DESIGN AND DEVELOPMENT OF AN ENERGY MODEL FOR MEXICAN ELECTRICITY SYSTEM

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1. INTRODUCTION

Climate change is unequivocal, human influence on the system is clear, anthropogenic greenhouse gas (GHG) emissions are becoming higher because of economic and demographic growth. Earth's average temperature has increased, ice and snow volumes have decreased, and sea level has risen (IPCC 2014).The extreme meteorological phenomena are becoming more and more frequent and they do not stop accentuating.

The United Nations 2030 Agenda for Sustainable Development and its Sustainable Development Goals (SDGs) call on countries to take urgent measures to combat climate change and its effects. Guarantee access to affordable, safe, sustainable and modern energy, being part of the SDG and it is essential to eradicate poverty, protect the planet and ensure prosperity, it is also an axis of efforts to tackle climate change (UN 2015).

According to the International Energy Agency (IEA), the energy sector represents more than 80% of carbon dioxide (CO_2) emissions worldwide. Although emissions increased the electricity sector accounted for almost two thirds of total growth. In 2016, global CO_2 emissions from burning fossil fuels were 32 $GtCO_2$ (IEA 2018).

Against this background, in the framework of the Conference of the Parties (COP 21), held in Paris in 2015, several countries committed to significantly reduce their GHG emissions to a level of not increasing the planet's temperature above 2 ° C. All parties must submit their Intended Nationally Determined Contributions (INDC). INDCs are a commitment by the international community to reduce national emissions and adapt to the effects of climate change; the parties must adopt internal mitigation measures, in order to achieve the objectives (UN 2015).

As part of efforts to regulate emissions of greenhouse gases and compounds, in 2012 the General Climate Change Law (LGCC) entered into force, with the aim of establishing the basis for Mexico to contribute to compliance with the Paris Agreement. Its function is to regulate, promote and incorporate adaptation and mitigation actions with a long-term focus, defines the obligations of the authorities and establishes institutional mechanisms to face the challenge (SEGOB 2012).

In order to meet the objectives, it is essential to design and implement public policy instruments to strengthen the LGCC. One of the planning instruments is the National Climate Change Strategy (ENCC) vision 10-20-40, which describes the lines of action to be followed based on the available information of the present and future environment, to meet national priorities and achieve the country's long-term goals.

Mexico has made an international commitment to reduce 22% of its GHG emissions by 2030, a figure that could rise to 36% on a conditional basis if it receives international support (SEGOB 2014).

These ambitious climate action objectives are framed in the new context of a reform of the Mexican energy sector. After a long period in which the energy system was dominated by oil, it gradually lost direction, due to this, in 2013 the Energy Reform (RE) was approved as part of the efforts to modernize and diversify the national economy (SEGOB 2013). The general objective of this reform was to provide a more sustainable, efficient, transparent and productive energy sector, to increase the benefits obtained from the country's resources, while promoting the growth of low-carbon energy sources (IEA 2016).

The institutional changes created a new architecture for the organization of the Mexican electricity system where the public monopoly model opened up private investment, specifically the Federal Electricity Commission (CFE) ceased to have full control of the electricity sector, allowing competition in the generation and marketing segments.

In this context, it seeks to build and evaluate scenarios of technological options to reduce GHG emissions in the electricity sector, based on the use of renewable energies, involving all participants in the new organization scheme, as well as considering the measures of mitigation and adaptation to climate change.

1.1 Mexican Electricity System

The National Electric System (SEN) is a component of the energy sector that involves the generation, transmission, distribution and commercialization of electrical energy. Today the electricity industry is made up of various public and private actors involved in the process of generating electric power, although transmission and distribution for public service are activities reserved for the Mexican State.

The demand for electricity has more than doubled in the last twenty years, more than 99% of the population has access to this service, but consumption per capita is relatively low. According to data from the National Electric System Development Program (PRODESEN) (SENERa 2018), in 2017 per capita electricity consumption was 2,098 kilowatt-hours per person (kWh / p).

