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The Colombian Energy Policy Challenges in Front of Climate Change

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ABSTRACT

Climate change is the biggest problem that humanity has faced in recent decades, one of the main causes are the greenhouse gases (GHG). To mitigate it, it has been proposed and international agreement in Paris 2016, known as COP21 by several countries. On it, the Colombian government got engaged a 20% reduction on its GHG to achieve it they will focus on the energy sector and deforestation to zero in the Colombian Amazon. This article analyzes the implications and challenges of energy policies for GHG mitigation in Colombia related to opportunities in energy demand, electric power generation sources, smart grid systems, reduction on energy loss in transport, demand schemes and management of methane in carbon deposits. The main conclusion reached in this analysis is that in energy matters COP21 objectives will not be met, the strategies that the government has chosen are not well focused based on the emission source in the country, five of the six strategies have not yet been legislated and much less implemented. Being in the second semester of 2020, the objectives will not be met this year or in the short term, the government opted for strategies that could not have been achieved.

Keywords: Climate Change, COP21, GEI
JEL Classifications: K2, O2, Q2, Q3

1. INTRODUCTION

Climate change (CC) is the most complex economic, environmental and social problem humanity has ever faced. This complexity includes transnational and transgenerational aspects, which require intergovernmental actions to combat it (Keohane and Victor, 2011). At a global level, the most polluting sectors in terms of GHG emissions are transportation and electricity generation, with 28% of total emissions each, estimated at 6,511 million tons of CO_2 equivalent (CO_2e); followed by the industrial sector with 22% of emissions; the commercial and residential sectors represent 11% of emissions each; and finally, agriculture with 9% emissions (EPA, 2018). Around 25% of the primary energy consumed corresponds to electrical energy. In 2016, 80% of this was produced by fossil sources (main GHG emission factor), while only 10.4% was produced by renewable energies, specifically hydroelectric, biomass, solar, wind and biofuels, on 7.8% was generated by traditional biomass and 2.2% by nuclear (REN21, 2018).

Given such GHG emission panorama, several international efforts have been made to mitigate them. The most recent was COP21 (Conference of the Parties held in Paris-France, within the framework of the United Nations Conference on Climate Change in 2015) and convened intersectoral participants and companies, governments, various NGOs and civil society, to promote the green economy (COP21, 2017). The main conference objective was holding the temperature increase below 2°C by the end of the century, but with the aspiration that could be 1.5°C, compared to pre-industrial temperature levels average.

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To achieve this, the agreement requires the ratification of at least 55 countries, which together produce 55% of GHG emissions. However, the multilateral agreement was signed and ratified by 48 and was ratified without signing by another 146 highlighting that around 40% of the emissions are produced by the United States and China, therefore the Agreement is not signed by of these countries generates a risk to compliance with it (UN, 2016); The United States generates about 15% of emissions and is the only country that has decided to exit the Conference and eliminate the Agreement since June 1, 2017 (WEF, 2017), while China generates about 28.5% of emissions and although it ratified it has not signed the Agreement. The agreement is legally binding but not fully, the national GHG reduction targets are voluntary. Besides, it would come into effect in 2020, and every 5 years they must verify their reduction targets (Nodal, 2015).

Initial results suggest that the agreed commitments represent a significant step towards bringing the world closer to meeting the long-term Paris Agreement goals on temperature. But, it is still not enough to keep the global temperature rise at levels "well below 2°C" and work to limit it to 1.5°C (Lütkehermöller et al., 2018). There is an urgent need for accelerated national policies in the short term so that the objectives of COP21 remain achievable (UN environment, 2017).

Agreement objectives are very important for world policy and represent a great challenge for developing countries more vulnerable to CC, because ENSO increases the substantial variability of precipitation (Power et al., 1999; Ropelewski and Halpert, 1988; Australian Bureau of Meteorology and Commonwealth Scientific and Industrial Research Organisation - CSIRO, 2011), is the dominant climatological phenomenon that produces extreme conditions in several countries (Cai et al., 2015) and will continue to be a source significant variability (Collins et al., 2010; Intergovernmental Panel on Climate Change, 2007). ENSO events depend essentially on the coupled interactions between the dynamics of the Pacific Ocean and the atmosphere in terms of heat exchange, as a result of variations in ocean temperatures in the equatorial Pacific and the associated atmospheric circulation (Neelin et al., 1990). It is an alternate phenomenon with two phases, the warm phase (El Niño) and the cold phase (La Niña), which occur every 3-7 years (NOAA Climate.gov, 2016) and its effects are opposite. For example, in Colombia and the northern equator region, La Niña represents periods of lower than average temperatures, and El Niño is characterized by patterns of high precipitation.

