Long-Term Abatement Potential and Current Policy Trajectories in Latin American Countries


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Long-term abatement potential and current policy trajectories in Latin American countries

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ABSTRACT

This paper provides perspectives on the role of Latin American and Latin American countries in meeting global abatement goals, based on the scenarios developed through the CLIMACAP-LAMP modeling study. Abatement potential in Latin America, among other things, is influenced by its development status, the large contributions of non-CO2 and land use change CO2 emissions, and energy endowments. In most scenarios in this study, the economic potential to reduce fossil fuel CO2 as well as non-CO2 emissions in Latin America in 2050 is lower than in the rest of the world (in total) when measured against 2010 emissions, due largely to higher emission growth in Latin America than in the rest of the world in the absence of abatement. The potential to reduce land use change CO2 emissions is complicated by a wide range of factors and is not addressed in this paper (land use emissions are largely addressed in a companion paper). The study confirms the results of previous research that the variation in abatement costs across models may vary by an order of magnitude or more, limiting the value of these assessments and supporting continued calls for research on the degree to which models are effectively representing key local circumstances that influence costs and available abatement options. Finally, a review of policies in place in several Latin American countries at the time of this writing finds that they would be of varying success in meeting the emission levels proposed by the most recent IPCC reports to limit global temperature change to 2 °C.

Keywords: Scenarios, Latin America, Climate mitigation

1. Introduction

Stabilizing GHG concentrations and limiting associated temperature change will eventually require deep emission reductions from all regions of the world. However, the manner and timing of abatement will differ across countries and regions. Each country’s or region’s contribution will depend on the nature of its emissions in the absence of abatement (baseline emissions) and the associated potential to reduce those emissions. An important issue within this context is the nature of possible emission reductions in any country or region consistent with ambitious long-term global climate goals.

This study aims to explore several dimensions of abatement in Latin America. In specific, it explores the following questions. First, what are key characteristics of Latin America that might influence opportunities to reduce emissions, including states of development, emission profiles, and energy mixes. Second, is the economic abatement potential higher or lower in Latin America than in the rest of the world? This question is related to the appropriate Latin American abatement commitments in the context of global climate discussions. Third, how might the
economic abatement potential vary across countries within Latin America? Fourth, how much would it cost to implement substantial emission reductions in Latin America through 2050? Finally, how consistent were plans in Latin American countries at the time of this writing with longer-term climate or abatement goals? To explore these issues, this study makes use of recently developed scenarios from the CLIMACAP–LAMP modeling study \(^1\) (van der Zwaan, et al., in this volume).

The remainder of this paper proceeds as follows. Section 2 first provides background on development and energy patterns in Latin America, both of which will influence opportunities for abatement in Latin American countries. Section 3 discusses the specification of scenarios used in this study and describes the models participating in the study. Section 4 then discusses economic abatement potential in Latin American countries and the possible reductions in the region as a whole consistent with the goal of limiting the increase in global surface temperature to less than 2 °C at the lowest global economic cost. Section 55 then explores the degree to which planned activities in Latin American countries (at the time of this writing) were consistent with a 2 °C goal. Section 7 provides final perspectives and identifies several future research needs.

2. Key issues for understanding policy in Latin America

The opportunities for abatement vary across countries for several reasons. One of these, the level of development, is particularly important for understanding global climate discussions and in drafting policies that are adequate to national circumstances. The level of development influences the capacity of countries to take action on abatement, gives some indication of the potential for economic growth and associated emission growth, and raises important issues surrounding the linkage between abatement and sustainable development.\(^2\) The level of development in the different Latin American countries influences climate policy choices, as countries try to balance costs and benefits of abatement while allowing for human development (see Section 6).

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1. The Integrated Climate Modeling And CAPacity building in Latin America (CLIMACAP) and Latin American Modeling Project (LAMP) were conducted jointly to explore issues associated with abatement in Latin America. Data used for this paper can be found at https://ntnicat.iiasa.ac.at/CLIMACAP-LAMPDDB/.

2. An analysis of the relationship between climate policy and development in Latin America can be found in Samaniego (2009), including concerns about the high vulnerability of the region to climate impacts and issues surrounding costs and opportunities of regional and international abatement policy.

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According to the UNDP, the state of human development in Latin America\(^3\) is second among the developing world, and above the global average, as measured by the inequality-adjusted human development index\(^4\) (IHDI) (see Table 1). On average, the region enjoys higher living standards than China and India, but it remains behind developed countries such as the U.S. and those in Europe (Table 1). Latin America's income per capita is 2.9 times that of India, but only 27% of that of the U.S., and it lags behind in important indicators such as access to electricity and improved sanitation. Urbanization is high in the region, with a 79% of the population living in cities, as compared to, for example, 31% of the Indian urban population.

Although countries in Latin America have made progress in reducing income inequality, Latin America still has the highest disparities in wealth distribution in the world. Brazil and Mexico, for example, are characterized by very high Gini coefficients measuring income inequality (Table 1) and all of the Latin American countries in this study have substantially lower IHDIS than unadjusted human development indices (HDIs). In 2010, 37 million people lived in extreme poverty in the region (with less than $1.25 per day) (UNDP, 2013). Thus, climate policy for Latin America needs to carefully consider distributional issues, both at the international and national levels (Chakravarty et al., 2009; Markandya, 2011).

