Informing transparency in the Paris Agreement: the role of economic models

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Henry D. Jacoby[1*], Y.-H. Henry Chen[2] & Brian P. Flannery[3]

Abstract

Establishing a credible and effective transparency regime to support the Paris Agreement—broader than its formal 'transparency framework'—will be both crucial and challenging. The Agreement provides for review of achievements under national pledges (Nationally Determined Contributions, or NDCs), but much of this information will become available only well after key steps in the launch of this latest attempt to control human influence on the climate. Still, in these early years, information and understanding of individual and collective performance, and of relative national burdens under the NDCs, will play an important role in the success or failure of the Agreement. However, because of the phasing of various steps in the 5-year cycles under the Agreement and the unavoidable delays of two or more years to produce and review government reports, the Climate Convention and other intergovernmental institutions are ill-suited to carry out timely analyses of progress. Consequently, in advance of formal procedures, academic and other non-governmental groups are going to provide analyses based on available data and their own methodologies. The paper explores this transparency challenge—using the MIT Economic Projection and Policy Analysis (EPPA) model to construct sample analyses—and considers ways that efforts outside official channels can contribute to the success of the Agreement.

Policy Relevance

1. Because key national decisions are faced before full implementation of the transparency framework, being negotiated by the Ad-Hoc Working Group on the Paris Agreement (APA), urgent attention is needed to activities supporting the regime's system of pledge and review.
2. Outcomes of these APA negotiations, explored here, including features of reported NDCs and guidelines for tracking progress, will influence the effectiveness of the Agreement in encouraging greater mitigation effort.
3. Whatever the outcome of the APA negotiations, studies by academic and other non-governmental analysis groups will in the near term have a particularly great influence on the transparency objectives of the Agreement.
4. Challenges to the provision by these groups of clear, coherent, credible analyses are explored, leading to recommendations for improved documentation of methods and standards of practice in analysis.

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1. Sloan School of Management, Massachusetts Institute of Technology, Cambridge, MA
2. Joint Progam on the Science and Policy of Global Change, Massachusetts Institute of Technology
3. Resources for the Future, Washington, DC

* Corresponding author

1. LAUNCHING A NEW CLIMATE REGIME

The international response to the climate threat cannot afford a repeat of the experience of the 1997 Kyoto Protocol, where many years have been spent trying to implement legally binding, national emission targets for developed nations. In 2009, at the 15th meeting of the Conference of Parties (COP 15) in Copenhagen, the failure to fulfil the Bali Action Plan ultimately resulted in a reframing of the regime to one based on universal participation, with voluntary pledges and reviews of performance. It has taken another six years to conclude the Paris Agreement, that entered into force on 4 November 2016.[1] Disagreements remain unresolved, e.g., concerning finance and how common but differentiated responsibilities (CBDR) will manifest, and key procedures and guidelines are still under negotiation. Moreover, it is argued that a regime based on pledge and review cannot meet the challenging, long-term objectives of the Agreement (Barrett and Dannenberg, 2016; Nordhaus, 2016). It is, nonetheless, the system the world now has—perhaps the best possible given the nature of the problem (Keohane and Victor, 2016)—so nations have every incentive to gain maximum results from it. To this end, effectiveness in its early years—building the 'rulebook' and procedures, and, even more, achieving emissions reductions—will determine whether another long period will be spent in frustration, trying to reduce global emissions by this approach.

Here the focus is on one central aspect of the Paris Agreement that will be important for its early success: building the process to understand and review progress, both in individual pledges and collective outcomes, that will inform decisions to renew pledges going forward. The discussion considers ways that non-state actors contribute to this effort, with special attention to the role of economic models and how they may be made more effective, not just to support the transparency framework in Article 13 (Winkler et al., 2017), but also in a broader context to inform governments and other stakeholders.

The Agreement covers many aspects of the global climate effort, including mitigation, adaptation, capacity development, technology transfer, and diverse forms of financial aid. Its Article 4 (Mitigation) describes the process for voluntary emissions pledges, a component of the Nationally Determined Contributions (NDCs). In the run-up to Paris, nations were asked to declare their *Intended* NDCs (INDCs), and, by the start of the meeting, over 190 nations had done so—bringing essentially the whole globe into a mitigation regime for the first time. Most of these INDCs are being submitted, unchanged, as the first NDCs. As each nation joins, it declares its NDC of emissions reduction and other actions, extending through to at least 2025. This initial pledge is the first of a series, renewed in five-year cycles, wherein nations are expected to increase their mitigation efforts with each cycle. Most nations stated their INDCs in terms of a 2030 goal, though several (including the U.S.) chose target dates of 2025. By 2020 all parties to the Paris Agreement are required to submit or provide updated pledges for the second cycle, through to 2030.

Developed nations pledged economy-wide, absolute emissions reduction targets, though not all use the same base year or endpoint, and most are framed in terms of a single target year and not a budget over time. Developing nations are free to state their contributions in whatever form they find appropriate to their national circumstances. Most state their contributions in terms of the Kyoto basket of greenhouse gases, but some pledge reductions in

[1] For the history of the path to Paris and its provisions see Flannery (2015), Bodansky (2016).

CO_2 only. Some pledge a reduction in emissions intensity (e.g., tons per dollar of GDP) below a base year by some future year, but a large number frame their INDCs as a reduction relative to a business-as-usual projection of national emissions. Finally, some parties pledge to undertake specific policy measures, not an overall national target.[2]

Flexibility to accommodate domestic conditions made agreement in Paris possible, but also makes it challenging to construct a clear picture of the individual pledges, gauge collective achievement across the entire portfolio of INDCs, or evaluate the relative effort of parties to the Agreement.

1.1 The Role of Transparency within and Beyond the Paris Agreement

While transparency has specific meaning in the Paris Agreement (Winkler et al., 2017), the overarching framing encompasses a larger set of issues dealing with the progress of individual nations and the collective effort, as all these will inform and shape decisions regarding future pledges. One aspect concerns tasks and controversies that in previous climate discussions fell under the heading of measuring, reporting and verification, or MRV (Singh et al., 2016). All international agreements involve some system of MRV, and it serves many important functions (Wiener, 2015). Two among these are most important for this discussion: revealing the performance of the individual parties (i.e., through reports and reviews), and assessing the aggregate achievement of the pledges in reducing global emissions. The Paris Agreement contains provisions for both, but precisely how they will be implemented remains a matter of negotiation.

The expectation is that the transparency processes in the Agreement will take effect in the period after 2020, building from and enhancing procedures now in effect. For now, parties operate under reporting and review procedures established under the UNFCCC, as updated at COP 16 and COP 17, to monitor their progress under the 2010 Cancun Agreements and the UNFCCC more broadly. These consist of biennial reports for Annex 1 parties (developed nations), with a process of international assessment and review; and biennial update reports for most non-Annex 1 parties, with a process of international consultation and analysis. Differing approaches, with less stringent requirements for developing nations, were necessary to reflect CBDR.

The Agreement's Article 13 establishes a transparency framework to track both action and support by parties, with flexibility to account for differing national capacity. The objectives of the framework it establishes include the 'clarity and tracking of progress towards achieving Parties' individual nationally determined contributions under Article 4.' Free riding is a threat to such a voluntary regime, giving crucial importance to its review component. The effort nations put into meeting their first NDCs, and their willingness to take on additional reductions in subsequent cycles, will depend on credible information about whether others are doing what they pledged, and on perceptions of the fairness of the relative distribution of burdens. Of course, national pledges will continue to depend on national priorities and circumstances and, for developing nations, availability of support from developed parties.

[2] The NDCs of developed nations provide little or no information regarding assistance to developing nations, that may be important in interpreting and implementing their pledges.

The negotiators worked hard to overcome long-standing conflicts over MRV[3] to provide this information in as credible a form as possible. All but the least developed countries and small island states (who are given greater flexibility) are to report biennially, and each nation's report shall undergo a 'technical expert review' and be subjected to a 'facilitative multilateral consideration of progress.' The Ad Hoc Working Group on the Paris Agreement (APA) is to work out details of this review process, including the modalities, procedures and guidelines (MPGs) for accounting of the NDCs, deciding the content and timing of the reports by different categories of parties, and establishing review procedures.

Though not under the formal transparency framework, Article 14 establishes another information process that will, in fact, be an essential element of the broader transparency regime. Beginning in 2023, and each five years thereafter, the parties are to conduct a 'global stocktake' where they assess their collective progress in achieving various provisions of the Agreement, especially progress towards long-term goals. The hope is that each stocktake will lead the parties to take on greater efforts in their follow-on NDCs. Because 2023 is so far in the future, the parties also agreed to convene a 'facilitative dialogue' among the parties in 2018, to 'take stock' of the collective progress of all parties and to inform the preparation of future NDCs. Overall, the transparency process aims to demonstrate effective progress and provide understanding and support for more ambitious future pledges.