The nature of ENSO has varied significantly over time, historical data show a longer and stronger El Niño trend (Trenberth et al., 2001). Therefore, every 3-7 years, the water electricity supply systems will experience a considerable reduction in the levels of stored water during the El Niño phase, while the system will experience an abundant water flow exceeding capacity and therefore puts the generation at risk during the La Niña phase. According to some authors, the longer the El Niño phase, the more severe the next phase of La Niña will be (Trenberth et al., 2001).

This article presents the commitments made by Colombia before COP21, the methodology used by the Government to determine what the GHG reduction will be, as well as the mitigation measures that it would carry out to meet the objectives. The efficiency of these measures is analyzed under the Colombian context in its economic and technical capacities and its form of emission. Finally, the evolution of these commitments in the institutional framework and their application in specific regulatory measures is presented.

2. ENERGY POLICY IN COLOMBIA

In the COP21framework, Colombia has committed to reducing 20% of its GHG emissions by 2030 concerning the baseline. To achieve this, it focuses on three objectives: to have an electric power generation matrix with higher than 77% from renewable sources by 2020; stimulate growth in the use of fuels such as ethanol and biodiesel; and finally, reduce deforestation to zero in the Colombian Amazon.

To determine the commitment and mitigation measures, the Government issued a report called "Colombia towards COP21" (MinAmbiente, 2015) where three scenarios are analyzed: the first, proposes a 13% GHG reduction, whose mitigation measures have a cost less than 30 USD/tnCO_2e, and it does not depend heavily on measures that modify regulatory frameworks; the second proposes a 20% reduction with the same economic cost of the first scenario, but with the political and institutional transformations not contemplated in it; finally, the third scenario proposes a 25% GHG reduction including all the previous mitigation measures, at a high investment cost above 100 USD/tn$CO2_e$, which exceed the national investment capacities in CC mitigation (MinAmbiente, 2015).

According to the report, in all three cases the established objectives can be achieved, although, with different national effort levels and support from the international community, Colombia decided to assume scenario 2. "In this context, Colombia will commit to an ambitious reduction objective, sufficiently robust and with technical support, to guarantee its successful fulfilment" (MinAmbiente, 2015). If Colombia meets the proposed objectives, it could be close to maintaining the same level emissions per capita of its baseline: 4.8 tons of CO2e/ha. The mitigation measures designed for COP21 according to the national budget and the government's commitment are increase in energy efficiency in-demand sectors, diversify the portfolio of renewable energies, implement smart grid systems, use of generation schemes with unconventional sources, reduction in transport and energy losses, demand participation through price and incentive schemes, methane management in coal fields and mines (CBM and CMM), and carbon capture and storage (MinAmbiente, 2015).

3. ANALYSIS AND DISCUSSION

3.1. Pollution by GHG Emissions in Colombia

In Colombia, the main polluting sector according to the IPCC (Intergovernmental Panel on Climate Change) classification corresponds to AFOLU[1] with 43% of emissions; the second sector

1 Agriculture, Forestry and Other Land Uses (AFOLU)

is Energy with 38% of GHG; the Waste sector emits 8%; IPPU[2] 6%; and, the manufacture of fuel represents 5% of emissions (IDEAM, PNUD, MADS, DNP, CANCILLERÍA, 2015).

The energy sector includes fuel-burning activities, such as the energy industry, manufacturing and construction (In the burning of fossil fuels and biomass), transportation; Fugitive emissions from the manufacture of fuels such as fossil, solid and biomass fuels from the residential, commercial, institutional and agricultural sectors.

3.1.1. Main challenges regarding climate change

From studying GHG emissions and their relationship with the ENSO for the 2009-2017 period, it is observed that 2015 presents a high relationship between CC and GHG emissions with 14.65 Mtn CO2e, representing an increase of 20.5% compared to 2014. During the second semester of the year, the ENSO occurred, which reduced the hydroelectric-dams reservoirs level to 63%; Besides, the *Guatapé* hydroelectric plant, with 140 MW of installed capacity, was kept offline due to technical problems, ceasing to produce electricity. Consequently, during that year Colombia went from exporting 460 to only 0.44 GWh, while imports increased from 45 to 71 GWh (UPME, 2019).

