Transiting to a low-carbon economy in Mexico: an application of the ThreeME model

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Abstract

This document offers an empirical application of the notion of energy transition to the Mexican economy and it takes the next step of simulating medium- and long-term impacts of proposed and future energy and fiscal policy on the environment and the Mexican economy. The starting point of the analysis comes from ThreeME framework, a Multi-sectoral Macroeconomic Model based on the Keynesian theory. It is designed to address dynamics of global economic activity, energy system development and carbon emissions causing climate change. The ThreeME model is well suited for policy assessment purposes in the context of developing economies as it informs the transitional effects of policy intervention. In particular, disequilibrium can arise in the form of involuntary unemployment, inertia of technical systems and rigidity of labour and energy markets, as a result of delayed market-clearing in the goods markets and slow adjustment between prices and quantities over the simulation time path.

Calibrated to updated sectorial and aggregated national accounts data, a Mexican version of the ThreeME has been developed and accounts for 24 commodities-including 3 energy sources-and 32 sectors, with an explicit distinction between 11 energy sectors and 7 transport sectors. Electricity production is disaggregated into 9 technologies: hydro, geothermal, wind, solar, biomass, nuclear, coal-based, oil-based and gas-based. The ThreeME-Mexico model is used to gauge the economic and environmental effects of energy and fiscal policy measures in Mexico (namely the phasing out of energy subsidies and the implementation of a carbon tax). Different policy scenarios are assessed, each reflecting a different strategy of fiscal revenue recycling. We consider fiscal policy for energy transition in Mexico of the type of carbon tax and simulate the effects of alternative government's patterns of transferring tax revenues on Mexico's economy and its carbon emissions. The level of the carbon tax is endogenously computed to meet national emissions reduction targets, as stated in the Mexican "Climate Change Law".

In line with an scenario we have called "IDEAL scenario", we consider emissions cuts of 40% in 2030 and 50% in 2050, as compared with the baseline and the 2000 levels respectively. This requires carbon tax to reach US$ 100 in 2030 and US$ 700 in 2050. We take the case with no tax compensation for this first scenario. Because of substitution effects in energy-intensive production inputs and consumption goods, the policy is successful in reducing CO_2 emissions by 75% by 2050 with respect to BAU. But the environmental goal is achieved at very high economic costs, with GDP dropping approximately 8% after 2040 in comparison with the reference scenario.

Then we tested the hypothesis of full redistribution of carbon tax revenues among consumers (through reducing household income taxes) and producers (through compensating for social security payroll taxes), which appears as a way to reconcile environmental and economic goals. It is shown that such pattern of revenue transfer has beneficial impacts both on GDP and CO_2 emissions reduction. With respect to the no-redistribution scenario, gains on the latter feature are slightly lower (72% versus 75% decrease in emissions, respectively) because of rebound effects: increased economic activity from redistribution leads to enhanced production and consumption, which ultimately drive energy use. Our results support the notion that promoting a carbon tax is compatible with both environmental and economic gains.

Sensitivity tests are undertaken including the utilization of alternative parameter values for the alternative substitution mechanisms. It is found that CO_2 emissions reduction is low when the

elasticity of substitution between capital and energy is constant (in absence of endogenous energy efficiency) and when the elasticity of substitution across types of commodities is low. Moreover, the economic gains from the tax crucially depend on the inflationary pressure resulting from the taxation policy (and therefore on the wage setting process) and on the responsiveness of Mexico's economy to foreign competition.

This document is the result of a two-year research collaboration involving the National Institute of Ecology and Climate Change (INECC) the French Economic Observatory (OFCE) and the French Agency for Development (AFD).

1. Introduction

Global warming presents a major threat for the development and prosperity of humanity. According to the fifth assessment of the IPCC (2014), the current emission trends of greenhouse gases will cause further warming and long-lasting changes in all components of the climate system, increasing the likelihood of severe, pervasive and irreversible impacts for people and ecosystems. The same report indicates that surface temperature is projected to rise over the 21st century under all assessed emission scenarios and that it is very likely that heat waves will occur more often and last longer, and that extreme precipitation events will become more intense and frequent in many regions. Finally, it concludes that climate change will amplify existing risks and create new risks for natural and human systems. These risks are unevenly distributed and are generally greater for disadvantaged people and communities in countries at all levels of development (IPCC, 2014).

Current United Nations efforts aim at developing a new approach to substitute the Kyoto Protocol that would require greenhouse gases (GHG) emissions reductions by all nations. Reducing GHG emissions will entail the cooperation of at least the 15 countries (including large emerging economies like China, India, Brazil, South Korea, Mexico and South Africa) and one region (the European Union) that together account for about 80 percent of global carbon dioxide equivalent (CO_2e) emissions. The new global agreement seeks to limit the average global temperature rise to below 2°C compared to pre-industrial levels as a prerequisite to avoid dangerous climate change. According to a World Bank report on trends on carbon pricing (2014), global GHG emissions reached approximately 50 gigatons of CO_2e in 2010 and are projected to climb to 59 $GtCO_2e$ by 2020. This World Bank report states that international community needs to reduce GHG emissions by 15 $GtCO_2e$ to 44 $GtCO_2e$ to limit temperature rises to 2°C during the 21st century.

Achieving the United Nations' target for reducing emissions would reduce economic growth by about 0.06 percent annually from now through 2100, according to the IPCC (2014). This cost projection assumes optimal conditions like the immediate implementation of a common global price or tax on carbon dioxide emissions, a significant expansion of nuclear power and the advent and wide use of new, low-cost technologies to control emissions and provide cleaner sources of energy.

Given such a scenario, widening emission reductions and lowering their cost is crucial to tackle climate change. This requires the implementation of market and economic instruments, as well as regulatory frameworks, and all these policies should complement each other. In recognition of the considerable financial resources required and the limited public funds available to confront the problem, carbon pricing instruments are essential.

Within this context, Mexico is both vulnerable[1] to climate change and an important contributor to the problem[2]. Not only its geographical characteristics makes it vulnerable, with drastically uneven distribution of precipitation between north and south regions, but with major income distribution

[1] Mexico is particularly vulnerable to extreme weather events such as hurricanes, floods, droughts and heatwaves and cold. From 1999-2011, the human losses and economic damage from hydro meteorological events are calculated at an annual average of 154 deaths and 21,368 million pesos (INECC, 2012).

[2] According to IEA (2012), Mexico is the 14th largest emitter in the world from energy consumption.

inequalities that places half of its population in different degrees of poverty[3], aggravating this vulnerability even more. Development based on fossil fuel exploitation has generated environmental degradation and public health problems nationwide. The strong dependency of Mexican economic growth over crude oil production and fossil fuel consumption presents serious challenges to implement both mitigation and adaptation measures.

1.1. The technical cooperation between INECC-AFD-OFCE

Energy resources are essential inputs for most economic activities. Understanding the dynamics of anthropogenic climate change involves taking into account the complex relationship between economic activity and environmental impact linked to fossil fuel consumption and GHG emissions. On one hand, the level of economic activity determines the technological progress of the processes of production and consumption patterns. This promotes innovation and diffusion of more efficient technologies that can satisfy the same level of activity with less environmental damage. On the other hand, it determines the available capital invested in infrastructure used by energy-intensive activities (i.e. transport and industry). Therefore, these structural changes require massive investments, which in turn entail the creation of economic measures that can change patterns of consumption and production. These economic measures will have an impact on production costs and thus on the competitiveness of the economy and the distribution of household wealth. Given all the aforementioned, the mitigation of climate change is a complex task that needs economic evaluation instruments capable of showing the different paths in the medium and long term according to a defined environmental and economic strategy.

The Multi-sector Macroeconomic Model for the Evaluation of Environmental and Energy policy (ThreeME) developed by the French Economic Observatory (OFCE) in collaboration with the Netherlands Organization for Applied Scientific Research (TNO), and funded by the French Environment and Energy Management Agency (ADEME), allows consideration of this complex system. This model has been used in France to estimate the macroeconomic effects of prospective scenarios for the 2030-2050 energy transition prepared by the ADEME. This prospective scenario provides the vision, both on energy demand and the energy mix necessary on the supply side.

A technical cooperation was established between the National Institute of Ecology and Climate Change (INECC), an independent technical institute of the Mexican Government, and OFCE with the support of the French Development Agency (AFD) to develop the ThreeME model for the Mexican economy. This cooperation began in mid-2013 with the objective to provide INECC with the appropriate tools that allow for the analysis of energy and climate policies in the country. In this respect, environmental taxes included in the 2014 tax reform are a very first step of the Mexican government to institutionalize mechanisms and necessary economic measures to limit GHG emissions. Economic evaluation is the key to estimate both the costs and benefits of such measures and their optimal level, which will feed into the policy debate on the economic and social impact.