4.2 The Timing of Initial Cycles, Reporting Guidelines and Stocktakes

The rapid pace of events in the next decade creates a daunting challenge for the transparency objectives of the Paris Agreement. Figure 1 places its launch, the initial pledge cycles and the stocktakes, in the context of paths to alternative emissions futures constructed using the MIT Economic Prediction and Policy Analysis (EPPA) model. (Model details, expected NDC performance, and comparison of results with other models are provided in online supplementary materials.) The figure shows a projection of greenhouse gas emissions in CO_2 equivalents (CO_2-e), in the absence of mitigation effort pledged in the Agreement (providing baselines for discussion below of measures of national effort). Also presented is an estimate of the achievement expected from NDCs pledged for 2025 and 2030, with a projection of contributions to 2040. Actual global emissions from 2030 forward could well be lower than this NDC estimate, as a result of increased effort in subsequent pledge cycles, or higher if assumed initial NDC performance is not sustained. They will, in any case, depend on as yet unknown future commitments that are the concern in this discussion.

[3] See Niederberger and Kimble (2011) and Gupta et al. (2014).

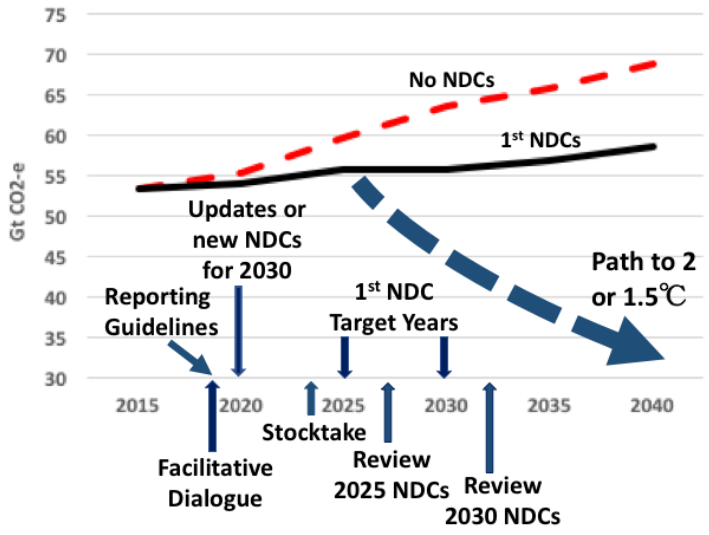

Figure 1. NDCs and Stages of Review

Also plotted is a cartoon of an emissions path consistent with a longstanding goal of the climate negotiations, restated in Paris, of holding the global temperature increase below 2°C (and to pursue efforts to limit it to 1.5°C). There are many and varied estimates of the emissions reductions needed in the first few pledge cycles to put the world on such a path (e.g., EC-JRC, 2015; Climate Interactive, 2016; Climate Action Tracker, 2015; International Energy Agency, 2015; Jacoby and Chen, 2014, 2015; Le Treut et al., 2015; Chen et al., 2016a; UNEP, 2016). What matters for this discussion is that all of these projections presume that very strong emissions reductions will be achieved in the second and subsequent pledge cycles. Indeed, the fate of the new regime likely will be largely determined in this early period—by pledges to be made in 2020 and 2025.

Transparency will thus be particularly important in the initial stages of the Agreement to develop confidence in reported numbers, and trust—not only among the parties, but also among engaged stakeholders and the public. Without it, nations may find greater difficulty in taking the decisions required for an effective launch. One major challenge of achieving this result is suggested by the sequence of events in Figure 1: the crowded timing of early events and decisions. COP 22, held in Marrakesh in 2016, laid out the APA's agenda to negotiate reporting guidelines for the pledge-and-review system. Unfortunately, these implementation details are not due for completion and submission for approval by the Conference of the Parties of the Paris Agreement (CMA) until 2018, with first reports by the parties under the new system unlikely to appear until after 2020. In the meantime, key steps in the Paris launch must be successfully accomplished. The second-cycle NDCs, new pledges for 2030 (or updates of those NDCs initially set through 2030), are to be made by 2020, at which time there will be little official information on performance under the first NDCs and likely only a rough impression of efforts undertaken in preparation for them.

Moreover, the 2023 Global Stocktake, which is to cover all aspects of the Agreement, must be carried out several years before final reports are available on achievements under the first NDCs. The 2018 facilitative dialogue, with its focus on mitigation, comes in the same year that reporting guidelines are to be submitted for adoption by CMA!

A second challenge is to achieve effective transparency provisions in these APA negotiations, which must confront long-standing disagreements over MRV not resolved in the Paris text—especially those related to differentiation between developed and developing countries. The delicacy of the task is suggested by the language of the Agreement: the transparency framework is to be 'implemented in a facilitative, non-intrusive, non-punitive manner, respectful of national sovereignty, and avoid placing undue burden on [developing country] Parties.' Three of the agenda items assigned to the APA are relevant to this discussion (APA, 2016):

Agenda Item 3: Further guidance regarding the features of the NDCs. Great flexibility was provided to nations stating their INDCs, but now they are to consider the information needed to facilitate clarity, transparency and understanding.

Agenda Item 5: Modalities, procedures and guidelines for reporting on NDC performance. This concerns fleshing out the information, methods and procedures to report, review and consider progress formally under the Agreement.

Agenda Item 6: Matters related to the global stocktake. Agreement must be reached on the purpose and goals of the stocktake meetings, sources and content for input, and procedures to be followed.

Overriding all of these topics is the 'undue burden' question: the degree of differentiation of reporting and review obligations according to the level of national development and internal capacity to prepare the required data and analysis.

Agreements reached in the APA negotiations will have a substantial effect on the credibility of the formal transparency framework and its ability to motivate evolution of the Agreement. They are explored further in Section 2. Even with APA success in agreeing to the desired MRV, however, procedures built into the Agreement, plus the lags in report preparation, mean that in its critical early years insufficient information will be available for timely review of the NDCs of individual parties, and of global progress toward long-term goals. The resulting demand for transparency, within and outside the Paris Agreement, will then be filled, for better or worse, by analyses carried out largely by groups outside the bodies of the Climate Convention and other intergovernmental organizations—mainly non-governmental analysts in NGOs, academia, business, etc. Section 3 explores ways that these efforts may be made more effective in supporting the overarching transparency regime, to inform stakeholders as well as satisfy the formal requirements of the Agreement.

4.3 Using Economic Models to Inform the Transparency Regime

While a variety of approaches can be applied to support the overall transparency regime, quantitative analyses using climate and economic models are essential tools for assessing NDC mitigation achievements, comparing national efforts, and tracking progress toward long-term goals. Here the focus is on economic models like the EPPA model used here, which provide a capability to evaluate interactions involving multiple sectors, regions, technologies and policies.

These analysis frameworks are of different structure and capability (Kriegler et al., 2016), and they share the limitations of any effort to represent complex economic institutions. In particular, they usually must aggregate groups of smaller countries, and can only roughly approximate the policies and measures applied in emissions control. Still, the usefulness of the insights they can provide is indicated by a long history of inclusion in assessments by national and international bodies: e.g., IPCC Working Group 3 (IPCC, 2014), UNEP (2016), and the secretariat of the UNFCCC (2016).

In addition to *ex ante* simulations of anticipated domestic and collective results from initial NDCs, going forward these models can provide insights not only to inform but also to help improve transparency processes—illuminating progress and trends, and aiding in *ex post* analyses of outcomes. For example, potential contributions include:

Understand (I)NDCs: To simulate performance, analysts must translate national pledges into quantitative specifications. Even for the reference case, this may include assumptions for population change, productivity gains, GDP, and the cost and performance of future technologies. Moreover, study of (I)NDCs requires detail regarding policy measures, frequently requiring analysts to supply information not available in the pledge itself. A summary of key gaps and their relevance to assessment would improve the transparency process (Damassa et al., 2015).

Clarify *ex ante* projections: Although (I)NDCs come in many varieties, once they have been translated into quantitative parameters for model simulation, results can be exhibited in common formats, units and base years—helping to clarify emissions implications and the comparability of national pledges.

Account for economy-wide and cross border interactions: IAMs allow quantitative evaluation of interactions that may enhance or interfere with presumed outcomes based on analysis of single sectors or individual nations. Because economic feedbacks and interactions—among domestic sectors, along supply and value chains and across borders—are ubiquitous, assessment not only of global, but also of domestic outcomes requires consideration of the full portfolio of NDCs. These effects include both direct impacts and changes in the terms of trade (the relative prices of a nation's imports and exports).

