Effect of the energy and climate policies in the future Mexican electricity system

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Abstract

In 2012, Mexico produced 1.6% of the global primary energy, the main source being hydrocarbons. Even when the country is one of the 10 largest oil producers in the world, in the last years energy dependence has grown with increasing gas and fuel oil imports and decreasing oil exports due to natural production declines since 2005. Total energy consumption is strongly based on oil (53%) which is increasingly being replaced by natural gas (36%) mainly in power generation. But there are other potential energy sources such as wind, solar or shale gas that might play a relevant role in the future Mexican energy panorama.
The Mexican government has recently launched an ambitious energy reform to modernize the energy system. The main aim of this reform is to make the most of the indigenous resources in a rational and sustainable way under the principles of national sovereignty, economy efficiency and social benefit.
By using a global energy optimization model, three strategic future scenarios have been built to analyse the evolution of the Mexican electricity system in the long term under different energy and environmental policies.
Results show that the objectives set are fully achievable even with no extra costs for the system. Wind onshore, concentrated solar power, natural gas combined cycle and nuclear technologies will play a relevant role in the future sustainable energy system. In the case of a hypothetical fission phase out, new advanced technologies such as Carbon Capture and Sequestration or nuclear fusion emerge.

1. Introduction

In 2012, Mexico with around 117 million inhabitants and a GDP of 1,028 billon 2005 USD$, produced 1.6% of the global primary energy, the main source being hydrocarbons. Even when the country is one of the 10 largest oil producers in the world, in the last years energy dependence has grown with increasing gas and fuel oil imports and decreasing oil exports due to production declines since 2005. On the other hand total energy consumption was strongly based on oil (53%) which is increasingly being replaced by natural gas (36%) in power generation.

The structure of the electricity system in Mexico consisted of the public and private sectors. The first manages the infrastructure of the Comisión Federal de Electricidad (CFE) and the independent producers' facilities. The second is composed by the cogeneration, self-consumption, continued own uses, small production, imports and exports. In 2012, total electricity generation amounted to 1,067.88 PJ (296,632.85 GWh). Public stations produced 60.4%, producers 28.1%, and cogeneration 11.6%.

In the last 10 years, electricity production with natural gas combined cycle plants (NGCC) has almost trebled reaching a share of 50% in the public electricity system in 2012 (see Figure 1). This high increase is the result of a considerable NGCC plants installation which went from 7 GW in 2002 to 18 GW in 2012. In the same period, power generation with oil has reduced 30%

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while with coal has remained the same (SENER, 2013b). In addition, there are two nuclear boiling water reactors (BWR) which contributes with 3% and no plans for installing new capacities. Regarding the production with renewable sources, it is worth noting that hydropower grew 27% meaning 12% of the total production in 2012, and wind power went from 0.03 PJ to 5 PJ. This year the total share of renewables reached 15% (SENER, 2013a; EIA, 2014).

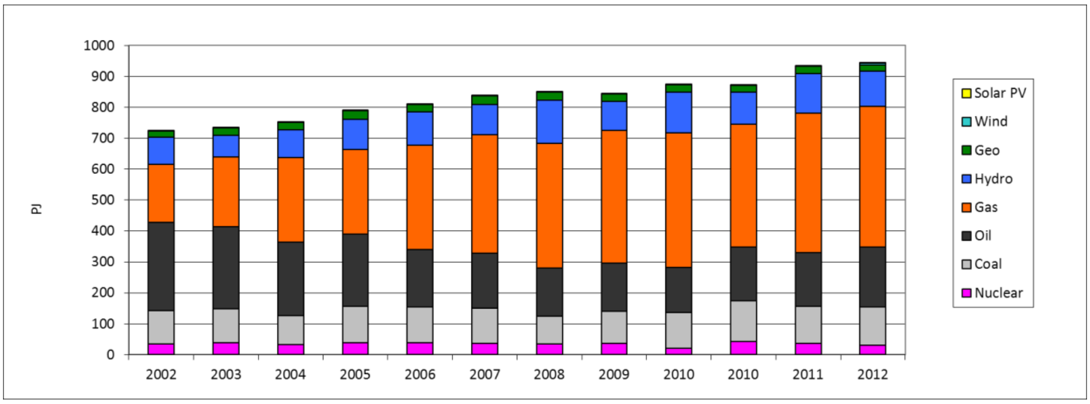

Figure 1. Evolution of the public electricity system in Mexico in the period 2002-2012

Based on Figure 1, we can observe that the Mexican electricity system is moving from oil to natural gas and, to an extent, to renewables. According to the National Inventory of Renewable Energies, there is a good renewable potential for electricity production in Mexico as can be seen in Table 1.