Energy decarbonization has energized the sector due to the incorporation of clean energy sources and new players in the electricity market. Regarding electricity generation in Mexico, it is dominated by natural gas, which has replaced fuel oil as the main fuel (IEA 2016).

According to the National Inventory of Gas Emissions and Greenhouse Compounds (INEGyCEI), electricity production contributes with 25.9% of national emissions due to the burning of fossil fuels, which mainly release carbon dioxide (CO_2) from the carbon content, although they also release methane (CH_4) and nitrous oxide (N_2O) according to the characteristics of the fuels, the technology used and the reduction measures. In this sense, there is a great challenge in the electricity sector. Mexico has made various commitments that it will face in order to move towards a low-carbon economy, both the inclusion of clean energy and adaptation and mitigation of climate change.

1.2. GHG emission commitments.

Mexico's unconditional goal was to reduce GHG emissions by 22% by 2030 against a baseline. This mitigation is equivalent to 210 MtCO2e. Specifically, the electricity generation sector could contribute a reduction of 63 MtCO2e, that is, 31% of its emissions, around a third of the unconditional national goal (INECC 2018).

1.3. Clean energy goals.

The LGCC recognizes the potential of the electricity sector to contribute to the mitigation of climate change. Therefore, it promotes energy efficiency practices and promotes the use of renewable energy sources for electricity generation. It also points out the importance of developing incentives for both public and private investment in the generation of electrical energy from renewable sources and the inclusion of the costs of social and environmental externalities.

For its part, the ENCC aims to accelerate the energy transition towards clean energy sources, by replacing fossil fuels, strengthening regulatory, institutional and economic schemes and reducing environmental and social impacts (SEMARNAT 2013).

The Energy Transition Law (LTE) establishes clean energy goals so that the consumption of electrical energy is satisfied through a portfolio of alternatives that lead to a reduction in emissions, that promote energy efficiency and that are economically viable. This law promotes and generates incentive planning instruments for the execution of renewable energy projects in the country (SEGOB 2015).

2. METHODS

Due to the current situation, there is a need for a tool that allows flexible evaluation of the evolution of the SEN. The proposed Energy Model of the Mexican Electrical System to 2050 (SEN-50) is structured in the Low Emissions Analysis Platform (LEAP) program, a computational tool that allows evaluating various scenarios of energy policy, economic development, population growth, technological progress and GHG emissions impact.

The model operates for a period from 2017 to 2050; It includes a historical period with statistical data from 2013 to 2017 that allow the model to be calibrated, this because information is available from official documents. Its structure is made up of four main modules: user variables, demand, transformation and resources, which represent the integration of the transformation and electricity consumption sectors.

The proposed model considers population growth as a function of determining electricity demand, focuses on the production of electrical energy, and is based on a detailed list of generation technologies. The production processes include 27 technologies, of which 13 are existing and the rest are alternatives.

The SEN-50 model considers population growth as a function to determine the demand for electricity. Official estimates from the National Population Council (CONAPO 2016) and the World Population Prospects of the United Nations (UN) were used, based on probabilistic projections of total fertility and life expectancy at birth. The UN methodology to estimate the population and its prospects presents a low fertility model (LVF) and another with constant growth (CVF) (UN 2017).

Two per capita consumption scenarios are considered: the first with a value of 2.0 MWh, based on the average consumption of the period 2000 to 2015 in Mexico, according to IEA data, and the second with a value of 4.0 MWh, considering the consumption of some developed countries during 2015 according to data reported by the IEA.

The electricity generation module considers historical information on installed capacity and electricity production by type of technology in accordance with the PRODESEN reports (SENERa 2018) and the prospects for the electricity sector published annually (SENERb 2018).The technologies were characterized according to the technical lifetime, maximum availability, efficiency, the investment cost, and the fixed and variable operation and maintenance costs (CFE 2015).