Provide insight into progress and trends through *ex post* reviews: To inform future pledges it will be important to understand efforts to meet earlier ones. Reality may differ from assumptions that underlay early NDCs: i.e., unforeseen and unforeseeable circumstances such as changes in government, recessions, natural disasters (e.g., tsunamis), and technological advances (e.g., fracked oil and gas). Analyses can help sort out the validity of earlier assumptions, the effectiveness of policies, and the consequences of unanticipated developments.

In this way, analyses using quantitative models can be useful not only to provide data for use within the transparency process, but also to indicate the types of information, reports and metrics that could be used to improve the entire process going forward.

2. PROVIDING TRANSPARENCY

Three components of transparency are needed to support the mitigation goals of the Paris Agreement: credibility (reliably describing national performance in mitigation and support), effectiveness (in achieving national and aggregate global emissions outcomes), and fairness

(regarding relative effort). Each has its own problems of data, definition and analysis that are unlikely to be resolved in time to support transparency provisions of the Agreement in its crucial early years, illustrated in Figure 1. Indeed, rather than a process alternating between pledging and reviewing outcomes, during the startup phase of the Paris Agreement the sequence is pledge (2015 to 2025 or 2030), pledge or renew pledge (2020 to 2030), pledge (2025 to 2035), report outcomes (through 2025, in perhaps 2027) and then review (2027 or later). In this period, the transparency system must depend heavily on model studies based on partial reports and reviews of trends (rather than outcomes) and model projections of progress.

2.1 Individual Performance

A crucial early task is clarification of the 'features' of the NDCs. Even for the developed nations, who pledge economy-wide reductions below a base year, there are issues to be resolved. NDCs based on a business-as-usual (BAU) projection, a decrease in emissions intensity, or a sectoral outcome, leave much to be desired (Damassa et al. 2015)—and to be assumed by analysts. For example, some NDCs based on a reduction below BAU do not include the implied emissions forecast. Similarly, intensity pledges usually do not specify the future GDP level to which the intensity target will apply. Negotiations within the APA's Agenda Item 3 will attempt to refine the elements of a clear pledge and an adequate report, e.g., including starting points and future reference values that underlie the proposed NDC. For reductions below BAU emissions, inclusion of a clearly defined emissions forecast seems an obvious requirement. The GDP projection underlying an intensity pledge is more controversial. Nations making this pledge prefer the flexibility to adjust their contribution to uncertain future growth. Also, they perhaps fear that the projection will be used to convert the NDC into an absolute emissions goal, like that expected of developed nations.

Then there are the issues under the APA's Agenda Item 5: guidelines for reporting on NDC performance. Inventories of greenhouse gas emissions and sinks will build on decades of experience with previous UNFCCC reports and methodologies developed by the IPCC, but additional information desired to track progress on the NDCs is yet to be determined. There are proposals for the guidelines to include metrics for progress on policies and measures being applied and how they are consistent with the NDC, and perhaps with other features of a low-emissions development strategy (e.g., APA, 2017). On this point the negotiations will confront the requirement that the procedure must be 'non-intrusive' and 'respective of national sovereignty'—familiar aspects of controversy over the ongoing requirement for CBDR in MRV.

In the absence of reliable and timely national reports and reviews under the Paris Agreement, outside groups are developing frameworks for study and documentation of institutional development and policy formation (e.g., Barua et al., 2014). Much of this effort is intended to inform and guide domestic mitigation actions, however, and proposed frameworks are too complicated for inclusion in studies of aggregate achievement or comparisons of effort at the national level. For example, they often distinguish policy instruments by greenhouse gas, economic sector, and national institutional structure & history, and cover multiple stages of formulation: public consultation, legislation, licensing and permitting, financing and implementation, and expected effects. These efforts can nonetheless contribute to projections of individual effort and likely emissions results and thereby contribute to larger transparency challenge.

Also to be determined in negotiations under APA Agenda Item 5 is the timing of the first national reports under the new guidelines. Initial NDCs involve goals through 2030 (or in some cases 2025), and with expectation of updates in 2020 (through 2030) and 2025 (through 2035). However, the first national reports under the emerging transparency framework might be expected no earlier than 2022. Experience with previous reports under the Framework Convention shows that, because of the normal lags in preparing inventories (and other items likely to be agreed) these reports cannot be expected until many months after the close of the report year. So information for 2022 might not be available until perhaps some time in 2023 or 2024. Moreover, national reports on performance over the full course of the first NDC period would not be available, also indicated in Figure 1, until well over a year after its close.[4] For the preponderance of pledges stated in terms of a 2030 goal, of course, the information on their ultimate performance will come even later.

2.2 Aggregate Achievement

The willingness of nations to take on burdens under the Paris pledge-and-review system will depend not only on information about individual performance but also on confidence that the effort is producing global results in line with long-term goals. As the Agreement proceeds through the years of the first NDC, national inventories will provide some indication of the trajectory of emissions. Unfortunately, as noted above, important steps in regime implementation must be taken before this component of the transparency framework will be available to guide the construction of a global picture. One such event is the 2018 facilitative dialogue. It is to consider collective progress on emissions mitigation in the light of the Agreement's temperature goals and to inform preparation of the next cycle of NDCs. Various sources of mitigation information will be available to the dialogue. The IPCC is undertaking a Special Report on pathways to limit warming to 1.5°C, and anticipated impacts. Other intergovernmental efforts, like the annual Emissions Gap Report prepared by the UN Environmental Programme (UNEP, 2016), will include a summary of emissions projections under the first-cycle NDCs. As with past reports by these organizations, however, these studies will be based mainly on analysis published by non-government groups. Also, many studies focus primarily on emissions outcomes without providing insight into economic and social consequences that will be essential to judging comparability of effort.

Unfortunately, as noted above there are significant questions about how to interpret many of the NDCs for inclusion in forecasting models—issues that may be clarified in negotiations by the APA under its Agenda Item 3, but in any event not before 2018. When these differences in interpretation and baseline projections are input to forecasting models of differing structure and parameter assumptions, the result is a wide range of estimates of national and aggregate achievement under the initial NDCs (e.g., UNEP, 2016; Levin and Fransen, 2015). Several aspects of these analyses contribute to variation in results, for example:

Base year data. While commonly-accepted historical data are available on fossil and industrial CO_2 emissions, there is greater uncertainty about human emissions of methane and nitrous oxide. Also, estimates of land-use emissions of CO_2 differ substantially (IPCC, 2014, Chapter 11).

[4] These lags do not consider the additional time required for the other two stages in the transparency framework: technical expert review and facilitative, multilateral consideration of progress.

Economic and Emissions Baselines and Unbounded Pledges. Estimates of emissions of nations pledging a reduction below a projected emissions path, or in emissions intensity, differ in their assumptions about population, economic growth, and associated energy use and greenhouse emissions, as noted above. For later years projections are also sensitive to differing assumptions regarding technology cost and performance. Until the reporting guidelines require more information on the assumptions underlying the NDCs, these essential details will remain uncertain. In addition, many pledges do not set a clear bound on emissions.

Contingent Pledges and Assumed Performance. The NDCs of several developing countries are conditioned, often in an unclear way, on the provision of financial assistance, with limited confidence that it will be forthcoming—largely because lack of clarity, or complete absence of information, on financial commitments by developed nations. Also, for some countries the expected performance must be conditioned on uncertain domestic circumstances (e.g., the climate policies of the new US administration). In general, estimates by government agencies and international groups (e.g., the UN Environment Program and International Energy Agency) are constrained to take the NDCs at face value, even when nations lack policies to achieve them.

Macroeconomic and Trade Effects. Because analysis of most pledges (other than those of developed countries) are based on projections of national emissions or GDP, results differ depending on whether projections account for the economic effects of a nation's own NDC and those of other parties. Emissions outcomes cannot be established based on pledges or policies that deal with only a part of the economy; quantifying national and global outcomes needs to take account of the full domestic and international response to the entire portfolio of NDCs. As illustrated in Section 2.3, the effects through trade of the actions of others can have a substantial effect. Nonetheless, most analyses of aggregate achievement under the Paris pledges are based on partial equilibrium studies, nation by nation, and ignore the macroeconomic effects. If, however, other studies may attempt to account for these effects—for example, in projecting emissions reduction under an intensity target—there will be inconsistency among the study definitions.