Resources	**Geothermal**	**Small Hydro**	**Wind**	**Solar**	**Biomass**
Possible	58.19	-	315.36	23400	41.35
Probable	344.05	6.50	34.55	-	1.41
Proven	3.21	4.91	35.24	1.95	2.08

Table 1. Renewable energies potential in Mexico (PJ/año). Source: (SENER, 2013c)

Besides, there is also a good potential for shale gas. According to the U.S. Energy Information Administration's (EIA, 2014), Mexico has one of the world's largest shale gas resource bases, estimated in 545 Tcf (Trillion cubic feet) technically recoverable. Most of the resources are in the northeast and east-central regions of the country.

Up to here everything points to a reasonable development of alternative energy sources in the country which would lead to improvements in the energy dependence and climate change mitigation. Along these lines, the Government launched a series of policies such as the General Law of Climate Change, the Law for the Renewable Energies Exploitation and Energy Transition Financing, and the Energy Reform. The main Government targets are described in Table 2.

Law	**Target**
Law for the Renewable Energies Exploitation and Energy Transition Financing	▪ Max gen with fossil fuels 65% by 2024 60% by 2035 50% by 2050
General Law of Climate Change	▪ Min gen with clean energies (Renewable + Nuclear + Carbon Capture and Storage technologies) 35% by 2024 ▪ Creation of a system to support renewables ▪ Development of non-methane emissions

	infrastructures to manage solid wastes ▪ Implementation of technologies to produce electricity from methane emissions

Table 2. Energy and climate targets. Source: (SENER, 2013b)

2. Methodology

Energy models are advanced mathematical tools that allow the analysis of energy systems in the medium and long term under different constraints. The EFDA TIMES Model (ETM) is a techno-economic model of the global energy system which belongs to the TIMES models family. Developed within the EFDA-SERF project (European Fusion Development Agreement-Socio Economic Research on Fusion), this is the first time that the model is used for an analysis out of the EUROfusion framework.

ETM has been chosen for this study because it is a technology-rich optimisation model recently updated, improved, recalibrated to 2005 and re-regionalised. Besides, in comparison with other TIMES global models, it has a very detailed and complete description of the whole nuclear fuel cycle including new fission generation and fusion power plants and fuels, and renewable energies potentials and advanced technologies.

In the model, the world is divided into 17 regions, one of them being Mexico. ETM allows the investigation of the Mexican energy system evolvement over a long term time horizon taking into account the trade of energy commodities between the country and the other regions. The data about the regional energy demand at the base year are mainly taken from IEA database and improved with national data from the Secretaría de la Energía (SENER), Instituto de Investigaciones Eléctricas (IIE) and Instituto Nacional de Estadística y Geografía (INEGI). Future demands of energy services in each sector are linked to socio-economic driver projections such as GDP, GDP per capita, population or number of households, via elasticities. The projections of those drivers are the result of the general economic model GEM-E3. The energy production sector is composed of the primary production of raw fossil fuels, biomass and nuclear fuel; the secondary transformation where the primary energy forms are turned into fuels for the end-use sectors and for electricity and heat generation; and finally the production of electricity and heat which is technologically explicit. Zero-emission-technologies and carbon sinks are also included.

The model generates scenarios based on different hypothesis on the projection of the main socio-economic drivers, such as GDP or population, and a set of constraints related to the policies, plans or commitments to be analysed. The solution of each scenario is the combination of technologies of the energy system that meet the energy demand at minimum cost satisfying specific constraints.

3. Long term scenarios

Scenarios are suitable tools to explore the future. In this work, some scenarios have been built to analyse the evolution of the Mexican energy system under different policies. First, the BaU scenario (Business as Usual), which represents the evolution of the energy system if there were not any environmental or energy target.

One of the policy tools implemented for the compliance of the General Law of Climate Change is the National Strategy of Climate Change (Estrategia Nacional de Cambio Climático, ENCC), Vision 10-20-40 (SEMARNAT, 2013). The ENCC sets several objectives for the next 10, 20 and 40 years. The environmental objectives are translated into a limit of GHG emissions to 672 $MtCO_2e$ by 2020 (-30% regarding a baseline scenario with no mitigation measures) and 320 $MtCO_2e$ by 2050 (-50% compared to 2000 levels). Regarding the energy targets, the ENCC sets a share of clean energies in electricity production of 35% by 2024, 40% by 2034 and 50% by 2054. The ENCC scenario has been built to introduce the CO_2 emission limits, taking into account that CO_2 is responsible of 65.9% of GHG (SEMARNAT, 2013), and the clean energy targets.

