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Research Paper

Towards a low-carbon Mexican chemical industry

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HIGHLIGHTS

- A BAU and a low carbon scenarios are constructed in MCI's energy end-use terms.
- The implementation of 15 mitigation measures of greenhouse gases is analyzed.
- 10 efficient energy measures and 5 renewable energy technologies are considered.
- The proposed low carbon scenario generates a net economic benefit of $7.2 billion.
- The low carbon scenario reduces 65% the cumulative GHG emissions from BAU scenario.

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ABSTRACT

In 2014, the Mexican Chemical Industry (MCI) energy consumption represented 13.5% of the industrial sector total consumption (211 PJ), being the industry with the second highest greenhouse gases (GHG) emissions in Mexico with 13.8 $MtCO_{2e}$. This article shows that in the medium and long term it is feasible to transform the MCI into a low-carbon industry. To prove this hypothesis, two scenarios are constructed in terms of the MCI's final energy uses: a business as usual (BAU) scenario and an alternative one, a low-carbon scenario which analyzes 15 GHG mitigation measures, 10 related to efficient energy use (EEU) and 5 associated with the implementation of renewable energy sources (RES). The results show that, when compared to the BAU scenario, the low-carbon scenario reduces the MCI's energy consumption by 63.5% in 2030 and by 78.5% in 2050, resulting in a cumulative total GHG emissions reduction of 65%. Additionally, the low-carbon scenario will not generate costs in the analyzed period; on the contrary, it would produce a global economic benefit above 7200 million USD (MUSD). Likewise, the results show that the implementation of this alternative scenario requires an incremental investment over 377 MUSD/year within the analysis period. Finally, implementing the proposed low-carbon scenario results in a significant modification of the MCI energy end-use structure.

1. Introduction

The chemical industry is a complex industry that covers a large number of processes, ranging from continuous processes to produce basic chemicals to large volumes of batch processes to produce specialty chemicals and pharmaceutical ingredients. Chemicals are used in a wide variety of final consumer products, playing an important role in the global economy, for example in the European Union, more than 140,000 chemicals are registered for marketing and expects that about 30,000 new substances will be registered in 2018 [1]. The chemical industry is one of the world's largest industry with a 7% share of world GDP and global sales of 4,730 billion[1] USD [2]. This is reflected both in its energy consumption and in its generation of GHG emissions. Indeed, in 2012 the energy consumption of the global chemical industry was 15 EJ, representing 10% of the final consumption of world energy, which shows the energy intensive nature of its production processes, which

Abbreviations: AV, added value; BAU, business as usual; CHP, combined heat and power; COP21, twenty-first meeting of the Conference of the Parties of the United Nations Framework Convention on Climate Change; E, electricity; EEU, efficient energy use; EJ, Exajoule; EU, European Union; FF, fossil fuels; GDP, gross domestic product; GHG, greenhouse gases; NG, natural gas; GWP, global warming potential; IC, investment cost; kWh, kilo-watt hour; LC, low carbon; LPG, liquefied petroleum gas; MCI, Mexican chemical industry; $MtCO_{2e}$, million ton of equivalent carbon dioxide; MUSD, millions of U.S. dollars; NC, net cost; NDC, nationally determined contribution; O&M, operation and maintenance; PJ, petajoule; RES, renewable energy sources; SEN, national electric system; USD, United States dollars

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[1] Monetary amounts are expressed in constant US dollars for 2007.

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require high temperatures and in consequence, they generate significant GHG emissions, mainly due to fossil fuels (FF) burning for process heat generation used in their production processes. In this way the global chemical industry is responsible for generating 7% of global GHG emissions [3]. Therefore, it is important to analyze and propose mitigation measures to move towards a global low carbon chemical industry. For example, global studies show that in the European Union (EU) since 1990 the chemical industry has reduced its GHG emissions by 59% as a result of a gradual decoupling between its energy consumption and its production and is planning a reduction of 89% by 2050 [4,5]. Also in the United Kingdom (UK) it is anticipated that its chemical industry will reduce its GHG emissions by 90% by the same year [6]. In both cases, these reductions are achieved through the implementation of various GHG mitigation measures, such as combined heat and power (CHP), process integration and the use of low-carbon electricity.

The Mexican chemical industry (MCI) is no exception to this climate problem generated by the world chemical industry. In fact, the MCI consumed 211 PJ in 2014, which represented 13.5% of the total consumption of the Mexican industrial sector, which places it as the second most energy intensive industry in Mexico. Where 88% of its consumption corresponds to the use of FF, where natural gas (NG) is the most used fuel with 84% (156 PJ) of total consumption, while 12% (25 PJ) was electricity (E) and the remaining 4% belongs to the consumption of diesel (2.3%), petroleum coke (0.3%), fuel oil (1%) and liquefied petroleum gas (LPG) (0.4%) [7], see Fig. 1.