Transparency in studies of the expected aggregate performance of the NDCs, and of pledge cycles to come, will be increased if parties to the Agreement establish clear requirements for the information and assumptions that should be contained in national NDCs. Even with greater clarity in the NDCs themselves, however, users trying to understand the NDCs and their effect on global emissions will be aided if groups performing analyses can agree on assumptions about those inputs where coordination makes sense, and provide clear standards for documentation when common assumptions may lead to the loss of valuable information. Furthermore, as suggested in Section 1.3, greater coordination and documentation of results using economic models can yield better information for negotiators as they resolve guidelines for accompanying information to describe NDCs, and on metrics to measure progress.

2.3 Comparability and Relative Effort

Measures of national effort and means of comparison among nations are not part of the transparency framework established in Article 13 of the Paris Agreement. APA Agenda Item 6 concerning plans for the Global Stocktakes (to begin in 2023) does not include them either, nor

are they likely to be considered in the 2018 facilitative dialogue. They are nonetheless very important for the Paris launch. Credible information about what others are doing is needed to develop trust and an expectation of reciprocity (Ostrom. 1998; Wiener, 2015); and much of the discussion of equity in the climate regime has long been framed in part in terms of national mitigation effort (e.g., Reiner and Jacoby, 1997; Cazorla and Toman, 2001). These measures will therefore be a potent input to national decisions whether to take current NDCs seriously, and to increase ambition in the second and subsequent NDC cycles.

Non-state actors are devising these indicators for the NDCs under the Paris Agreement, showing a variety of pictures of effort levels—e.g., Climate Action Tracker (2016) assigns grades for the ambition of the parities. Seeking some order in this process, Aldy and Pizer (2015) lay out desired features of metrics of national effort that will serve the dual function of revealing a nation's effort and providing a basis for international comparison. They should be comprehensive (covering a nation's overall effort), measurable and replicable, and universally applicable to all countries. No one measure meets all these criteria; clearly a portfolio of measures will be needed. Even beyond the difficulties created by poor definition of the NDCs, puzzles arise in constructing these analyses. The MIT EPPA model is used to illustrate these difficulties and highlight the likely disagreements in interpretation of the numbers. To simplify the presentation, calculations focus on just eight of the 18 EPPA regions, which contributed just over 60% of global greenhouse emissions in 2015: United States (USA), European Union (EUR), Japan (JPN), Canada (CAN), China (CHN), India (IND), Mexico (MEX) and Middle East (MES)[5].

*Reduction from Baseline & Lowered Intensity***.** Effort based on the reduction below a baseline projection would be a sound measure of national effort if there were a standard, commonly-accepted way to construct the emission outlook—and, going forward, if the accompanying information required for that approach were incorporated in guidelines agreed upon by APA. Moreover, even if the guidelines ask for the GDP projection underlying an intensity pledge, interpretation of this measure will be confounded by the baseline question, as illustrated by Figure 2. It shows the emissions intensity of the eight regions in 2005, and in 2030 as a result of the NDCs of each country or aggregate region.[6] Also shown is the EPPA model estimate of the emissions intensity of each region under the baseline (No NDCs) projection in Figure 1. Emissions intensity is falling even with no mitigation effort because of the continuation of a long-established pattern of greater efficiency of energy and emissions use with time, technology change and economic growth.

This natural pattern of intensity change, even without climate policy, raises the question of which level of intensity improvement is appropriate as a measure of individual effort. Is it the achieved (or projected) level, or the change net of achievement that would have come in any case? The latter number seems more relevant, but in any case a clear comparison requires modeling assumptions about baseline growth and other characteristics of the economy (rates of technology change, efficiency improvement) that are consistent across regions.

[5] The Middle East region includes Bahrain, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Palestine, Qatar, Saudi Arabia, Syria, UAE and Yemen.

[6] The INDCs of China and India are in intensity terms, Mexico's is a reduction below a business-as-usual projection, and pledges of some of the MES nations are a collection of specific actions.

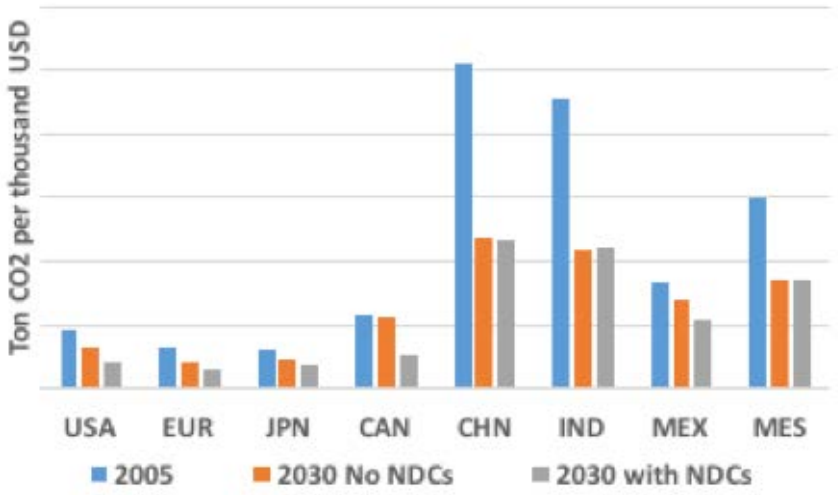

Figure 2. Emissions Intensity, 2005 and 2030, with and without NDCs

Emissions Price and Welfare Cost. A common measure of a nation's mitigation effort is the economic burden imposed on its citizens, stated as GDP loss or a reduction in some more direct measure of welfare such as equivalent variation (a measure of willingness to pay to avoid the change) or reduction in personal consumption. In most such estimates an economic model is used to compute the welfare loss assuming the pledged reduction is achieved by applying a national price on emissions (e.g., Aldy et al., 2016). Figure 3 shows the result of such a calculation using the EPPA model. The upper panel presents the emissions price in 2030, and the lower panel shows the associated welfare change, measured as the percentage reduction in consumption. (Note that, for clarity, MEX and MES are plotted at a different scale. Also, Japan's cost is effectively zero.) The solid bars show price and welfare change if all nations are meeting their NDCs.

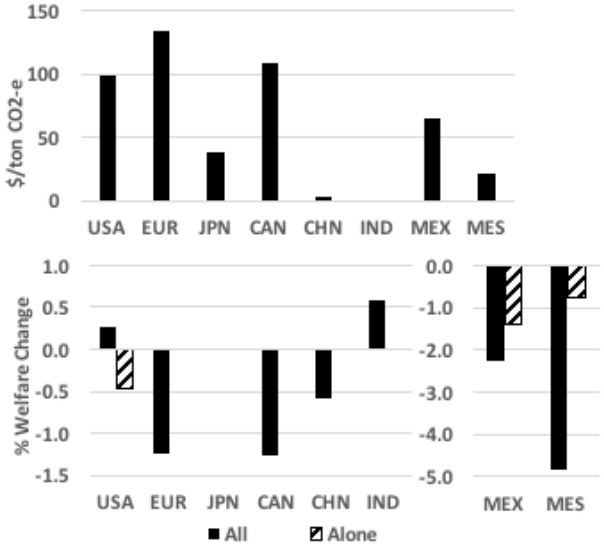

Figure 3. CO_2-e Price & Welfare Change, Alone and All Participating, 2030

First, notice that emissions price is not a good measure of conventional notions of economic burden. Countries have very different economic structures, and sensitivity of domestic energy prices to the emissions price. Also evident are the effects of international trade on the relative percentage welfare burdens of the NDCs. The U.S., with a relatively high price, experiences near zero welfare loss; India with in effect a zero price sees a welfare benefit; and the MES sees the highest welfare loss of all. These seemingly odd outcomes are the result of the effect of a global mitigation effort on prices and trade volumes of many goods but, most importantly, of fossil fuels.

This trade effect can be further illustrated by following experiment: what would be the welfare cost if a country were acting alone, meeting its NDC while the rest of the regions did nothing? The hatched bars in the lower figure present such an example for 2030 using the United States (a net energy importer), Mexico (with substantial energy exports) and the Middle East (where energy exports are a dominant portion of GDP). Acting alone, the U.S. would experience a loss of roughly ½%, MEX about 1½% and MES ¾%. When all nations take action, the U.S. benefits from the effect on its terms of trade, for a welfare gain of about ¼%, while the nations of the Middle East get hammered. The welfare loss in Mexico rises to over 2%, and in the Middle East to almost 5%.

These results raise a caution and a question. First, care should be taken with partial equilibrium estimates of the cost of NDCs under the Paris Agreement—that is, those based on individual country studies that necessarily ignore trade effects. And second, which is the correct cost-based measure of mitigation effort, the partial equilibrium measure or the actual impact within the global trade system? At the very least, studies of relative effort should be transparent as to which measure is being used.

