Launching a New Climate Regime

Henry D. Jacoby and Y.-H. Henry Chen

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Abstract

At the 2015 UN Framework Convention on Climate Change (UNFCCC) meeting in Paris, participants in a new international climate agreement will volunteer Nationally Determined Contributions to emissions reductions. To put the planet on a path to declared temperature goals, the growth of global greenhouse gas emissions must cease, and begin to decline, by 2035 to 2040; however, the expected contributions do not yield results consistent with this timeline. Three achievements in Paris and follow-on activities are then crucial components of the new climate regime: a robust system of review with widely accepted measures of national effort; an established, durable plan of future pledge cycles; and increased financial support for the mitigation efforts of less-developed countries. The MIT Economic Projection and Policy Analysis (EPPA) model is applied to assess emissions outcomes of expected pledges and national performances in meeting them, and to elaborate the components of a successful launch.

Contents

1. FROM KYOTO TO PARIS

Frustrated by the lack of progress in emissions control under the Kyoto Protocol, the parties to the UN Framework Convention on Climate Change (UNFCCC) are formulating new regime architecture, with negotiations to be concluded in Paris in December 2015. The Kyoto Protocol sought legally binding commitments by the Annex I (developed) countries to quantitative emissions reductions below a 1990 base year level. Non-Annex I (developing) nations had no emissions obligation. The next two decades saw heroic efforts to make this Kyoto system successful; however, the U.S. signed the Protocol, but never moved to ratify it. Several Annex I nations that did ratify the Protocol either refused to participate in a second Kyoto commitment period or dropped out altogether. Meanwhile, over time, some Non-Annex I nations without emissions reduction

commitments (most notably China) grew to middle-income status and came to dominate global emissions.

At the 2009 meeting of the UNFCCC Conference of the Parties (COP), held in Copenhagen, the attempt to continue under the Kyoto architecture essentially collapsed in disagreement. Fortunately, a few heads of state acted to create an alternative path. In a process outside the rules and procedures of the UNFCCC, they framed an approach based on voluntary emissions reductions with review of achievements. From this point on, all nations would be expected to contribute in one way or another to global emissions reduction. In the next COP, held in Cancún, the so-called Copenhagen Accord was granted official status under the Convention. At the COP in Durban in 2011, a new set of instructions to negotiators— the Durban Platform agreement—was reached. This system of voluntary pledges was to be implemented in a more formal, comprehensive agreement, to be negotiated at the 21st COP in Paris in December 2015.

The process from Copenhagen through Durban yielded substantial improvements in the structure of the negotiations. Now, all countries must volunteer Nationally Determined Contributions (NDCs), and the distinction between rich and poor nations, formerly embodied in a strict and divisive interpretation of the UNFCCC concept of common but differentiated responsibilities, has been softened. The scope of the discussions was extended to include adaptation on a more equal footing with mitigation. An Ad Hoc Working Group on the Durban Platform for Advanced Action (ADP) was formed and has met regularly over the intervening years to develop a "protocol, another legal instrument or an agreed outcome with legal force" (UNFCCC, 2012). These negotiations blossomed to encompass a complex set of issues including emissions mitigation, adaptation to climate change, financial aid, technology transfer and capacity building. They also include a proposal for compensation to developing countries for "loss and damage" associated with the adverse effects of climate change.

In the Warsaw COP in 2013, the parties agreed to a preliminary stage in the pledging process. In the months preceding the Paris COP (or by the first quarter of 2015 for those ready to do so) parties were to submit to the FCCC their *Intended* Nationally Determined Contributions (INDCs). Though justification for the "intended" step in the process may have been to provide a push for greater ambition in the final Paris negotiations, these INDCs now very likely represent the nations' ultimate NDCs in this first attempt to implement the new regime architecture.

The INDCs represent substantial progress in emissions mitigation, as will be shown in Section 2. The process has been aided, no doubt, by a rising awareness of the seriousness of the climate change threat, and encouraged by the consistent support of some nations, particularly those in the E.U. A recent joint agreement by China and the U.S., the world's two largest emitters, has been a crucial factor in support of the new climate agreement (White House, 2015).

As of February 2015, the ADP had produced a 90-page negotiating text, riddled with alternative paragraphs and brackets indicating withheld approval. To cut through the

tangle of concerns, the delegates requested the ADP co-chairs to produce a more manageable document. In July they provided a so-called Co-Chairs' Tool, which was down to 76 pages, with the first 19 pages concentrated on the items they expected to actually be contained in a Paris agreement. On 5 October 2015 the co-chairs released a still more refined Non-Paper comprised of a nine-page Draft Agreement with a ten-page list of items in a Draft Decision (ADP, 2015a). Though this Non-Paper may still represent the text most likely to emerge in Paris, it was not accepted in the final ADP meeting before Paris (19–23 October 2015), and was replaced by a 55 page Draft Agreement, which was again riddled with alternative paragraphs and bracketed text (ADP 2015b).[1]

Though the various issues under negotiation are connected to one another (particularly mitigation, adaptation and finance), here we focus on implementation of the system for pledge and review of mitigation efforts, initiated in Copenhagen and called for in the Durban Platform. Each party is to pledge its NDC to go into effect in 2020. Each developed nation will summarize its contribution in a quantitative emissions goal, but it is generally agreed that developing countries may state their pledges however they want. The time period for this first pledged contribution and the review procedures are topics for resolution in Paris, and in years of follow-on negotiation of the details.

Three achievements are crucial to a successful launch of this new regime.

- There must be agreement on a robust process of review, to ensure that these first pledges are met. Provisions for measurement, reporting and verification (MRV) have long been a contentious issue in climate discussions. The sections on "transparency" in the Co-Chairs' Non-Paper, and in bracketed text in the 23 October Draft Agreement, indicate that points of disagreement have not yet been resolved.
- A cycle of contribution updates must be implemented, since Paris is just the first stage of a regime that will need to stimulate increased effort over time. The negotiations appear to be settling on a five-year cycle, which means that institutions and procedures must be set in place very quickly to have any chance of meeting such a timetable.
- To realize INDCs and potential follow-on efforts by less-developed parties, financial transfers from the richer countries will be required.

In the following analysis, we show our expectations for the pledges in Paris, highlighting the importance of review and follow-on cycles, and the role of financial transfers.

