Climate Mitigation in Latin America: Implications for Energy and Land Use: Preface to the Special Section on the findings of the CLIMACAP-LAMP project

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Introduction

The CLIMACAP-LAMP project, completed in December 2015, was an inter-model comparison exercise that focused on energy and climate change mitigation in Latin America. The project partners report their findings in this Special Issue of *Energy Economics*, exclusively dedicated to articulating the role of Latin America in addressing climate change and understanding the manner in which global and regional models of energy systems and climate change mitigation represent Latin American countries. The exercise has brought together modelers from across the world who commonly participated in efforts to explore international climate policy architectures, and regional experts possessing specific knowledge and understanding of data, developments and policies in this domain in Latin America. Our research endeavor included several of the most prominent energy modeling groups from Latin America, as well as a representative set of global integrated assessment modeling teams from Europe and the US. About two dozen universities, research institutions, and environmental consulting organizations took part in the CLIMACAP-LAMP cross-model comparison project. These groups met at a series of workshops over the past four years in several countries in Latin America. The main outcome of our project, as reported in the present Special Issue, has been a coordinated cross-model comparison study that has linked these communities together to provide more effective quantitative analysis of Latin America energy, climate change and land use topics in a global context.

The academic outcome of our work, published in this Special Issue, includes two basic sorts of papers. One set of articles reports the efforts of teams that, through multiple models, investigated individual countries on the Latin American continent, exploring key elements and sensitivities for Argentina, Brazil, Colombia and Mexico. The second set of papers represents the work of several subgroups that explored specific issues across multiple countries and models, such as baseline scenarios, climate mitigation potential, and key characteristics and requirements of climate mitigation, including technology diffusion, investment requirements, biomass, agriculture and land-use effects, and macroeconomic impacts. We hereby connect to previous work done at the global level (IPCC, 2014, and e.g. Weyant and Kriegler, 2014; Kriegler et al., 2014; Tavoni et al., 2015) or at the regional level for Asia (Calvin et al., 2012).

In this Preface we (a) list the models used and concisely describe the scenarios investigated in the CLIMACAP-LAMP project, (b) shortly list some of the main findings as detailed in our scientific articles (as also reported, but with a policy focus, in our Policy Briefs) and (c) summarize non-exhaustively our suggestions for future research.

Models and scenarios

The fourteen models used in the CLIMACAP-LAMP project are: ADAGE, E3ME, EPPA, GCAM, IMACLIM-BR, IMAGE, iPETS, LEAP-Argentina, MEG4C, MESSAGE-Brazil, Phoenix, POLES, TIAM-ECN and TIAM-WORLD. Short descriptions of these models are given in those articles of this Special Issue that use their respective outcomes, so we refrain from repeating that information here. The Special Issue articles provide references to documents that give more extensive explanations of the details, assumptions and functionality of the models used in our project, for those readers who want to learn more about them.

All articles in this Special Issue are centered around a set of common scenarios that can be classified in four distinct categories: baseline scenarios (Type 1), CO_2 price path scenarios (Type 2), emission reduction scenarios (Type 3), and radiative forcing target scenarios (Type 4). Most articles report the main features of the scenarios that they researched, but, since not all scenarios are investigated by each of the 11 articles in this Special Issue, we here summarize the complete list of all scenarios that the CLIMACAP-LAMP project investigated, in terms of their most important characteristics, categorized by type (see Table 1).

These 11 scenarios explore a range of issues associated with Latin American climate mitigation efforts. The CO_2 price scenarios provide insight into the level of mitigation that would occur given a specific CO_2 price, as well as the uncertainty in the corresponding mitigation response. The emissions abatement scenarios explore the characteristics, across multiple models, of the mitigation pathways needed to meet a particular (in-country) mitigation goal. These pathways constitute potentially useful inputs to policy design exercises organized to serve meeting mitigation commitments, such as through the current UNFCCC process. The global climate objective scenarios enhance our understanding of what the economic, emission, and technology deployment implications could be at the national and continental level, if globally a common ambition is aimed at for the maximum allowed concentration of GHGs in the atmosphere, with consideration of minimizing the total global cost of mitigation (e.g. through the eventual introduction of a uniform world-wide price associated with CO_2 emissions). The policy baseline was intended to explore the implications of policies in place or planned at the time our study was developed. The details of these policies may, to some degree, meanwhile have been overtaken by national commitments through the UNFCCC process, but are in principle roughly in line with these Nationally Determined Contributions (NDCs).