Associated with the level of economic development, final energy and primary energy consumption per capita in Latin America are well below that of Europe and the U.S., and generally below the world average (Table 1). Chile, Argentina and Brazil have the highest final energy consumption per capita in Latin America, but these values are still at about half of that of the EU and around 25% of that in the U.S. Similar patterns hold with respect to primary energy consumption. Emissions per capita are strongly linked to economic output, and to the level of development more broadly, but there is variation in this correlation (Fig. 1). For example, the Latin American and Caribbean region (LAM&C) has a similar IHDI as China but lower emissions per capita. These variations in emission intensity of the different Latin American economies reflect different structures of the energy system, but also differences in policies and resource endowments.

An important consideration in understanding the potential for climate abatement is the structure of the energy system. The future...
abatement potential of energy systems depends on the role of renewables and fossil energy sources in the energy mix and the available future resources for non-carbon energy sources. As with most countries, oil constitutes a large portion of the energy system in Latin America (Fig. 2), primarily for use in transportation. However, unlike the U.S., the EU, or China, most Latin American countries currently have only a minimal reliance on coal. Only Argentina and Mexico currently consume natural gas as a large portion of the electricity sector. Several Latin American countries currently rely heavily on hydropower, particularly Brazil and Colombia.

The characteristics of the electricity sector are of particular importance (Fig. 1 in the Supplementary material), because studies generally indicate that this is an important near-term priority for decarbonization (Clarke et al., 2014; van der Zwaan et al., 2013). The most noticeable difference between Latin American electricity systems and those of the rest of the world is that those in Latin America generally use little coal, which limits the potential to reduce emissions by rolling back the use of coal. Instead, Latin American countries are far more reliant on natural gas (especially Argentina and Mexico) and hydropower (notably Brazil and Colombia). Both of these provide for lower emissions per unit of electricity than coal-based electricity systems. It is important to note, however, that these electricity mixes may change substantially in the coming decades even without climate policy (see van Ruijven et al., in this volume and van der Zwaan et al., in this volume). In particular, expansion of hydropower may be limited, meaning that an expanding electricity system will potentially need to rely on other sources, including fossil sources or other renewables.

A final issue of importance for understanding abatement in Latin America is the sources of GHG emissions. In most regions, and particularly the developed regions, CO₂ emission from energy and industry accounted for at least 95% of total CO₂ emissions in 2008 (Fig. 3), which made up about 80% of all GHG emissions. In Latin America, however, over 30% of CO₂ emissions in 2008 were from land use changes and about 40% of GHG emissions were from non-CO₂ emissions. However, there are large variations from this distribution across Latin American countries. Mexico and Chile are comparable to many developed countries in terms of emission structure, but land use related emissions and non-CO₂ greenhouse-gases accounted for about two-thirds of GHG emissions in Brazil and Colombia and almost half of the GHG emissions from Argentina in 2008. This means that climate policy in these countries may need to focus more heavily on land and agriculture than in other world regions. However, it should be noted that Brazil has reduced its emissions from deforestation considerably in recent years (Lapola et al., 2014) and that there is a large potential to keep future deforestation levels low (Cohn et al., 2014). The overall complexities associated with land use change CO₂ emissions imply difficulties in assessing their abatement potential in a manner consistent with CO₂ from fossil fuel and industrial sources. For this reason, land use change CO₂ abatement potential is not addressed in this paper. It is, instead, addressed as a distinct topic in a companion paper (Calvin et al., in this volume).

Although non-CO₂ emissions continue to be substantial in Latin America, the importance of non-CO₂ emissions is expected to decrease over time (Fig. 4) due to disproportionate growth in fossil fuel and industrial CO₂ emissions. In addition, the potential for deep reductions in many non-CO₂ substances, for example CH₄ and N₂O in agriculture, is substantially more limited than for CO₂. This means that, despite their emissions being roughly comparable in the recent past, reductions in CO₂ will be more important in climate abatement than reductions in non-CO₂ substances in the long-term.

3. Scenarios and models

3.1. Overview of the study design

The CLIMACAP–LAMP project is based on a large set of scenarios intended to understand climate change abatement in Latin America. This paper relies on a subset of these scenarios (Table 2). The baseline
scenarios provide the starting point for all abatement scenarios in this analysis. The policy baseline scenario is the basis for the discussion of current and planned policies in Section 6. The global climate goal scenarios – those leading to CO2-equivalent concentrations of 450, 550, and 650 – could only be produced by a subset of models with full global coverage. These scenarios are useful for understanding the linkage between global climate goals and Latin American emission trajectories. To understand abatement within Latin America, we have relied on scenarios leading to emission reductions across Latin America of 20% and 50% by 2050 relative to 2010 levels. One set of these scenarios focuses only on fossil fuel CO2 abatement (FF&I); another includes both fossil fuel CO2 and non-CO2 emissions (GHG). Implementation of these abatement measures is achieved through a common price on carbon across Latin American countries.5

Beyond these common requirements regarding abatement approaches, no additional harmonization was required among models. This means that model assumptions about key technologies as well as assumptions about socioeconomic drivers such as population and economic growth vary across the models. These differences, along with differences in model structure, are responsible for the variation in results among models.

As noted above, emissions related to land use are a critical element of abatement in several Latin American countries. However, the approaches to land use abatement are complicated by a range of issues that makes comparability difficult. For this reason, land use change emissions are addressed specifically in a separate paper in this volume (Calvin et al., in this volume).

3.2. Participating models

Ten models participated in construction of the global abatement scenarios and the 20% and 50% abatement scenarios (Table 3). Additional models also produced information for the policy baseline scenarios explored in Section 6. Not all models completed all scenarios discussed in this paper.

