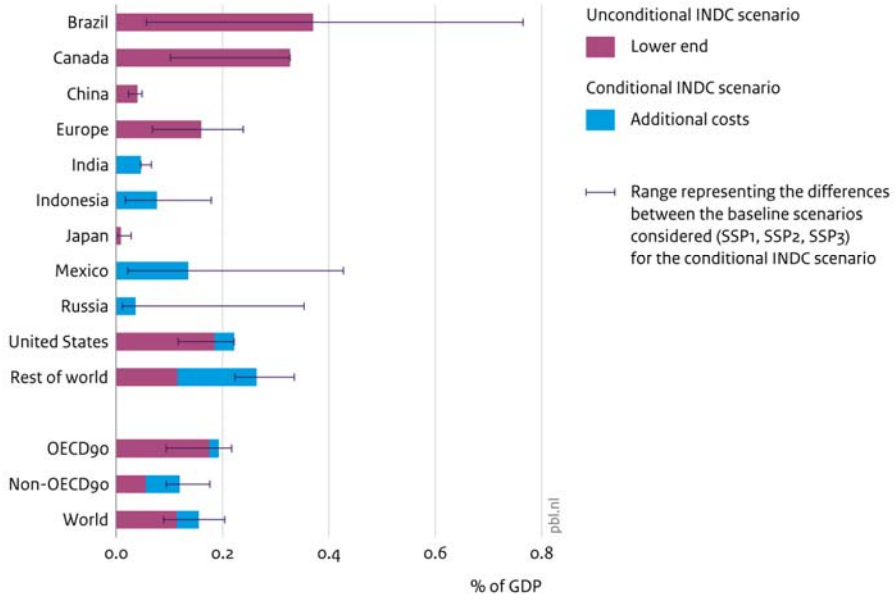
The costs of achieving the additional reductions of the conditional INDCs is estimated at about USD 39–56 billion, of which USD 33–46 billion for non-OECD90 countries (final column Table 2). The latter range can be regarded as the part of the INDC that is subject to

international financing. About one third of the difference in non-OECD90 abatement costs between the conditional and unconditional INDCs is due to South Africa's difference in costs, which has a very large range in their INDC reduction target.

Regional costs are highly sensitive to baseline assumptions

Global abatement costs are projected at 0.05% to 0.15% of world GDP for full implementation of the unconditional INDCs, and at 0.09% to 0.20% for the conditional INDCs (Figure 2). The abatement costs for almost all regions are very sensitive to baseline assumptions. For instance, for Brazil, costs range from 0.06% under the SSP1 baseline to 0.77% under the SSP3 baseline. Abatement costs for India and China are less sensitive to baseline assumptions, as the absolute emission targets of these countries depend on baseline developments.

Figure 2
Abatement costs for INDCs under SSP2 baseline, 2030



Source: PBL FAIR/TIMER model

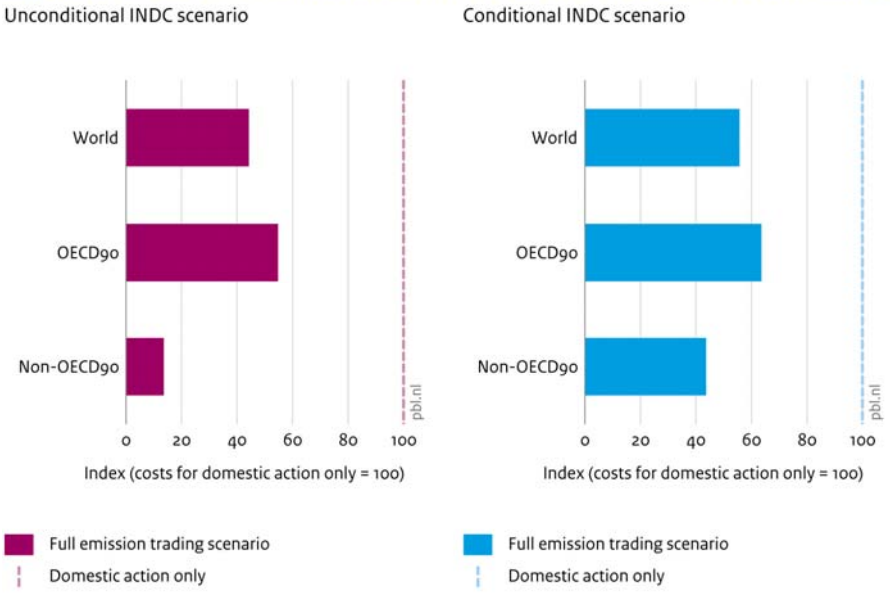
Allowing emission trading could reduce costs by about half