2. TEMPERATURE GOALS, INDCS AND FUTURE CYCLES

2.1 The Near-Decade Challenge

The 1992 Framework Convention stated the goal of the effort—to prevent "dangerous anthropogenic interference with the climate system"—and in recent years this objective

[1] For an in-depth analysis of the climate negotiations, history and current issues, see Flannery (2015).

has been framed as limiting the increase in global average temperature to 2°C above the pre-industrial level. With the passage of time and inexorable growth in global emissions, it has become evident that this target is rapidly passing into the rear view mirror (Jacoby and Chen, 2014; Victor and Kennel, 2014), yet the Durban Platform opens by "*Noting with grave concern* the significant gap between the aggregate effect of Parties' mitigation pledges and […] pathways consistent with having a likely chance of holding the increase in global average temperature below 2°C."

The challenge of meeting this goal is illustrated in **Figure 1**, which shows studies of paths to stabilization of atmospheric greenhouse gas concentrations in the Fifth Assessment Report (AR-5) of the Intergovernmental Panel on Climate Change (IPCC, 2014). The concentration level of 530 to 580 ppm CO_2-e is roughly associated with temperature increases by 2100 of 2°C and 3°C above the preindustrial level (IPCC, 2014), and none of these analyses find that these concentration levels can be avoided unless global emissions turn around and begin to decline by 2035 to 2040. The longer the delay in achieving this reversal, the higher the range of temperature change that likely cannot be avoided, even given urgent efforts in the following decades. Even this IPCC summary is optimistic; because the analyses summarized in Figure 1 were necessarily completed some years before the publication date of the AR-5, the results are out of date. In 2015, global emissions will be over 50 Gt CO_2-e, above the path associated with stabilization at 530–580 ppm CO_2-e.

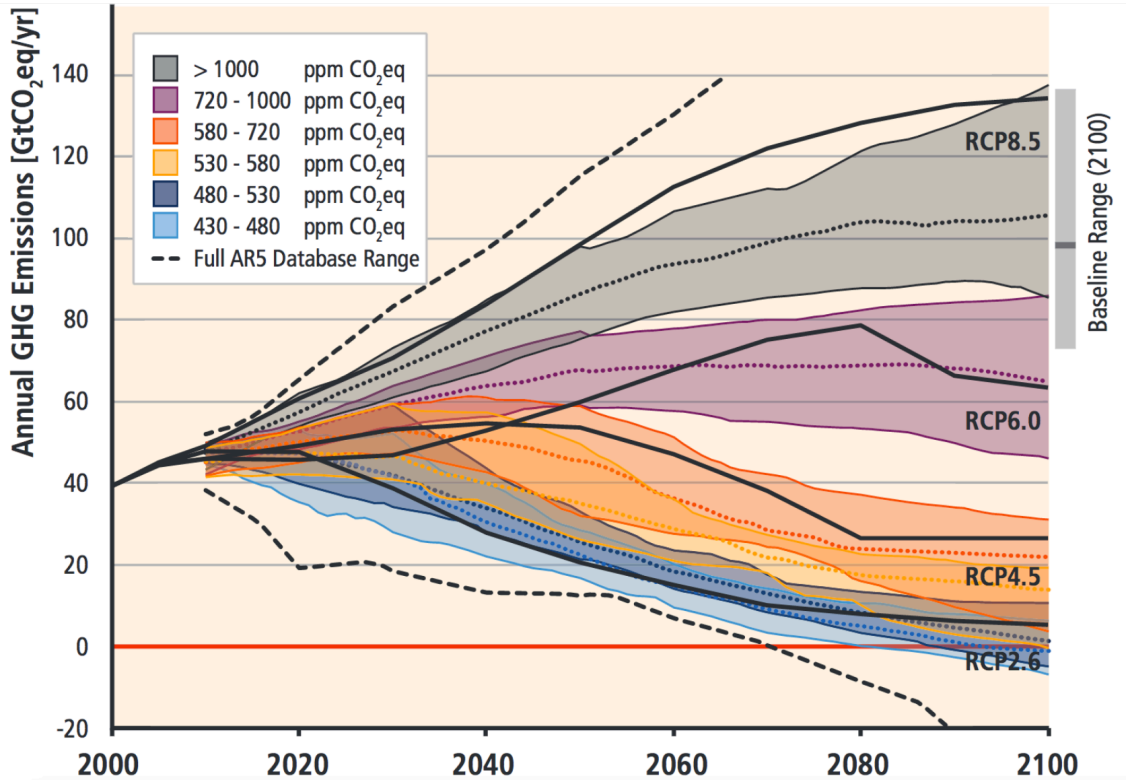

Figure 1. Emissions Pathways & Stabilization Levels (IPCC, 2014).

One crucial point can be drawn from this IPCC analysis, and similar conclusions reached by others:[2] unless global emissions peak and start to decline by around 2035 to 2040, increases in the neighborhood of 2°C above the pre-industrial level become impossible to avoid, and substantially larger temperature increases become far more likely. The main challenge in Paris and follow-on negotiations is, with the new pledge-and-review architecture, to turn global emissions around in the near term. Also, the system must offer the prospect of striking a continuing downward path through subsequent decades. This focus leads to two questions: what global emissions reduction is expected from the INDCs, and what is important to achieve in Paris given this expectation?

2.2 INDCs and Expected Emissions Measures

To explore the emissions reductions likely to be realized in the Paris negotiations, we analyze the results of what we expect from INDCs submitted by some 150 nations to date and others likely to be published in the future. These actions are then simulated in the MIT Economic Projection and Policy Analysis (EPPA) Model. EPPA is a general equilibrium model that represents the world in terms of the individual countries and aggregate regions shown in Table 1. The model contains a multi-sector representation of the economies of these regions, with greatest detail in the energy supply and use, and it accounts for international trade in energy and all other goods. **Table 1** shows the 16-region breakdown of the model, and the aggregates employed in displaying results.[3]

Table 1. Classification of the 16 EPPA Regions.

Developed		Other G20		Rest of World	
ANZ	Australia-New Zealand	BRA	Brazil	AFR	Africa
CAN	Canada	CHN	China	MES	Middle East
EUR	E.U.+	ASI	Dynamic Asia	LAM	Other Latin America
JPN	Japan	IND	India	REA	Rest of East Asia
USA	United States	MEX	Mexico	ROE	Rest of Eurasia
		RUS	Russia		

Our expectations for results in Paris draw on several sources. We consider INDCs submitted to the Framework Convention as of the time of this analysis. All the developed regions plus China, India, Mexico and Russia have placed INDCs into the FCCC website. Most countries in the regional aggregates have submitted INDCs, and they provide information for constructing an estimated pledge for each group. Based on national communications and discussions with observers of plans in various countries, we impose our expectations of the emission-reducing measures likely to be adopted, whether or not yet incorporated in an INDC pledge.

