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Towards a low-carbon electric power system in Mexico

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ABSTRACT

The energy sector is one of the largest sources of Greenhouse Gas (GHG) emissions in Mexico and the World due to the intensive use of fossil fuels. This article is developed on and examines from an environmental and economical approach an alternative scenario towards a Mexican Low Carbon Electric Power System, by analyzing 36 GHG mitigation options on the electric demand side, namely −23 for an energy-efficient use and 4 for distributed generation, across the residential, commercial, public, industrial and energy sectors and, 9 options of electric power generation with Renewable Energy Sources (RES) on the electric power supply side. Our results reveal that, regarding the GHG baseline, towards 2020, this alternative scenario minimizes 33% of the GHG emissions, and towards 2035 these emissions are dramatically minimized at 79%. Furthermore, results also show that there is a possibility to reach a GHG peak in the electric power industry in very few years with this alternative scenario. Moreover, it is found that this alternative scenario will entail no cost in the analyzed period; on the contrary, it creates a global economic benefit of over 8000 MUSD, where 74% is related to the application of the mitigation options in the electric demand sectors and the remaining 26% comes from RES technologies in the electric power supply. Results show that the implementation of this alternative scenario requires an incremental investment of almost than 2 Billion USD/year within the analysis period. Lastly, it is shown that national goals for the electric power sector that have been recently established in the General Climate Change Law, the Energy Transition Law as well as the proposed Intended Nationally Determined Contribution in the Paris COP21 Agreements are feasible for achievement in this alternative scenario.

Introduction

Since 1990, greenhouse gas (GHG) emissions from the electric power sector worldwide have increased at a yearly rate of 2.7% reaching, in 2011, 12,954 $MtCO_2e$, which amounted to 41% of the total GHG emissions derived from energy use (IEA, 2013a). Taking these trends into account, it is forecast that these emissions from the electric power sector worldwide will keep on growing alarmingly towards year 2035 until it reaches 19,123 $MtCO_2e$ (IEA, 2013b).

In this context, the utilization of Renewable Energy Sources (RES) for electric power generation becomes an important factor for the uncoupling of electric power generation and GHG emissions. Nonetheless, electric power technologies based on RES, although these may be at diverse technological and commercial maturity stages (Grubb et al., 2008), face significant barriers for its wide usage, such as recognizing negative externalities from fossil fuels and establishing appropriate financial sources and mechanisms to allow a widespread use of the RES in electric power systems. Therefore, it is essential to use other feasible mitigation options, both from the technical and economic standpoint to achieve significant GHG reductions in the electric power system, such as energy savings and an efficient use of energy. To a large extent, the originality of this article lays in showing that a mitigation option portfolio including intensive measures for energy savings and energy efficient use (EEU) and distributed generation (DG) based on solar energy in the electric power demand and, RES in the electric power supply is a solution with economic benefits to establish low-carbon electric power systems.

On the other hand, in a national context, it must be noted that Mexico is one of leader countries in the world that has Climate Change Law that enabled establishing an institutional framework to set goals

Abbreviations: AC, Air conditioning; AS, Agricultural sector; AAGR, Average annual growth rate; AUEC, Average unit electricity consumption; BAU, Business as usual; CFL, Compact fluorescent lamps; COP21, Twenty-first meeting of the Conference of the Parties of the United Nations Framework Convention on Climate Change; CS, Commercial sector; DG, Distributed generation; EEU, Energy efficient use; GHG, Greenhouse gas; GW, Giga-watt; GWp, Giga-watt peak; HS, Oil and Gas sector; INDC, Intended Nationally Determined Contribution; IPVS, Interconnected photovoltaic systems; IS, Industrial sector; kW, Kilo-watt; kWh, Kilo-watt hour; kWp, Kilo-watt peak; LEAP, Long-range Energy Alternatives Planning System; LGCC, General Climate Change Law; MUSD, Millions of U.S. Dollars; $MtCO_{2e}$, Million ton of equivalent carbon dioxide; MW, Mega-watt; MWp, Mega-watt peak; PS, Public sector; PV, Photovoltaic; RES, Renewable Energy Sources; RS, Residential sector; TS, Transportation sector; TWh, Tera-watt hour; USD, U.S. Dollars.

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and foster plans, programs and mechanisms that favor GHG mitigation and the adaptation to climate change in Mexico. This law was recently enacted in 2012 and named the General Climate Change Law (LGCC) (DOF, 2012) establishing three ambitious and volunteer goals specially to minimize GHG emissions in the medium and long term. The first one aims to minimizing national GHG emissions in 30% by 2020 against the current base line; the second one, and the most relevant for this article, provides for that by 2024, the percentage of electric power generation with clean energies must be 35%, while the third one sets a 50% national GHG emission reduction goal by 2050 against GHG emissions in 2000.