We refer to our Scenario Protocol for a more detailed description of all scenarios listed in Table 1, which can be consulted at https://tntcat.iiasa.ac.at/CLIMACAP-LAMPDB/. The database containing the complete output of our scenario runs, for all models contributing to the CLIMACAP-LAMP project, is also publicly available at this website. In van Ruijven et al. (2016) and Clarke et al. (2016) more extensive narratives are provided for particularly the core baseline and a diverse set of policy scenarios, respectively. The implications of these scenarios, as described in our articles as well as our project's Policy Briefs (for the latter, see www.climacap.org), can assist governments in Latin America in furthering national low-carbon growth paths and in designing the policies

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Table 1
Main types and features of the scenarios investigated in the CLIMACAP-LAMP project.

Scenario	Description
Core baseline	Business-as-usual scenario including climate and energy policies enacted prior to 2010.
Policy baseline	Business-as-usual scenario including "Copenhagen pledges" enacted since 2010.
Low CO_2 price	A carbon tax is levied of 10 $/tCO_2e in 2020, growing at 4%/yr to reach 32$/tCO_2e in 2050.
High CO_2 price	A carbon tax is levied of 50 $/tCO_2e in 2020, growing at 4%/yr to reach 162$/tCO_2e in 2050.
20% abatement (GHG)	GHG emissions, excluding LUC CO_2, are reduced by 5% in 2020, linearly increasing to 20% in 2050, w.r.t. 2010.
50% abatement (GHG)	GHG emissions, excluding LUC CO_2, are reduced by 12.5% in 2020, linearly increasing to 50% in 2050, w.r.t. 2010.
20% abatement (FF&I)	Fossil fuel and industrial CO_2 emissions are reduced by 5% in 2020, linearly increasing to 20% in 2050, w.r.t. 2010.
50% abatement (FF&I)	Fossil fuel and industrial CO_2 emissions are reduced by 12.5% in 2020, linearly increasing to 50% in 2050, w.r.t. 2010.
650 concentration	Global radiative forcing is kept below 4.5 W/m2 (650 ppmv CO_2e) throughout the century.
550 concentration	Global radiative forcing is kept below 3.7 W/m2 (550 ppmv CO_2e) throughout the century.
450 concentration	Global radiative forcing is brought to 2.6 W/m2 (450 ppmv CO_2e) by 2100 (concentration can overshoot before 2100).

required to implement their NDCs to global climate change control as agreed upon at COP-21 in Paris in December 2015.

Outline of contributions

In Table 2 we list, in order, the 11 articles that appear in this Special Issue, with a short indication of their respective subjects as well as lead authors (by which they are referred to in the remainder of this Preface, as well as through cross-referencing by the authors of other papers published in this Special Issue). Also indicated are the number of models that contributed to each of these 11 studies, as a possible measure for the robustness of the reported findings. The first four contributions investigate a number of over-arching themes – baseline projections, mitigation potential, low-carbon technology diffusion, and low-carbon investment requirements – from a regional (that is, intra-national, Latin American) perspective. The next five papers make deep dives into the policy and low-carbon development context of four specific large countries in the region: Argentina, Brazil, Colombia and Mexico (with one study based on one model dedicated to a joint analysis of Brazil and Mexico). The last two articles present studies of topics that are of particular importance in the context of the implementation of climate mitigation policy in Latin America: its implications in terms of agriculture and land use, and its impacts in a macro-economic context, i.e. in terms of issues that extend beyond the direct scope of the energy system and climate change mitigation.

The article by van Ruijven et al. (2016) presents the range in baseline projections for Latin America (and several individual countries within this region), identifies key differences between model projections, and presents indicators for how these projections compare to historic trends. Despite relatively large differences across models in especially population and GDP projections, an exercise involving a Kaya-factor decomposition of CO_2 emission pathways indicates that the set of baseline scenarios used in our study captures trends experienced over the past decades.

In Clarke et al. (2016), perspectives are provided on the role of Latin American and countries in the region in meeting global mitigation goals. It is found that the economic potential to reduce fossil fuel CO_2 as well as non-CO_2 emissions in Latin America in 2050 is lower than for the world as a whole, when measured against 2010 emissions. This is due largely to higher emissions growth in Latin America than in the rest of the world in the absence of climate mitigation. A review of policies in place in several Latin American countries at the time of our study finds that they would be of varying success in meeting the emission levels proposed by the IPCC (2014) to limit global average temperature change to 2°C.