The Mexican economy will be modelled in the ThreeME, which is a neo-Keynesian dynamic general equilibrium model where prices and quantities adjust slowly to their optimal values; this allows identification of the transition mechanisms in the short and medium terms. These mechanisms are essential for an accurate assessment of the effects on employment and activity. Another important

[3] According to CONEVAL (Consejo Nacional de Evaluación de la Política de Desarrollo Social) 45.5% of the total population in Mexico in 2012 was in some degree of poverty: http://www.coneval.gob.mx/Medicion/Paginas/Medici%C3%B3n/Pobreza%202012/Pobreza-2012.aspx

feature is its hybrid component, since it combines a macroeconomic modeling (top-down) and a technical modeling of energy consumption (bottom-up). This ensures an explicit treatment of the effects of decisions on the national economy, taking into consideration direct and indirect impacts, such as feedback between prices and quantities and rebound effects. Likewise, the multisectoral nature of the modeling allows the effects of an activity transfer from one sector to another to be seen.

1.2. Structure of the report

The present report is divided in 5 sections. Section 2 describes Mexico's national policy on climate change. It also presents elements to understand the current Mexican economic context as well as the recently approved reforms, in particular the energy reform. This section concludes with an overview and outlook of the most important energy sectors of the country. Section 3 provides a short description of the ThreeME model and how it was adapted to Mexico. Section 4 presents the simulation results and section 5 concludes.

2. Mexican Context and National Policy on Climate Change and Energy

2.1. Climate change policy

Mexico has been an active player in the search for solutions to climate change in the international arena. The progress achieved in Cancun during COP16 is a clear evidence of this commitment. Mexico advocated helping mobilize public and private funding for mitigation and adaptation of climate change to developing countries under the Green Climate Fund, including technology transfer mechanisms, instruments to enhance the transparency of national commitments, and an international scheme to reduce deforestation, which includes market mechanisms.

At a national level, climate change is also a major issue in Mexico's domestic agenda. Mexico is one of the few developing countries to have a domestic law addressing climate change including specific emission targets relative to a baseline scenario in the short term and relative to a base year in the long term. It has also published diverse national planning documents such as the National Development Plan 2013-2018 (PND, 2013) that include the topic, the publication of the National Climate Change Strategy (ENCC, 2013) and the Special Climate Change Program 2014-2018 (PECC, 2014).

2.1.1. General Law on Climate Change

The General Law on Climate Change (LGCC, 2012) governs the scope and content of the national climate change policy; it defines the obligations of the State authorities and those of the three levels of government. In order to achieve effective coordination between different levels of government and cooperation between public, private and social sectors, the LGCC mandates the integration of the National Climate Change System (SINACC). This system should promote synergies to jointly confront the vulnerability and risks of the country to the phenomenon and identify priority actions for mitigation and adaptation. The SINACC includes the Inter-ministerial Commission on Climate Change (CICC), the National Institute of Ecology and Climate Change (INECC), the Council on Climate Change (C3), the States, associations of local authorities and the Congress. In terms of the policy mitigation, the LGCC sets mitigation targets for Mexico for the years 2020 and 2050. These targets are 30% of GHG emissions in reference to a baseline in 2020 and the second target is 50% relative to emissions of the year 2000.

The previous special program of climate change, published in 2009, started a series of mitigation actions taken by the federal government agencies that aimed to mitigate 50 million tons of CO_2e ($MtCO_2e$) by 2012. The program included regulations, subsidies, and direct interventions aiming to change the supply side in different economic sectors. The mitigation measures range went from energy efficiency standards to voluntary standards for the construction sector. It also included topics on public information, cash-for-clunkers programs for heavy and light duty vehicles, mandates for the two energy state monopolies (CFE and PEMEX) to lower emissions through investments, and in general the mass provision of efficient light bulbs and energy efficient equipment. It is important to highlight that this program did not include any economic instrument aiming to change economic decisions of producers or consumers by internalizing the social costs of their emissions. The second program of climate change was launched in this administration with the same vision (PECC 2014-2018). This second PECC aims to reduce 83 $MtCO_2e$ by 2018. All these efforts, even though well-intentioned, are not enough to radically change the current fossil fuel dependent economy towards a low carbon economy.

2.1.2. Tax reform

In 2013, Mexico set the first carbon tax in the country. The carbon tax is part of the economic package for the fiscal year of 2014. This tax covers about 40% of total GHG emissions nationwide. It is not a tax on the total carbon content of fuels, but rather, additional emissions compared to natural gas. Natural gas, therefore, is not subject to the carbon tax. This should be changed rapidly to achieve a real energy transition since there is a risk that a large supply of natural gas may delay investments acting as a lock in on the development of renewable energy[4]. The tax rate varies between 10 and 50 pesos per ton of CO_2 (\$1-\$4 USD/tCO_2) in 2014 depending on the fuel type and with a limit of 3% of the selling price of the fuel. According to the Law on Federal Revenues for Fiscal Year 2014, it was estimated that the Federation would receive 14,641.7 million pesos (approximately 1 billion USD that represents 0.328% of total revenue of the federal government). For the year 2015, it is expected a revenue of 9,871.8 million pesos (0.210% of total revenues). So far, the revenues from this tax are not labelled to direct investments on environmental measures.

2.1.3. Energy reform

The energy sector has a crucial role in the transition to a low carbon economy. The characteristics of the energy supply have a strong relationship with the emissions of global and local pollutants, so to the extent that energy dependence on nonrenewable fossil fuels is not reduced, any improvement in energy efficiency, although desirable, is insufficient.

In 2014, Mexico approved a series of structural reforms in the energy generation sector. There are many opportunities in the recently passed energy reform to enhance clean energy generation. The reform introduces a sustainability mandate which provides that the State should look for the protection and care of the environment through sustainability criteria, and promoting cleaner energy and cleaner fuels. Such regulation favors the incorporation of the private sector in activities of generation and sale of electricity and transmission and distribution, which will help diversify the energy mix in a context of competition. However, it is also important to mention that it is expected that this reform will boost investments to increase the production of unconventional sources of energy such as deep-water oil, heavy and ultra-heavy oil, and in particular tight oil and shale gas. These unconventional sources have a lower Energy Return on Investment (EROI) and higher environmental impact. All these new sources will increase Mexico's oil and gas production and therefore its GHG emissions. If government's production projections with the reform are correct, oil and gas production will increase from 2.1 million barrels per day (MMbd) of crude oil to 3.6 MMbd in 2030 (SENER, 2014), and this most likely will increase emissions from 87 $MtCO_2e$ in 2013 to 150 $MtCO_2e$ in 2030 (INECC, 2014a).

[4] According to Davis and Shearer, without new climate policies, increased supply of natural gas makes energy cheaper, thereby encouraging higher energy consumption and discouraging investment in energy efficiency. It also competes for market share not only with coal, but also with very low carbon energy sources such as renewable and nuclear.

2.2. Macroeconomic context

Mexico faces great economic challenges. In order to escape the middle income trap, the country needs to find the way to increase its productivity to achieve higher rates of growth. According to the National Institute of Statistics (INEGI, 2015a) GDP has grown at an average annual rate of 2.1% since 2000, while GDP per capita has grown only at a rate of 0.8%, resulting in approximately $12,130 USD per capita (2010-2014 World Bank PPP conversion factor) in 2013. This ranks Mexico as the economy with the lowest income within OECD countries. Even though there are good perspectives of economic growth and a demographic dividend to exploit for the next years[5], there are important barriers to overcome. According to a Mckinsey report (Mckinsey Global Institute, 2014), there are two economies in Mexico moving at different speeds. The first one is a modern fast-growing Mexico, with globally competitive multinationals and cutting-edge manufacturing plants that raise productivity at 5.8% a year. The second one is a Mexico of small slow-growing enterprises with a productivity that falls by 6.5% a year. The report concludes that Mexico needs to triple its productivity growth from the recent yearly average of 0.8% if it wants to increase its growth above 2.0%.

Past economic reforms aimed to increase economic and productivity growth by opening the economy to international trade, but failed at encouraging competition and breaking inefficient public and private monopolies within the country. At the same time, with greater competition Mexico would need to create strong institutions to watch over market rules and to ensure property rights. In order to be able to do it, the Mexican government needs to achieve higher rates of tax collection. This is one of the main problems of Mexico; it has a very small tax base. Tax collection in Mexico is not only the lowest among OECD countries, but it is also lower than the average in Latin America if oil production income is not considered (OECD, 2010). Thus, the dominant role of indirect taxation and the weak income tax collection contribute to a low progressiveness of the taxation system as a whole.