More recently, in the framework of the international negotiations of the Conference of the Parties of the United Nations Framework Convention on Climate Change during its twenty-first meeting (COP21), Mexico presented its Intended Nationally Determined Contributions (INDC) to minimize GHG, by establishing, on the one hand, an unconditioned goal to reduce 22% its GHG emissions by 2030 against the current base line and, on the other hand, a conditioned goal to reduce 36% its GHG emissions in that same year if a global agreement is to be reached to ensure the financial support and technology transfer to enforce mitigation actions in developing countries (Gobierno de la República, México, 2014). Regarding the electric power sector, the INDC for Mexico established that for the unconditioned goal, the Mexican electric power sector achieves a 31% GHG reduction against its GHG emission sector base line (SEMARNAT, 2015). The goals set under the LGCC and the INDC of the Mexican government for the electric power sector are, furthermore, framed in a new institutional context derived from the most recent Mexican energy sector reform (Alpizar and Rodríguez, 2016), especially with the new Energy Transition Law (DOF, 2015) which established a minimum number of clean energy involvement in electric power generation, namely: 25% in 2018, 30% in 2021 and 35% in 2024.

Before these important mitigation goals and the legal provisions to establish clean energy involvement goals, reliable and accurate data is required to develop a GHG mitigation action portfolio that is deemed feasible in Mexico to achieve them. This article addressed this issue focusing on the Mexican electric sector, which is responsible for 24% of the total GHG emissions due to the use of energy in Mexico. For this purpose, this article shows the development of an alternative scenario for the Mexican electric sector based on an intense use of EEU and DG on the electric power demand side and RES on the electric power supply, which is critical to attain a cost effective low-carbon scenario that is aligned with the national GHG reduction goals. Several studies were developed mitigation scenarios for the electric power sector in Mexico, focusing on the electric power supply mainly from RES (Manzini et al., 2001; Islas et al., 2003, 2004a, 2004b; Santoyo et al., 2014; Vidal et al., 2015) and, this way, EEU and DG mitigation options have been overlooked for the electric power demand. Very few studies in Mexico (McKinsey and Centro Mario Molina, 2009; Johnson et al., 2010; Martínez and Sheinbaum, 2016) include GHG mitigation options, both on the electric power demand and supply. However, the EEU and DG are not explored in an exhaustive way in the electric power demand as mitigation options; accordingly, the potential in the mitigation options for the electric demand have not been properly taken into account to develop more ambitious GHG mitigation scenarios in the electric power sector and, this way, to make them feasible from a technical and economical approach.

The current situation in the Mexican electric power sector

The Mexican electric power sector, according to the world's trend, has characterized over the last decades for the prevalence of fossil fuels as energy input which amounted to 82% (SENER, 2015a). This has caused a significant GHG emission contribution that reached 127 $MtCO_2e$ (INECC, 2015), which represented, as stated above, about 24% of the national GHG emissions (522 $MtCO_2e$) from combustion of energy fuels and over 19% of the global emissions in Mexico (665 $MtCO_2e$) (INECC, 2015). Accordingly, if this country is pursuing a route to significantly reduce its GHG emissions, the electric power sect must be de-carbonized.

Table 1 shows data about the total installed capacity based on RES in Mexico for the electric power generation in 2014 (SENER, 2015b) and the maximum and minimum values of the RES potential, which has been reported in several studies (CFE, 2010; CONUEE, 2011; CRE, 2011; García et al., 2015; Islas et al., 2013; NREL, 2003; SENER and IIE, 2011; SENER, 2012a, 2013). According to this table, this trend towards a predominant use of fossil fuels and low participation of RES in the electric power sector seems paradoxical when we know that Mexico has an important RES potential.

On the other hand, since the beginning of the 1990s, especially through the implementation of The National Commission for Energy Savings (Comisión Nacional para el Ahorro de la Energía) (today CONUEE — Comisión Nacional para el Uso Eficiente de la Energía), EEU has been part of national energy policies and in the context of national commitments and targets for climate change and the reduction of proven national oil reserves, it appears that EEU policies in Mexico will become more important. To date the Mexican Ministry of Energy through the CONUEE has issued 27 EEU standards of which 22 impact the consumption of electricity (CONUEE, 2016). This article takes into account 23 EEU options which 8 are Mexican standards and 4 DG (distributed generation) solar energy based options and try to show that all these options imply an important reduction of electric power demand which may significantly reduce the consumption of fossil fuels for electricity generation. Even more, this article is seeking to prove the technical and economic feasibility of low-carbon scenarios in the electric power systems based on an intensive use of EEU and DG based on renewable energy in the demand side and the use of RES power plants in electricity supply. The method used to prove this feasibility is the development of scenarios and the global cost-benefit analysis of an alternative scenario against the base scenario. This research may be a benchmark for national studies conducted in other countries

General methodology

To develop this work the following steps are made:

- First and foremost, the reference year is established as 2010, since in this year there are enough data to duly represent the electricity demand and the power supply in Mexico to develop the business as usual (BAU) scenario and the low-carbon alternative scenario, for a forecast period of 25 years.
- Secondly, the BAU scenario is created by following the official forecast to develop the electric demand and the power supply (mainly based in combined cycle and coal plants) in Mexico.
- Thirdly, the low-carbon alternative scenario is created based in two main components. On the one hand, by representing intense GHG mitigation actions on the electric demand side, with the implementation of 27 emission mitigation options, out of which, 23 are related to EEU and 4 are related to DG. On the other hand, with GHG mitigation actions on the power supply considering 9 RES-based technologies.
- Finally, a cost-benefit analysis is conducted to define the economic viability of the low-carbon scenario in relation to the BAU scenario.

All of this is simulated in LEAP software (Heaps, 2008), which is an accounting bottom-up model, where a draw between the electric demand and the generation supply is an unavoidable condition to simulate in an adequate way for the whole analysis period (Grande, 2013).