Finally, a scenario for a hypothetical nuclear fission phase out has been built to analyse the possibility of meeting the targets only with renewable technologies.

Table 3 shows the scenario matrix object of study.

Scenario	Assumptions
BaU	No energy or climate policies
ENCC	• Climate objectives 442,859 kt CO_2 total by 2020 (-30% compared to 2000 levels) 210,880 kt CO_2 total by 2050 (-50% compared to 2000 levels) • Energy objectives 35% share clean energies in electricity generation by 2024 40% share clean energies in electricity generation by 2034 50% share clean energies in electricity generation by 2054
ENCC-NoFission	The same objectives as in ENCC scenario but fission phase out

Table 3. Scenario matrix

4. Results

As can be seen in Figure 2, in a scenario where there are no restriction to the CO_2 emissions or clean energy targets (BaU scenario), the electricity system strongly relies on the fossil fuels until 2030, mainly on advanced natural gas combined cycle plants (53% in 2020 and 48% in 2030) and coal power plants (21% in 2020 and 2030). From 2030, the installation of renewable technologies almost doubles generating, in 2040, 44% of the total electricity in the public system. At the end of the period, more than half of electricity is produced with renewable and the rest with fossil and a very small participation of nuclear technologies (1%). From 2020 to 2050 coal and gas power plants increase the production mainly due to CHP coal and natural gas combined cycle facilities. There is also a considerable development of solar PV centralized plants, geothermal facilities, wind onshore turbines and hydro dams.

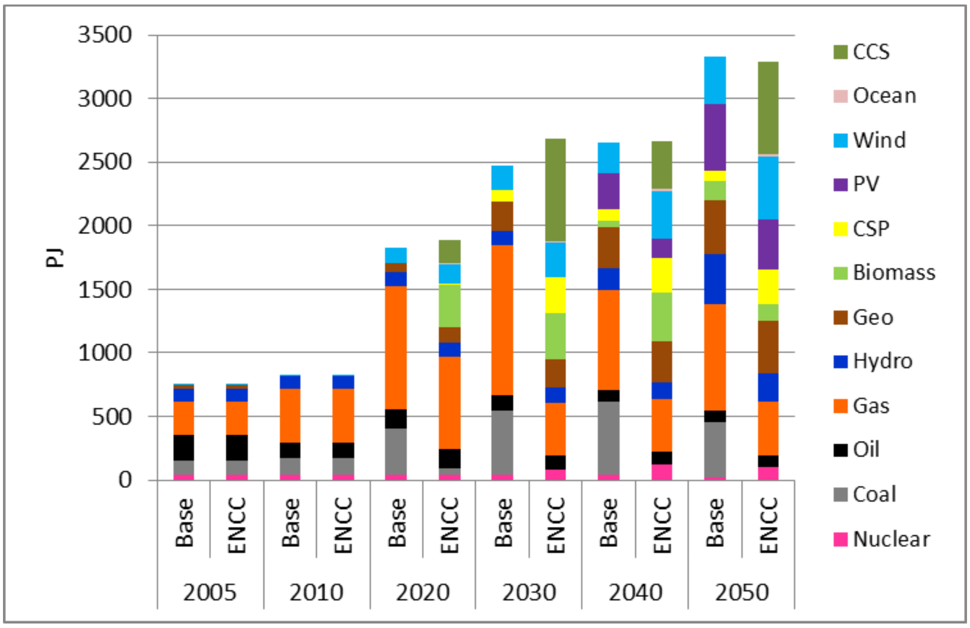

Figure 2. Mexican public electricity system evolution under the BaU and ENCC scenarios

When the ENCC targets are set (ENCC scenario), there is a high increase in electricity generated with renewable technologies from 2020, with a relevant participation of biomass gasification and CHP plants, solar thermal parabolic troughs, and onshore wind turbines. Coal power plants extinguish in 2030 and natural gas power plants reduce their production until reaching only 16% in 2040. The main differences in the involved technologies respect to the BaU scenario are the penetration of the coal and gas technologies with CCS and offshore wind power from 2030. At the end of the period, clean technologies, which include renewable, nuclear and CCS, are responsible of 84% of the total production being the rest generated with fossil fuels.

It is worth noting that from 2030 to 2040, electricity demand remains almost constant and the production with CCS is reduced. Next analysis will focus on demand issues such as socioeconomic drivers and sectorial demand in order to improve those results.