One important feature of the Mexican economy is a growth based on the exploitation of nonrenewable hydrocarbons. This kind of growth based mainly in the oil rent may lead to inequalities as they could benefit only a small well organized groups that capture this rent, keeping privileges by favoring generalized subsidies, monopolistic markets, poor accountability, and lack of regulatory enforcement (Karl, 2007; Schubert, 2006). All these result in a large loss of social welfare, a more polluted environment, and finally a weak economy that depends on oil prices and is not able to compete with products and services with high value added coming from innovative economies.

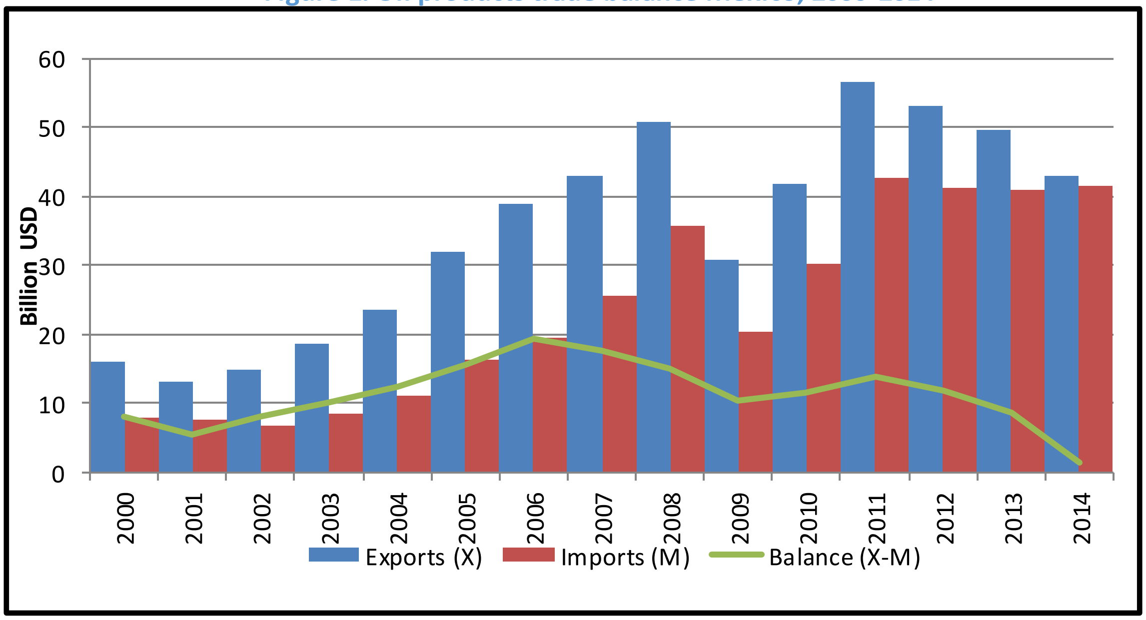
This weakness is reflected in how currency exchange rate plays a major role in the Mexican economy. After the 2008 recession, it remained relatively stable with fluctuations between 12 and 14 Mexican pesos per US dollar. However, along with the fall of international oil prices, the Mexican peso has reached its lowest levels against US dollars in January 2015 (INEGI, 2015a) since 2009. In the face of these facts, the Federal Government has recently announced a budgetary reduction by around 9.5 billion pesos, as well as the cancellation of some infrastructure projects expenditures for this year.

The trade balance has also been affected. In this respect, Mexico is a net importer of goods in general. Regarding oil trade in particular, Mexico is a net exporter. However, in 2014 oil imports

[5] According to the World Bank the age dependency rate in Mexico in 2014 was 54. It is defined as the ratio of dependents -- people younger than 15 or older than 64 -- to the working-age population--those ages 15-64. It is presented per 100 working-age population.

increased by around 1% compared to 2013, whereas oil exports decreased by 13.5%. As shown in the following Figure 1, the gap between exports and imports of oil products (including crude oil and natural gas) has been narrowing since 2006. Moreover, most of oil refined products consumed in Mexico are imported whilst the country does not export any, which stresses the fact that Mexico is not independent in terms of energy production (INEGI, 2015b).

Figure 1. Oil products trade balance Mexico, 2000-2014



Source: Banco de Información Económica (INEGI, 2015a)

Despite the falling oil production and the heavy reliance on international oil refined products, especially from the United States, general prices in the economy have been kept in adequate levels in the last years. Inflation rates in Mexico have been stable since a decade ago with levels between 3% and 5% per year with a 6.5% peak during the 2008 recession. It must be recalled that the target inflation rate is 3% and maintaining this rate is the mandate of the Mexican Central Bank (Banco de México) as an autonomous body. In this sense the interest rates are currently in their lowest historical levels at around 3%.

Employment has also been stable in the past years. According to INEGI, only 3.7% of the economically active population is unemployed. This is one of the lowest unemployment rates among OECD countries. However, out of the total economically active population, 28.3% is considered under the *informal employment* classification (INEGI, 2015c). This means employees working for enterprises that are either not established, lack accountability or with a very low scale of operation. This implies low productivity and low added value in at least one fourth of the total employment, which is detrimental to the economy.

During this administration, reforms in different sectors have been implemented by the Federal Government trying to cope with all these issues. Hence, amendments to the laws on labor, education, fiscal and energy have been set since 2014. According to the Federal Government, the reforms that have been implemented aim to promote productivity, innovation and quality education, which are key variables to increase competitiveness.

The labor reform seeks to modify the structure of the labor market in order to have a more flexible hiring and stimulate the creation of new formal jobs, especially for young people and women. Meanwhile, educational reform aims to improve the quality of basic education by reducing inequality in access to schools and strengthening the quality of education by evaluating professors' performance. The tax reform aims to expand tax collection in order to increase public spending in priority areas such as education, health, social security and infrastructure. To achieve this, the reform proposes to reduce informal employment by simplifying taxes and reducing inequality of the current tax system. It is still early to say if the reforms will fully comply with the expected results. It is likely that the adjustments will take time and the question remains if Mexico would be able to do it before he loses the momentum of its demographic dividend.

2.3. Energy outlook

Mexico's energy supply heavily relies on fossil fuels. According to the National Balance of Energy (BNE, 2013), in 2013, 88.09% of the total primary energy supply (TPES) came from fossil fuels (64.29% from oil, 22.68% from natural gas and 1.12% from condensate liquids); whereas renewable energy accounted for 7.05%, nuclear for 1.36% and mineral carbon for 3.51%. Table 1 summarizes the gross domestic energy supply by energy source.

Although Mexico remains among the biggest energy producers around the world (the 10th biggest crude oil producer), it is still a net importer of natural gas and refined products to meet the domestic energy demand. In 2013, the trade balance of primary energy showed a deficit of 7.3% in comparison to 2012. In fact, in 2013 the domestic energy consumption reached the domestic energy production for the first time, due to a constant annual reduction of energy production of around 0.4% over the last years, and a constant increase of energy consumption of 2.3% since 2005 (BNE, 2013).

Table 1. Gross domestic supply by energy source (PJ)

	2012	2013	Change (%) 2013/2012	Share (%) 2013
Total	**8,809.36**	**9,011.83**	**2.30**	**100**
Coal and coke	554.26	560.85	1.19	6.22
Natural gas and liquefied products	3,626.06	3,834.28	5.74	42.55
Oil and oil products	3,932.76	3,880.19	-1.34	43.06
Nuclear energy	91.32	122.60	34.26	1.36
Renewables	620.22	634.44	2.29	7.04
Net trade of electricity	-15.26	-20.54	34.57	0.23

Source: BNE (2013)

On the demand side, the domestic energy consumption grew by 2.3% in 2013 with respect to 2012. The energy consumption by the energy production sector[6] accounted for 33.97% of the total domestic energy consumption, while final energy consumption accounted for 56.95%. In 2013, final energy consumption (*i.e.*, the energy consumed for goods production and final use) increased by 0.6% compared to 2012.

Table 2 shows the energy consumption by sector. Transport turns out to be the largest energy-intensive sector accounting for nearly 44% of the total energy consumption, followed by industry (31%) and residential and commercial sector (17.72%).