The models used in this study differ in a number of ways that can have important implications for the resulting scenarios. One important area of difference is sectoral coverage. Because of its importance for climate change, all the models include some representation of the energy sector (see van der Zwaan et al., in this volume, for more on the energy system representations in the models). Some models, in addition, include explicit representations of land use (see Calvin et al., in this volume). Finally, a number of participating models are “general equilibrium” models, meaning that they have a representation of the full economy and can track changes to GDP or consumption. Models also vary in terms of the number of countries they cover. Models that provide information on the whole world provide a basis for understanding Latin American emission reductions within a global context. Models which focus on specific countries can often provide detailed information at the country level. Models that include all of Latin America may break the region into a number of subregions or countries or may simply consider Latin America as a whole. Models carry representations of different emissions, ranging from CO2 only, to CO2, the remaining Kyoto gases, and short-lived species such as aerosols. Models capture the time

5 Note that the implementation approach to achieve a common carbon price across Latin America was not specified in the study protocol, meaning that modelers were free to choose whatever method would most effectively lead to the common carbon price. It could be achieved through multiple mechanisms, for example a trading scheme or a carbon tax. In addition, the approach for treating any carbon revenues was also not specified.
emissions by more or by less than 50%? The answer to this question is 2050. Would it be appropriate for Latin American countries to reduce the goal to reduce emissions by, for example, 50% below 2010 levels by 2050, relative to 2010, as being roughly consistent with maintaining temperature change below 3 °C. It is therefore reasonable to consider 50% global reductions "IPCC assessment also found that these scenarios provide at least a 66% or better chance of maintaining temperature change below 2 °C.

A recent assessment by the IPCC (Clarke et al., 2014), informed by a wide range of scenarios, found that emission reductions on the order of 40% to 70% globally by 2050, relative to 2010, are roughly consistent with meeting a concentration goal of 450 ppmv CO2e by 2100. The current international climate discussions have centered on the goal of limiting the increase in global average surface temperature. Given the uncertainty in the relationship between global greenhouse gas (GHG) concentrations and temperature change, most studies, including this one, have focused instead on the change in global GHG concentrations. At the same time, actual commitments or goals by countries are commonly expressed in emission reductions. It is therefore necessary to develop links between the emission reductions in any country or region, on the one hand, and long-term global goals such as concentrations or temperature on the other.

A recent assessment by the IPCC (Clarke et al., 2014), informed by a wide range of scenarios, found that emission reductions on the order of 40% to 70% globally by 2050, relative to 2010, are roughly consistent with meeting a concentration goal of 450 ppmv CO2e by 2100. The IPCC assessment also found that these scenarios provide at least a "likely" (66%) chance of limiting temperature change to below 2 °C this century. It is therefore reasonable to consider 50% global reductions by 2050, relative to 2010, as being roughly consistent with maintaining a 66% or better chance of maintaining temperature change below 2 °C. Abatement leading to emissions roughly at 2010 levels by 2050 might be considered to be roughly consistent with maintaining a 66% or better chance of maintaining temperature change below 3 °C.

Within this context, a relevant question is the level of abatement that is appropriate in Latin American countries if there exists a global goal to reduce emissions by, for example, 50% below 2010 levels by 2050. Would it be appropriate for Latin American countries to reduce emissions by more or by less than 50%? The answer to this question is bound up in a wide range of issues having to do with economic efficiency, equity and fairness, the design of international policy, and international geopolitics. Hence, no study can provide a definitive answer to this question. Studies such as this one can, however, provide information that is useful for those people actually engaged in setting abatement goals for different countries or negotiating international agreements.

This study explores the economic abatement potential of Latin American countries relative to the world as a whole. In modeling studies, relative economic abatement potential is assessed from scenarios with an economically-efficient global allocation of emission reductions; that is, scenarios in which emission reductions are distributed among countries in a manner that minimizes the total global economic cost of abatement. In general, and under the admittedly idealized assumption that there are no market failures or pre-existing economic distortions and that all markets function effectively, the economically-efficient allocation is the allocation that emerges based on the implementation of a uniform carbon price across all sectors and countries (Clarke et al., 2014).

It is critically important to emphasize that economic efficiency is only one consideration when assessing effort-sharing approach to abatement. A wide range of metrics for effort-sharing have been proposed, many of which can be linked to different fundamental ethical principles (Höhne et al., 2014). The capacities of countries to undertake abatement while maintaining sustainable development are a key consideration (see Section 2). It is also important to note that where emission reductions occur can be separated from who pays for those emission reductions. In the context of a fully-efficient mechanism for financial transfers across countries, emission reductions made within any particular region can largely be separated from who pays for those reductions. Under a fully-efficient trading program, emission trading would lead to abatement across regions consistent with the economically-efficient outcome explored here, but the costs for abatement would be borne by countries in large part based on initial allocations. Without effective mechanisms for financial transfers, or a willingness to provide such transfers on the part of the developed countries, however, the actual allocations or commitments for individual countries may more closely resemble their actual emission reductions. With these caveats in mind, this paper compares economically-efficient abatement in Latin America with that of the world in total for the global abatement scenarios produced in this study (the 450, 550, and 650 ppmv scenarios) and in the recent AMPERE model intercomparison study (Kriegler et al., 2015).

Results for 2030 (Fig. 5) and 2050 (Fig. 2 in the Supplementary material) tell a mixed story. In most models, overall GHG emission reductions are less aggressive in Latin America than for the world, but they are more aggressive in several models. When splitting these overall emissions into three parts – fossil fuel and industrial CO2 emissions, land use change CO2 emissions, and non-CO2 emissions – a different story emerges. The primary cause of variation in total GHG emission reductions is variation in land use change CO2 emissions (note again that land use and land use change emissions are discussed in Calvin et al. (in this volume)).