In the case of a hypothetical nuclear fission phase out where no new fission power plants are installed (ENCC-NoFission scenario), there is a high development of renewable technologies such as geothermal, biomass, centralised and photovoltaic solar power, and wind power. Generation with fossil fuel decreases from 2020 relying mainly on advanced natural gas combined cycle facilities. Coal power plants phase out by 2020. The main results from this scenario, as can be seen in Figure 3, are the great growth of biomass gasification and CHP, solar thermal parabolic troughs and photovoltaics, binary high temperature geothermal plants, hydro dams, tidal facilities and onshore and offshore wind turbines, but also stands out the incorporation of natural gas combined cycle and coal integrated gasification combined cycle (IGCC) with Carbon Capture and Sequestration (CCS). From 2030, the share of renewables in the system is 70% in 2040 and 60% in 2050. In terms of clean energy, the shares raise until 77% and 84% in 2040 and 2050 respectively, being the rest produced with fossil.

As in the ENCC scenario, more research is needed to analyse the transition between 2030 and 2040 periods.

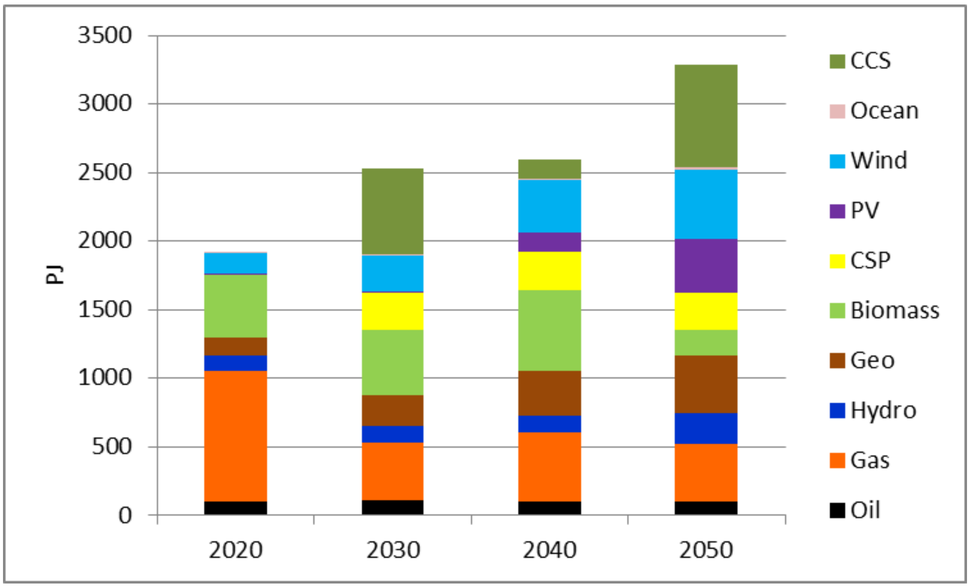

Figure 3. Mexican public electricity system evolution under the ENCC-NoFission scenario

In terms of costs, comparing the total costs of the energy system along the whole period with and without climate and energy targets, the ENCC scenario costs are 9% higher than the BaU.

When the objectives are met without nuclear fission power plants, the costs would be much higher than in the BaU. Discount rate chosen in the analysis is 5%.

Lastly, the results regarding the total share of renewables by 2030 are in line with the newly projection for Mexico published by IRENA within its REmap 2030 plan (IRENA/SENER, 2015). According to REmap 2030, Mexico could generate up to 46% of its electricity from renewable sources by 2030. The results of the present work give a share of 47% in the ENCC. In any case, this is a first approach to the evolution of the Mexican energy system using the ETM model and next works will provide more accurate and reliable data as a result of the update and improvement of input data with national sources.

5. Conclusions

The Mexican government has recently launched an ambitious energy reform to modernize the energy system (GobMex, 2013). The main aim of this reform is to make the most of the indigenous resources in a rational and sustainable way under the principles of national sovereignty, economic efficiency and social benefit. One of the planning tools implemented by the Government within the framework of the reform is the National Strategy of Climate Change which defines the pathway to meet the environmental and energy objectives.

Through the use of a global energy optimization model, three scenarios have been built to analyse the evolution of the public Mexican electricity system under different assumptions on policies. The results of the analysis show that meeting the CO_2 emission limits and clean energy targets is achievable in terms of technologies and resources availability. The objectives are fully met with a new electricity technology portfolio, with and without including nuclear fission facilities. In the first case, the most representative technologies in the medium and long term will be natural gas combined cycle, wind onshore and solar photovoltaics. In the case of a hypothetical fission phase out, new advanced technologies emerge such as the fossil fuel facilities with CCS, wind offshore and centralized solar power.

The costs of implementing those policies will be 9% higher when nuclear fission plants are installed but much expensive when those plants are not considered.

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