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Energy technology roll-out for climate change mitigation: A multi-model study for Latin America

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ABSTRACT

In this paper we investigate opportunities for energy technology deployment under climate change mitigation efforts in Latin America. Through several carbon tax and CO_2 abatement scenarios until 2050 we analyze what resources and technologies, notably for electricity generation, could be cost-optimal in the energy sector to significantly reduce CO_2 emissions in the region. By way of sensitivity test we perform a cross-model comparison study and inspect whether robust conclusions can be drawn across results from different models as well as different types of models (general versus partial equilibrium). Given the abundance of biomass resources in Latin America, they play a large role in energy supply in all scenarios we inspect. This is especially true for stringent climate policy scenarios, for instance because the use of biomass in power plants in combination with CCS can yield negative CO_2 emissions. We find that hydropower, which today contributes about 800 TWh to overall power production in Latin America, could be significantly expanded to meet the climate policies we investigate, typically by about 50%, but potentially by as much as 75%. According to all models, electricity generation increases exponentially with a two- to three-fold expansion between 2010 and 2050. We find that in our climate policy scenarios renewable energy overall expands typically at double-digit growth rates annually, but there is substantial spread in model results for specific options such as wind and solar power: the climate policies that we simulate raise wind power in 2050 on average to half the production level that hydropower provides today, while they raise solar power to either a substantially higher or a much lower level than hydropower supplies at present, depending on which model is used. Also for CCS we observe large diversity in model outcomes, which reflects the uncertainties with regard to its future implementation potential as a result of the challenges this CO_2 abatement technology experiences. The extent to which different mitigation options can be used in practice varies greatly between countries within Latin America, depending on factors such as resource potentials, economic performance, environmental impacts, and availability of technical expertise. We provide concise assessments of possible deployment opportunities for some low-carbon energy options, for the region at large and with occasional country-level detail in specific cases.

1. Introduction

The CLIMACAP-LAMP project investigated, among others, the energy technologies needed in Latin America for the region to contribute to global climate change control. The main tools of the research teams contributing to this project – energy–economy, integrated assessment and/or energy system models that serve studying the energy-economic

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implications of climate change mitigation efforts – allow in principle for determining the extent, direction and cost of the technological change necessary to significantly abate emissions of greenhouse gases (GHGs). We inspect in this article how much technological change is required, in the short- to mid-term (i.e. until 2050), if countries in Latin America adopt, for example, carbon taxes or abatement targets to stimulate GHG emission reductions. We examine which energy options should be reduced, as well as how fast, and which others need to be expanded, and at what scale, in a similar way as has recently been done on the global scale in e.g. Wilson et al. (2012), Riahi et al. (2013) and van der Zwaan et al. (2013b). We do not assess what the direct implementation costs would be of the technological transformation associated with climate change mitigation action in Latin America, as was done in some previous studies (see e.g. McCollum et al., 2013). For an inspection of the investment requirements associated with climate-mitigating technological change in Latin America we refer to another publication in this special issue (Kober et al., 2015).

With our analysis we connect to a growing body of literature on energy system transition pathways, in particular those that involve renewable forms of energy (see e.g. GEA, 2012; IPCC, 2011). Given our focus on Latin America, our work also pertains to the UN's Sustainable Energy for All initiative (UN, 2012), even while we here do not explicitly nor extensively assess energy transformation in relation to economic development. Technology transformation pathways have recently been studied in a number of publications, both at the global level (such as in Krey et al., 2014; Weyant and Kriegler, 2014) and regional level (Calvin et al., 2012; Clarke et al., 2012, for Asia; Clarke et al., 2014a, 2014b; Fawcett et al., 2014, for the USA; Knopf et al., 2013, for Europe). In this paper we attempt to put our work on energy technology transitions in Latin America into a broader perspective, by comparing it to the existing literature on the subject matter and by reflecting on questions like how the decarbonization scenarios presented here differ from (or are similar to) those reported in the literature. We investigate whether possible technology transformation pathways for Latin America have commonalities or dissimilarities with those in other regions. Likewise, we are interested in knowing whether our results are similar or not to those obtained for the energy system transition required at a world-scale, in the context of which we inspect the global average perspective provided by the Intergovernmental Panel on Climate Change (see Clarke et al., 2014a, 2014b; IPCC, 2014). Other publications in this special issue also present narratives on how the CLIMACAP-LAMP findings relate to the literature on transition pathways and climate policy, such as notably Clarke et al. (2016). In this paper we also inspect the reasons for differences in technology roll-out that we observe across models, some of which relate to structural differences between models, others to different parameter assumptions (see e.g. Kriegler et al., 2014a, 2014b, who present results of extensive analysis in an effort to do the same through novel work on the basis of diagnostic indicators).