The story is more consistent for both fossil fuel and industrial CO2 emissions and non-CO2 emissions. Most models find that economically-efficient emissions in 2030 and 2050 relative to 2010 are higher in Latin America than for the world. This would indicate, for example, that if a 50% global reduction in fossil fuel and industrial CO2 emissions relative to 2010 is the global goal, then it is economically-efficient for Latin America to take on less aggressive emission reductions relative to 2010.

Table 2
Scenarios explored in this paper.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core baseline</td>
<td>Business-as-usual scenario including climate and energy policies enacted prior to 2010. “Copenhagen Pledges” not included.</td>
</tr>
<tr>
<td>Policy baseline</td>
<td>Assumes implementation of policies implemented beyond 2010 or currently under consideration, including &quot;Copenhagen Pledges&quot;. Approach is left to modeler’s choice.</td>
</tr>
<tr>
<td>650 concentration</td>
<td>Global radiative forcing is kept below 4.5 W/m² throughout the century.</td>
</tr>
<tr>
<td>550 concentration</td>
<td>Global radiative forcing is kept below 3.7 W/m² throughout the century.</td>
</tr>
<tr>
<td>450 concentration</td>
<td>Global radiative forcing is brought to 2.8 W/m² by 2100. Concentrations exceed (&quot;overshoot&quot;) this level before 2100.</td>
</tr>
<tr>
<td>20% abatement (FF&amp;I)*</td>
<td>Fossil fuel and industrial CO2 emissions are reduced across Latin America by 5% in 2020, linearly increasing to 20% in 2050, with respect to 2010.</td>
</tr>
<tr>
<td>50% abatement (FF&amp;I)*</td>
<td>Fossil fuel and industrial CO2 emissions are reduced across Latin America by 12.5% in 2020, linearly increasing to 50% in 2050, with respect to 2010.</td>
</tr>
<tr>
<td>20% abatement (GHG)*</td>
<td>GHG emissions, excluding LUC CO2, are reduced by 5% across Latin America in 2020, linearly increasing to 20% in 2050, with respect to 2010.</td>
</tr>
<tr>
<td>50% abatement (GHG)*</td>
<td>GHG emissions, excluding LUC CO2, are reduced by 12.5% across Latin America in 2020, linearly increasing to 50% in 2050, with respect to 2010.</td>
</tr>
</tbody>
</table>

* These scenarios assume a common carbon price across Latin American countries. These scenarios also assume a comparable emission reduction trajectory for the rest of the world. However, because no trade of permits or other means to equalize prices is assumed, the carbon prices in Latin America may be different from those in the rest of the world.

A recent assessment by the IPCC (Clarke et al., 2014), informed by a wide range of scenarios, found that emission reductions on the order of 40% to 70% globally by 2050, relative to 2010 levels, are roughly consistent with meeting a concentration goal of 450 ppm CO2e by 2100. The IPCC assessment also found that these scenarios provide at least a "likely" (66%) chance of limiting temperature change to below 2 °C this century. It is therefore reasonable to consider 50% global reductions by 2050, relative to 2010, as being roughly consistent with maintaining a 66% or better chance of maintaining temperature change below 2 °C. Abatement leading to emissions roughly at 2010 levels by 2050 might be considered to be roughly consistent with maintaining a 66% or better chance of maintaining temperature change below 3 °C.
There are two primary factors that figure into the variation among models with respect to fossil fuel and industrial CO2 emissions and non-CO2 emissions. First, given that these reductions are compared to 2010 emissions, the level of baseline emission growth is a critical indicator of possible reductions (for more on baseline growth assumptions, see van Vuuren et al., in this volume). The second issue is the potential to reduce emissions from the baseline. As discussed above, countries with lower reliance on high-emitting fuels such as coal should, all other things being equal, have a lower capacity to reduce emissions. The major cause of the less aggressive emission reductions, relative to 2010, in Latin America is baseline emission growth (Fig. 3 in the Supplementary material). Economic abatement potential relative to baseline emissions is both higher and lower than for the world, and there is no consistent bias. Emission growth, however, is consistently higher in Latin America than the world.

There are several outliers from this pattern; that is, there are several scenarios in which emissions in 2050 relative to 2010 are higher in the world in total than in Latin America. Focusing on three scenarios from AMPERE (see the three green dots in the upper left panel of Fig. 2 in the Supplementary material that lie below the line), these outliers raise important issues regarding the way that models represent relative abatement opportunities in different regions and how users of these models should interpret results. The reason for the higher Latin American abatement in all three of these scenarios is that bioenergy coupled with CCS (bioCCS) is a major abatement option and that Latin America uses this option disproportionately relative to the rest of the world. One reason why this might make sense is that there may be limits on bioenergy trade (see Clarke et al., 2012), and as a major bioenergy producer, Latin America would then be obliged to preferentially use its bioenergy internally. Reasons this differentiation might not make sense are that bioenergy trade may not, in reality, prove all that limited and that CCS capabilities and resources could be less viable in Latin American countries than other countries for several reasons. Untangling these differences goes beyond the goal of this paper; and it is beyond the scope of this paper to comment on the realism of these assumptions in the context of a world 35 years from now that is taking on aggressive global emission reductions. However, it is nonetheless useful to raise the issue, because it points to the importance of understanding the ways that scenarios represent regional circumstances and the assumptions they are based on more broadly. It is often these assumptions, rather than the behavior of the models themselves, that most directly lead to key results.