In the article by van der Zwaan et al. (2016), opportunities are investigated for energy technology deployment under climate change mitigation efforts in Latin America. The analysis explores the resources and technologies, most notably for electricity generation, that would be most economic to significantly reduce energy sector CO_2 emissions in the region. According to all models, electricity generation in Latin America increases two- to three-fold between 2010 and 2050 in the baseline (and for some models also in the mitigation scenarios). In the mitigation scenarios, renewable energy expands overall typically at double-digit growth rates annually, with large roles for options like biomass- and hydropower, but there is substantial spread in model results for options such as wind and solar power, as well as CO_2 capture and storage (CCS).

Kober et al. (2016a) investigate energy supply investment requirements in Latin America, and find that more than a doubling of annual investments materializes in the baseline scenario between 2010 and 2050, while investments may triple over the same time horizon when climate policies are introduced. Their analysis suggests that, in comparison to the baseline scenarios, an average additional 21 billion US$/yr[1] of electricity supply investment is required under a 450 ppmv CO2-e concentration goal (identified by the IPCC as leading to a 66% chance of maintaining global temperature change below 2°C). This investment is directed primarily at low-carbon electricity technologies based on wind and solar energy resources as well as the application of CCS, in conjunction with a divestment in fossil fuel extraction and transformation.

In the paper by Di Sbroiavacca et al. (2016) the impact is evaluated of a variety of climate change control policies (including CO_2 pricing and emissions constraints) on primary and final energy consumption, the development of the electricity sector, and CO_2 emission savings in the Argentinian energy sector between 2010 and 2050. They find that if Argentina fully implements the most feasible mitigation measures currently under consideration by official government bodies and key academic institutions, for both energy supply and demand, a cumulative incremental economic cost of 22.8 billion US$ until 2050 is expected, associated with a 16% reduction in GHG emissions compared to the core baseline scenario.

The study by Lucena et al. (2016) assesses the effects of market-based mechanisms and CO_2 emission restrictions on the Brazilian energy system by comparing the results of integrated assessment models under different scenarios for CO_2 prices and abatement targets up to 2050. Their results show an increase over time in emissions in the baseline scenario due, largely, to a higher penetration of natural gas and coal. Climate policy scenarios with sufficiently high CO_2 prices, however, indicate that such pathways can be avoided. CO_2 prices starting at approximately 50 US$/tCO_2e in 2020 and increasing to about 160 US$/tCO_2e in 2050 induce emission reductions of around 60% on average in comparison to the baseline.

The article on Colombia by Di Sbroiavacca et al. (2016) investigates possible CO_2 emission scenarios until 2050 and the effects of implementing CO_2 prices and mitigation targets on the Colombian energy

Table 2
Articles published in this Special Issue based on the findings of the CLIMACAP-LAMP project.

Subject or Country Focus	Lead Authors	Number of Models
Baseline projections	van Ruijven et al. (2016)	11
Economic mitigation potential	Clarke et al. (2016)	10
Low-carbon technology diffusion	van der Zwaan et al. (2016)	6
Low-carbon investment requirements	Kober et al. (2016a)	4
Climate mitigation in Argentina	Di Sbroiavacca et al. (2016)	3
Climate mitigation in Brazil	Lucena et al. (2016)	6
Climate mitigation in Colombia	Calderon et al. (2016)	4
Climate mitigation in Mexico	Veysey et al. (2016)	6
Climate mitigation in Brazil and Mexico	Octaviano et al. (2016)	1
Agriculture and land use	Calvin et al. (2016)	4
Macro-economic impacts	Kober et al. (2016b)	8

[1] Unless otherwise stated, US$ in this Special Issue refers to US$(2005).

system. As with Brazil, the carbon intensity of today's energy system in Colombia is relatively low in comparison to many other countries in Latin America, but this may change as a result of rapid economic growth and an increase in the use of carbon-based technologies. The study confirms that the power sector plays a fundamental role in achieving CO_2 emission reductions in Colombia, particularly through the increase of hydropower, the use of wind energy and the deployment of CCS technology.

Veysey et al. (2016) observe that Mexico's current climate policy sets ambitious national GHG emission reduction targets – 30% relative to the baseline by 2020 and 50% relative to 2000 by 2050 – but that these goals are at odds with recent trends. They investigate how Mexico might reverse these trends. They conclude that decarbonization of electricity generation is needed, along with changes in transportation towards the use of more efficient vehicles, potentially in combination with the use of low-carbon fuels. Their results suggest that Mexico has some technological flexibility in meeting deep mitigation targets, although the costs of deep mitigation may be higher than official estimates indicate.

