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Industrial low carbon futures: A regional marginal abatement cost curve for Sao Paulo, Brazil

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ABSTRACT

Sub-national and regional greenhouse gas (GHG) mitigation policies are being stimulated by the Paris Agreement. Several low carbon studies have been conducted for important emitters such as California State in the US and Chinese provinces. At the same time, carbon mitigation studies have focused on the industrial sector, especially in developing countries. In comparison to the national scenario, the Sao Paulo state in Brazil shows a distinct emission profile. The industry in Sao Paulo is responsible for 14.7% of the total emissions, and this share increases to 31.5% considering energy indirect emissions. Therefore, Sao Paulo mitigation efforts depend on industry's leadership such as in other parts of the world. The present study has evaluated the Sao Paulo state's industry mitigation potential between 2014 and 2030 based on a Marginal Abatement Cost (MAC) curve. In contrast to previous MAC studies, the MAC-SP study has also considered cement related emissions released outside its jurisdictions but that are driven by industrial choices within its boundary. Nine out of seventeen technologies show a negative MAC value, and energy efficiency technologies yield the lowest cost with a weighted average value of -$122/metric ton of CO_2. Considering only the territorial based approach, the Sao Paulo state's Industry would avoid 78.4 million metric ton of CO_2 until 2030. Although emissions under Sao Paulo's responsibility increase 27%, if the consumption-based approach is adopted, the assessed mitigation potential enhances 83% and entails US$ 2.3 billion savings until 2030. In conclusion, the mitigation potential for São Paulo state's industry is sizeable and consumption-based strategies are worthwhile, especially when regional policies are considered. Results can assist in formulating climate change policies and innovative incentive mechanisms to maximize the regional mitigation potential.

1. Introduction

The Cancun agreement (2010) has set the 2 °C limit on global warming, and the Paris agreement (2015) has enabled an emission mitigation strategy based on regional, national, and sub-national policies (Bodansky et al., 2016). This means that different policy instruments in distinct jurisdictions may be connected by reciprocal recognition and crediting for compliance. The advantage of such mutual initiatives is that they facilitate the emergence of least cost mitigation options. Several sub-national jurisdictions around the world have set emission reduction targets.

In North America, twenty states in the USA and the District of Columbia have set 2020 and longer-term goals. In California, the Global Warming Solutions Act (AB32), which was enacted in 2006, has determined that emissions in 2020 should be equal to emissions in 1990 (Morrison et al., 2015). As a result, several models have been run to evaluate the deployment of alternative low carbon scenarios to achieve the mitigation goals in California. A recent assessment has evaluated nine different energy models that sought medium and long-term greenhouse gas mitigation goals for the State of California (Morrison et al., 2015). Results show that, compared to 1990 emissions, emission reductions in 2030 are between 8% and 46%.

In China, seven sub-national emission trading schemes (ETS) have been launched (Xing et al., 2017). China has established a carbon intensity reduction target of 18% by 2020, considering 2015, and there was a previous goal to reduce carbon intensity by 40–45% in 2020, considering emission levels in 2005 (Xing et al.,

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2017). The experience with such regional ETS will be fundamental to establish a nationwide market and meet the national targets. Seven emission-intensive industries, including papermaking, electricity generation, metallurgy, non-ferrous metals, building materials, the chemical industry, and the aviation service industry will be targeted by the future Chinese ETS scheme, which denotes the prominence of industrial emissions in the national GHG budget. Another regional study on China's cement industry has shown that ancillary environmental benefits, such as air pollution reduction and air quality improvement, can be achieved by regional climate policies (Yang et al., 2013). Besides economic advantages, the regional focus also draws attention to regional pollution benefits.

The steel industry, which is another major source of CO_2 emission in China, has been assessed by the Long-range Energy Alternative Planning (LEAP) software (Wang et al., 2007). The average cost of CO_2 mitigation in 2015 and the cumulative emission reductions in 2030 were respectively $57 per metric ton of CO_2 (tCO_2) and 142 million (M) tCO_2 (Wang et al., 2007). The study has concluded that it is possible to reduce the CO_2 emission intensity from the Chinese steel industry by 33–41% in 2020, considering emissions in 2000. To a great extent, the growth in industrial energy use has occurred in developing and emerging economies (Selvakkumaran et al., 2014). In Thailand, the industrial sector, which consumed 20% of the country's energy in 2010, was responsible for 37% of the total emissions (Selvakkumaran et al., 2014). An assessment of the Thai industrial sector has demonstrated that it is possible to mitigate 19.5% of the emissions between 2010 and 2050 (Selvakkumaran et al., 2014). Similarly to China and Thailand, and considering differences in scale, industry related emissions are also relevant in Brazil, especially at the regional level.