In the calculations above, we assumed that all reduction targets for the INDCs would be achieved domestically, as the mitigation actions submitted by most Parties relate to domestic reductions only. Within regions, we assumed full flexibility in emission reductions (cost-optimal mitigation across sectors). However, allowing for flexible mechanisms *between* regions could reduce global costs substantially, as countries with relatively high marginal abatement costs can partially achieve their target by paying for emission reductions in regions with relative low costs. Global costs can be reduced by 56% under the unconditional INDC scenario, and by 44% under the conditional INDC scenario, by reducing emissions wherever it is cheapest to do so (Figure 3). The reduction in costs is larger under the unconditional INDC scenario, as here the regional emission reduction targets are less evenly distributed (see Figure 1). Countries without a substantial reduction target relative to the

baseline (India, Japan, Russian Federation) could profit by reducing emissions domestically and selling emission credits, but both OECD and non-OECD countries could benefit strongly by allowing flexibility mechanisms in their INDC.

Figure 3

Impact of full emission trading on abatement costs for INDCs under the SSP2 baseline, 2030



Source: PBL FAIR/TIMER model

Emissions and costs for 2 °C and 1.5 °C

Global emission level of 42 $GtCO_2$ eq by 2030 is needed for 2 °C

According to UNEP (2015), global 2030 emission levels that correspond with emission pathways that are likely to limit the global temperature increase to 2 °C are in the order of 42 $GtCO_2$ eq (median level), with a range of 31 to 44 Gt CO_2 eq. The 2015 Paris Agreement also mentions that efforts should be pursued to limit global temperature increase to 1.5 °C, which implies a 2030 emission level of about 39 Gt CO_2 eq, according to the same UNEP study.

Gap between conditional INDCs and 2 °C is projected to be 7.4–10.6 $GtCO_2$ eq by 2030

Under the SSP2 baseline scenario, the 2030 emission level will be 60.9 (SSP1-SSP3 range 56.1–63.1) $GtCO_2$eq, including 1.1 $GtCO_2$ eq in LULUCF emissions and 1.8 $GtCO_2$ eq in emissions from international aviation and shipping. Under the conditional INDC emission scenario, global emissions will reach a level of about 51.8 (49.4–52.6) $GtCO_2$ eq (Table 3). Although this is 9.2 (6.7–10.5) $GtCO_2$ eq below the baseline emission level, there still remains an emission reduction gap of about 10 (7.4–10.6) $GtCO_2$ eq for achieving the 2 °C target and about 13 (10.4–13.6) $GtCO_2$ eq for the 1.5 °C target (see Table 3). Regarding this gap, it is assumed that international shipping and aviation could reduce emissions from 1.8 to 1.3 $GtCO_2$ eq by 2030, based on Cames et al. (2015) and our own model calculations. LULUCF emissions are assumed to reduce to net zero by 2030, from baseline levels of 1.1 $GtCO_2$ eq. This leaves a remaining gap of 8.5 (5.8–9.0) $GtCO_2$ eq for achieving the 2 °C target and 11.5 (8.8–12.0) $GtCO_2$ eq for the 1.5 °C target.

Table 3. Emissions under the various scenarios ($GtCO_2$ eq)

	2030 Baseline	2030 Conditional INDCs	2030 2 °C	2030 1.5 °C
Global emissions (excl. LULUCF and international aviation and shipping)	53.1–60.2	46.5–49.7	40.7	37.7
International aviation and shipping emissions	1.8	1.8	1.3	1.3
LULUCF emissions	1.1	1.1	0	0
Global emissions	56.1–63.1	49.4–52.6	42.0	39.0

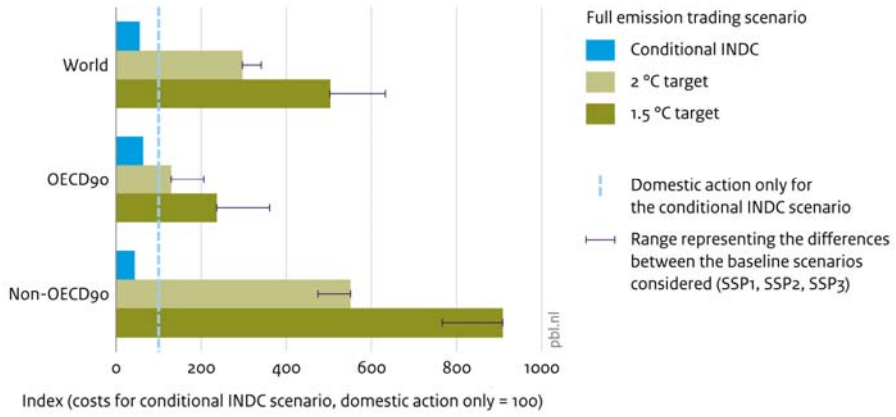
Ranges are due to different baselines considered (SSP1, SSP2, SSP3)