Price Instrument vs. Policies and Measures. Studies that assume a price-based implementation of the NDCs (e.g., Aldy et al., 2016) yield a flawed measure of welfare cost for most countries. A uniform national price is an analysis-facilitating fiction that does not reflect the combinations of policies and measures (PAMs) actually being employed. The difference between the two approaches can be illustrated with an estimate of PAMs being adopted by the eight regions explored here. The welfare effects of PAMs *vs*. a universal emissions price can be illustrated by imposing just those being applied in electric generation and transport (details are provided in online supplementary materials). Figure 4 shows the resulting welfare cost for 2030, compared with the cost under a uniform emissions price, repeated from Figure 3.[7]

[7] Another question, not dealt with here, is whether either measure of climate-related burden should be corrected for non-climate co-benefits. For example, air pollution control alone can provide a substantial justification for China's NDC (Karplus, 2015; Li, 2016).

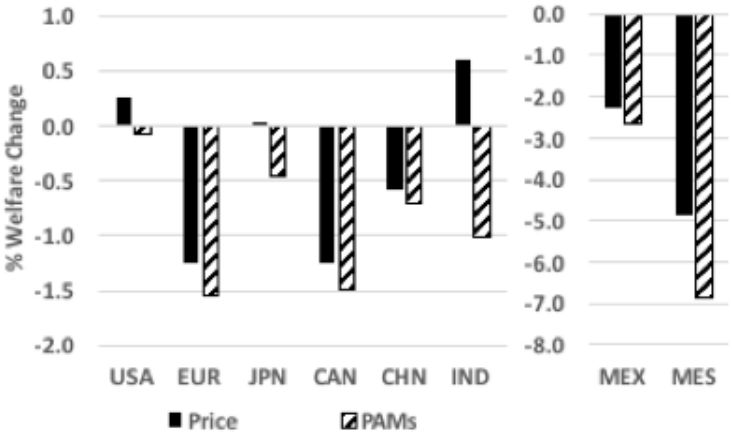

Figure 4. Welfare Effects of NDCs: Price vs. Policies and Measures, 2030

There is a long history of studies showing examples of the much higher cost of meeting a target using PAMs rather than by a uniform price (e.g., Goldberg, 1998; Rausch and Karplus, 2014), so, not surprisingly, the estimated level of effort is higher with the less-efficient policies and measures that are being implemented in most nations. Of course, detailed information on country PAMs is not yet available; some parties may not have yet chosen them. But more complete PAMs descriptions—perhaps including other sectors, such as efficiency standards on various products and industrial processes and controls on agriculture and land use—will nonetheless yield similar results.

Though the PAMs actually being applied are the proper basis to assess the cost of a national effort, many of the economic models applied to analysis of the cost of mitigation lack the internal structure to represent even a rough approximation of them, and no current model is able to study them in their full variation and detail. Also, there is an argument by some economists that an effort measure should not consider the PAMs actually applied (rather than a cheaper universal price) because it rewards a nation for pursuing inefficient policy. Analysis using both policy assumptions—uniform prices and PAMs—will be found in studies of effort implied by the NDCs. At the very least, transparency will require clear documentation of the procedures followed.

3. ENHANCING THE TRANSPARENCY REGIME

The preceding discussion suggests ways that analyses of the NDCs by non-state groups will be important to the transparency objective, particularly in the early years of the Paris Agreement. These groups are likely to continue to produce and publish analyses of individual and aggregate achievement, and estimates of various measures of the country effort. Regrettably, there are likely to be confusing differences among studies for reasons suggested above: differing projections of BAU emissions and GDP projections, different assumptions about contingent pledges and assumed performance, alternative concepts of effort or welfare

cost, and calculations applying different types of economic models.[8] Unfortunately, these differences are generally not well documented, and there currently is no organization that can bring about greater order in the studies where it is appropriate, and document the differences where it is not.[9] This lack of coherence and documentation limits the transparency that would aid the Paris launch.

It is unlikely that national and intergovernmental organizations in the climate domain can adequately meet this institutional need, and certainly not in time to be relevant to the rapid pace of events shown in Figure 1. The IPCC has played a central role in setting guidelines for emissions inventories. An extension of this work into the wider transparency domain is a possible route to coherence, and likely is essential in developing the formal process. The IPCC would, however, face several barriers to improving model studies of NDCs and projection of global outcomes. Largely limited to summarizing the peer-reviewed literature, the IPCC is not organized to recommend solutions to the types of technical economic questions outlined above. Even if it were, the timing is wrong as the IPCC's process involves long lags in initial organization, deadlines for consideration of literature, and extensive review procedures.

Alternatively, a variety of non-governmental organizations and institutions could provide useful analyses that contribute to, inform and improve the overall transparency process. While a wide range of governmental organizations are involved in the climate issue (Keohane and Victor, 2010), it is also the case that a number of functions, including governance functions, is being performed by informal, non-governmental institutions—what Abbott et al. (2016) call private transnational regulatory organizations, or what Green (2010) terms private entrepreneurial authority. These entities propagate standards for measurement and reporting and verification that have come to be accepted by private, non-profit and governmental entities—e.g., standards prepared by the World Resources Institute and the World Business Council for Sustainable Development for measuring and reporting greenhouse emissions (www.ghgprotocol.org), or those developed and improved over time by a number of industry sector groups.

It is possible that existing or new private organizations will step up to recommend standards of practice for *ex ante* studies of the NDCs, for analyses of progress and trends in performance of actual NDCs, for comparison of relative effort, and overall aggregate accomplishment. Several existing organizations have the capacity and international reach to take on the task. For example, as cited above, a number of NGOs are active in the domain of measurement, reporting, and verification with experience in collection, reporting and review of domestic institutional and policy developments.[10] However, many lack the internal modeling expertise to organize such an effort by international modeling groups—such as has characterized the Stanford Energy Modeling Forum (e.g., Clarke et al., 2009), the study of models of long-term climate change mitigation by the AMPERE project (Kriegler et al., 2015), or working groups of

[8] Differences in model structure are another source of variation in estimates of mitigation cost. For example, models with less sectoral detail, or simpler representation of capital vintages, tend to show lower costs (Chen et al., 2016b)

[9] Indeed, the focus of many of these efforts is not on these first pledges, or enhancement of transparency, but on the emissions 'gap' to be closed to remain consistent with temperature goals (e.g., Rogelj et al., 2016).

[10] Examples include the International Standards Organization and its ISO 16064, the World Resources Institute (Singh and Vieweg, 2015) and IDDRI (Deprez et al., 2015).

the Integrated Assessment Modelng Consortium (www.globalchange.umd.edu/iamc). To improve analyses of the Paris results these resources need to interact and, where appropriate, recommend common approaches for their own analyses. Also, while there is no ideal transparency system or economic model of it, such informal, unofficial approaches and providers can help point the way to continuous ongoing improvement in the formal process under the Paris Agreement.

The success of a system of pledge-and-review will be strongly influenced by the credibility of the transparency process. Later in the cycle of NDC updates *ex post* reports will provide a clear basis to judge actual progress. As can be seen in the crowded set of events in Figure 1, however, time is short to evolve a widely-accepted set of standards to help bring greater order into the *ex ante* studies, and analyses of early progress and trends, that will inform the initial stages of the Paris launch. These studies and analyses will be from many sources. To the extent they are inconsistent and confusing, or colored by advocacy, it will be useful to clarify differences that result from varying assumptions and methods, and whether they are appropriate. This will help to assure credibility to support domestic decisions about current effort and more ambitious future pledges.

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REFERENCES

Abbott, K., Green, J. & Keohane, R. (2016). Organizational Ecology and Institutional Change in Global Governance. *International Organization,* 70(2), 247-277.

Aldy, J. & Pizer, W. (2016). Alternative Metrics for Comparing Domestic Climate Change Mitigation Efforts and Emerging International Climate Policy Architecture. *Review of Environmental Economics and Policy,* 10-1, 3-24.

Aldy, J., Pizer, W., Massimo, M., Reis, J., Akimoto, K., Blanford, G., Carraro, C., Clarke, L., Edmonds, J., Iyer, G., McLeon, H., Richels, R., Rose, S. and Sano, F. (2016). Economic tools to promote transparency and comparability in the Paris Agreement. *Nature Climate Change*, 6, 1000-1004.

APA [Ad Hoc Working Group on the Paris Agreement]. (2016). Items 3 to 8 of the Agenda: Draft conclusions proposed by the Co-Chairs, Framework Convention on Climate Change, FCCC/APA/2016/L.4.

APA [Ad Hoc Working Group on the Paris Agreement]. (2017). Workshop on the development of modalities, procedures and guidelines for the transparency framework for action and support referred to in Article 13 of the Paris Agreement, FCCC/APA/2017/INF.2.