[2] For example, see Peters *et al.*, 2015; US NCA (2014) Ch. 27; Clarke *et al.*, 2009.
[3] A brief description of the EPPA model is provided in Appendix A.

We expect that policies and measures—mainly regulatory actions and various forms of subsidy—will dominate the implementation of nations' contributions. Cap–and–trade systems and emissions taxes are being applied in a few countries and are planned for future application (e.g., by China), and they would lower the cost of emissions reductions (Paltsev *et al.*, 2013; Jacoby and Chen, 2014). These emissions-pricing policies are not likely, however, to play a significant role on the time horizon of the NDCs in a Paris agreement.

We assume that intensity of effort will differ among the three broad groups in Table 1, with expectations for India and the *Rest of World* groups influenced by the level of financial aid they might expect to receive. The analysis focuses on sectors that are both large sources of emissions and likely to be a target of control measures:

- Electric power is the largest emitting sector in most countries, and we expect measures to be taken to retire current coal-fired capacity, and to impose renewable energy mandates.
- In wealthier countries personal vehicles are the primary source of transport emissions while commercial trucks tend to dominate at lower levels of economic development. We expect that tighter auto design standards will spread across the new personal vehicle fleets of all nations, and that efficiency standards for trucks will be tightened everywhere as well.
- In most countries there is some effort to increase the efficiency of energy use in the household sector, and we expect continuing improvement to be sought in this emissions source.
- In regions with large tropical forests we expect a reduction in the CO_2 emissions from programs devoted to reducing deforestation and forest degradation.
- In recent years there have been increased domestic and international efforts to control emissions of non-CO_2 greenhouse gases and black carbon, and this effort is represented by programs to reduce the most important of these sources, methane, from the fossil energy system and from agriculture.

The details of these expected measures, region by region, are provided in Appendix B. Where the aggregate emissions results yielded by these assumed policies and measures do not match our expectations for the INDCs submitted to the FCCC, adjustments are made to ensure consistency.

2.3 Expected Global Emissions

The results of pledges in the first stage of the new agreement are shown in **Figure 2**, denoted *Paris*.[4] For analysis of the cost of mitigation efforts, and to approximate trade effects, a comparison is made with a scenario of emissions growth to 2040 if no further reductions were put in place beyond pledges in the Copenhagen Accord—accounting for the fact that some of those pledges likely will not be fulfilled**.** Based on the *Copenhagen* baseline, the anticipated achievement from pledges expected in Paris is substantial: a reduction of around 13% by 2030.

Under its section on Transparency, the Non-Paper calls for "clarity and tracking of progress made in implementing and achieving individual Parties' respective [NDCs]". Indeed, the success of this regime of voluntary pledges will require credible, mutually accepted measures of relative effort. This is a special challenge in a regime lacking a common target definition as in the Kyoto Protocol, no shared group of mitigation actions, and likely flexibility in accounting procedures. Yet, even achievement of the projected reductions under NDCs agreed in Paris may depend on anticipation of an effective review procedure.

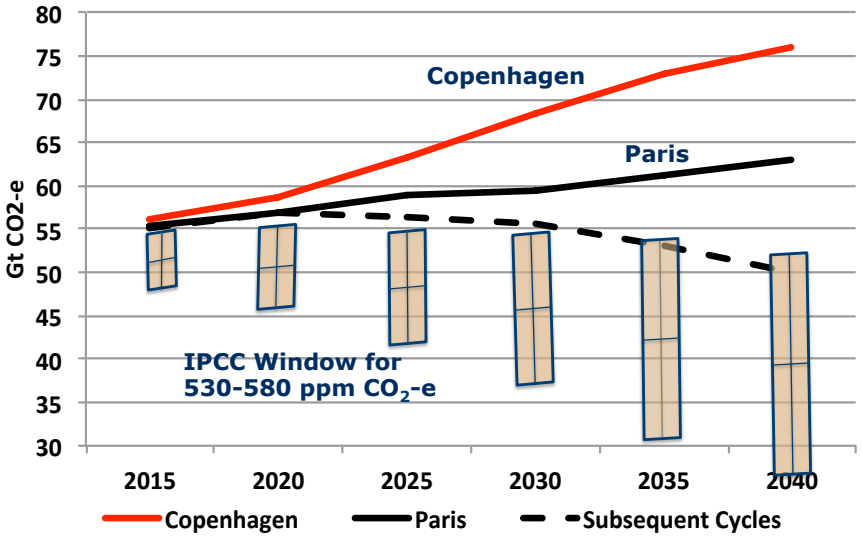

Figure 2. Projections to 2040 of Copenhagen Baseline & Paris Pledges with Potential Second Cycle, and Windows Consistent with Stabilization at 530-580 ppm CO_2-e.

[4] Our projected emissions in 2030 are about 4.5% higher than the Synthesis Report by the UNFCCC (2015). Many assumptions may contribute to the difference, including economic growth rates, expectations about national performance in meeting the INDCs, and whether the total considers emissions leakage. Another likely factor is net land use emissions, where the uncertainty is very great—being the difference between two large numbers, uptake and release. Our estimate is based on MIT analysis (MIT Joint Program, 2014) whereas an estimate by the FAO (http://faostat3.fao.org/browse/G2/*/E) shows roughly one-quarter the net emissions. The 2030 estimate of post-Paris emissions is 6% below our earlier effort (Jacoby and Chen, 2014) reflecting the incorporation of actual pledge information and some revision in projected economic growth rates.

Thus, it will be crucially important in Paris to resolve contentious political issues of monitoring reporting and verification, and to achieve agreement on a credible, timely review process. Details of a review process cannot be resolved in a single COP meeting, given all the other issues to be dealt with; they will be passed to a committee, such as the Convention's Subsidiary Body on Implementation. If fundamental issues are not settled in Paris, their later resolution could take several years, perhaps relieving the pressure on parties to follow through on their initial NDCs.

Though many national reviews will be concerned with specific policies and measures pledged, a set of effort indicators applied across many countries is likely to weigh heavily in this process. We explore the characteristics of several of these commonly applied indicators in Section 3.