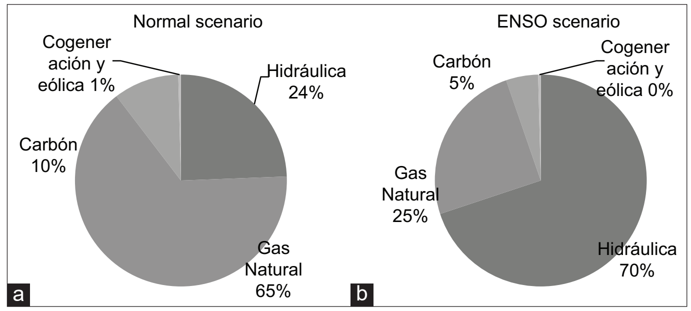
The years 2009, 2010, 2014 and 2016 showed a moderate ENSO effect with increase of emissions, compared to the immediately previous year, 45.9% (2009), 9.5% (2010), 8.2% (2014), although in 2016 there was a decrease because in 2015 the strongest ENSO phenomenon occurred. However, in years in which the ENSO is not presented, emissions decrease, as happened in 2017 when emissions were reduced 128%, from 12.59 Mtn to 5.52 Mtn. During the years with the presence of ENSO there is an increase in GHG emissions, a situation in which the Colombian electricity generation system is highly vulnerable, due to climate variability.

Now, the increase in pollution during the ENSO phenomenon could be explained by the fact that almost 70% of the electricity generation matrix in Colombia corresponds to water sources. Therefore, during the ENSO, the water level in the reservoirs decreases, limiting the generation of electrical energy through hydroelectric plants, for which the thermoelectric plants must replace the deficit in the generation of electrical energy, generating significant GHG contributions. The foregoing implies that the electricity generation matrix in Colombia changes dramatically during the ENSO periods. For example, in 2015, the year in which the last strong phenomenon was reported, the generation of electrical energy through hydraulic sources decreased by 45%, as shown in Figure 1. According to UPME (2015), Colombia is the third most vulnerable country to CC, especially the electricity sector.

In conclusion, it can be said that, although due to the configuration of the electricity generation matrix in Colombia, the electricity sector contributes very little to the emission of GHG, the electricity sector is very sensitive to climate change, precisely because it has a generation matrix-based mainly on water sources. Hydroelectric

2 Industrial Processes and Product Use (IPPU)

Figure 1: (a and b) Colombian electricity generation matrix, the year 2015



Source: Own elaboration, data obtained from UPME

power systems are susceptible to ENSO, making thermoelectric plants currently the only form of firm power. With COP21, several policies were proposed, which are expected to have a positive impact on reducing GHG emissions, but the efficiency of these proposals must be analyzed in detail.

3.2. Mitigation Energy Policies

In this section, an of the policies proposed analysis by the government to achieve a 20% reduction in GHG emissions in the energy sector is carried out. It is important to clarify that the electricity sector in Colombia does not contribute significantly to GHG emissions, therefore, of the main mitigation measures (having an electric power generation matrix with more than 77% from renewable sources by 2020, stimulating the growth in the use of fuels such as ethanol and biodiesel, and reducing deforestation to zero in the Colombian Amazon), the two related to the electricity sector do not seem to be relevant according to the current pollution panorama. However, the other mitigation measures proposed by the Government aimed at the energy sector in the framework of COP21 are analyzed below.

3.2.1. Opportunities in energy demand

Energy efficiency seeks that the processes or activities that include the use of electricity service are carried out with less use, which implies that the same activities are carried out at a lower cost. However, the increase in energy efficiency does not necessarily guarantee a decrease in the demand for electrical energy. According to the Jevons paradox, by benefiting from energy savings, due to the transition to high performance in consumption, the savings can act as an incentive by increasing the consumption of electrical energy (Copiello, 2017). When a process or activity becomes more efficient electrically, the effect that it is carried out with greater intensity occurs, therefore, the objective of reducing consumption is not achieved due to the increasing inactivity.