Barrett, S. & Dannenberg, A. (2016). An experimental investigation into 'pledge and review' in climate negotiations. *Climatic Change,* 138, 339-351.

Barua, P., Fransen, T. & Wood, D. (2014). Policy Implementation Tracking Framework, World Resources Institute Working Paper. http://www.wri.org/sites/default/files/climate_tracking_framework_working.pdf

Bodansky, D. (2016). The Paris Climate Change Agreement: A New Hope? *American Journal of International Law,* 110(2), 288-319.

Cazorla, M, and M. Toman (2001). International Equity and Climate Change Policy, M. Toman (ed.), *Climate Change Economics and Policy: An RFF Anthology*, Washington, DC, RFF Press.

Chen, Y.-H., Ejaz, Q., Gao, X., Huang, J., Morris, J., Monier, E., Paltsev, S., Reilly, K., Schlosser, A., Scott, J. & Sokolov, A. (2016a). Food, Water, Energy and Climate Outlook: Perspectives From 2016. MIT Joint Program on the Science and Policy of Global Change. http://globalchange.mit.edu/files/2016-JP-Outlook.pdf

Chen, Y.-H., Babiker, M., Paltsev, S., & Reilly, J. (2016b). Costs of Climate Mitigation Policies. MIT Joint Program on the Science and Policy of Global Change, Report 292, March.

Clarke, L., Edmonds, J., Krey, V., Richels, R., Rose, S., & Tavoni, M. (2009). International climate policy architectures: Overview of the EMF 22 International Scenarios. *Energy Economics*, 31, 564-581.

Climate Action Tracker. (2015). Tracking INDCs. http://climateactiontracker.org/indcs.html

Climate Action Tracker (2016). Tracking (I)NDCs: Assessment of mitigation contributions to the Paris Agreement. http://climateactiontracker.org/indcs.html

Climate Interactive. (2016). Tools for a Thriving Future. https://www.climateinteractive.org/

Damassa, T., T. Fransen, B. Haya, M. Ge, K. Pjeczka and K. Ross (2016). Interpreting INDCs: Assessing Transparency of Post-2020 Greenhouse Gas Emission Targets for 8 Top-Emitting Economies, World Resources Institute Working Paper. http://www.wri.org/publication/interpreting-indcs

Deprez. A., Colombier, M. & Spencer, T. (2015). Transparency and the Paris Agreement: driving ambitious action in the new climate regime. Institut du development durable e des relations internationals (Sciences Po). http://www.iddri.org/Publications/Collections/Idees-pour-le-debat/WP0315.pdf

EC-JRC (European Commission Joint Research Center). (2015). Analysis of scenarios integrating the INDCs (EC JRC IPTS/J1), October. http://www.indcforum.org/wp-content/uploads/2015/10/Analysis-of-scenarios-integrating-the-INDCs_201510_JRC97845.pdf

European Union. (2016). Modalities, procedures and guidelines for the transparency framework for action and support referred to in Article 13 of the Paris Agreement, Submission by the Slovak Republic and the European Commission on Behalf of the European Union and Its Member States, to the Ad Hoc Working Group on the Paris Agreement. FCCC/APA/2016/INF.3/AD.1.

Flannery, B. (2015). The State of Climate Negotiations. In C. Barrett, C. Carraro & J. de Melo (Eds.) *Towards a Workable and Effective Climate Regime*, a VoxEU.org eBook, CEPR Press, London. http://voxeu.org/sites/default/files/file/flannery.pdf

Goldberg, P. (1998). The effects of the corporate average fuel economy standards in the US. *The Journal of Industrial Economics,* 46(1), 1-33.

Green, J. (2010). Private Standards in the Climate Regime: The Greenhouse Gas Protocol. *Business and Politics,* 12(3), 1-37.

Gupta, A., Vijge, M., Turnhout, E., & Pistorius, T. (2014). Making REDD+ Transparent: The Politics of Measuring, Reporting, and Verification Systems. In A. Gupta & M. Mason (eds.). *Transparency in Global Environmental Governance: Critical Perspectives*, MIT Press, Cambridge, MA.

International Energy Agency. (2015). Energy and Climate Change: World Energy Outlook Special Briefing for COOP21. https://www.iea.org/media/news/WEO_INDC_Paper_Final_WEB.PDF

IPCC. (2014). Climate Change 2014: Mitigation of Climate Change, Working Group III: Mitigation of Climate Change. https://www.ipcc.ch/report/ar5/wg3/

Jacoby, H. & Chen, Y.-H. (2014). Expectations for a New Climate Agreement. MIT Joint Program on the Science and Policy of Global Change, Report 264, August. https://globalchange.mit.edu/publication/15806

Jacoby, H. and Chen, Y.-H. (2015). Launching a New Climate Regime, MIT Joint Program on the Science and Policy of Global Change, Report 286, November. https://globalchange.mit.edu/publication/16227

Karplus, V. (2015). Double Impact: Why China Needs Coordinated Air Quality and Climate Strategies. Tsinghua-MIT China Climate & Energy Project (reprinted from Paulson Papers on Energy and Environment). http://globalchange.mit.edu/files/document/MITJPSPGC_Reprint_15-1.pdf

Keohane, R., & Victor, D. (2010). The Regime Complex for Climate Change. Harvard Project on International Climate Agreements, Discussion Paper 10-33.

Keohane, R. & Victor, D. (2016). Cooperation and discord in global climate policy. *Nature Climate Change*, 6, 570-575.

Kriegler, E., N. Ptersmann, V. Krey, V. Schwanitz, G. Luderer, S. Ashina, V. Bosetti, J. Eom, A. Kitus, A. Mejean, L. Paroussos, F. Sano, H. Turton, C. Wilson, and D. Van Vuuren (2015). Diagnotic indicators for integrated assessment models of climate policy, *Technological Forecasting & Social Change* 80: 45-61.

Le Treut, H., et al. (2015). Groupe Interdisciplinaire sur les Contributions Nationales: Working Paper – Preliminary Version, IPSL Climate Modelling Center, Scientific Note No. 32, November. http://cmc.ipsl.fr/images/publications/scientific_notes/GICN_working_paper2.pdf

Levin, K. & Fransen, T. (2015). Why Are INDC Studies Reaching Different Temperature Estimates? World Resources Institute. http://www.wri.org/print/43483

Li, C.-T., Li, M., Zhang, D., Mulvaney, K., Selin, N. & Karplus, V. (2016). Air Quality Co-Benefits of Climate Policy in China, *PNAS*, submitted.

Niederberger, A. & Kimble, M. (2011). MRV under the UN climate regime: paper tiger or catalyst of continual improvement? *Greenhouse Gas Measurement and Management,* 1:47-54. http://www.tandfonline.com/doi/pdf/10.3763/ghgmm.2010.0009?needAccess=true

Nordhaus, W. (2016). Projections and Uncertainties about Climate Change in an Era of Minimal Climate Policies, Cowles Foundation Discussion Paper No. 2057. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2881947

Ostrom, E. (1008). A Behavioral Approach to the Rational Choice Theory of Collective Action, *American Political Science Review* 92(1):1-22.

Rausch, S., & Karplus, V. (2014). Markets versus Regulation: The Efficiency and Distributional Impacts of U.S. Climate Policy Proposals. *The Energy Journal,* 35(S11), 199-227.

Reiner, D. and H. Jacoby (1997). Annex I Differentiation Proposals: Implications for Welfare, Equity and Policy, MIT Joint Program on the Science and Policy of Global Change, Report 27. https://globalchange.mit.edu/sites/default/files/MITJPSPGC_Rpt27_0.pdf

Rogelj, J., M. den Elzen, N. Höhne, T. Fransen, H. Fekete, H. Winkler, R. Schaeffer, F. Sha, K. Riahi and M. Meinshausen. (2016). Paris Agreement climate proposals need a boost to keep warming well below 2°C, *Natur*e, 354, 631-639.

Singh, N., Finnegan, J. & Levin, K. (2016). MRV 101: Understanding Measurement, Reporting, and Verification of Climate Change Mitigation, World Resources Institute Working Paper, August. http://www.wri.org/publication/mrv-101-understanding-measurement-reporting-and-verification-climate-change-mitigation

Singh, N, & Vieweg, M. (2015). Monitoring Implementation and Effects of GHG Mitigation Policies: Steps to Develop Performance Indicators. World Resources Institute Working Paper, December. http://www.wri.org/sites/default/files/Monitoring_Implementation_and_Effects_of_GHG_Mitigation_Policies.pdf

UNEP [United Nations Environment Program]. (2016). The Emissions Gap Report 2016: A UNEP Synthesis Report. ISBN: 978-92-807-3491-5.