Despite the progress represented by the many submissions of INDCs in advance of COP-21, the pledges are not sufficient to stop global emissions growth to 2040 and beyond, and so are not consistent with the temperature goal motivating the negotiations. Also shown in Figure 2 is a rough approximation of the IPCC's windows of global emissions to 2040. These windows encompass the emissions scenarios collected by the IPCC that are consistent with stabilization of greenhouse concentrations around 530–580 ppm CO_2-e and a temperature increase by 2100 of 2°C to 3°C above the pre-industrial level. Additional mitigation effort is required to place the world within this domain, and this can only be achieved by establishment of a durable cycle of updates to national commitments (see the *Subsequent Cycles* as illustrated in Figure 2).

The establishment of a credible and timely review process is even more urgent if there is to be a timely sequence of future cycles of pledges. For example, if the COP establishes 2025 as the first review period, for contributions to take effect from 2020, data for an *ex post* review of performance for many countries could be difficult to assemble in less than a couple of years after the close of the period, say 2027. If UNFCCC approval of national reviews is required, the needed information could be delayed even further. The existence of these natural lags in an *ex post* review process then means that discussion of a second cycle would have to start well before performance under the first cycle can be documented. To initiate a durable cycle of pledges, therefore, some form of *ex ante* review will be desirable (Aldy *et al.*, 2015). For this purpose a portfolio of effort measures like those discussed in Section 3 will be needed.

2.4 The Importance of Financial Aid

Figure 3 shows the expected emissions of selected countries and aggregate groups. The emissions of the developed countries are projected to decline to 2030 and beyond. China has pledged to stabilize greenhouse gas emissions by around 2035 (Zhang *et al.*, 2014), and emissions of the rest of the *G20*, excluding India, also do not grow over the period. On the other hand, the emissions of India and the *Rest of World* groups are

expected to grow substantially over the period to 2030 and beyond, even though almost all are likely to pledge INDCs in the run-up to Paris.

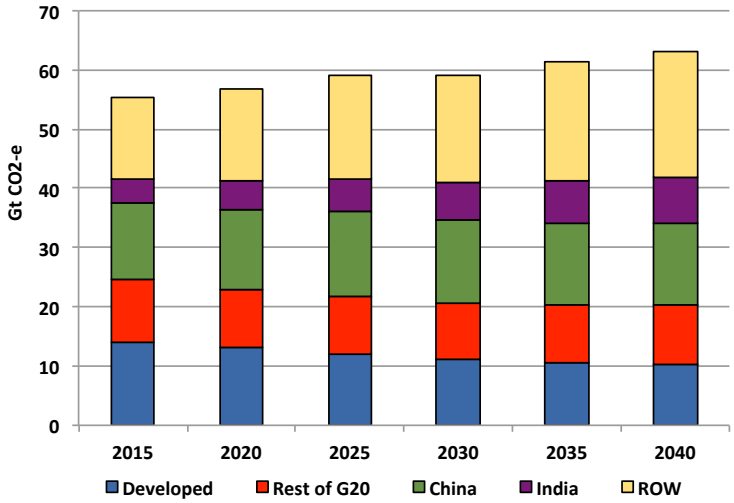

Figure 3. Expected Post-Paris Emissions.

As argued above, to meet any plausible temperature objective all nations will have to increase their contributions in second and subsequent cycles of the pledge process. Under principles of common but differentiated responsibility, a heavy obligation will fall on the developed countries. Still, unless emissions growth in less developed nations can be slowed there is scant hope of turning global emissions around by 2035 to 2040. Under INDCs expected in Paris, Africa's emissions, which total about one-third of the *Rest of World* group, are projected to be larger than those of the U.S., as are India's. Augmenting the mitigation efforts of these countries is going to require financial aid at unprecedented scale. The need is made evident by the fact that many of the INDCs of less developed countries are stated conditional on the receipt of financial assistance.[5]

In the 2009 Copenhagen COP the developed nations pledged to "mobilize" $100 billion per year by 2020 in aid for mitigation and adaptation. There is general agreement that this target falls far short of what will be needed to support conditional INDCs, much less to achieve ambitious temperature targets while contributing to adaptation.[6] Just how that money will be raised is unclear. While there is no commonly accepted definition of which financial flows should count toward the $100 billion target (CPI & WRI, 2015), a study by the OECD (2015) credits over two-thirds of the finance contributing to the goal

[5] For examples, see the submissions by Algeria, Colombia, Ethiopia, India and Kenya on the Framework Convention website: http://unfccc.int/focus/indc_portal/items/8766.php.

[6] For example, though India's INDC doesn't detail what proportion would have to come from international climate finance, or on concessionary terms, it estimates that meeting the country's climate change actions to 2030 will require $2.5 trillion in additional financial resources. A further impression of the challenge is provided by Jacoby *et al.* (2009) who consider the financial transfers to be required if developing countries are protected from economic loss under a 50% global emissions reduction.

in 2013–14 to public sources—including bilateral flows, activities of multilateral development banks and institutions under the FCCC. Meeting even a proportion of the needs of mitigation and adaptation through these channels will overwhelm the likely contributions from developed country budgets. A more effective tapping of private capital flows will be required, leveraging available public resources. Creative mechanisms will be needed to lower the private risks and otherwise assist the arrangement of concessionary terms.

The Co-Chairs' Non-Paper and the 23 October Draft Agreement indicate that a Paris agreement will reaffirm the $100 billion pledge and will likely include the call by some nations for a much larger commitment. Practical implementation of these financial initiatives is not the subject of COP negotiations, however. It will require years of follow-on effort by donor countries and international organizations, and improvement in the capacity of recipient countries to attract private finance (Bloomberg, 2014).

3. EFFORT MEASURES

The Kyoto Protocol provided a clear (if imperfect) measure of effort in its targets for percentage reductions below 1990 levels. Given the wide variation in circumstances and forms of NDCs, no single measure can be applied consistently to all parties. A truly useful indicator would 1) clearly identify a country's effort to reduce emissions, 2) would be measurable and replicable using publicly available data, and 3) could be applied to all countries. No single measure meets all three requirements, so a portfolio of indicators will be necessary (Aldy and Pizer, 2015). Moreover, the definition of each indicator in the portfolio will involve a number of complexities, so cooperative effort by nations and outside analysts will be needed to produce widely acceptable standards and procedures for their construction.