The final question this section explores is how much variation there might be in the economically-efficient emission reductions among Latin American countries. Because of limited information on most countries in Latin America, we concentrate here only on Brazil and Mexico (Fig. 6 and Figs. 4, 5, and 6 in the Supplementary material). A fully consistent story does not emerge from the scenarios in either 2030 or 2050, although Brazil in general appears to take on lower emission reductions relative to 2010 than does Mexico. Again, a large reason for differences has to do with key results.
means to understand these costs is to create marginal abatement cost functions based on scenarios, such as those in this study. These are constructed by plotting carbon prices relative to emission reductions. Emission reductions can be expressed relative to 2010 or relative to the corresponding baseline scenario.

Consistent with numerous previous studies (see, for example, Clarke et al., 2014), an enormous range of carbon prices are estimated for Latin America as a whole by different models, with an order of magnitude separating the low and high estimates (Fig. 7, Fig. 8, and Figs. 9 and 10 in the Supplementary material). For a 20% reduction by 2050, in fossil

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**Fig. 5.** Emissions in 2030 relative to 2010 for Latin America (vertical axis) relative to the world as a whole (horizontal axis). The upper left panel shows all GHGs, the upper right panel shows only fossil fuel and industrial emissions, the lower left panel shows non-CO2 emissions (including non-CO2 emissions from agriculture), and the lower right panel shows CO2 emissions from land use change. The chart includes information from the 450, 550, and 650 concentration scenarios along with similar information from the AMPERE model intercomparison study (Kriegler et al., 2015). [Note on AMPERE data points: POLES, IMACLIM and MERGE are missing from the All GHG, Non-CO2 and Land Use Change CO2 charts because they do not report Non-CO2 or LUC data. In the All GHG chart, WITCH and GCAM are not shown for the 450 scenario because the data does not lie within the range of the displayed axes. In the Land Use Change CO2 chart, DNE21 and GCAM are omitted because the data does not lie within the range of the displayed axes.]

**Fig. 6.** Fossil fuel and industrial CO2 emissions in 2030 relative to 2010 for Brazil and Mexico (vertical axis) relative to Latin America as a whole (horizontal axis).
industrial CO₂ emissions and total non-CO₂ emissions relative to 2010 levels, the lowest carbon price is 50$/tCO₂-e and the highest is 450$/tCO₂-e. For a 50% reduction, the lowest carbon price is 110$/tCO₂-e and the highest is 1320$/tCO₂. This variation is most extreme for the deep abatement that is associated with larger transformations of the energy system. The marginal abatement cost functions are more convex for some models than others. Those with greater convexity indicate larger relative difficulties in achieving these higher levels of abatement.

It is important to note that cost estimates associated with reductions relative to a particular base year (in this case, 2010) are confounded by the baseline scenario assumptions (Figs. 9 and 10 in the Supplementary material). The higher are emissions in the baseline scenario, the more that emissions must be reduced to meet the abatement goal, and therefore the higher the costs. Hence, these cost estimates are potentially subject to more uncertainty than those associated with emission reductions relative to associated baseline scenarios (Figs. 7 and 8). Even when controlling for differences in baseline scenarios by expressing abatement in terms of reductions from the baseline, however, carbon prices still exhibit an enormous variation. This result further highlights that if the costs from these models are to be used in policy analysis, greater information is needed on why estimates vary so substantially across models. Nonetheless, these differences have existed for many years.

A more general method for controlling differences between models is to look at the variation in costs among countries or regions within particular models (Fig. 9). Of the eight models producing information for marginal abatement cost curves, about half exhibit very little difference in abatement costs across regions. The remaining half exhibit meaningful variations. The basis for these variations is not explained in this study. However, it is possible here to raise potential issues that might influence these results. In general, those with similar results are leaning toward a more “global” approach to abatement in which the highest carbon price is 110$/tCO₂-e and the highest is 1320$/tCO₂. This variation is most extreme for the deep abatement that is associated with larger transformations of the energy system. The marginal abatement cost functions are more convex for some models than others. Those with greater convexity indicate larger relative difficulties in achieving these higher levels of abatement.

Fig. 7. Marginal abatement cost functions for total Latin America fossil fuel and industrial CO₂ emissions – relative to baseline emissions – in 2030 and 2050. The round symbols show the 20% abatement (FFI) scenarios; the triangular symbols the 50% abatement (FFI) scenarios. [Note: Marginal abatement cost functions approximated by plotting carbon prices against emission reductions relative to baseline emissions.]

Fig. 8. Marginal abatement cost functions for total Latin America fossil fuel and industrial CO₂ emissions and non-CO₂ emissions – relative to baseline emissions – in 2030 and 2050. The round symbols show the 20% abatement (GHG) scenarios; the triangular symbols the 50% abatement (GHG) scenarios. [Note: Marginal abatement cost functions approximated by plotting carbon prices against emission reductions relative to baseline emissions.]
assumptions about political or societal limits on the deployment of particular technologies in specific countries or regions (see van der Zwaan et al., in this volume; Clarke et al., 2012).

It is tempting to conclude that models with higher regional cost variations are more representative of reality. Only a limited literature, however, has identified some of the potential reasons for these differences (see, for example, Clarke et al., 2012). This literature does not assess the realism of the assumptions that lead to these different perspectives on regional abatement opportunities, particularly in the context of a world decades from now that is taking on substantial global emission reductions and undergoing dramatic changes to global and regional energy systems. In addition, there are fundamental conceptual issues associated with assessing economic cost estimates in the context of comparability when a major factor influencing those costs may not be...
inherent characteristics of the country in question, but rather country-
level policies or societal outlooks that limit the ability to use particular
technologies (e.g., bans on nuclear power) or approaches to abatement
(e.g., limited appetite for market-based approaches).