In this increasingly worrisome energy balance scenario, energy efficiency measures play a crucial role in energy consumption with economic impacts in the public and private sectors, which trigger off a better use of energy resources. So far, the largest impacts on energy efficiency have been reached through highly efficient systems and equipment, and better practices. The instruments used for that purpose are: standards, equipment substitution programs, and information and education programs. According to PRONASE (2014), energy savings from 1995 to 2012, derived from energy efficiency norms (NOM) are 47,508 Gigawatt-hour; whereas energy saving from programs promoting efficient equipment (CFL, labeling among others) have accounted for 17,000 GW-hr in consumption and 3,500 MW in demand. In the public sector, efficiency programs for public building have saved around 5,483 GW-hr by promoting energy efficiency in buildings operation and the vehicular fleet used by government institutions.

Table 2. Total final energy consumption (PJ)

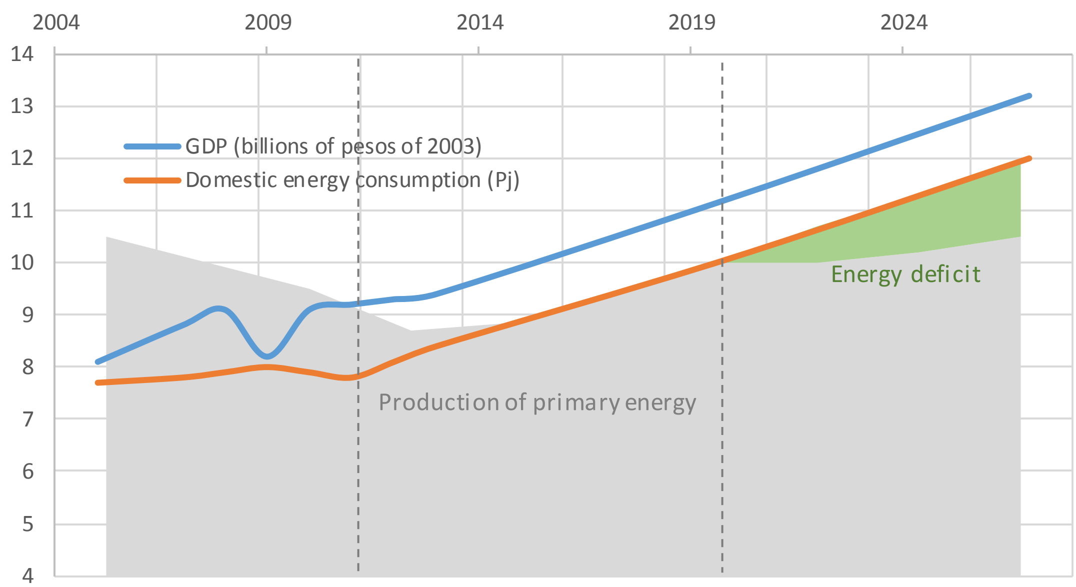
	2012	2013	Change (%) 2013/2012	Share (%) 2013
Total final Consumption	**5,100.35**	**5,132.32**	**0.63**	**100**
Total non-energy consumption	**200.05**	**190.91**	**-4.57**	**3.72**
PEMEX petrochemical branch	112.56	136.53,	21.30	2.66
Other branches	87.49	54.38	-37.84	1.06
Total energy consumption	**4,900.30**	**4,941.41**	**0.84**	**96.28**
Transport	2,298.82	2,262.28	-1.59	44.08
Industry	1,522.30	1,612.31	5.91	31.41
Residential, commercial and public	920.73	909.22	-1.25	17.72
Agriculture and livestock	158.45	157.6	-0.54	3.07

Source: BNE (2013)

[6] It is the energy consumed for transformation (60.3%), *i.e.*, that used in the processes to obtain secondary energy from primary energy. It also considers the own consumption of energy (33.6%), which is the energy absorbed by equipment supporting the transformation processes. Finally, loses in transmission, transport and distribution (6.0%) are included.

Energy consumption and economic growth play a key role due to the fact that harnessing economic development inevitably requires increasing energy to meet future needs in the coming years. According to the International Energy Agency (IEA, 2012), energy demand will continue to increase at an average of 1.5% a year to 2035, considering an expansion of global economy of around 140% and an increase of population in 1.7 billions[7]. According to the Mexican National Energy Strategy 2013-2027 (ENE, 2013), during the last decade average energy consumption growth rate has been larger that the GDP growth rate, in general terms as well as per capita, *i.e.,* growing today is more expensive than 10 years ago in terms of energy consumption. In fact, Mexico's energy demand could increase by more than 50% in 2027 with respect to energy demand in 2011 (see Figure 2).

Figure 2. Energy balance trend



Source: Estrategia Nacional de Energía (ENE, 2013)

2.4. Key energy sectors

2.4.1. Electricity sector

During the past 50 years, the national electric system has been controlled by the federal government through the Federal Commission of Electricity (CFE), a public monopoly responsible of the control, generation, transmission and commercialization of electricity in the country. Therefore electricity has been produced under non-competitive schemes, where the determination of prices does not correspond to market criteria. This has led to the existence of net losses for the company, low competitiveness and low investment in infrastructure, as well as high subsidies, mostly for the residential and agricultural customers. Under this scheme, the central planning has been focused mainly on fossil fuel based-technologies, especially in natural gas, contributing to the establishment of an undiversified system and dependent on this fuel availability and price volatility.

[7] Considering a current population of around 7.3 billion people according to the UN Population Division, it will represent a 23% increase of world population in 2035 in comparison to 2015.

In 2012, the subsector of generation, transmission and distribution of electricity contributed with 3% of GDP (PROMEXICO, 2013) and employed 127,252 people (INEGI, 2015d), 0.25% from the economically active population. The exports accounted for 2.2%, imports 2.5%, and 0.3% from foreign direct investment as share of GDP (PROMEXICO, 2013). In terms of energy consumption, in 2013 the electricity sector used 27% of the national energy consumption, where 81.7% of the generation was based on fossil fuels technologies (50.6% natural gas, 18.9% from oil products and 12.3% from coal), 4.6% nuclear and the remaining 13.7% on renewable energy (10.6% hydro, 2.4% geothermal, and 1% wind) (SENER, 2013). In terms of GHG emissions, in 2013 the power generation sector emitted 126.6 $MtCO_2e$ (INECC, 2014), representing 26% of total GHG emissions in the country and the second emitter after the transport sector.

The energy transition of the power sector involves important changes in at least three areas. The most important one is its deregulation. As it was already mentioned, the recently approved energy reform provides an opportunity to transform the sector by diversifying generation sources, favoring the entry of new private producers and creating new investments opportunities for renewable energies. Correct implementation of different instruments such as the clean energy certificates market will be vital to incentivize clean generation technologies. The second area of opportunity is the ambition in issuing the new Energy Transition Law (LTE) that is still in discussion and that substitutes LAERFTE (Law on the Use of Renewable Energies and Financing of Energy Transition) and its mandates to generate electricity from clean energy up to 35% by 2024 and 50% by 2050. Confirm these targets will provide clarity for new investments in the sector. The third area of opportunity is the electricity prices. In 2013, the electricity subsidies accounted for 0.85% of GDP (CFE, 2014). Electricity tariffs have risen sharply over the past years, with industrial customers bearing the impact of the increases. Industrial customers pay electricity rates that are 70 percent higher than those in the U.S., which places a heavy burden on the competitiveness of Mexico's industry. Additionally, heavy government subsidies account for more than 60 percent of the cost of electricity for residential and agricultural customers. Gradually phasing out these subsidies in the years to come would increase the real costs incentivizing energy efficiency and making renewable energy competitive relative to fossil fuels.

2.4.2. Oil and gas sectors

Mexico is an important producer and exporter of crude oil worldwide, having produced 2.5 million barrels per day (MMbd) of oil in 2013. However, domestic production in Mexico has shown a declining trend due to the fact that 80% of the national production comes from mature fields that are currently in decline (SENER, 2014). The marginal increase in production during the recent years is essentially due to unconventional oil, mainly deepwater oil.

In 2012, the sales revenues of the oil and gas sector accounted for 10.56% of GDP (calculation based on PEMEX, 2012 and INEGI, 2015a). Although the annual export earnings from crude declined 8.8% in 2013 compared to 2012 (SENER, 2014), it still stands for 26% of total exports of the country and 3.8% of GDP. In this sense, Mexico remains an important producer of fossil fuels but has been unable to process and refine its own oil products to meet the domestic demand.

Oil and gas production has decreased by 26% in the last 7 years after reaching a production peak in 2004 of 3.4 MMbd (Ferrari, 2013). A more technically difficult oil extraction process with higher costs has been causing the country to pass from relatively cheap and abundant oil to right the opposite situation within a few years. If the trend of recent years is maintained, Mexico could soon become a net importer of oil products because of the decreasing domestic production and an increasing demand of oil refined products.