Most indicators of mitigation effort fall into one of three categories: emissions prices, emissions quantities, and cost of activities undertaken. Prices resulting from a cap–and–trade system or tax regime would be a very useful measure of effort, and these instruments may be more widely used in the future, but as noted earlier they are not expected to play a role in the Paris agreements and near-term future rounds of pledges. Energy taxes might serve as a proxy measure, but again, their application is too spotty to be of much use. Emissions results and cost are thus likely to make up any portfolio of effort measures for the next few decades, and we look at several of these to explore the challenges in their construction and interpretation using EPPA model results behind Figures 2 and 3.

Many of the potential measures are model dependent, so these EPPA results are valuable not for their particular magnitudes but for the insights they offer into the general problems faced by analysts trying to inform the negotiations about relative effort. Aldy *et al.* (2015) lay out these comparability measures as they might be constructed *ex ante* and *ex post*. Our concern below is with the issues arising in *ex ante* application, though

many challenges remain in the interpretation in *ex post* studies that may be involved in the review process, where unanticipated events (e.g., tsunamis, recessions) may play a role.

3.1 Emissions Abatement

Figure 4 shows two quantitative abatement measures that are used in climate discussions. To elaborate the impression given in Figure 3 of the relative scale of the various regions, their percentage contribution to 2030 global emissions under expected Paris results is shown in parentheses.

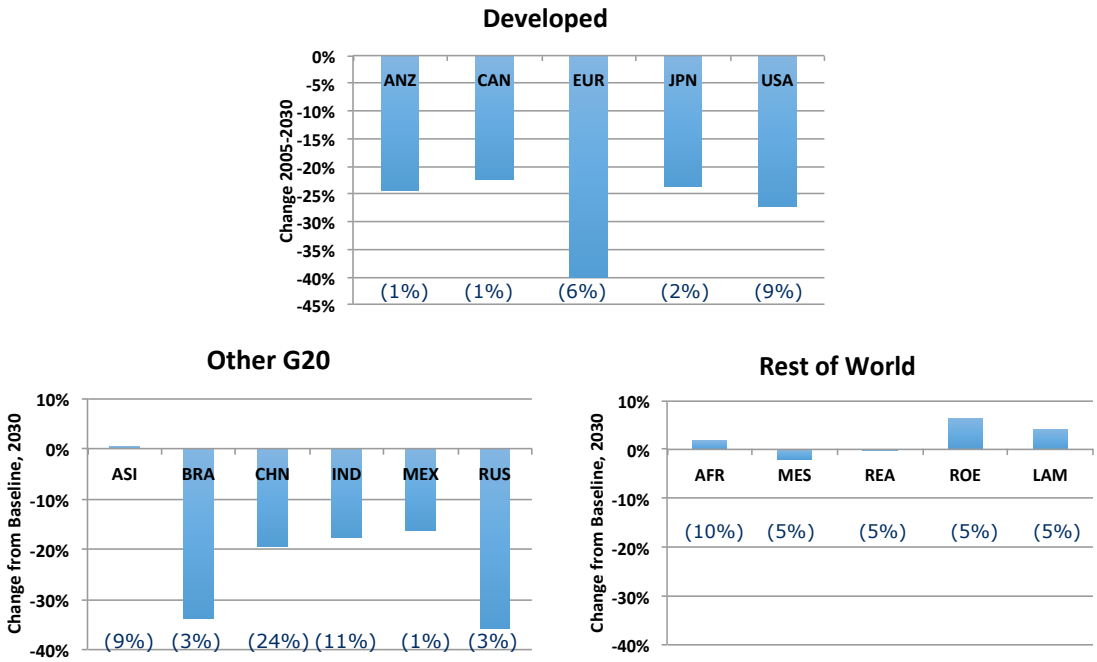

Figure 4. Percentage Emissions Changes in 2030: From 2005 for *Developed*, and from a Copenhagen Baseline for *Other G20* and *Rest of World*. (Percentage of global emissions in 2030 under Paris Pledges shown in parentheses.)

The developed countries pledge achievements in relation to a base year. All may not use the same comparison year (the E.U. tends to state in relation to 1990 while the U.S. uses 2005), but here we state all in terms of the percentage reduction in 2030 emissions below the 2005 level. Other nations state expected achievement in terms of a reduction below a business-as usual-projection. The bottom two panels in the figure show this result for the members of the *Other G20* and *Rest of World*.

Three aspects of these measures limit their usefulness as a single measure of mitigation effort. First, indicators based on change from a historic year are not easily comparable with those based on a projected baseline. Second, there is no agreed set of assumptions to guide the projection of future-year baselines. We use our Copenhagen projection for illustrative purposes, but in practice each nation is free to construct this

estimate as it likes. Interpretation of relative effort then will depend on judgments about the credibility of the baseline projection.

Finally, trade effects will influence measures of ultimate emissions and relative effort for any set of pledged policies and measures. Global summaries of independent national estimates will not account for emissions leakage. Countries in the *Rest of World* group are expected to undertake substantial emissions-limiting activities (see Appendix B), yet Figure 4 shows small net reductions or even increases in emissions relative to the Copenhagen baseline. In part, the small national totals are due to the leakage that the EPPA model takes into account. Ignoring trade effects will distort measures of national achievement, which is evident in a scenario where only the USA and Russia undertake the expected emissions-reducing measures. This case is shown in **Figure 5** as *USA and RUS Only*. Compare with the results (repeated from Figure 4) if all parties are taking action, denoted *All Regions*. The difference in reduction below baseline is due to trade effects.

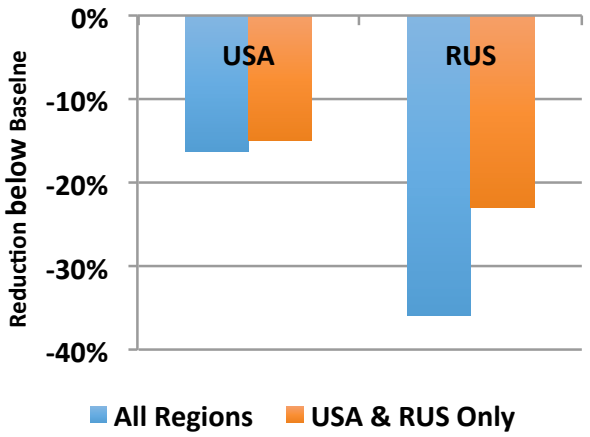

Figure 5. Trade Effects on Projected Reductions Below Baseline, 2030.