6. The implications of current policies on abatement in Latin
American countries

To examine the role of current policies in meeting longer-term re-
duction targets, this section contrasts business as usual baselines,
which include abatement measures adopted prior to 2010, with stylized
policy baselines, which include measures adopted or ratified after 2010
(see Table 2). The analysis focuses on Argentina, Brazil, Colombia, and
Mexico because these countries are individually represented in a num-
ber of the models in this study. The policies and their implications are
first examined for each of these countries and then put in the context
of global abatement targets with an emphasis on the 2030 timeframe.

6.1. Argentina

Argentina’s “National Strategy on Climate Change: Structure,
Background, Overall Goals and Means” was adopted in 2010 by the
Governmental Committee on Climate Change. As part of the implemen-
tation of this plan and its third National Communications on Climate
Change, Argentina is officially developing its baseline. To this end, as
part of the CLIMACAP/LAMP project, a specific BAU baseline for
Argentina has been developed to analyze the impact of a series of
abatement measures to be applied in the energy sector. The policy bas-
eline considers the implementation of plausible abatement measures
in the energy sector to the year 2050 using the LEAP-FB model
(Di Shroia vacca et al., in this volume).

The BAU scenario takes into account the energy policies implement-
ded shortly before the year 2010, which consist primarily of demand-side
efficiency measures in lighting, refrigeration, and air conditioning.
Meanwhile, the policy scenario considers a series of demand- and
supply-side abatement measures. The demand-side measures include
solar heaters in the household sector, better thermal efficiency in resi-
dential buildings, eco-driving in freight transport and public transport,
and the introduction of hybrid cars. Supply-side measures include
higher level of biofuel penetration in transport; the promotion of hydro-
electric, wind, nuclear, and combined cycle generation; and greater use
of biomass in electricity generation.

On the basis of the implementation of this set of measures in the
LEAP-FB model during the period 2010–2050, emissions fall from the
baseline by roughly 9% in 2020, 14% in 2030, 17% in 2040 and 18% in
2050. Applying these percentage emission reductions from baseline in
the two global models that represent Argentina, GCAM and TIAM-ECN
leads to emission prices of about 15 and 110$/tCO2. The wide disparity
in carbon prices reflects the issues discussed in Section 5.

6.2. Brazil

Brazil’s National Plan on Climate Change was based on the general
directives of the National Policy on Climate Change, which was ap-
proved in December 2009 under Federal Law No. 12,187. The plan has
four general themes: abatement; vulnerability, impact and adaptation;
research and development; and enhancement of skills and dissemina-
tion. Its main objectives are to: (1) stimulate efficiency increases in a
constant search for better practices in the economic sectors; (2) keep
the high share of renewable energy in the electric matrix, preserving
the important position Brazil has always held; (3) encourage the sus-
tainable increase in the share of biofuels in the national transport matrix
and work toward the structuring of an international market of sustain-
able biofuels; (4) seek sustained reductions in deforestation rates, in all
Brazilian biomass, in order to reach zero illegal deforestation; (5) elimi-
nate the net loss of forest coverage in Brazil by 2015; (6) strengthen
inter-sector actions concerned with the reduction of the vulnerabilities
of populations; and (7) identify environmental impacts resulting from
climate change and stimulate scientific research that can trace out a
strategy to minimize the socio-economic costs of adaptation in the
country (Brasil, 2010).

Though much of the potential abatement measures in Brazil involve
the forest and agriculture sector, the focus of the present analysis is lim-
ited to energy-related emission reductions (see Calvin et al., in this
volume, this issue for a discussion of forest and agricultural issues).
The proposed energy sector actions considered in the National Plan for
Climate Change include: improve energy efficiency, increase the use of
bio-fuels, increase the energy supply by hydroelectric power plants, in-
crease the use of alternative energy sources and, finally, increase in the
use of charcoal from planted forests in the iron & steel industry.

The construction of Brazil’s policy baseline scenario follows Brazil’s
energy expansion plan out to 2022 (EPE, 2013). Hydropower and wind
to the greatest growth. In the policy baseline scenario, the models replicate the power sector capacity and/or output specified in
the energy expansion plan. Emission changes in 2030 are modestly
negative (−1% to −14%) for most models. However, general equilibri-
um effects in fuel markets lead to slight increases in emissions in the
Phoenix and EPPA models of 1.4% to 2.8%, respectively. Unlike other
countries in the policy baseline scenario, the representation of Brazil’s
policy does not cap emissions. Emission reductions in other countries
reduce their own demand for fossil fuels and consequently market
prices for fossil fuels fall. Lacking a cap on emissions, Brazil’s economic
sectors in the CEG models respond by marginally increasing fossil fuel
consumption in the baseline policy scenario due to the lower fuel prices.

6.3. Colombia

The foundation for Colombia’s policy baseline is the Colombian Low
Carbon Development Strategy (CLCDS). It is composed of sectoral and
total emissions for the country after the implementation of 80 abate-
ment measures in the sectors analyzed. The CLCDS constitutes a
program that focuses on the short, medium and long run planning de-
velopment of the country. It is led by the Ministry of Environment and
Sustainable Development through its Climate Change Deputy Director-
ate with the support of the National Planning Department and the Sec-
torial Ministries. The CLCDS aims at decoupling GHG emissions from
Colombia’s economic growth. This will be achieved by designing and
implementing plans, projects and policies that promote abatement of
GHG and simultaneously strengthen the social and economic growth
of Colombia following international standards in terms of efficiency,
competitiveness, and environmental performance. The sectors that par-
ticipate in the CLCDS are industry, energy, mining, transport, housing,
wastes and agriculture. The CLCDS has three main objectives: (1) identi-
fy and value actions directed to avoid the accelerated growth of GHG
emissions while the productive sectors grow; (2) develop abatement
action plans for each productive sector of the country; and (3) create
and promote tools for the implementation of the abatement action
plans, including monitoring and reporting.