1.4 RESULTS

According to the selected population models, CONAPO estimates that the population in Mexico will be 148,134,871 people in 2050. For its part, the projections of the world population of the UN under the LVF scenario estimates that by 2050 the population will be 134,123,000 people, while the CVF scenario calculates that there will be 180,776,000 inhabitants (Figure 1).

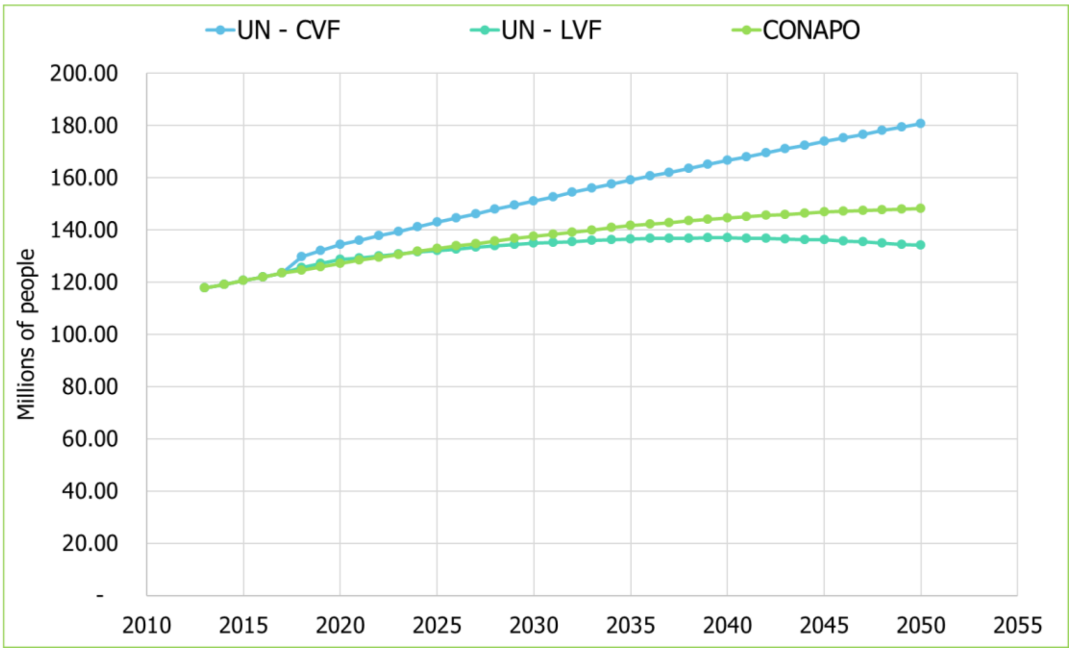

Figure 1. Population growth projections in Mexico.

According to the population models of CONAPO and the UN described above, and the per capita consumption taken from the IEA, it was possible to estimate the expected demand for electrical energy by 2050 (Figure 2).