Therefore, increasing energy efficiency may not be the best way to reduce electrical energy consumption due to Jevons paradox. Although it could be a mitigation option, to be effective it requires additional education work in the use of electricity service aimed at consumers.

3.2.2. Electric power generation in Colombia

Currently, 69.9% of the electricity generation matrix in Colombia corresponds to hydroelectric sources, 0.1% to wind and 0.5% to cogeneration and the remaining 29.5% is supported by different hydrocarbons (gas, coal, diesel fuel, fuel oil, Jet A1). To reduce emissions, the government has proposed increasing electricity generation with renewable sources to 77%; However, this increase, which corresponds to 6.5%, will be a challenge for the country given that electricity generation with renewables is done through hydroelectric plants, which are highly sensitive to ENSO and therefore the reliability of the energy is questioned. long-term service under extensive and intense climate variability scenarios. It is evident that investment in infrastructure is directed at other renewable sources, such as solar, wind, small-scale hydroelectric or biomass.

Regarding solar energy in Colombia, it has gained momentum in the last 10 years, especially in La Guajira (Mendoza Fernández et al., 2018), but there has been no new investment since the Paris agreements. Specifically, two solar parks have been inaugurated: one by *CELSIA Yumbo* - Valle del Cauca, with 9.8 MW capacity and another by *Enel Green Power* in El Paso - Cesar, with an installed capacity of 86.2 MW (ENEL Green Power, 2018). So far, this measure is not reflected in energy policy, despite investment by private companies, the goal of increasing by 7% is still a long way off, unconventional renewable energy in Colombia does not reach 1% of the total.

However, the new investments in electrical energy (Table 1) respond to the "firm energy obligation" of the Colombian system, designed to guarantee the energy supply reliability at efficient prices (CREG, 2015). Other renewable energies are not yet considered, while hydroelectric energy remains the most widely used technology, followed by coal-fired thermoelectric plants and natural gas. Therefore, it can be evidenced that this mitigation measure will not be complied with and that, on the contrary, an increase in emissions in this sector could be expected.

3.2.3. Smart grid systems

A smart grid is the integration of electrical generation, transmission, distribution, storage and commercialization systems, to guarantee an economically efficient energy system, with low electrical losses, high levels of quality and security of supply (ETSI, 2019).

This measure would be efficient in the Non-Interconnected Zones in Colombia, mainly due to the substitution of conventional sources for renewable ones and because in these zones electrical energy can be generated by these sources in places close to the distribution point; these systems have positive implications on CC since they contribute to reducing GHG emissions (Feldpausch-Parker et al., 2018), losses in electricity transmission and the electrical infrastructure size (Ourahou et al., 2018).

Table 1: Short-term investment plans in electrical infrastructure

Generation technology	Period			
	2018–2019	2019–2020	2020–2021	2021–2022
Hydraulic	30.399	27.689	29.078	31.625
Gas-fired power plants	4.441	5.343	6.117	6.289
Coal-fired power plants	7.124	6.864	7.209	7.051
Oil-fired power plants	4.522	4.377	4.597	4.497

Source: Own elaboration, data obtained from XM

In 2016, the Energy Mining Planning Unit (UPME) carried out the "Colombia, smart vision 2030 of Smart Grids" study presenting the background and the conceptual technology framework, implementation recommendations and proposed a regulation and legislation (UPME, 2016); however, it is not yet legislated, therefore, in the short term it does not materialize as a mitigation measure.

3.2.4. Reduction of energy loss in transport

In Colombia, as in many parts of the world, electrical energy is, for the most part, produced in areas far from urban centres. To bring energy from the generation place to the consumption point is required an electrical distribution network carrying lost inherent of the transport process.

In particular, in Colombia, the electrical energy losses in the distribution system have historically represented a high cost for its consumers, as well as for the companies that provide this service (Romero-López and Vargas-Rojas, 2010). Smart grid systems could solve this energy loss by reducing the distance between the end-user and the generation point, even if the energy cost increased due to the cost of the land to generate it. However, since the agreements, although this issue is mentioned as a mitigation measure, there is no evidence with specific actions in the current government agenda.