The following abatement actions were prioritized by the CLCDS and
are included in the policy baseline scenario. (1) Agriculture: forestry
and grazing systems, rational grazing, expanding avocado and mango
plantations, pastures renovation, improved forages in theamazon, ex-
tension program for better fertilization practices and potato production,
and biodigestors for dried coffee; (2) Transport: better standards of per-
formance in private and public transportation and green driving, elec-
tric and hybrid vehicles, bicycle promotion, cargo fleet scrapping,
renovation of cargo fleet, cargo fleet LNG, cargo fleet CNG, substitution
of road transport for railway, substitution of road transport for water;
(3) Energy (demand): energy efficiency, fuel substitution, new technol-
gies, substitution of incandescent light bulbs, replacement and scrapping
of refrigerators, improvement in the efficiency of natural gas stoves, improvement on the efficiency of air conditioning equipment,
Mexico enacted its climate change actions and support technology transfers. In 2012, Mexico’s foundation to advance climate policy (Federal Government of Mexico) gets, based on its abatement capacity, meant to align to the global effort to reduce greenhouse gas emissions. Although Mexico’s emissions contribute only to 20% of the global total, and for 2050, the country has pledged a potential 50% reduction from its 2010 levels, provided that developed countries are held constant thereafter. This is less than the potential pledge of a 50% reduction by 2050, which is contingent upon financing from developed countries. The constant emission target from 2020 to 2030 is intended to represent one plausible future emission pathway that is consistent with limited outside financing.

Mexico’s ambitious long-term strategy will require a major transformation of the energy sector. For example, the National Commission for Climate Change has targeted emissions from power generation, with the goal of reaching a 35% participation of clean energy (non-fossil) by 2024, 40% by 2030 and 50% by 2050. The representation of the National Climate Strategy in the policy baseline targets a 30% reduction in emissions below BAU in 2020. Emissions are held constant thereafter. This is less than the potential pledge of a 50% reduction by 2050, which is contingent upon financing from developed countries. The constant emission target from 2020 to 2030 is intended to represent one plausible future emission pathway that is consistent with limited outside financing.

The carbon prices in 2030 needed to reach these emission reductions fall within a range of 50 to 75$/tCO2 for six of the seven models with the remaining model at 205$/tCO2. The two CGE models, EPPA and Phoenix, estimate the GDP loss in 2030, relative to baseline GDP, at 1.5% and 1.8% respectively.

6.5. National policies in the global context

Having examined country-level policies for four major countries in Latin America, it is useful to understand if these policies are consistent with global climate goals discussed in the previous sections. Although the four countries above constitute the majority current emissions, the treatment of the remaining countries in Latin America will affect the comparison. For the purpose of this exercise we assume that the other countries in Latin America will undertake emission reductions at the average level of the four we have already analyzed, with the exception of Chile, which has a 2020 Copenhagen pledge of 20% below baseline emissions. This translates to a 17% reduction from baseline for Latin America in 2030. The policy baselines for non-Latin American regions use the emission pathways from Kriegler et al. (2013) from the LIMITS “strengthened policy baselines”, which follow Copenhagen pledges to 2020 and lower emission intensity thereafter. The pathway for non-Latin American regions is calculated as the average emissions of the GCAM, IMAGE, and WITCH models and caps CO2 emissions at 24% above 2010 emission levels in 2030 for these regions.

The policy baseline reductions are then compared against the reductions in the globally economically-efficient scenarios considered in previous sections. It is worth reiterating that the globally economically-efficient policies are only one input for examining appropriate emission reductions across the globe (see Section 4). In addition, as noted earlier, the economically-efficient allocation indicates where emission pre-heating of water with solar energy; (4) Energy (supply): wind, solar, geothermal, biomass, diesel and co-generation electric generation, good management practices, capture of CO2; (5) Wastes: establishment of parks for waste recovery, minimization of wastes sent to landfills, increasing of recycling, energy recovery from industrial wastes, recovery of organic wastes, composting, biogas recovery, capture and burnt of biogas generated in landfills and wastewater plants, more efficient means for recollection and transportation of solid wastes.

The measures analyzed above had the highest abatement potential. Reductions include the potential for reductions in non-CO2 GHG’s but do not include reductions from land use and land use change, which account for 20% of Colombia’s emissions. The baseline policy, constructed from the expected reductions from these policies and measures, is implemented as an emission cap from 2015 through 2050. In 2030 the policy caps CO2 emissions at about 60% above 2010 levels or 33% for all GHG’s. Under the cap, emission reductions from baseline in 2030 for the three models that break out Colombia are about 40% in GCAM and Phoenix, yet only 25% in TIAM-ECN because of lower baseline emissions. The corresponding carbon prices needed to reach those reduction levels are about 35, 50, and 55$/tCO2 respectively. The GDP loss in 2030 estimated by the Phoenix model, the only computable general equilibrium model of the three, is 1.6% relative to baseline GDP.

6.4. Mexico

Mexico’s low-carbon growth strategy responds to both the recognition of its high vulnerability to the risks of climate change and its role as a facilitator of the international negotiation process to reach a global climate agreement. Although Mexico’s emissions contribute only to roughly 2% of global GHG emissions, the country has set ambitious targets, based on its abatement capacity, meant to align to the global effort to reach a stabilization scenario of 550 ppm. For 2020, Mexico’s emission reduction goal is to reduce 30% from its baseline emissions, and for 2050, the country has pledged a potential 50% reduction from 2010 levels, provided that developed countries finance clean energy and adaptation actions and support technology transfers. In 2012, Mexico enacted its General Law for Climate Change that sets the legal foundation to advance climate policy (Federal Government of Mexico, 2012 & 2014).