In the context of the energy reform in Mexico, one of the main objectives is to increase the extraction of natural gas. The strategy includes investments in domestic production of natural gas, the expansion of pipeline infrastructure, the exploration of potential oil and shale gas reserves and the expansion of hydrocarbons' production. Hence, it is expected that Mexico's oil production will increase from 2.5 MMbd of oil in 2013 to 3.4 MMbd in 2030 while is expected to triplicate its natural gas production going from 4.5 million cubic feet per day (MMMcfd) in 2013 to 12 MMMcfd in 2030. Refined oil products will remain stable, having a 1.2 MMbd production in 2013 and a 1.4 MMbd production in 2030. Finally, a decrease in the production on basic petrochemicals is expected passing from 2.5 MMcfd to 0.8 MMcfd in 2030 (SENER, 2014).

Regarding GHG emissions, one main characteristic of this sector is that even when its energy consumption is not significantly high compared to other sectors, the oil and gas extraction accounted for a relatively high amount of fugitive emissions (methane, CH_4). Emissions from oil and gas sector in 2013 accounted for 52.5MtCO_2[8], representing 12% of total GHG emissions from energy consumption (INECC, 2014a).

2.4.3. Industry sectors

Basic industry -such as cement, iron and steel, chemicals and chemical products, cellulose and paper, and glass- are a key component of economic growth in Mexico. Between 1994 and 2010, their average contribution to GDP was around 30%, including manufacturing industry (González, 2012). However, its share has been decreasing over the last decade due to a low average growth rate of 2.1% between 2003 and 2013 (INEGI, 2014a).

The economic growth of industry has been accompanied by an increasing pressure on environment. Industry is a highly energy-intensive sector. During 2013, industry accounted for 32.6% of the total energy consumption (BNE, 2013), which ranks this sector as the second most consuming one, just behind transport. From 2003 to 2013, energy demand from industry increased by 32%, while CO_2 emissions have been steadily increasing during the last years. Industry accounted for 105.37 MtCO_2e of GHG in 2013 (INECC, 2013). Even when industry efficiency has shown increases in energy efficiency due to a rising international competition, energy consumption continues growing given that increasingly scarce raw materials require even more energy to be extracted and transformed, mainly in the extractive industry. Furthermore, industry sector productivity has stagnated during the last years: gross value added (GVA) has barely increased from 29.8% to 29.3% as a share of the gross production value (INEGI, 2014a).

The growing demand of energy has also driven higher emissions. GHG have increased by 13% from 2000 to 2010, that is, from 104.5 to 117.9 MtCO_2*e* (INECC, 2013). According to INEGI (2014b), the cost associated to natural resources depletion and exhaustion was around 3.79% of the total environmental cost of the economy as a whole, or 1.7% of the GDP of the industry sector in 2012.

[8] Emissions from energy consumption in the extraction process, it includes no fugitive emissions.

2.4.4. Transport sector

Transport is the most energy-intensive sector in Mexico. In 2012, 44.7% of the total energy consumption in the country was used by this sector. The share of the on-road fleet consumption represents 91.9%; while 5.3% is air transport; 1.43% seaborne; 1.16 % rail, and 0.17 % is electric transport. In terms of fuel consumption figures show an undiversified matrix based on 97.7% of fossil fuels such as gasoline and diesel. Transport in all its modes is completely dependent on oil and it contributes with 37.8 % of total GHG emissions from fossil fuel consumption (BNE, 2012).

The transport sector has a fundamental role for competitiveness. It is an important factor that determines the efficiency of a country and its economic development. In this sense, it is important to distinguish between the movement of goods and passengers. Whereas the movement of goods is in the scope of trip demand and accounts as an economic activity, the movement of passengers can be understood under the idea of mobility and does not stand for an economic activity itself. In this sense, the transport sector has a small contribution to GDP with 5% in 2014 (INEGI-BIE, 2015), but a great impact on the total of GHG emissions.

Since 2002, the demand for fossil fuels in this sector has increased at a rate of 3.8 % per year and it is expected to continue rising in the next two decades (SENER, 2014). Behind this enormous increase is the fast growth of the vehicle stock that can be explained, among other variables, by constant fuel real prices, supply of cheap import used vehicles and in general a high income elasticity that characterizes this sector. The motorization rate per 1000 inhabitants has gone from 179 in 2008 to 206 in 2013 (INECC, 2015). The total demand for vehicles in the country is around 1.9 million vehicles in 2013 (including new and imported used, both light and heavy duty vehicles as well as motorcycles) and with an income elasticity that ranges from 0.72 to 0.86 depending on the vehicle category (INECC, 2015), it is expected that vehicle ownership could reach 328 vehicles per 1000 inhabitants by 2030 (INECC, 2015).

Finally, the policy of keeping real fuel prices constant during the last two decades has distorted the vehicle market not only in terms of stock but also in its energy efficiency. The new light duty vehicle fleet has barely changed its fuel economy with an annual rate of 2.6% in the period 2008-2012 (Islas, Fernandez and Inclan, 2012). Recent changes in fuel prices policy together with the approved energy efficiency regulation for new light duty vehicles (NOM163, published in 2013 for the period 2014-2016) will incentivize technological changes as well as a change in the sales mix of passenger vehicles versus light trucks. Both measures will generate a positive impact on the fuel economy of the fleet. During the period 2010-2014, regular gasoline and diesel prices increased approximately 38% in real terms (2010 Mexican pesos), reducing the implicit subsidy and sending the right price signal to consumers. However, having a tax or a subsidy depends on international prices and the recently approved Hydrocarbons Law (2014) states that prices will only adjust for inflation in the period 2015-2017, leaving to the Federal Government the control over national prices in the case of high volatility in the international market. It is only from 2018 that prices will be set under market conditions but the law does not mention any other change in fiscal terms regarding a fuel tax. This means that price policies could still turn around with a detrimental impact for fuel economy and without a new fuel economy regulation for the period 2017-2025 in place (as it was already launched in USA), any lean gains that could have surged lately would fade away rapidly.

3. ThreeME for Mexico

3.1. Main characteristics of ThreeME

ThreeME (Multi-sector Macroeconomic Model for the Evaluation of Environmental and Energy policy) is a **country-generic and open source model** developed since 2008 by the ADEME (French Environment and Energy Management Agency), the OFCE (French Economic Observatory) and TNO (Netherlands Organization for Applied Scientific Research)[9]. Initially developed to support the energy/environment/climate debate in France, ThreeME is now been applied to other national contexts such as Mexico and Indonesia.

The model is specially designed to evaluate the medium and long term impact of environmental and energy policies at the macroeconomic and sector levels. For this, ThreeME combines several important features:

- Its **sectorial disaggregation** allows analysis of the effect of transfer of activities from one sector to another in particular in terms of employment, investment, energy consumption or trade balance.
- The **energy disaggregation** allows analysis of the energy behavior of economic agents. Sectors can arbitrate between different energy investments: substitution between capital and energy when the relative energy price increases; substitution between energy sources. Consumers can substitute between energy sources, between transports or between goods.
- ThreeME is a **CGEM** (Computable General Equilibrium Model). It therefore takes into account the interaction and feedbacks between supply and demand (see Figure 3). The demand (consumption, investment) defines the supply (production). The supply defines in return the demand through the incomes generated by the production factors (labor, capital, etc.). Compared to bottom-up energy models such as MARKAL or LEAP, ThreeME goes beyond the mere description of the sectoral/technological dimension by linking those with the global economic system.
- ThreeME is a **neo-Keynesian model**. Compared to standard Walrasian-type CGEM, prices do not clear instantaneously supply and demand. Instead the model is dynamic and prices and quantities adjust slowly. This has the advantage to allow for situations of disequilibrium between supply and demand (in particular the presence of involuntary unemployment). This framework is better suited for policy purposes because it provides information regarding the transition phase of a particular policy (not only about the long term).