None of the energy technological transformation questions we raise can be answered with certainty, but integrated assessment models (as used for essentially all of the previously mentioned studies) can take away some of the uncertainties, in addition to help understanding some of the key drivers of technology developments in view of the strong linkages within the energy systems: the benefit of using a set of different models, as we do in this study, is that the diversity in their outcomes may be indicative for the nature of the technological change that needs to be initiated in the energy system. In this article we focus mostly on the energy sector and CO_2 as contributor to climate change, since sectors like agriculture and emissions of other GHGs (e.g. from AFOLU[1]: agriculture, forestry and land-use) are investigated in other contributions to this special issue (see e.g. Calvin et al., 2016). We particularly zoom in on electricity generation, as in developing countries (and especially in Latin America), this sector is likely to grow fast over the decades to come, with a two- to three-fold expansion between today and 2050 (see for example IEA-ETP, 2012, 2014). A number of recent studies have shown that the decarbonization of non-electric energy supply, such as in the transport sector and industry, poses crucial challenges for low atmospheric CO_2 concentration stabilization, since either fewer technology options exist or low-carbon technologies abound but are more expensive than for electricity generation (see e.g., Krey et al., 2014; Kriegler et al., 2014a, 2014b; Luderer et al., 2012; Rösler et al., 2014; van der Zwaan et al., 2013a). A detailed inspection of these other sectors, however, is beyond the scope of the present paper. In Section 2 of this paper we briefly introduce the methodology used for our work, list the models on which our research results are based, and concisely describe the scenarios that we investigated. Section 3 reports our main findings in several subsections dedicated, respectively, to (1) CO_2 emissions, (2) primary energy supply (including fossil and renewable resources), (3) electricity production (overall tendencies and fossil fuelled power plants versus alternative options such as nuclear energy or renewables like hydro, solar and wind power), (4) the potential expansion of CO_2 capture and storage (CCS), (5) energy efficiency, and (6) short-term technology deployment implications, as applied to Latin America. In Section 4 we discuss our results, draw some conclusions and formulate several recommendations for stakeholders in the public and private sectors.

2. Models and scenario design

The features of the integrated assessment models used in this technology diffusion comparison analysis vary widely: some are of a general equilibrium type, while others are partial equilibrium models; they include different simulation and/or optimization routines; they vary in terms of technological detail, diversity and inclusiveness in the energy system, as well as technical and (macro-)economic parameter assumptions; they are distinct with regards to the way in which they represent technological change, endogenously or exogenously; they differ with regard to assumptions on land-use emissions and greenhouse gas species; they are diverse vis-à-vis assumed natural resource availabilities and prices, such as of fossil fuels (but also e.g. CO_2 storage options); et cetera (see also van der Zwaan et al., 2013b). For detailed model descriptions we refer to publications by their respective modeling teams: EPPA (Paltsev et al., 2005); GCAM (Calvin et al., 2011); Phoenix (Sue Wing et al., 2011); POLES (Criqui et al., in press; Kitous et al., 2010); TIAM-ECN (Rösler et al., 2014; van der Zwaan et al., 2013a) and TIAM-WORLD (Loulou, 2008; Loulou and Labriet, 2008).

A multi-model comparison study of technology diffusion for Latin America under climate change measures can involve investigating many possible aspects of technological change. Our focus is first on the options available for the primary energy mix, in order to comprehend the dynamics behind the main energy resources required if the region adopts climate change mitigation policies. We particularly investigate electricity production. The reason for choosing this sector is that it represents a rapidly growing GHG emitting sector, which may in some respects be more easily adaptable to (partial or complete) decarbonization than some other sectors, while it can contribute to GHG emission reductions in these other sectors by their electrification (IEA-ETP, 2012; IPCC, 2014). Also, other sectors and emissions associated with AFOLU, that are particularly relevant for Latin America, are studied in other contributions to this special issue from the CLIMACAP-LAMP research project (see Calvin et al., 2016). We inspect the behavior under carbon taxes and emission reduction targets of a broad range of different energy technologies, including high-carbon coal, oil and natural gas-based electricity, as well as low-carbon nuclear, hydro, solar and wind-based power (while leaving biomass-based options for Calvin et al., 2016). We thus try to answer how and how fast the transition may materialize from fossil to non-fossil energy options. We also assess the potential widespread use of CCS, because this technology could prolong the use of fossil fuels in an emissions-constrained world and is hoped to play an important role in reaching ambitious climate change control, either as bridging technology or not.

[1] Previously referred to as LULUCF: land-use, land-use change and forestry.