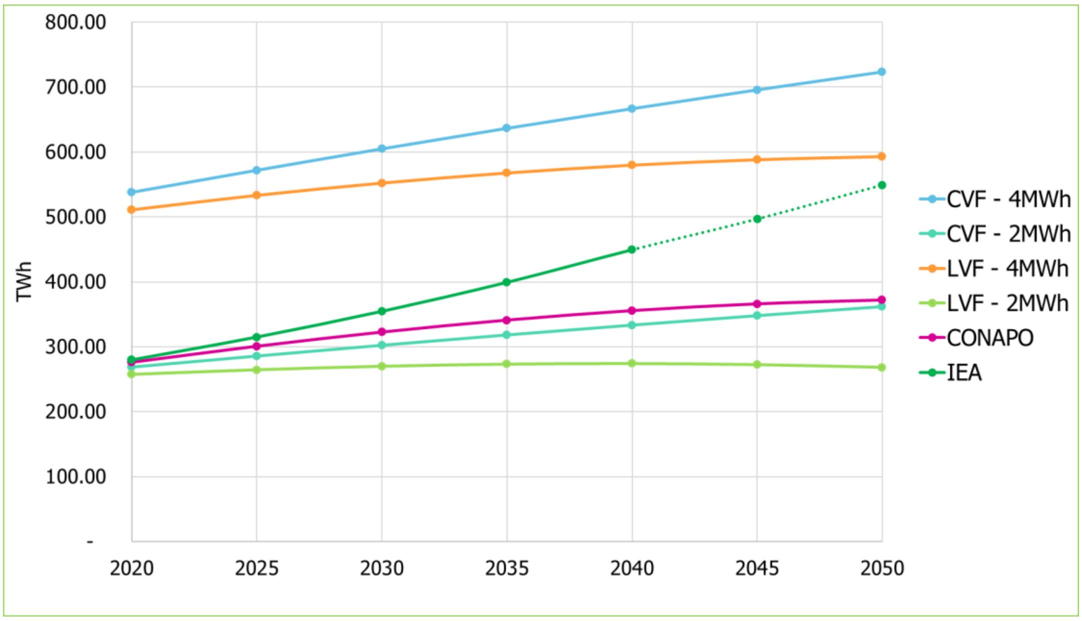

Figure 2. Projections of demand for electrical energy to the year 2050.

According to the International Energy Agency (IEA), electricity demand in Mexico will grow at an annual rate of 2.4%, reaching 459 TWh in 2040 (IEA 2016). When making an analysis, it can be inferred that the IEA projections are within the range of the expected demands of the SEN-50 model.

The International Energy Agency (IEA) forecasts that the installed capacity for electricity generation in Mexico will be 161 GW in 2040 (Figure 3). It also makes an evaluation of electricity generation; its results show that to satisfy demand it will be necessary to produce 518 TWh in 2040 (Figure 4).