Being a neo-keynesian CGE model, ThreeME takes into account:

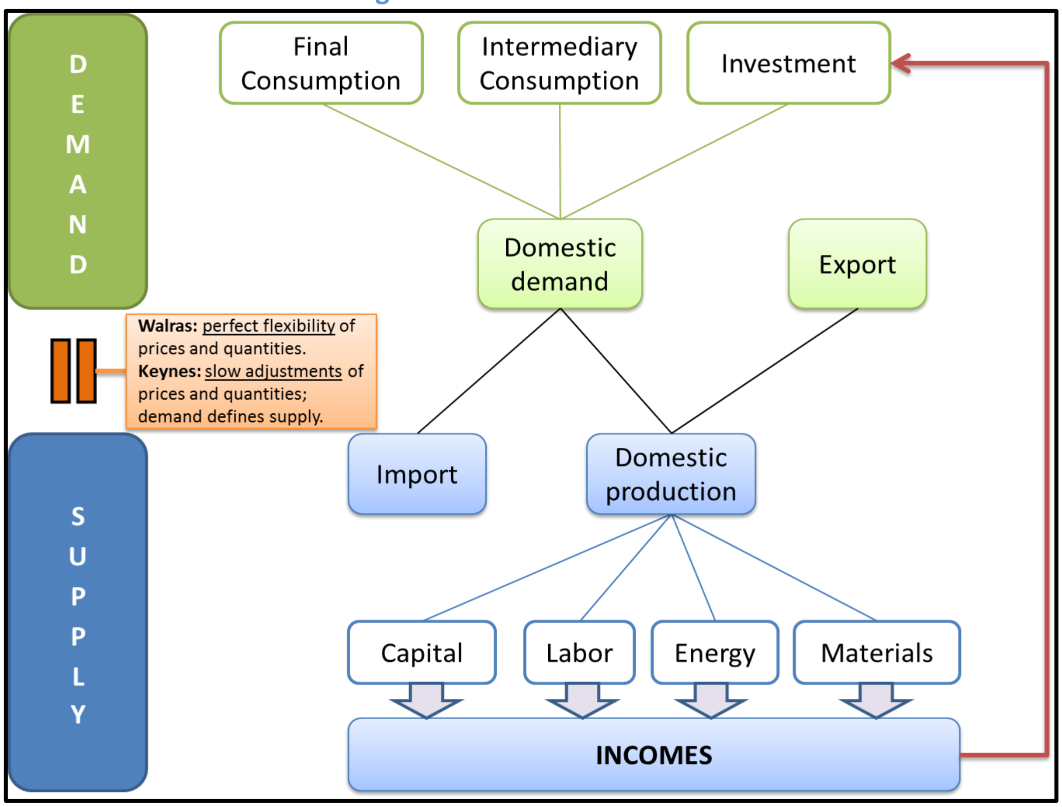
- *General equilibrium effects*: supply influences demand and vice versa
- *Direct and indirect effects of the energy transition*: the direct effects are the impacts for the energy, building, transport sectors whereas the indirect effects (or rebound effects) are the

[9] (OFCE/ADEME/TNO, 2013). A full description of ThreeME is provided on: www.ofce.sciences-po.fr/indic&prev/modele.htm.

impacts for the rest of the economy (in particular the other sectors, the government, households).

- *A double dividend (environmental and economic) is possible* through the improvement of the trade balance, the reduction of fiscal distortion (e.g. reduction of the taxation of labor and capital financed by a tax on carbon) and the positive macroeconomic effects due to the demand increase (positive multiplier).

Figure 3. Architecture of a CGEM



Source: OFCE/ADEME/TNO, 2013

ThreeME can be used to simulate the economic impact of various policies. Examples of scenario simulations related to energy and climate policies include:

- A carbon tax
- A phasing out of energy subsidies
- A tax credit in favor of energy renovation in the building sector
- Subsidies in favor of green investments in the buildings, automotive and public transport sectors
- The impact of transitions in the energy sectors (such as an increase of renewables).

3.2. Main characteristics of the Mexican version of ThreeME

The Mexican version of the ThreeME model follows a generic architecture also used in the French version. The choice of sectors is specific to Mexico and they are shown in Table 4. The model has 24 commodities (including 3 energy sources: refined oil, gas and electricity) and 32 sectors with an explicit distinction between 11 energy sectors and 7 types of transports. The rationale behind this disaggregation is the energy intensity of sectors and the contribution of each sector in terms of CO_2 emissions.

National data source have been used for the calibration. National account data come from INEGI [10]: supply and use [11] tables and input - output tables (262 Branches) and institutional sector (Household account and Government accounts [12]). 2008 is used as the base year since it corresponds to the most recent release regarding input - output tables when this project began. Additional data regarding the public sector such as the financial situation of the federal government and social security come from the Mexican ministry of Finance (SHCP [13]). Population projection comes from the National Council of Population (CONAPO [14]) and the 2008 level of CO_2 emissions is calibrated using the National Inventory of Greenhouse Gases (INEGEI [15]) data. Finally, for the disaggregation of energy sectors, we use data from Energy Information system (SIE-SENER [16]): more specifically, domestic sales of gas and import of gas and final energy consumption by power technologies and sectors.

Table 3 provides some key Mexican macroeconomic data for 2008. Energy subsidies represent 97% of the total subsidies and 2.2% of the total GDP. Mexico's crude oil export represents 3.8% of the GDP and the country imports a large amount of refined oil and gas product: 2.6% of the GDP. Tax on hydrocarbons is an important source of revenue for the Federal Government which represents 7.5% of GDP and 32% of its total revenue in 2008. Accounting for 415 million tons of CO_2 from energy consumption, Mexico is the 14th largest emitter in the world and the largest source of such emissions in Latin America. Moreover, Mexico is ranked 100th for the level of emissions per capita [17].

[10] Instituto Nacional de Estadística y Geografía

[11] Set of matrices that describe the magnitude of the inter-industrial flows depending on production levels of each economic sector (INEGI, 2012), (INEGI, 2013). http://www3.inegi.org.mx/sistemas/tabuladosbasicos/cou.aspx?c=33604

[12] http://www.inegi.org.mx/est/contenidos/proyectos/cn/si/tabulados.aspx

[13] http://www.shcp.gob.mx/POLITICAFINANCIERA/FINANZASPUBLICAS/Estadisticas_Oportunas_Finanzas_Publicas/Informacion_mensual/Paginas/ingresos_gasto_financiamiento.aspx

[14] Consejo Nacional de Población, http://www.conapo.gob.mx/

[15] (INEGEI, 2013) http://www.inecc.gob.mx/descargas/cclimatico/inf_inegei_public_2010.pdf

[16] http://sie.energia.gob.mx/

[17] http://www.eia.gov/

Table 3. Key macroeconomic data for Mexico in 2008 (base year)

Features 2008			
Public Deficit, %GDP	1.7%	Import of refined oil and gas product % GDP	2.6%
Debt, %GDP	31%	Export of refined oil and gas product % GDP	0.6%
Energy Subsidies (electricity and oil), %Total subsidies	97%	Export of crude oil % GDP	3.8%
Energy Subsidies (electricity and oil), % GDP	2.2%	Emisions of CO2 from energy uses MtCO2	415
Tax on Hydrocarbon (Derechos a los hidrocarburos), % GDP	7.5%	Household emisions, %	31%
Trade Balance, %GDP	-2.7%	Sector emisions, %	69%

Source: INEGI 2012

Table 4. Sectorial disaggregation of ThreeME for Mexico

N°	Sectors	Production %	N°	Sectors	Production %
1	Agriculture, livestockand fishing	2.9%	17	Transport via pipeline	0.1%
2	Forestry	0.1%	18	others transports	0.6%
3	Mining	1.3%	19	Business services	33.8%
4	Manufacture of food, beverages and snuff	7.0%	20	Public services	6.7%
5	Manufacture of articles of paper and paperboard	0.9%	21	Extraction of oil	4.7%
6	Manufacture of chemical	2.5%	22	Manufacture of refined petroleum products	3.7%
7	Manufacture of cement and concrete	0.4%	23	Manufacture and distribution of gas	1.7%
8	Manufacture of steel	0.8%	24	Hydraulic	0.3%
9	Manufacture of motor vehicles and truck	2.0%	25	Geothermal	0.1%
10	Others industries	15.1%	26	Wind	0.0%
11	Construction of buildings	9.1%	27	Solar	0.0%
12	Air transport	0.5%	28	Biomass	0.0%
13	Rail transport	0.1%	29	Nuclear	0.1%
14	Water transport	0.1%	30	Coal-based	0.2%
15	Freight transport by road	2.4%	31	Oil-based	0.4%
16	Passager transport by road	1.6%	32	Gas-based	0.9%

Source: INEGI 2012

Electricity sector is disaggregated into 9 technologies: hydro, geothermal, wind, solar, biomass, nuclear, coal-based, oil-based and gas-based. However, the evolution of each technology is determined exogenously. This assumption is realistic for the electricity production sector, since the government delivers the authorization for installing power plants. Hence, the investment choices in electricity technologies sectors do not obey to the same market rules as the others economic activities. They are almost entirely determined by public policy (something that is expected to change in the years to come with full implementation of the energy reform). The parametrization of the electricity mix in the base year uses data from the Energy Information System. For each technology, the share of labor, capital, intermediary consumption, and fuel consumption into the production cost have been parameterized with data from the Ministry of Energy (SENER, 2014).