In the article by Octaviano et al. (2016), based on results from the EPPA model, it is demonstrated that the commitments by Brazil and Mexico for 2020, made during the UNFCCC conferences in Copenhagen and Cancun (prior to the formulation of their NDCs), are reachable, but come at different costs. They find that Brazil's commitments could be met through reduced deforestation, at basically no additional cost, while Mexico's pledges could cost around 4 billion US$ in terms of reduced GDP in 2020. While the calculated absolute magnitude of these costs is much determined by the particular model chosen for this analysis, the comparisons in this paper nonetheless suggest the need for climate policy designed for the specific characteristics of every country, accounting for variables such as natural resources and economic structures.

Calvin et al. (2016) observe that nearly 40% of GHG emissions in Latin America derive from agriculture, forestry and other land use, more than double the global fraction of AFOLU emissions. They investigate the future trajectory of GHG emissions from AFOLU in Latin America, with and without climate mitigation. They find significant uncertainty in future AFOLU emissions, both with and without mitigation, due to differences in a variety of underlying assumptions, including: (1) the role of bioenergy, (2) where and how bioenergy is produced, (3) the availability of afforestation options in climate mitigation policy and (4) N_2O and CH_4 emission intensities.

The authors of the publication by Kober et al. (2016b) analyze macroeconomic consequences of GHG emissions mitigation in Latin America up to 2050. Two CO_2 price scenarios are contrasted with a baseline scenario of anticipated energy demand. In the short term, with CO_2 prices reaching \$15/tCO_2e by 2030, most models agree that the reduction in consumer spending, as proxy for welfare, is limited to about 0.3%. By 2050, at CO_2 prices of \$165/tCO_2e, there is much more divergence in the estimated impact on consumer spending and GDP across models and regions, which reflects uncertainties about technology costs and substitution opportunities between technologies, among other things.

Further research

During the course of the CLIMACAP-LAMP project a number of themes were found that could be further investigated, as well topics that haven't been addressed yet but that deserve detailed studies. We hope that the findings reported in the articles of this Special Issue stimulate further research into the subjects they address, especially along the lines of the indicated shortcomings that the authors describe in their respective contributions. A broad range of additional issues need to be studied in depth in the near term: we here list – non-exhaustively – some of the principal avenues of future work that the authors believe should receive priority.

A first set of questions relate to the broader area of sustainable development: What are the key co-benefits of the mitigation pathways presented in this volume, in terms of for example avoided health impacts (from particularly transportation) or precluded water and environmental footprints (from e.g. the power sector)? In what sectors could co-benefits result, including also industry, land use, livestock and agriculture (as a result of the introduction of new technologies, but also thanks to increased efficiencies)?

A second set of topics involves the features of the required and/or possible technology pathways: are the reported scenarios realistic from an institutional, political, resource potential and social acceptance point of view? There are undoubtedly specific domestic issues that limit or favor certain possible responses to climate change, rendering some scenarios more realistic than others, with large heterogeneity across countries in Latin America. Topics in this context include the role of demand-side measures and response in climate mitigation, international financing and technology transfer, the feasibility of options like CCS and nuclear power, the role of new energy laws, energy reform and deregulation in the fossil fuel sector, import and export opportunities for both renewable energy and fossil-based energy carriers (such as biomass and coal), as well as the broad set of feasible policy instruments or available implementation barriers that could make or break specific technologies.

Other subjects for further research are more economic in character, including distributional issues, revenue recycling, and the development impacts of climate change mitigation. Also climate change impact and adaptation, as well as their interactions with mitigation policies, constitute an important field for future research. Our findings reported in this Special Issue repeatedly highlight the importance of bioenergy, land use and non-CO_2 gases in most Latin America countries: topics fit for further investigation in this broad domain are, for instance, modified intensities of the use of pasture, the stopping of deforestation (particularly in the Amazon), the reduction of livestock emissions and limitations to land for e.g. palm oil production. Last but not least, the extent to which trade will develop over the next decades will substantially affect climate mitigation and the costs thereof: can Latin America integrate its energy trade within the region, what is the cost of non-integration, what are the trade implications of diversified or homogenized CO_2 (price) policies across the continent, and how will trade develop for renewable energy options, including especially for biomass and what could be the agriculture and land use implications thereof?

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