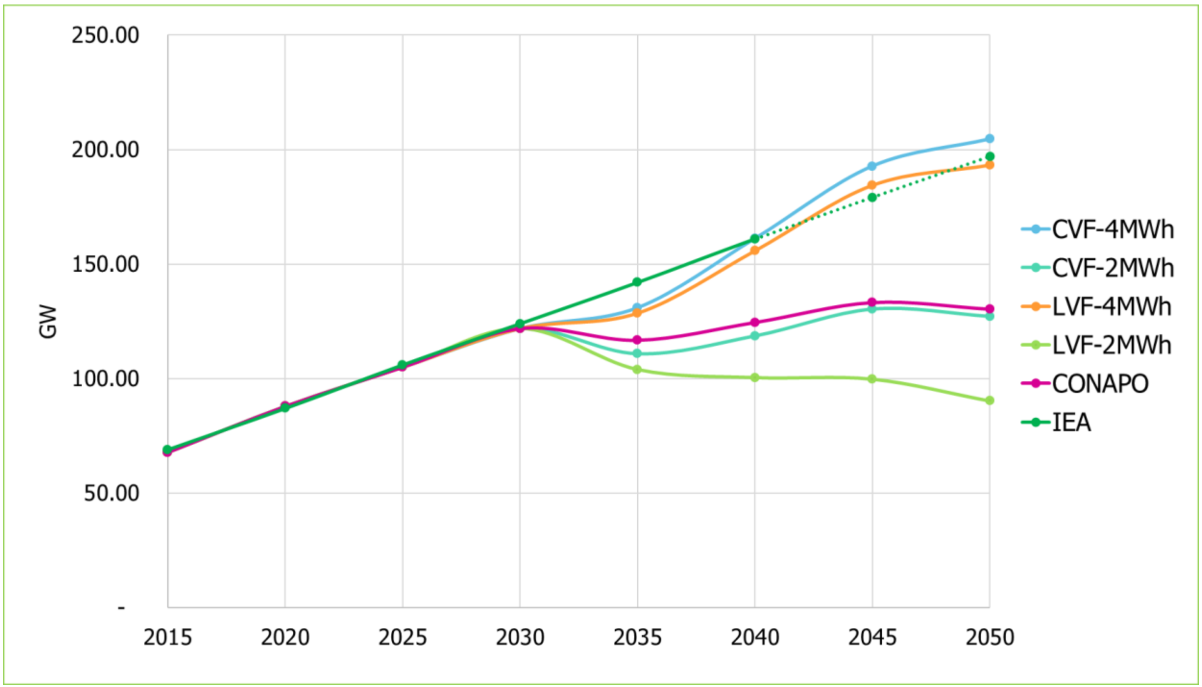

Figure 3. Projections of installed capacity to the year 2050.

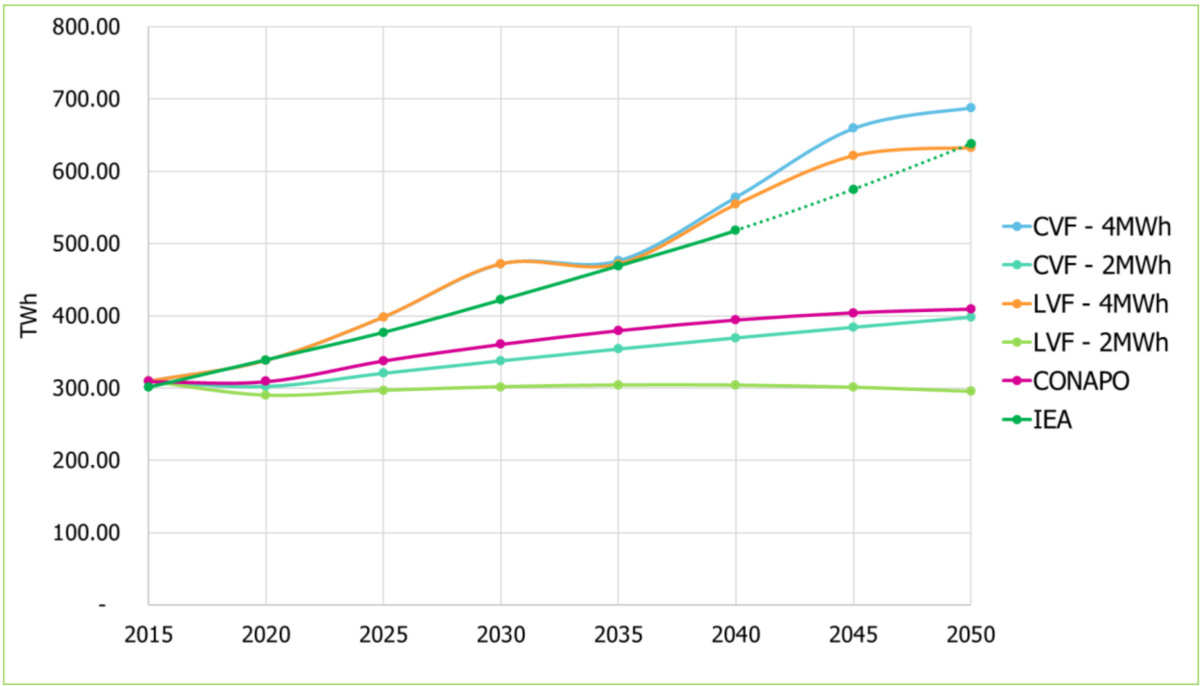

Figure 4. Electric power generation projections for the year 2050.

Analyzing the results of the SEN-50 model and making a comparison with the IEA model, it can be seen that its estimates approximate the values obtained in the scenarios with high electricity consumption per capita of this research.

Regarding the analysis of emissions, the baseline of the annual report of GHG mitigation potential in the electricity sector was considered, a projection exercise of future GHG emissions from Mexico. This trend scenario is a reasonable projection of the emissions that would occur in the absence of climate change mitigation actions. Its objective is to serve as a basis for the identification of the emission reduction potential at the national level, for the design of initiatives that allow the capture of such abatement potential and for the evaluation of the actions undertaken in this context.