UNFCCC (2016). Aggregate effect of the intended nationally determined contributions: an update: Synthesis report by the secretariat, FCCC/CP/2016/2.

Weiner, J. (2015). Towards an effective system of monitoring, reporting, and verification. In C. Barrett, C. Carraro & J. de Melo (Eds), *Toward a Workable and Effective Climate Regime*, a VoxEU.org eBook, CEPR Press, London. http://voxeu.org/sites/default/files/file/weiner.pdf

Winkler, H., B. Mantlana and T. Letete (2017). Transparency of action and support in the Paris Agreement, *Climate Policy*, on line 10 April 2017.

Online Supplementary Materials

A. The MIT EPPA Model

The MIT Economic Projection and Policy Analysis (EPPA) model is a multi-region, multi-sector recursive–dynamic computable general equilibrium (CGE) model of the world economy (Chen *et al.*, 2016). The recursive formulation means that production, consumption, savings and investment are determined by current prices. The model is comprised of eighteen nations and multination regions shown in Table A1, and it includes the effects of international trade among the regions in both energy and non-energy goods and services.

EPPA 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, NOx, 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.

Table A1. The Eighteen EPPA regions.

Developed		Other G20		Aggregations	
Australia-New Zealand	(ANZ)	Brazil	(BRA)	Africa	(AFR)
Canada	(CAN)	China	(CHN)	East Asia	(ASI)
E.U.+	(EUR)	India	(IND)	E. Europe & Cent, Asia	(ROE)
Japan	(JPN)	Indonesia	(IDZ)	Latin America	(LAM)
United States	(USA)	Mexico	(MEX)	Middle East	(MES)
		Russia	(RUS)	Rest of Asia	(REA)
		South Korea	(KOR)		

As summarized in **Table A2**, the model identifies a set of energy and non-energy sectors that produce goods and services and their inter-sector trade, and the sectors that consume final goods and services (not shown). Technology options in energy production and conversion are represented in detail, as also shown in the table.

Table A2. Sectors and Energy Technologies in the EPPA Model

Sectors	Technology Options
Agriculture - Crops	First Generation Biofuels
Agriculture - Livestock	Second Generation Biofuels
Agriculture - Forestry	Oil Shale
Food Products	Synthetic Gas from Coal
Coal	Hydrogen
Crude Oil	Advanced Nuclear

Refined Oil	IGCC with CCS
Natural Gas	NGCC
Electricity	NGCC with CCS
Energy-Intensive Industries	Wind
Other Industries	Bio-electricity
Ownership of Dwellings	Wind with Bio-electricity
Services	Wind with Gas-fired Power
Commercial Transport	Solar Generation

Personal transportation is broken out within household final demand and the model considers vintages of internal combustion engine (ICE) vehicles and the change in efficiency standards over time. The one low-emission alternative to the ICE is an electric vehicle.

B. NDCS AND POLICIES AND MEASURES

B1. First NDCs

The 2030 emissions underlying the projection of the first NDCs (see Figure 1) are based on INDCs submitted to the Framework Convention website (UNFCCC, 2016) and summarized in Table B1. Adjustment of national and regional emissions from the No-NDC projection begin in many countries in 2020, and behavior under the first NDCs is extended to 2040 based on author judgment of the follow-on effects of pledges to 2025 and 2030. The first NDC projection does include additional contributions to emissions reduction that may be pledged in subsequent rounds of the Paris Agreement's 5-year cycles.

Table B1. INDCs and Assumed Performance in 2030

Region	INDC[1]		CO_2-e 2005 Mt or t/$1000	Other Features	Expected CO_2-e[2]
	Type/Base	Reduction			
USA	ABS 2005	26-28% by 2025	6220		25%[3]
EUR	ABS 1990	40% by 2030	5370 (1990)	27% renewables in electricity by 2040	40%
CAN	ABS 2005	30% by 2030	789	Mainly land use & forestry with 18% reduction in industrial	25%
JPN	ABS 2005	25% by 2030	1260	2.5% LUCF. Nuclear = 20-22% of electric, solar/wind = 9%, also biomass. Assumes ITMOs. Target = 1.04b ton CO_2-e	20%[4]

[1] Sources include UNFCCC (2016) and CAT (2016).

[2] Percentage is the assumed 2030 performance under the target in column 2.

[3] Based on assessments by Greenblatt and Wei (2016), Larsen et al. (2016) and Vine (2016) and authors' judgment. The assumed 2025 reduction is 17%

[4] Discounts ITMOs and nuclear expectations.

ANZ	ABS 2005	26-28% by 2030	596		20%[5]
BRA	ABS 2005	37% by 2025	2.19	45% of primary energy renewable by 2030; LUCF down 41% 2005-12	35%[6]
CHN	CO_2 INT 2005	60-65% by 2030	2.55	INDC is CO_2 only, discount to account for other gases. CO_2 peak by 2030, Non-fossil 20% of primary energy	55%
KOR	BAU	37% by 2030	NA	PAMs on renewables and autos (no detail)	25%
IND	INT 2005	30-36% by 2030	2.29	2.5-3.0b tons CO_2 from forests. 40% non-fossil electric. Assumes un-specified financial assistance.	30%
IDZ	BAU	29% by 2030	NA	Role of LUCF (63% of current emissions) not clear. Industrial emissions increase.	30%
MEX	BAU	25% by 2030	NA	22% of CO2, 51% of BC, Intensity reduction of 40% 2013-2030.	25%[7]
RUS	ABS 1990	25-30% by 2030	3530	Reduction subject to "maximum accounting" from forests.	32%
ASI	BAU		NA	Malaysia 45% INT, Philippines 70% BAU, Thailand 20% BAU, Singapore ABS 36%.	10%
AFR	BAU		NA	Nigeria 45% BAU, South Africa 20-80% increase (ABS), limited information on other regions.	5%
MES	BAU		NA	Saudi & Kuwait actions only, Iran 15% BAU, UAE non-GHG actions	10%
LAM	BAU		NA	Argentina 15% BAU, Chile 35% INT, PERU 20% BAU, Colombia 20% BAU	10%
REA	BAU		NA	Bangladesh 5% BAU, Pakistan reduction after unspecified peak, Sri Lanka 7% BAU, Myanmar & Nepal miscellaneous actions	10%
ROE	BAU		NA	Azerbaijan 13% BAU, Kazakhstan 15% 1990, Turkey 21% BAU, Ukraine 40% BAU	10%

B2. Expected Policies and Measures

Many countries are applying emissions prices to some regions or sectors as part of their mitigation effort, but none applies a uniform emissions price across all sources as assumed in the estimation of welfare cost. Examples of the partial use of a price instrument include the

[5] Expectation discounted by political reversals in Australia.

[6] The assumed reduction in 2025 is 30%

[7] GHGs only. The potential influence of Mexico's pledge of reduction in black carbon is not included.

U.S., where emission prices cover some sources in California and the RGGI states; the EU, where the ETS convers electric power and certain industry sources; and Canada, where some provinces have applied emissions taxes. However, even where emissions prices are being implemented, these countries also continue to apply regulatory and subsidy policies, driving up the overall welfare cost of the mitigation effort.

To get a preliminary estimate of the true cost of NDCs in this circumstance we assume an emissions price remains in effect, but impose the expected policies and measures (PAMs)—many of which have marginal costs higher than the emissions price that will meet the NDC without them. The focus is on measures in the largest emitting sectors: electric power and transportation. The PAMs satisfy some of each national pledge, but the overall NDC reduction is left in place as a constraint, to insure that the original pledge is always met, which yields an implied residual national emissions price (now much reduced).

Estimation of the full welfare cost of the current predominance of PAMs in emissions mitigation would impose the prices actually in place country by country, and (as is actually the case in most places) impose other measures one on top of another until the full targeted reduction is met. This procedure, which is beyond our current modeling capability, would yield a higher welfare burden than the simpler calculation applied here.

B2.1 Electric Power

The electric power sector is the largest single source of greenhouse gas emissions globally, as well as in most individual countries. Many forms of policy and different control measures are applied to this industry, but the most significant in terms of emissions reduction and cost are driving out coal and promoting renewables.

Coal-Fired Generation. Many nations are imposing policies that include the closing of existing coal-fired generation. Using a data set that includes all coal-fired units (Platts, 2016) for USA, CAN, EUR, JPN and MEX, it is assumed that no new units will be added after 2015 in these countries, and that existing capacity will be retired at age 60. The resulting reduction 2025 to 2030 is shown in Table B2; results indicate the advanced age of the coal fleet, particularly in the USA and EUR. China pledges to cap coal use "around" 2030. No PAMs directed at coal use in electric generation are assumed in IND and MES.