3.2.5. Demand for participation through pricing and incentive schemes

This measure seeks to use the interaction between supply and electricity service demand, assigning high prices to the consumption-peak hours and incentives to low-demand hours, to efficiently redistribute electricity consumption (Luo et al., 2019). Colombia has three hours-peaks of electrical-power consumption: in the morning (05:00–07:00), at noon (11:00–13:00) and night (18: 00–21:00) (XM, 2019). During peak hours hydroelectric do not supply all the electric demand so that the system relies on another source such as hydrocarbons, if these peaks are reduced, the use of hydrocarbons in those hours could be reduced also with the GHG emission.

However, Colombia has a subsidiary electricity system, made up of socioeconomic strata (1 is the lowest and 6 is the highest), strata 4 to 6 subsidize strata 1 and 2; This subsidy causes strata 2 and 3 to present higher demands than the others, while the highest stratum presents more savings (Universidad Nacional de Colombia, 2006). Therefore, for the measure analyzed to be efficient, the subsidiary regime must be annulled, otherwise, the subsidized strata until now will not be interested in participating in the price and incentive scheme.

This measure could be efficient; however, despite the subsidy model and the potential for reducing demand for this mitigation measure, this measure is not yet legislated, that is, it is still a plan without action.

3.2.6. Management of methane in carbon deposits and mines, carbon capture and storage

This measure seeks to capture and store the CO_2 (CCS) produced in some energy processes to prevent it from reaching the atmosphere, after retaining it is transported to geological storage to keep it isolated from the atmosphere. This technology can theoretically capture more than 90% of the CO_2 generated by power plants (Coutris and Brooks, 2015), however, the CCS is stagnant and doubts persist about its techno-economic viability (Vinca et al., 2018). CCS techniques have been recognized as the most promising method to mitigate GHG emissions (Raza and Rabiei, 2018), but it is not yet a proven and reliable method: it still has unresolved sensitive points, for example, leakage control, the effects on the ecosystems, the monitoring and control system, the transport of CO_2 (compression of gas to a supercritical state, corrosion of the pipeline and the effect of the fluid composition on the power to be consumed) and the higher consumption of energy (Wilberforce et al., 2019).

In this regard, a pilot plant was installed in China, the results of which indicate that this technology continues to be a challenge and that it will hardly become a reality (UNCCD and IRENA, 2017). Also some research conclude that large-scale CCS can induce seismic risk (NAP, 2012).

The government proposal is "CO_2 capture in the pre-combustion, post-combustion and oxy-fuel processes in refineries (especially in equipment such as heaters and boilers) and development of schemes for the storage of geological gas" (Ministry of the Environment, 2016); as previously presented, the technology for this mitigation measure will not be available in the immediate years, as this is not a real GHG reduction measure for 2020 in Colombia.

4. DISCUSSION

After COP21, the government proposed a series of mitigation policies in the field of electric power to reduce GHG emissions. However, not all policies designed for this purpose have been legislated. Table 2 presents the current Colombian legislation, and only, after the commitments of COP21, were the renewable energy matrix, non-conventional generation sources, and energy efficiency of the demand sector legislated.

Table 2: Legislation of policies in commitment to COP21

Politics	Legislation in force after 2016
Energy efficiency in-demand sectors	1543/2017 del MMA ordinance
Renewable energy porfolio	1283/2016 MMA resolution CREG 167/2017 resolution CREG 201/2017 resolution CREG 030/2018 resolution 1955/2019 law
Smart grid systems	No legislation available
Generation schemes with unconventional sources	No legislation available
Reduction in transport and energy losses	No legislation available
Demand participation through price and incentive schemes	No legislation available
Methane management in coal fields and mines (CBM and CMM)	No legislation available

Source: Self-made. *MMA: Ministry of the Environment

It is important to highlight that the energy efficiency policy of the demand sector had been legislated before under CREG resolution 011/2015; the energy reduction losses in transport according to 2492/2014 Ministry of Mines and Energy ordinance. Besides, the renewable energy matrix and unconventional generation sources used to be governed 1715/2014 Law, through which the integration of non-conventional renewable energies into the National Energy System is regulated, the most important and complex legislation in the field of electrical energy. With this, it is evident that the Colombian government has made some progress in diversifying the electricity generation matrix, but there is also a growing interest in other mitigation measures, especially those related to efficiency. Despite the government's commitment to the reduction established in scenario number two, the reality, five years later, is more similar to what was established in scenario number one, which does not have a great dependence on enabling measures such as developments and regulatory frameworks.