According to the ENCC, mitigation actions seek to transform the electrical matrix, increase the participation of clean technologies and use fossil resources more efficiently. The ENCC scenario (Figure 5) reflects the fulfillment of the GHG reduction goals of 30% by 2030 and 50% by 2050.

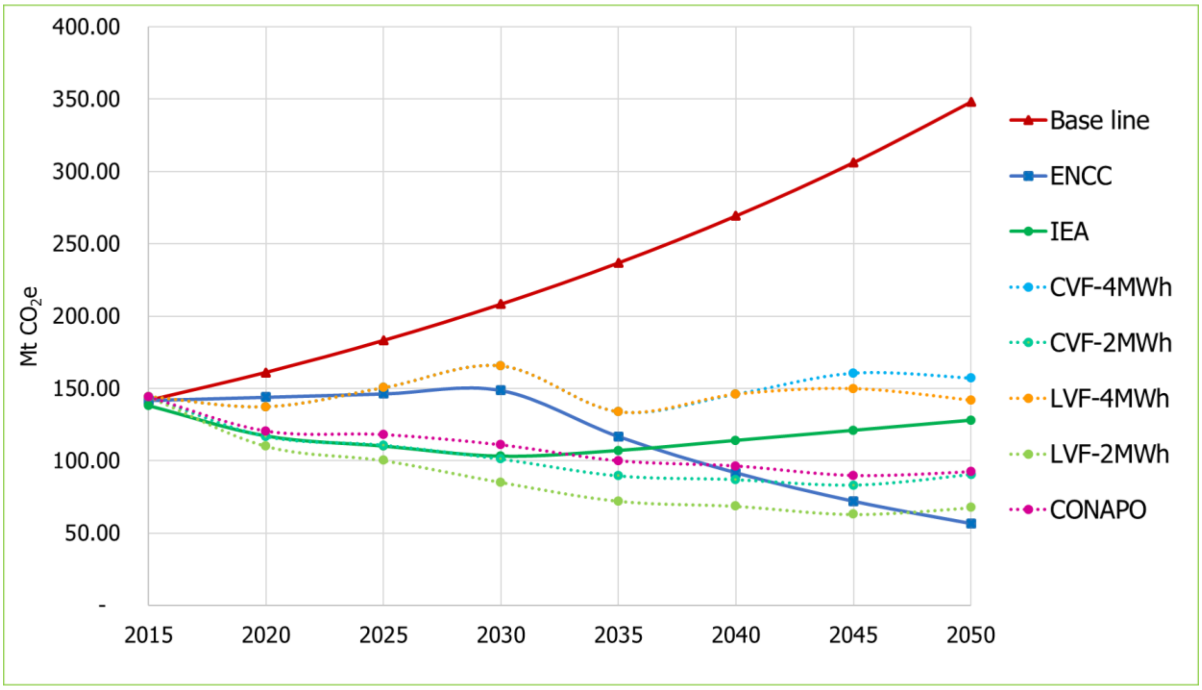

Figure 5. GHG mitigation in the SEN by 2050.

It is important to mention that, according to the SEN-50 model, the scenario that managed to mitigate the most GHG emissions was the LVF-2MWh scenario, in which mitigation reduced 280 Mt of CO_2e, followed by CVF-2Wh with a decrease of 258 Mt of CO_2e, while the high consumption scenarios (4MWh / per capita) only managed to reduce 190 Mt of CO_2e with constant population growth and 206 Mt of CO_2e with low population growth.

1.5 CONCLUSIONS

Energy planning is a necessary tool to explore possible alternative scenarios that allow meeting national and international objectives, both for the inclusion of renewable energies and for reducing GHG emissions.

In each analysis scenario, it was possible to estimate the expected electricity demand for the year 2050, by analyzing the behavior of population growth as an indicator of the evolution of electricity consumption.

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