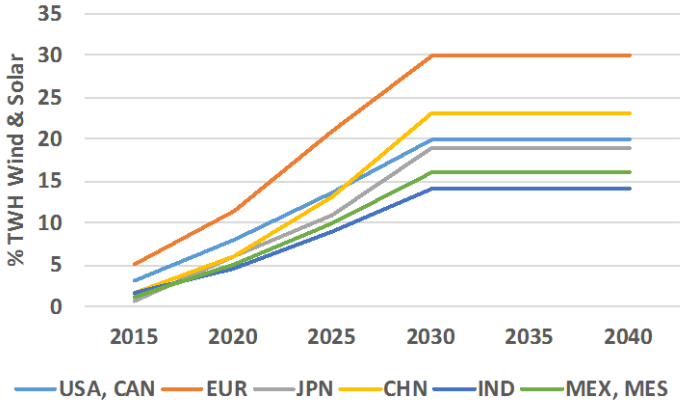
Table B2. PAMs Applied to Coal-Fired Electricity

Country/Region	Capacity Reduction in 2030 (% of 2015)	Other Features
USA	40	
CAN	25	
EUR	35	
JPN	10	
CHN	NA	Cap 2035 & 2040 at the 2030 level
IND	NA	No coal constraint

MEX	30	
MES	NA	No coal constraint

Renewable Energy Policies. Many countries are promoting solar and wind generation, by renewable energy mandates and various forms of subsidy, and many parties state these measures in their INDCs. Renewable sources of generation that are receiving policy attention include hydroelectric sources, biofuels and tidal and wave power, but the main focus is on solar and wind. We apply information about these plans as submitted to the Convention website (UNFCCC, 2016), and summaries by others (Chatterton and Du Reitz, 2015), to estimate the scale of these policies and measures for the eight subject regions. Their contribution to total generation is plotted in Figure B1. The projection takes account only of expected installations to 2030 on the assumption that any further wind and solar expansion would be achieved only under an enhanced effort in the second and subsequent NDCs.

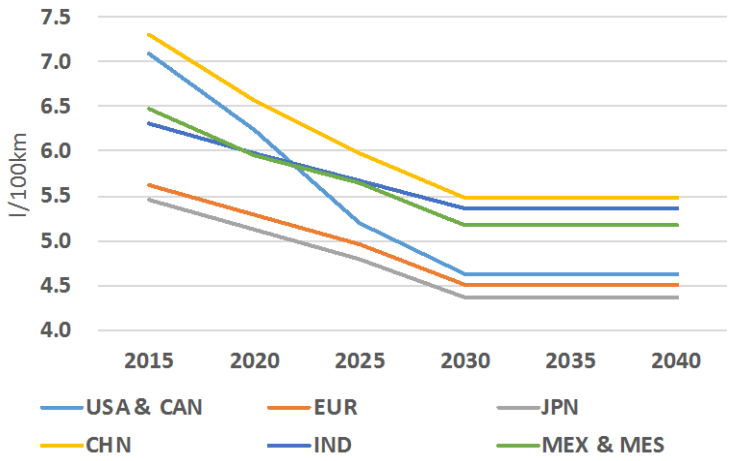
Figure B1. Minimum Levels of Wind and Solar Generation



B2.2 Transport

Light-Duty Vehicles. PAMs in the light duty vehicle sector are generally applied in the form of efficiency standards for new vehicle sales. Assumed PAMs, stated as a reduction (in gasoline-equivalent terms) in l/km from the 2015 level, are shown in Figure B1. The estimates draw on summaries by ICCT (2015a, 2015b) and assume 75% passenger cars and 25% light trucks (SUVs). Based on analysis by Heywood and MacKensie (2015) national efficiency targets for 2022 and 2025 are assumed to be met only by 2030, to account for the difference between measurement procedures for new vehicles and on-the-road performance. No further tightening of these standards after 2030, though additional improvement may accompany the second and subsequent NDCs.

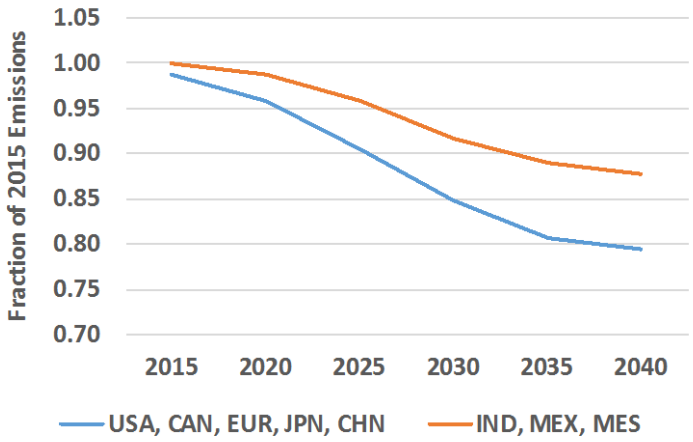
Figure B2. Efficiency Standards for Light Duty Vehicles to Meet the First NDCs



Commercial Transport. Most countries impose efficiency standards on heavy-duty trucks, and on other sectors of commercial transport. Trucks dominate energy use and emissions in commercial transport, representing toughly 2/3 of the total. Here, the U.S. truck standards are used as the basis for PAMs in this sector (ICCT, 2016). Both Phase 1 and Phase 2 standards are imposed in USA, CAN, EUR, JPN and CHN, but only the Phase 1 standards are assumed to be applied in IND, MEX and MES (ICCT, 2016).

It is assumed that reduction measures are taken as well in the 1/3 represented by air, rail and shipping, but that the reduction is only one-half of that achieved in trucking. The PAM is applied as a constraint on energy input to commercial transport (essentially refined oil).

Figure B3. Reduction of Energy Use in Commercial Transport



References

CAT [Carbon Action Tracker], 2016. Climate Analytics, Ecofys & the NewClimate Institute,. http://climateactiontracker.org/

Chatterton, R. and A. Du Reitz, 2015. Renewable Targets that Bite? Comparing renewable energy targets with BNEF's New Energy Outlook, Bloomberg New Energy Finance.

https://data.bloomberglp.com/bnef/sites/4/2015/11/BNEF_RN_Renewables-targets-vs-NEO_2015-07-20_v3.pdf

Chen, Y.-H., S. Paltsev, J. Reilly, J. Morris and M. Babiker, 2015. The MIT EPPA6 Model: Economic Growth, Energy Use and Food Consumption, MIT Joint Program on the Science and Policy of Global Change, Report 278, March.

Greenblatt, J., and M. Wei, 2016. Assessment of the climate commitments and additional mitigation policies of the United States, *Nature Climate Change*, on line 26 September.

Heywood. J and D. MacKensie (eds.), 2015. On the Road toward 2050: Potential for Substantial Reductions in Light-Duty Vehicle Energy Use and Greenhouse Emissions, Massachusetts Institute of Technology, Sloan Automotive Energy Laboratory, November. http://web.mit.edu/sloan-auto-lab/research/beforeh2/files/On-the-Road-toward-2050.pdf

ICCT [The International Council on Clean Transportation], 2015a. The State of Clean Transportation Policy: Light-Duty Vehicle Efficiency. http://www.theicct.org/sctp-ldv-e

ICCT [The International Council on Clean Transportation], 2015b. The State of Clean Transportation Policy: Heavy-Duty Vehicle Efficiency Standards. http://www.theicct.org/sctp-hdv-e

ICCT [The International Council on Clean Transportation], 2016. United States Efficiency and Greenhouse Gas Emissions Regulations for Model Year 2018-2027: Heavy-Duty Vehicles, Engines, and Trailers. http://www.theicct.org/sites/default/files/publications/US%20HDV%20Phase%202%20FRM_policy-update_08252016_vF.pdf

Karplus, V., P. Kishimoto and S. Paltsev, 2015. The Global Energy, CO2 Emissions, and Economic Impact of Vehicle Fuel Economy Standards, *Journal of Transport Economics and Policy* 49(4): 517-538.

Larsen, J., K. Larsen, W. Herndon and S. Monahan, 2016. Taking Stock: Progress Toward Meeting US Climate Goals, the Rhodium Group. http://bit.ly/2d3yJvj

Platts, 2016. UDI World Electric Power Plants Data Base (WEPP), Platts UDI Products Group, a division of McGraw Hill Financial.

Vine, D., 2016. US can reach its Paris Agreement goal, Center for Climate and Energy Solutions, 26 March. http://go.climate.com/2cWSZhs

UNFCCC, 2016. INDCs as communicated by parties. (http://www4.unfccc.int/Submissions/INDC/Submission%20Pages/submissions.aspx)