Due to these consumptions the MCI emitted a total of 13.8 $MtCO_{2e}$, which considers the indirect emissions from the consumption of electricity. These emissions account for just over 9% of global emissions from the Mexican industrial sector [8]. GHG mitigation in this industry represents a challenge for Mexico to meet its mitigation commitments, called Intended Nationally Determined Contributions (INDCs) that are part of the Paris COP21 agreement, in which Mexico commits itself to reduce their emissions by 22% unconditionally by 2030 and by 36% on a conditional basis [9]. Consequently, if Mexico is looking for a route to meet its international commitments on GHG mitigation, the MCI should be decarbonized. To achieve this, a technical and economic feasibility study of a low carbon scenario for the MCI based on 15 measures of GHG mitigation, 10 related to the efficient use of energy (EEU) and 5 to the use of renewable energy sources (RES) is presented. To prove this feasibility, two scenarios, a BAU scenario and a low carbon scenario were constructed, both in terms of MCI's final energy uses, and a net cost analysis of these scenarios was carried out.

1.1. The current situation of the Mexican chemical industry

The MCI is one of the main economic activities of the country. In 2014, this industry generated an added value (AV) of approximately $18,600 MUSD, which represented 1.8% of the national GDP, 11.8% of

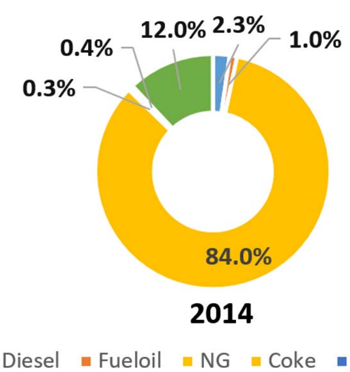

Fig. 1. Mexican Chemical Industry energy consumption structure in 2014.. Source: [7]

the industrial sector AV in Mexico with 150,000 employees in 583 companies [10]. According to a study carried out by the United Nations Development Program (UNDP) in conjunction with the National Chemical Industry Association (ANIQ) [11], it is expected that one of the main effects of the recent energy reform in Mexico, in the medium and long term, will be the reduction of the MCI imports. According to this study, this reduction will allow a greater self-sufficiency of raw material that will promote the growth of its AV, since we assume a substitution of 25% of imports, which would have consequently a MCI's AV growth at an annual average rate of 3.9% between 2014 and 2050 instead of the forecasted 2.1% before this reform. This higher growth rate is in line with the MCI growth forecasts estimated by various international organizations [1,2,12]. Taking as reference studies on final energy consumption in the chemical industry [13,14] and official data [7,15], it can be estimated that currently in the end-use energy structure of the MCI, 94% of FF is burned in boilers to produce steam, the remaining 6% is used in thermal fluid boilers (4%) and in furnaces & dryers (2%). Electricity is consumed mainly by electric motors, which represents 73% of its total consumption, distributed in compressed air (20%), pumping (19%), ventilation (9%), refrigeration (6%) and others 19%). The remaining 27% of electricity consumption is in illumination (17%) and other uses (10%), see Fig. 2.

Fig. 3 shows the GHG emissions by energy end-use. This structure confirms that the largest amount of emissions, 76.5% of the MCI, is generated due to FF burning in boilers for steam production, heating of thermal fluids, furnaces and dryers. Electricity consumption implies 17.5% used mainly for electric motors and the remaining 6% for lighting and diverse uses. From this structure, it is demonstrated that this industry is intensive in emissions, so this article will analyze various mitigation measures of GHG by energy end use to achieve a low carbon MCI.

2. General methodology

This study was carried out with the following method:

- First, the year 2014 is established as the reference year to construct the BAU and LC scenarios, which is the most recent year where there is available and complete, data to represent in detail the consumption of energy by MCI's end-uses.
- Secondly, a BAU scenario is constructed, considering the growth forecast for the MCI's AV [12] and the increase in energy consumption and in GHG emissions by MCI's energy end-uses is projected for the period 2015–2050.
- Third, to build a low carbon (LC) scenario, a portfolio of viable GHG mitigation measures based on efficient use of energy and in the use of renewable energy sources is developed.
- Fourth, the penetration level of each GHG mitigation measure considered for the LC scenario in the period of analysis was determined based on expert opinion obtained using the Delphi technique.
- Finally, a net cost (NC) analysis of the GHG mitigation measures of the LC scenario is carried out. Due to the fact that this article intends to carry out a conservative economic analysis, it is considered as an important work hypothesis to keep the costs of investment, O&M and fuels, constant and equal to the current ones. It is also part of the working hypothesis to consider only the direct costs in these areas.

2.1. BAU scenario

Once the energy end-use structure for the reference year is established (Fig. 2), the BAU scenario for the period 2015–2050 is calculated by projecting the energy consumption by energy end-use, taking as a guideline variable the growth of the MCI's AV established by [11] where, as already mentioned, the MCI AV grows at an average annual rate of 3.9% between 2014 and 2050. Table 1 shows the unit costs of