Global annual costs for achieving the 2 °C target by 2030 more than 3 times the costs of INDCs

The costs related to the *2 °C scenario* (under which full emission trading is allowed and an emission level of 42 $GtCO_2$ eq will be achieved by 2030) amount to 0.31% to 0.64% of global GDP by 2030, compared to a median level of about 0.6% and a 25th to 75th percentile range of 0.25% –1.17%, according to the IPCC (Clarke et al., 2014, Figure 6.21). This implies a global cost level of 3 to 3.5 times the costs under the conditional INDCs scenario without emission trading (Figure 4). This increase in costs in much larger than the increase in emission reductions relative to the baseline, as the reductions necessary for achieving the 2 °C target require relatively expensive reduction measures. For the 1.5 °C scenario, costs are even 5 to 6 times as high.

Figure 4

Impact of meeting the 2 °C and 1.5 °C target on abatement costs under the SSP2 baseline, 2030



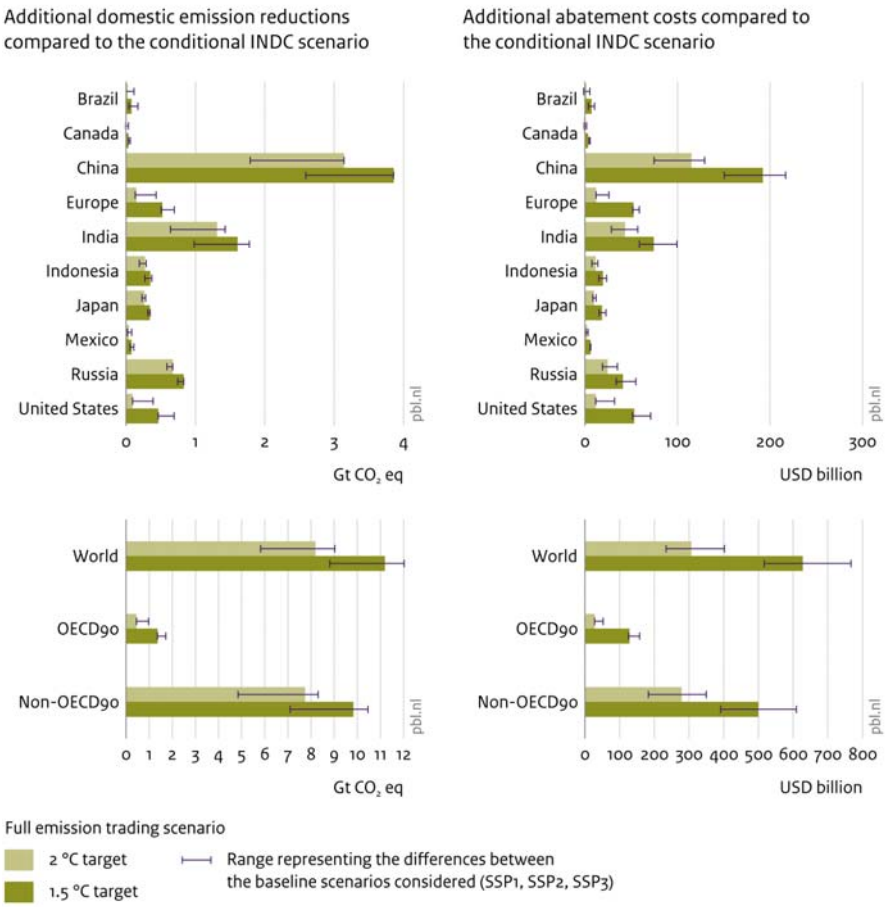
Source: PBL FAIR/TIMER model

Larger potential for reducing emissions in non-OECD countries

The increase in domestic abatement costs is larger, and sometimes much larger, for non-OECD countries, as the potential for emission reduction is also generally larger in these countries (assuming no financial transfers or effort-sharing combined with trading in emission credits, both of which may help to alleviate the burden for non-OECD countries). Looking at the 2 °C scenario in more detail shows that, compared to the conditional INDCs scenario, domestic emission levels are especially lower – and abatement costs higher – in China, India, and Russia (Figure 5). Of the 5.8 to 9.0 $GtCO_2$ eq difference in global emissions (excluding emissions from international aviation and shipping and LULUCF) between the conditional INDCs scenario and the 2 °C scenario, 1.8–3.1 $GtCO_2$ eq is in China, 0.6–1.4 $GtCO_2$ eq in India and 0.6–0.7 $GtCO_2$ eq in Russia. These countries have relatively large potential to reduce emissions further, relative to their conditional INDCs; for China and India, in particular by reducing non-CO_2 emissions that have not been included in their INDC. Naturally, this will lead to large increases in abatement cost, as well (USD 75–130 billion for China and USD 29–57 billion for India). Clearly, this raises large political questions regarding the financing of these emission reductions.