In 2009, the Sao Paulo State government established its Climate Change State Policy (Law 13.798). According to such Law, emissions in 2020 should be 20% below the 2005 emission level (São Paulo, 2009). In 2015, the Brazilian Nationally-Determined Contribution (NDC) established a reduction pledge of 37% of its total domestic emissions in 2025 and an additional pledge of 43% in 2030, both based on 2005 Greenhouse gases (GHG) emissions (Brasil, 2015).

Assessments of sub-national emission mitigation efforts are useful because they target the most important emission sources of the region and promote a closer dialogue with local stakeholders and local ancillary benefits such as pollution reduction and political climate leadership. For instance, the most significative emission sources in Sao Paulo State differ from the ones at the national level. Energy related activities in Brazil are not the most significant sources of GHG emissions because most emissions come from land use change (Borba et al., 2012). About 60% of the emissions in Brazil in 2005 were due to land use, land use change and forestry; conversely, in Sao Paulo State, 57.2% of the emissions were related to energy conversion (CETESB, 2011). The situation in Sao Paulo State is comparable to California and the industrialized Chinese Provinces, in which energy related emissions stand out.

In 2005, GHG emissions in Sao Paulo State totaled 140 $MtCO_2$, and the industry was responsible for 14.7% of the total (CETESB, 2011). However, the industry inventory comprises only process-based emissions even though part of energy conversion emissions are due to industrial activities. The allocation of such emissions to the industry enhances the significance of the industry as a player in the decarbonization quest. Worldwide, one third of all energy consumption and 36% of CO_2 emissions are related to industrial activities (Selvakkumaran et al., 2014). Considering process-based emissions plus direct and indirect energy emissions, iron and steel production was responsible for 4.1% of the worldwide emissions in 2000 (Wang et al., 2007). Likewise, if a share of emissions inventoried for the energy sector is allocated to the industry, the industry in Sao Paulo would be responsible for 31.5% of the emissions in 2005. Therefore, assessing alternatives available to the industry to mitigate GHG emissions is relevant in terms of the current regulatory framework.

For policy makers it is important that economic performance metrics are presented in parallel with the proposed GHG mitigation pathways (Morrison et al., 2015). The relevance of cost effectiveness assessments stands out when the industrial sector is at stake.

The goal of this study was presenting the results of a recent MAC curve for the industry of Sao Paulo (MAC-SP) between 2014 and 2030 and comparing its results to similar studies in other jurisdictions. A set of cleaner production alternatives, including material and fuels efficiency and its substitution, were considered for the industrial sectors responsible for most of the CO_2 emissions. We present a brief explanation about the MAC approach and a review of other MAC studies that have focused on industrial GHG emissions. Next, we present a brief description of MAC-SP methods and its results. Finally, we compare the results of MAC-SP with other regional assessments, and MAC studies targeting the industry and provide some suggestions for future regional MAC studies targeting the industry.

2. Marginal abatement cost curve

Marginal abatement cost (MAC) curves can inform government officials and companies on the possibilities to attain carbon emission reduction targets (Isacs et al., 2016), becoming an important assessment tool for decision makers. Besides the production of a possible carbon mitigation scenario, the methodology determines the average costs of each mitigation technology. MAC curves determine the least cost options to attain a desired CO_2 mitigation target (Tomaschek, 2015). Although the absolute costs of each alternative is not the most relevant outcome of a MAC curve, it is especially useful for ranking the technologies in a specific sector (Huang et al., 2016). The approach is widely used in climate policy studies, including analyses targeting the industrial sector.

2.1. Theoretical basis

The MAC curve adopts a static approach, in which the MAC of each technology was obtained considering the difference between a reference scenario and a low carbon scenario to costs and emissions (Tomaschek, 2015).

The reference scenario is the business-as-usual case, in which GHG mitigation actions are spontaneous. The low carbon scenario considers the active introduction of technologies or measures to reduce GHG emissions. Resulting low carbon emissions should be necessarily under the reference emissions, however, technology costs in the low carbon scenario may be higher (positive MAC) or lower (negative MAC) than in the reference scenario.

The costs of both scenarios are composed by capital expenditures (CAPEX), fixed and variable operational expenditures (OPEX). Although energy costs are part of variable OPEX, they were analyzed independently because energy (fossil fuel and electricity) price forecasts affect annual costs, and therefore, the final MAC values. The discount rate is another key parameter in the MAC approach, because it is responsible for levelizing CAPEX values. The higher the discount rate is, the higher is the annual cost to pay back the investment over the technology's lifetime.

MAC Results are used to rank the technologies according to the average cost of one tCO_2 avoided emissions. One of the methods available to construct MAC curves rely on expert opinion which is used to calculate the cost and the potential of individual technologies and produce a graph ordering the alternatives from least to highest cost (Almihoub et al., 2013).