In Mexico, the anthropogenic CO_2 emissions represent about 65% of the total greenhouse gas emissions[18]. They come mainly from the combustion of fossil fuels (more than 80% of the total CO_2 emissions), industrial processes, land use change and forestry. The modelling of the demand for fossil fuels is detailed by type of economic agent and by type of fossil energy (oil, coal and gas). This allows for a precise estimation of the variation in the domestic CO_2 emissions. In the Mexican version of ThreeME we consider only CO_2 emissions from the combustion of fossil fuels. The calculation of emission levels consists in multiplying the fossil energy demand by the corresponding emission coefficient. These coefficients are specific for each economic actor, each sector and each energy source depending on their carbon intensity. CO_2 emissions from the combustion of fossil fuels by sector and households are proportional to the quantity of energy consumed.

Technological innovations are a key factor for the reduction of the impact of economic activity on the environment since they allow for a reduction of emissions per unit of GDP. Improvements in energy efficiency mitigates the impact of economic growth on climate change, although the final impact of energy efficiency on energy use and CO_2 emissions is uncertain due to the *"rebound effect"*[19]. In the model there are two types of energy efficiency that have impacts on the results. The first one is exogenous, given the observed historical trends in Mexico in the production and consumption sectors, as it is explained in the next section. The second type of energy efficiency is endogenous since it depends on the energy prices in the model. We assume that higher energy prices, that may be the result of environmental policy, stimulate energy efficiency in economic sectors through a higher elasticity between capital and energy.

3.2.1. Observed trends of energy efficiency in Mexico

Energy efficiency plays a key role in the model, since it has relevant effects in energy intensity by sector. According to SENER (2011), energy efficiency in the industry sector has evolved over time depending on the sub sector. The highest energy intensive area is the manufacture sector, which in 2009 accounted for 9.8 Mj per 2003 US dollar produced; however, energy intensity has been reduced at a 0.8% per year between 1993 and 2009. Among the manufacture subsector, ferrous and nonferrous minerals, chemical products and cellulose and paper sectors have showed an energy intensity growth rate of -1.9, 0.4, -4.9 and -2.4% respectively.

[18] See (INEGEI, 2013), p.28.

[19] In this report we focus on the interpretation of the rebound effect at the macroeconomic level which includes direct and indirect effect. The macroeconomic rebound effect implies that the aggregate energy saving from climate change measures might be offset by associated increase in energy demand and therefore CO_2 emissions, due to the improvement of economic activity allowed by those same measure (Barker, Ekins, & Foxon, 2007)

Table 5. Energy intensity by industry and primary sector

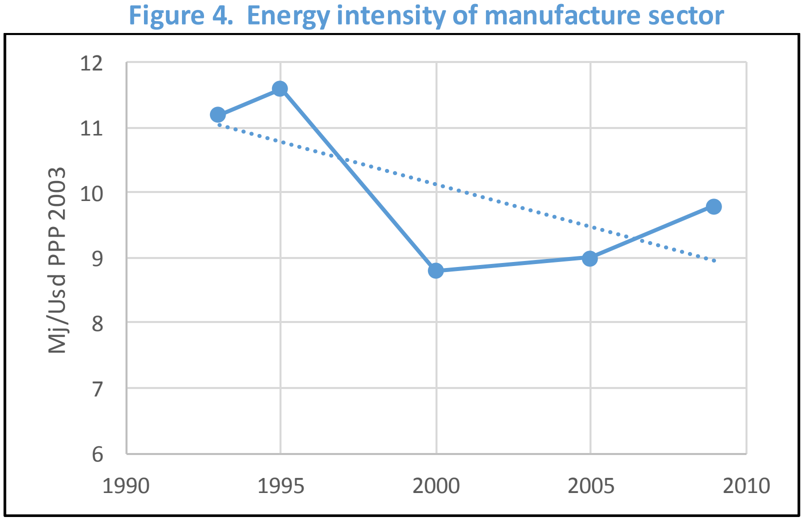
Sector	Indicator	1993	2009	Growth rate per year 1993-2009
Manufacture (total)	Energy intensity (MJ/PIB)	11.2	9.8	-0.8%
	Energy consumption share (%)	90.8	88.4	-0.2%
Basic metals	Energy intensity (MJ/PIB)	20.5	14.9	-1.9%
	Energy consumption share (%)	9.2	7.7	-1.1%
Non Ferrous minerals	Energy intensity (MJ/PIB)	12.4	13.2	0.4%
	Energy consumption share (%)	7.9	9	0.8%
Chemical products	Energy intensity (MJ/PIB)	18	8	-4.9%
	Energy consumption share (%)	17.7	8.5	-4.5%
Cellulose and paper	Energy intensity (MJ/PIB)	15.2	10.4	-2.4%
	Energy consumption share (%)	2.6	2.6	-0.1%

Source: SENER 2011

The energy efficiency path of the manufacture sector over 1993 to 2009 can be seen in Figure 4. It shows a decreasing path from 1993 to 2009. According to Enerdata (2011), industrial energy intensity has been falling at 2% per year; however, it has been decreasing less rapidly since 2000 at a 0.5% per year. The largest energy efficiency improvements were achieved in steel production (2.2% percent per year on average between 1990 and 2008) whilst the chemical industry has seen a rapid reduction in its energy intensity of around 7 percent per year since year 2000.

In summary, energy intensity varies differently across sectors. If we assume energy intensity as an adequate indicator of energy efficiency, and based on the above discussion as well, a 1% of increase per year for production sector seems to be a reasonable assumption of energy efficiency. Future modelling efforts will have to consider different efficiencies across sector that will vary accordingly.

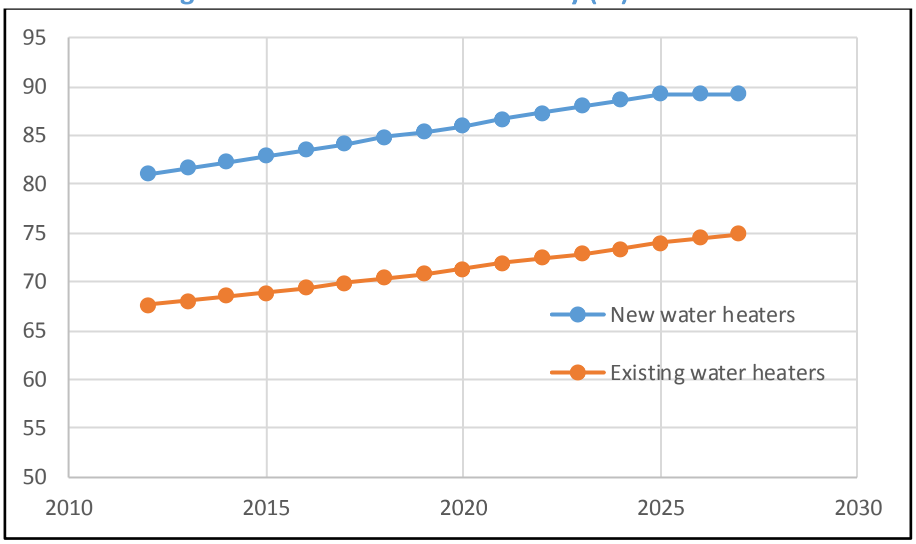
Figure 4. Energy intensity of manufacture sector



Source: SENER 2011

In the residential and commercial sector, energy efficiency will also play a crucial role in energy intensity. Most of the energy gains in the following years will come from illumination and water heating. In the case of water heating, 12.9 Mbd of L.P. gas were saved by energy efficiency of water heaters (67.9%), improvements in efficiency and in electric start of stoves (28.7%) and the use of microwaves (3.4%). In general, for water heating, it is expected that this efficiency gains will be 0.6% of average annual efficiency rate for water heaters between 2013 and 2027 (SENER 2013). Figure 5 shows the trend of water heaters efficiency. As in the case of industry, in the residential sector a 0.5% of annual increase in efficiency will be assumed for the model. This efficiency gains will mainly come from the increase of water heaters efficiency and other cooking appliances using gas.

Figure 5. Water heaters efficiency (%) 2012-2027



Source. SENER (2013)

4. Simulation results

As shown by the previous energy sector descriptions, reducing CO_2 emissions will entail the implementation of policies and measures to support green investments in the short and in the long run. A carbon tax accompanied by appropriate compensation mechanisms appears as a way to reconcile environmental and economic goals. It may not only attract financing for low carbon investments, but also boost both public and private investments as well as employment.