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7 The policy baseline for Colombia is in million metric tons of CO2 (CO2-eq for Kyoto gases) is 81 (163) in 2020, 106 (196) in 2030, 144 (247) in 2040 and 178 (293) in 2050.
reductions would take place, but not necessarily who would pay for these emission reductions.

For Latin America as a whole, the national policies produce emissions in 2030 that are generally consistent with reductions associated with 450 ppmv CO₂ emission goals from the CLIMACAP–LAMP and the AMPERE scenarios (Fig. 10).

Argentina’s policy baseline is consistent with emissions in the 550 ppmv CLIMACAP–LAMP scenarios for one of the two models (GCAM), yet remains above the 650 ppmv range for the other model (TIAM-ECN). (Note that range based on the concentration scenarios was only derived from these same two models, which also produced the policy baselines.) On average, Brazil’s policy baseline exhibits small emission reduction from baseline. The results are inconclusive as to whether these emission levels are consistent with a particular concentration target. Brazil’s 2030 policy baseline emissions stretch from above the 650 ppmv range sketched out by the CLIMACAP–LAMP models to within the upper part of the 450 ppmv range. Under Colombia’s policy baseline, two of the three models produce 2030 emissions that are consistent with the 450 ppmv range from the CLIMACAP–LAMP models and the third model is near the upper end of that range. Unsurprisingly Mexico’s aggressive policy baseline brings emissions from all models included in the analysis to within or below the 450 ppmv range.

7. Concluding thoughts

This paper has explored abatement potential in Latin American countries, and it has explored the consistency of current policy trajectories with those potentials. As with every region or country, Latin America has unique and important characteristics that influence its abatement potential. These include its development status, the heavy use of hydropower in some countries, and the importance of non-CO₂ emissions and land use change CO₂ emissions in some Latin American countries.

The research, based on scenarios generated in this study as well as those from previous studies, indicates that it would be economically-efficient for Latin America to undertake less abatement of fossil fuel and industrial CO₂ emissions and non-CO₂ emissions relative to 2010 levels than the rest of the world (note that land use change CO₂ emissions are treated separately in a companion paper, Calvin et al., in this volume). One implication is that if a global reduction of 50% relative to 2010 is consistent with limiting temperature change to less than 2 °C, then the economically-efficient Latin American reductions would be less than 50% relative to 2010 levels. In large part, this result derives from a common assumption across models that Latin American emissions will grow more rapidly than those of the world as a whole. Given the uncertainty inherent in long-term emission projections, it is therefore important to view these results with some caution.

Consistent with previous research (Clarke et al., 2014), there are orders of magnitude differences in the carbon prices associated with meeting the reductions explored in this study. Prices range from about 50 to 450$/tCO₂-e to obtain a 20% percent reduction in fossil and industrial CO₂ emissions and total non-CO₂ emissions in 2050 relative to 2010 levels. For a 50% reduction, they range from about 110 to over 1320$/tCO₂-e.

This study also analyzed the role that recently enacted and proposed policies may play in achieving long-term climate targets. Looking only at fossil fuel and industrial emissions out to 2030, the results indicate that such policies in Argentina, Colombia, and Mexico would limit the growth in emissions to roughly 17% above 2010 levels by 2030 compared to projected increases of over 40% over the same period without the policies. Acknowledging the importance of land-use policy in Brazil, the current energy-related policies show small reductions in 2030 emissions.

As much as this paper has identified some important issues associated with abatement potential and current policies, it has equally identified some important limitations in the ability of integrated models to inform policy discussions. Some of these may be rectified with improvements to modeling tools, but others are simply reflections of the uncertainty that surrounds policy making at national and international levels. Here we highlight several of these. First, although formal models can help to inform our understanding of the economics of abatement, every study of abatement relative to a particular base year is heavily confounded by baseline scenario assumptions, which are closely aligned with model inputs. Accordingly, every commitment or goal to reduce emissions relative to a particular year is subject to this same baseline uncertainty. Second, formal models continue to provide an extremely large range of estimates of economic costs for abatement, often differing by orders of magnitude or more, particularly for more ambitious abatement that would push energy systems far from their current configurations. Future research is needed to help users of information to understand the reasons for these differences. Third, although several models now include quite sophisticated models of land and land use change, there remain core issues about how to treat land use within national policy making and international negotiations that lead to very different results from models. This is particularly important for future assessments of abatement potential in Latin America. Future research is needed into the modeling of land use policy approaches and their integration into the broader modeling of climate policy. Fourth, there is a need to apply formal models to explore the implications of emerging policy commitments and proposals. However, doing so raises difficulties associated with understanding current and proposed policies in all their complexity and then implementing these policies in formal models. There is no easy solution for this challenge other than to keep the modeling community interacting with the policy-making community.

Finally, consistent with previous work, this study has made clear a key difference in the way that different models treat regional abatement opportunities. Many models take a relatively global perspective to abatement, assuming relatively similar opportunities across countries. These models find similar abatement costs and abatement approaches across countries. Other models find very different abatement costs and approaches across countries, reflecting unique local circumstances and limits on trade in key sectors (e.g., bioenergy or natural gas) that drive differences in abatement opportunities. This paper has not untangled the various reasons for these differences between models or come to any conclusion about which assumptions may or may not be most realistic. However, it is clear that these differences are important for informing both national and international policy discussions, and we believe that this would be a valuable direction for future research.

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Appendix A. Supplementary data

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