Figure 5

Impact of meeting the 2 °C and 1.5 °C target on emission reduction and abatement costs under the SSP2 baseline, 2030



Source: PBL FAIR/TIMER model

References

Cames M, Graichen J, Siemons A and Cook V. (2015). Emission Reduction Targets for International Aviation and Shipping. Policy Department A for the Committee on Environment, Public Health and Food Safety (ENVI), European Parliament, Brussels.

Clarke L, Jiang K, Akimoto K, Babiker M, Blanford G, Fisher-Vanden K, Hourcade J-C, Krey V, Kriegler E, Löschel A, McCollum D, Paltsev S, Rose S, Shukla PR, Tavoni M, Van der Zwaan B and Van Vuuren DP. (2014). Assessing Transformation Pathways. in Edenhofer O. et al. (eds.) Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge (UK) and New York, NY (US).

Den Elzen M, Admiraal A, Roelfsema M, Van Soest H, Hof AF and Forsell N. (2016). Contribution of the G20 economies to the global impact of the Paris agreement climate proposals. Climatic Change 137:655–665.

Den Elzen MGJ, Hof A, Mendoza Beltran A, Van Ruijven B and Van Vliet J. (2013). Implications of long-term global and developed country reduction targets for developing countries. Mitigation and Adaptation of Strategies for Global Change 18:491–512.

Den Elzen MGJ, Hof A, Van den Berg M and Roelfsema M. (2014). Climate policy. in Stehfest E, Van Vuuren D, Kram T and Bouwman L. (eds.), Integrated Assessment of Global Environmental Change with IMAGE 3.0 - Model description and policy applications. PBL Netherlands Environmental Assessment Agency, The Hague, pp. 71–152.

Hof AF, Den Elzen MGJ and Mendoza Beltran A. (2016). An EU 40% greenhouse gas emission reduction target by 2030 in perspective. Int. Environ. Agreem.: Polit., Law and Econ. 16:375–392.

O'Neill BC, Kriegler E, Riahi K, Ebi KL, Hallegatte S, Carter TR, Mathur R and Van Vuuren DP. (2014). A new scenario framework for climate change research: The concept of shared socioeconomic pathways. Climatic Change 122:387–400.

Rogelj J, Den Elzen M, Höhne N, Fransen T, Fekete H, Winkler H, Schaeffer R, Sha F, Riahi K and Meinshausen M. (2016). Paris Agreement climate proposals need a boost to keep warming well below 2 °C. Nature 534:631–639.

UNEP (2015). The Emissions Gap Report 2015: A UNEP Synthesis Report. United Nations Environment Programme (UNEP), Nairobi.

UNFCCC (2015a). FCCC/CP/2015/L.9/Rev.1: Adoption of the Paris Agreement. UNFCCC, Paris, France, pp. 1–32.

UNFCCC (2015b). Intended Nationally Determined Contributions (INDCs), http://www4.unfccc.int/submissions/indc/Submission%20Pages/submissions.aspx.

Van Vuuren D, Van Ruijven B, Girod B, Daioglou V, Edelenbosch O and Deetman S. (2014). Energy Supply and Demand. in Stehfest E, Van Vuuren D, Kram T and Bouwman L. (eds.), Integrated Assessment of Global Environmental Change with IMAGE 3.0 - Model description and policy applications. PBL Netherlands Environmental Assessment Agency, The Hague, pp. 71–152.

Van Vuuren DP, Stehfest E, Gernaat D, Doelman J, Van den Berg M, Harmsen M, De Boer HS, Bouwman L, Daioglou V, Edelenbosch O, Girod B, Kram T, Lassaletta L, Lucas P, Van Meijl H, Müller C, Van Ruijven B, Van der Sluis S and Tabeau A. (2016). Energy, land-use and greenhouse gas emissions trajectories under a green growth paradigm. Global Environmental Change (in press), http://dx.doi.org/10.1016/j.gloenvcha.2016.05.008.