3.2 Emissions Intensity

Reduction in emissions intensity is another common measure of a nation's contribution to reduced global emissions. Results for this measure are shown in **Figure 6**. We limit the display to the individual nations in the EPPA analysis, as the measure is less appropriate for the multi-country aggregates. Though trade effects may also influence this measure, it has the advantage of comparison using numbers that can be based on available data, i.e., a base year level such as 2005 as shown in the figure.

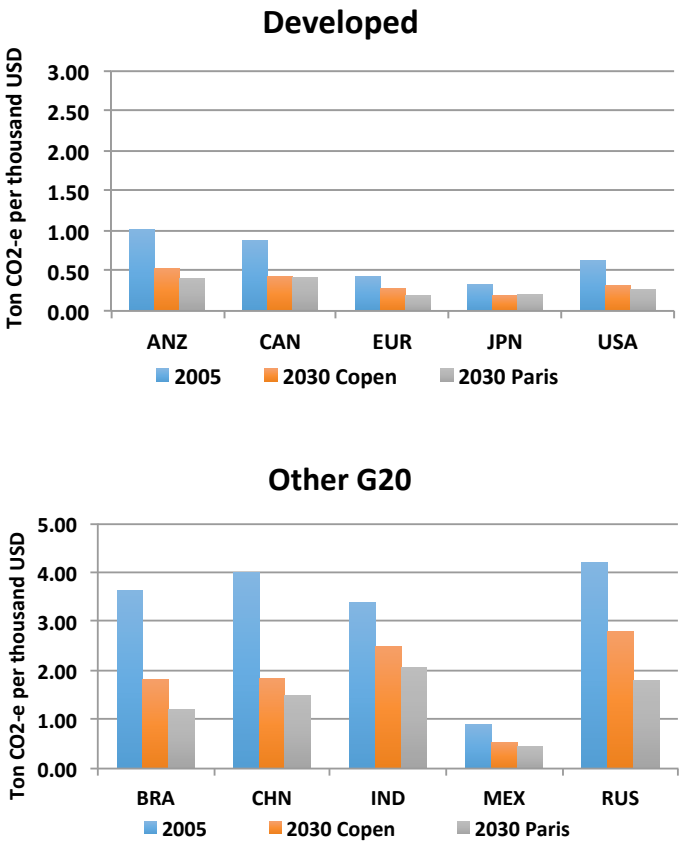

Figure 6. Emissions Intensity in 2005 and in 2030 under Copenhagen and Paris Cases.

However, to interpret this measure as indicating mitigation effort it is necessary to sort out the change in intensity that would be expected in the absence of INDC pledges. This calculation requires an estimate of intensity change, 2005 to 3030, under a business-as-usual projection, for which we use the Copenhagen baseline. The figure shows that, in many cases, mitigation policy is the smaller influence. Thus, interpretation of *ex ante* pledges based on overall intensity change, or *ex post* claims of the change realized, will need to include an adjustment for the change expected without climate policy, perhaps by an economic model analysis or judgment based on past experience.

3.3 Abatement Cost

Perhaps the best measure of mitigation effort is the cost of the measures employed, but compared with absolute reduction or intensity change it is more sensitive to the estimation method. Abatement cost for a particular party might be estimated by summing estimated costs from a set of partial equilibrium studies of economic sectors, by a multi-sector national model, or by a multi-nation model that takes account of international trade effects. Depending on the model used the cost may be in terms of GDP loss or a welfare measure; whichever indicator is chosen, each approach is likely to give a different answer.

Trade effects can also have a strong effect on the welfare cost of policies and measures adopted by the nations. **Figure 7** compares the welfare cost of the USA and Russia acting alone with an estimate of that cost measure if only these two countries undertook their Paris pledges—the latter case again approximating the results of standalone, country-by-country studies.[7] If all nations undertake their expected contributions, trade effects lead the U.S. to benefit slightly from the Paris agreement, while if most other countries do not, the welfare effect for the U.S. turns negative. Russia, on the other hand, bears a greater welfare cost when all nations are assumed to participate. The EPPA model considers trade in all the modeled goods, but the largest influence in this result likely is the differential effect of fossil energy prices, which are driven down by emissions mitigation, on the U.S. (a major energy importer) and Russia (heavily dependent on energy exports).

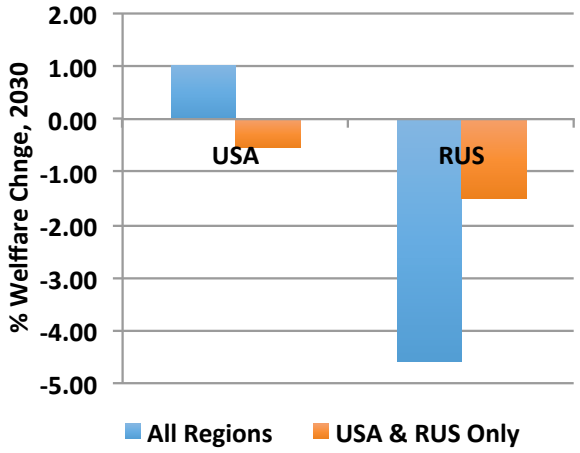

Figure 7. Trade Effects on Mitigation Cost of Paris Pledges.

4. COMPONENTS OF A SUCCESSFUL LAUNCH

Optimism builds as the Paris COP approaches, and there seems to be widespread support among nations for the process to establish a new climate regime, set in motion after years of effort, and culminating in the Durban Platform. The INDCs announced thus far represent a real achievement in emissions reduction. But even if there is an agreement in Paris, it will be a mistake to declare victory too quickly. This is only the first step in a long process. As important as the initial pledges are, success requires the establishment of an ongoing process of review, a robust cycle of updates, and arrangement of accompanying financial support.

[7] The welfare cost for Russia is relatively high, compared to policy costs reported in other studies of mitigation policy. This higher cost arises because we expect nations will apply regulatory and subsidy measures that are much more costly than the common emissions prices across sectors assumed in many economic models applied to cost estimation (e.g., see Paltsev *et al.*, 2013).