Colombia must continue deepening vulnerability assessments and the most profitable measures to adapt to the energy sector. As stated, ENSO represents a challenge for Colombia and is expected to be even more intense in the coming opportunities, causing a reduction in annual precipitation of 15-30% for the current century, accompanied by the intensification of storms (Ortega and Ortlieb, 2019). This may eventually cause an increase in the demand for electricity due to the use of electronic devices, such as air conditioners and fans; as well as the generation of electrical energy by hydric sources can also be affected.

Given the dependence on hydrocarbons due to the intermittency of renewable sources in the face of climate variability, Colombia will need more natural gas for electricity generation in the short term, while policies and large-scale renewable projects are available, creating a green paradox. It is puzzling because it seems to go against the commitments made by the government at COP21. Similarly, the energy price during these critical periods increases, and is expected to increase even more, despite having agreed on a "reliability charge" between the thermoelectric plants and the Colombian government. The current price per kW is 500 COP (0.13 USD[3]), while liquid fossil fuel generation can increase the price to 900 COP (0.24 USD), which corresponds to 44.4% more.

The other option for the Colombian scenario is to produce long-term energy through nuclear power plants, since it is efficient, has high power density, does not emit GHG and has a low production cost (Lau and Ching, 2019). However, this option is criticized due to a negative public perception associated with the risk of nuclear accidents (Knapp and Pevec, 2018).

In Colombia, the sector that consumes the most electrical energy is residential (65%), followed by industrial (30%) and commercial (5%). Therefore, GHG reduction policies would have

3 TRM August 19, 2020.

been expected to focus on the residential sector; but the opposite happened, the policies were designed for the industrial sector. Instead educational policies are required to reduce long-term residential demand; Consumers could respond positively in the short term in reducing demand with advertising campaigns during lean periods, as happened in 2015, contrary to what was expected by presenting a demand coefficient of elasticity for the service that is not very sensitive to changes in price. The government could take advantage of the positive residential consumers response in the aforementioned case, as well as its inclusion in the development of policies whose success has been proven in other countries (Morales et al., 2006).

The government has presented very varied mitigation energy policy measures, some with a more robust enforcement framework than others. However, it should be considered that these are strategies to reduce carbon dioxide emissions, but that they are not yet a legislated policy of the State. The leap from strategy to policy and especially to implementation is expected, which would reflect the intention to reduce GHGs by 20%.

5. CONCLUSIONS

The ENSO climate variability strongly amplified by the CC, puts at risk the country's ability to meet the reducing GHG emissions objective by 20% within the COP21framework. Although Colombia intends to increase electricity generation with renewable energies to reduce emissions, currently the predominant energy is hydroelectric, a technology highly vulnerable to CC. Given climate variability, the short-term solution is, in the best-case scenario, to generate electricity through gas-fired power plants, although in the face of fuel shortages emissions may increase due to the burning of coal, which is cheaper than liquid fuels such as gasoline, diesel or biodiesel. Faced with this scenario, the nuclear source is presented as an alternative, even when public perception could be critical to allow the development of effective policies for nuclear energy.

It should be noted that in Colombia emissions in the electricity sector have increased since 2006, mainly in the years of the ENSO. The increase in pollution during this phenomenon could be explained considering that 70% of the energy generation comes from hydroelectric sources. Therefore, during the ENSO, the water level in the reservoirs decreased limiting the hydraulic generation for which the fossil-fired power plants had to replace the deficit at the cost of an increase of significant GHG emissions.

In the legal framework, only the renewable energy matrix, the unconventional generation sources, and the energy efficiency of the demand sector were legislated before the COP21 commitments. With this, it is evident that the Colombian government had made some progress in diversifying the electricity matrix, but there is also an interest in other policies, especially those related to efficiency. Despite the government's commitment to reducing scenario number two, the reality five years later is that it is more like scenario one, which does not have a great dependence on enabling measures such as developments and regulatory frameworks.

As the residential sector is the major consumer of electricity in Colombia, public policy on electrical education is required to achieve a 20% reduction even in DC scenarios. Stronger institutional work is a must. The greatest mitigation potential is in sectors that depend on the common citizen rather than industry, such as land use, transportation and energy. It seems that the three clear objectives determined by the Colombian government will not be enough to achieve the COP21objectives.

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