Working out the details of a new climate architecture will take time, in subsequent meetings of the parties to the agreement: all that is needed cannot be realized in one meeting, particularly when so many issues are on the table. A successful launch will require the resolution of the main political barriers to a credible and timely review process, and establishment of a process for future cycles of commitment to emissions reduction. The effectiveness of the new regime will also depend on effort outside the UNFCCC, especially the means to deliver large-scale financial resources to support the climate actions of the less-developed nations. With achievement in these three areas, the Paris COP could mark the beginning of a serious global effort to preserve the climate.

Remaining work includes development of credible, reliable procedures to measure effort in mitigation and finance and to compare levels of effort among nations. Here a contribution could be made by analysis groups—in government agencies, NGOs and academia—coming together to develop standards of practice and realms of reasonable assumptions for model studies in order to summarize realized outcomes.

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APPENDIX A. THE MIT EPPA MODEL

The MIT Economic Projection and Policy Analysis (EPPA) model (Paltsev *et al.*, 2005), is a recursive–dynamic multiregional general equilibrium model of the world economy. It is comprised of sixteen nations and multination regions, and is built on the Global Trade Analysis Project (GTAP) data set of world economic activity, augmented by data on greenhouse gases, aerosols and other relevant emissions, and details of selected economic sectors. The model is used to project economic variables (e.g., gross domestic product, energy use, sectoral output, consumption), and emissions of greenhouse gases (CO_2, CH_4, N_2O, HFCs, PFCs and SF_6) and other air pollutants (CO, VOC, NO_X, SO_2, NH_3, black carbon and organic carbon) from the supply and combustion of carbon-based fuels, industrial processes, waste handling and agricultural activities.

As summarized in **Figure A1**, the model identifies a set of non-energy sectors that produce goods and services and estimates their inter-sector trade. Special detail is provided on personal transport and the sectors that consume final goods and services (not shown). Energy production and conversion sectors are represented in detail, and include coal, oil, and natural gas production (including conventional gas, shale gas, tight gas and coal-bed methane), petroleum refining, and an extensive set of alternative low-carbon and carbon-free generation technologies. The model's calculations include the effects of international trade among the regions in both energy and non-energy goods and services.

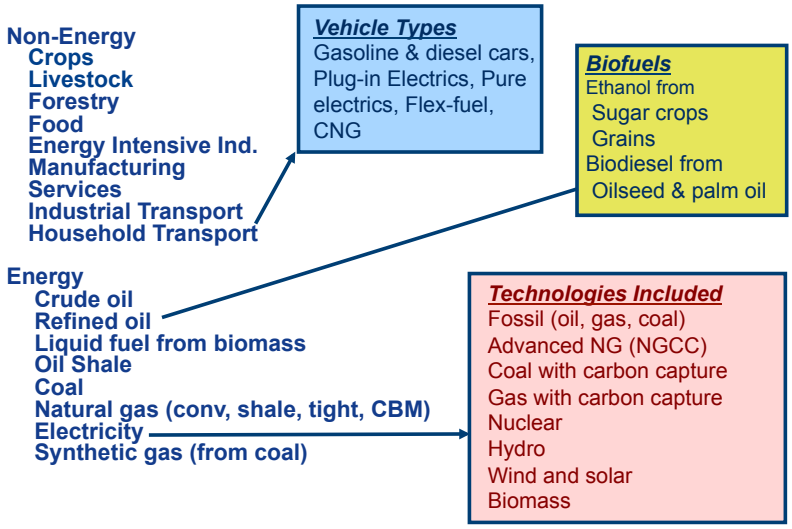

Figure A1. Sectors and technologies in the EPPA model.

To simplify the specification of expected contributions and emissions results, we aggregate the sixteen-region aggregation of the EPPA model into the three categories that are used in the MIT 2014 Climate and Energy Outlook: *Developed*, *Other G20*, and *Rest of World*. Nations within the several regional aggregations are detailed in the MIT Outlook (MIT Joint Program, 2014).

APPENDIX B. EXPECTED POLICIES AND MEASURES

The INDCs of the developed countries are stated in term of quantitative reductions below a base year—e.g., 40% below 1990 for the E.U., 26% to 28% below 2005 for the U.S., 25% below 2005 for Canada—whereas the pledges of the *Other G20* and *Rest of World* may be in terms of emissions intensity, reduction below a projected baseline or other measures. Our analysis of global emissions to 2040 reflects our expectation of performance given pledges submitted. Our assumptions about mitigation activity by those nations who have not yet declared their INDCs (see Table 1), and our analysis about performance of less-developed parties, are influenced by our expectation of the level of external aid they can count on.

The analysis of national effort depends on the policies and measures undertaken in the attempt to meet the declared emissions targets, and we expect that policies and measures—mainly regulatory actions and various forms of subsidy—will dominate this activity. The aggressiveness of implementation of these measures will differ depending on the economic position of the three groups of nations and regions in Table 1.

Note that the projection takes account only of INDCs submitted to date or pledged, and does not consider further achievements that might come with subsequent cycles of pledges. We project these activities to 2040.

B1. Electric Power

Electric power generation is the single largest emitting sector in most countries, and the main policy effects on emissions can be captured with just two options: controls on coal-fired generation and renewable energy mandates.

Coal-Fired Generation. Coal generation is the largest source of electric sector CO_2 emissions, and is the obvious target of emissions-reduction measures. Depending on the country or region, the means of reducing these emissions range from limits on the emissions rate of new plants to a gradually tightening squeeze on the emissions of the existing fossil fueled generation fleet. In many regions, air pollution control is a major motivation for regulations that force out coal generation. While the policy specifics may differ among countries, the net effect, at least on the horizon of this study, is to limit the building of new coal generation and to gradually take the oldest and least efficient units out of service.

Table B1 catalogs our assumptions of the effects of INDCs submitted to date and expected at some time in the future. We approximate the effect of the various measures they will apply by a simple rule: only new coal plants with CO_2 capture and storage will be built in these regions, and existing plants will be retired at age 60. This restriction is not applied to the E.U. and China because generation falls under subject to a national target, but all other regions in the *Developed* category are affected—particularly the U.S. Among the *G20* regions, Brazil is omitted because its coal generation is insignificant. India is assumed to reject any restraint on its coal use in the period to 2030, and therefore

Table B1. Expected retirement of old coal plants and constraints on new build.

Region	Expected Measures	Details
Developed		
Australia-New Zealand	Restricted coal generation	
Canada	Restricted coal generation	
E.U.+	---	Restricted by ETS target
Japan	Restricted coal generation	
USA	Restricted coal generation	Assume effective Power Plant Rule
Other G20		
Brazil	---	Insignificant coal generation
China	---	Restricted by intensity target
Dynamic Asia	Restricted coal generation	
India	---	Expected to reject restraint on coal use
Mexico	Restricted coal generation	
Russia	Restricted coal generation	
Rest of World	---	No restriction in AFR, MEA, REA, ROA

its coal generation emissions grow over this period. For the *Rest of World* regions, the main source of current emissions from coal-fired generation and projected growth is South Africa. We assume that South Africa, and the other *Rest of World* nations, will not pledge to reduce their coal use over the study period.

Renewable Energy Mandates. These measures increase levels of renewable generation via renewable portfolio standards, feed-in tariffs, tax subsidies, etc. They are motivated by a number of concerns other than reduction of greenhouse gases, including air pollution control, energy security and the long-term sustainability of the energy system; however, in recent years the issue of climate change has weighed more heavily in their justification.

We assume the *Developed* regions (E.U. excluded) will pledge to bring renewables (not including hydroelectric power) to 10% of electric generation in 2020, rising to 15% by 2030 and a constant percentage thereafter. The European Commission has proposed a target for 2030 of 27% renewables in total energy consumption, and it is assumed the E.U. percentage will increase further to 35% by 2050. The *Other G20* and *Rest of World* regions are expected to start at a lower percentage: 3% in 2020, rising to 5% by 2030 and maintaining a constant percentage thereafter.

B2. Transport

In wealthier countries like the U.S., personal vehicles are by far the primary source of transport emissions, while in other regions commercial vehicles (particularly large trucks) are the main source. Policies and measures undertaken in the transport sector are expected to address both categories.

***Personal Vehicles*.** Many nations have adopted (or are considering) design standards for new vehicles, some based on fuel efficiency and others on greenhouse gas emissions. Most of these standards differentiate between automobiles and sport utility vehicles used

for personal transportation, though some nations (e.g., the U.S.) apply a common standard based on weight or vehicle footprint. We expect that imposition and tightening of these standards will be part of the NDCs of all nations. Though the more developed countries tend to lead in this area, vehicle design and manufacturing is a global industry, so efficiency measures will influence all countries regardless of a political commitment to bear the cost of emissions reduction.

Our expectations for personal transport are stated in terms of fuel efficiency, and it is assumed that from 2020 forward the efficiency of new vehicles (in mi/gal including the effect of some substitution of hybrid- and all-electric units) will decline by 2% per year. For *Other G20* and *Rest of World* regions, the decline rate is 1% per year. The assumed vehicle efficiencies represent on-road performance, which is found to be worse than as measured by standard test procedures. Also note that these are new vehicle standards; the EPPA model also takes account of the rate at which more efficient vehicles enter the vehicle fleet.

Commercial Transport. In the EPPA model, commercial transport is one aggregate sector including road, water and air transport, though it is worth noting that around 80% of commercial transport CO_2 emissions are from commercial trucks. A number of measures have been adopted or proposed in various countries to lower the emissions of this sector, including efficiency standards intended to improve engine design and lower wind resistance, efforts to improve the efficiency of delivery networks, and measures to shift freight from truck to rail or water.

We expect efforts to lower the emissions of this sector to be included among policies and measures underlying the NDCs, and we reflect these measures in terms of a percentage reduction in oil use below the reference level.[8] We assume the reduction below reference levels for the *Developed* regions will be around 5% by 2020, rising to 10% in 2030, and constant thereafter. Because of the limited opportunities for mode shift and the fact that used trucks from developed countries tend to find their way into less-developed regions, the improvement in performance in the *Other G20* and *Rest of World* is assumed to be only about half that in the *Developed* regions.

B3. Household Efficiency

Most countries apply a range of regulations and incentives in an effort to lower their energy use and, more recently, cut their greenhouse emissions. Examples include building codes, appliance standards, household financial incentives for weatherization, and mandated electric and gas utility efficiency programs. Opportunities exist almost everywhere to push harder on efforts to improve household efficiency, and we assume *Developed* regions are likely to attain a 10% reduction by 2030, with the *Other G20*

[8] In the EPPA model, the efficiency of the Commercial Transport sector—like others—is assumed to improve year-to-year, independent of any efforts spurred by the climate negotiations. For details, see Paltsev *et al.* (2005).

realizing roughly half this improvement, and the *Rest of World* group realizing only a 3% improvement over this period.

B4. Land Use

A long-standing effort has been underway to reduce the emissions from land use, with a main focus on forest destruction under a program on Reducing Emissions from Deforestation and Forest Degradation (REDD). Three EPPA regions are responsible for the largest contributions to these land-use emissions: East Asia (ASI), which includes Indonesia and other forested Asian regions; Brazil (BRA); and Other Latin America (LAM), which includes a number of countries sharing the Amazon rain forest and other forested regions. These regions will, as in the Copenhagen Accord, include reductions in their emissions from forest destruction as a major component of their NDCs. Their estimated contributions take account of recent changes in forest policy in Brazil and includes additional reductions below the Copenhagen baseline projection, averaging 7.5% in 2020, and achieving 15% by 2030.

B5. Non-CO_2 Gases

Recent years have seen increased domestic and international efforts to address the emissions of short-lived greenhouse gases, with programs such as the multi-nation Climate and Clean Air Coalition for Reducing Short-Lived Climate Pollutants. These programs focus on methane, hydroflurocarbons (HFCs) and black carbon aerosols. We consider only the most prevalent of these climate influences: methane. The two main methane emissions sources are the agriculture sector and the energy sector (including the natural gas production, transmission and distribution system, and oil and coal production).

We expect that efforts will include control of fugitive emissions from the natural gas system, and of gas leakage from oil production facilities. Control of methane in coalmines has long been an important activity, but augmented efforts toward methane capture and use are likely to emerge as well. Emissions of methane from agriculture come mainly from flooded crops, like rice, and from ruminant animals. We expect that pledged policies and measures will include changes in crop practices, irrigation patterns, and animal feed, as well as expanded efforts to control emissions from animal feed lots. Finally, efforts to control emissions from municipal waste dumps are likely to expand worldwide.

The contributions from these methane control efforts are expressed as a percentage reduction below the Copenhagen baseline level. We assume that *Developed* regions will pledge a 20% reduction in these emissions by 2030, holding this percentage constant thereafter.

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