The carbon tax aims at increasing green activity to put Mexican economy on the track of a real carbon emissions reduction and to achieve in a cost-effective way the ambitious national mitigation commitment stated in the Climate Change Law[20] to reduce 30% of emissions with respect to the baseline in 2020, and 50% compared to the emissions of the year 2000 in 2050. A progressive carbon price is one of the tools to make carbon emission reduction takes place.

Recent experience has shown that carbon pricing may encounter serious opposition. A high carbon price would have negative effects that have to be considered, mainly through 3 channels (OFCE/ECLM/IMK, 2015):

1. Loss of consumption by high carbon emitters among households. High carbon emitters may be vulnerable households with low possibility of substitution because energy is a primary good and because choices made by households forbid rapid adaptation to a large shift in relative prices.

2. The same effect arises for producers who cannot rapidly shift investment (or without depreciating a large quantity of capital) on their production function when facing a change in relative prices. The high carbon price would have a strong negative impact on their balance sheet or on their ability to operate their business. The irreversibility of investment (as in the case of households) is the cause of the loss occurred.

3. Emission reduction at the world level may not even be achieved because of the free-rider problem

    a. A general loss of competitiveness in the short term generated by a higher cost of energy compared to the cost of energy in other parts of the world where such a carbon price would not be implemented.

    b. An energy demand reduction from those countries who applied a carbon pricing may conduct to a decrease of global energy prices which ultimately triggers higher energy demand elsewhere. It can be related to the rebound effect.

    c. A carbon leakage, through the localization of carbon emitting industrial processes where they are less priced or taxed, could result in an overall increase of global carbon emissions and jobs destruction in countries that implement carbon pricing.

[20] See (LGCC, 2012)

Positive experiences from the implementation of carbon price policies are often obtained through a full policy package that helps the transition, including decreases in others taxes[21]. Therefore, a full carbon price recycling would be part of the policy package, making the pricing of carbon more desirable. Redistribution of the carbon tax revenue is thus a way to offset the stepwise increase in carbon. As it can be directed on specific individuals or may be sectorial, it allows addressing different carbon pricing for different economic agents.

Thus, compensation is justified because it has a positive impact on the economy in the short term and it makes carbon pricing politically acceptable and less costly to economic agents. It may increase the success and the ambition of engaging the economy on a path towards lower carbon emissions.

The following section presents the results of different scenarios obtained with the Mexican version of the ThreeME model. We propose to address its negative effects through a compensation scheme. These scenarios include the phasing out of energy subsidies and the implementation of carbon tax with different strategy of fiscal revenue recycling. They also take account of different electricity mixes[22] by 2050. The level of the carbon tax is chosen such that we reach the target of the "IDEAL scenario" of the INECC of emissions from energy uses. It considers a reduction of 40% in 2030 compared to the baseline and a reduction of 50% in 2050 compared to 2000 level.

Box 1. Carbon tax trend

The concept of a carbon tax comes from the theoretical concept proposed by the English economist Arthur Pigou to address market failures. It consists in levying a tax on goods that impose spill over costs on society which are not supported by the externality's source. Then adding a tax allows, through private markets, to reflect the social cost in a cost-effective way. Climate change has been identified as a negative externality to the society by shaping the world in a less welcoming way and is directly linked to GHG emissions which are coming from our fossil fuels consumption. There is a large consensus on taxing carbon dioxide to reduce GHG emissions, although there is still a debate on its socially optimal price. The externality is quite difficult to clearly identify and estimate. Even if there is strong scientific evidence on the nature of the phenomenon, there is still uncertainty on its magnitude.

Empirical experiences have been put in place unilaterally or regionally by some countries to price carbon and there is some evidence of relatively high carbon price. For instance, the Swedish carbon tax is up to \$ 168/tCO_2 and the Tokyo Cap-and-Trade carbon price reaches \$ 95 USD/tCO_2. The majority of prices in existing systems lie below \$ 35 USD/ tCO_2. A recent study of the IMF (Parry et al., 2014) calculates for the top twenty countries how much the price of CO_2 emissions should be by only taking into account the domestic co-benefits from reducing other negative externalities (than climate change) such as local pollution, health harms and transport congestions. The authors found that an average nationally efficient price is \$ 57.5 / tCO_2. In the Deep Decarbonisation report (Sachs et al., 2014), the authors proposed, at least for France, a carbon price trajectory, initially formulated by the Quinet commission (Centre d'Analyse Stratégique, 2009) and which is compatible with the objectives of 75% emissions reduction by 2050 starting at USD^{2008} 36/tCO_2 in 2010, USD^{2008} 63/tCO_2 in 2020 and USD^{2008} 112/tCO_2 in 2030.

[21] See (World Bank, 2014)

[22] Defined as the share of the different technologies producing electricity.

4.1. Baseline scenario

The baseline (reference or business-as-usual) scenario is the path the model predicts when all exogenous variables follow their "business-as-usual" trend. The baseline scenario is meant to be a conservative vision of the future rather than a real forecast. It is the virtual scenario predicted by the model for a given trajectory of the exogenous variables. Although it excludes cyclical fluctuations, the idea is to reflect as much as possible the expected changes regarding key exogenous variables such as population, productivity gains, tax rates, elasticities, external demand. By definition, the baseline scenario always excludes the impact of any policy being studied since this can be seen as a shock compared to the reference scenario and is simulated as an alternative scenario (see Section 4.2).

Although the impact of a new policy is measured as a difference from baseline expressed as a percentage, the choice of the baseline may affect the results of the scenario simulated. Therefore it is important to define a coherent vision of the future but this may prove a difficult task in terms of calibration. To achieve the construction of a realistic baseline scenario, we focus on obtaining projections for a few key macroeconomic variables, such as real gross domestic product (GDP), population, evolution of labor productivity, and evolution of international energy prices.

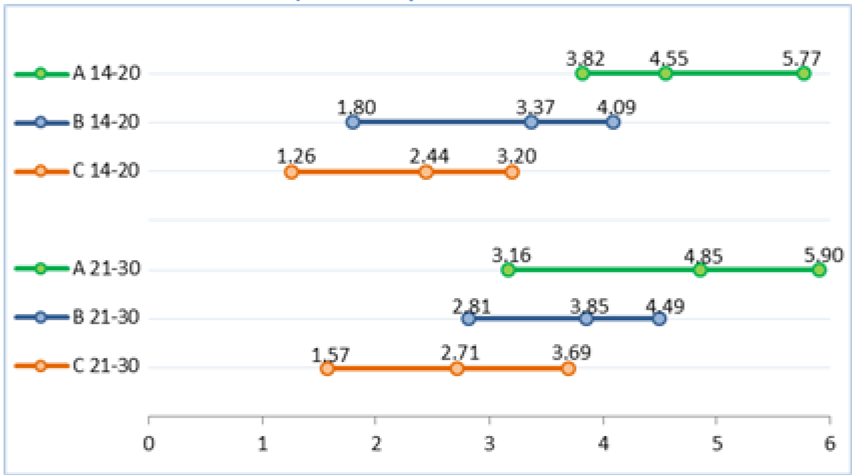
GDP projections for the Mexican economy to 2030 came from a study that is part of the *"Facilitating Implementation and Readiness for Mitigation" (FIRM)* project (INECC, 2014c) funded by the Ministry of Foreign Affairs of Denmark and the French Development Agency (AFD) implemented through the United Nations Environment Programme (UNEP) in partnership with UNEP DTU and INECC. The overall goal of this project was to improve Mexico's GHG emissions baseline. In Mexico, as in any other industrialized economy, economic growth and energy commodity prices are key drivers of greenhouse gas emissions. Estimates of likely developments in gross domestic product and fuel prices are major components of quantitative greenhouse gas emission scenarios used for planning purposes. Understanding the uncertainty associated with those estimates makes it possible to assess the uncertainty of the corresponding scenarios and, thereby, supports a more robust planning. The project used the *"Cooke"*[23] method to quantify the uncertainty around economic growth rates and energy commodity prices, in support to the government of Mexico's revision of its greenhouse gas emission scenarios.

As part of the methods to estimate the uncertainty, behavioral and mathematical approaches are available for the elicitation and aggregation of individual experts' assessments. Behavioral methods involve interaction of experts, with a view to reaching agreement on information of relevance to the experts' assessments of the variables of interest. In contrast, mathematical methods construct a 'combined' probability distribution per variable by applying procedures or analytical models that operate on the individual assessments produced by each expert. For this project a mathematical approach was favored, because the outcome of group interactions in behavioral approaches often amounts to a 'false consensus', reflecting simply the position of the dominant expert or experts in the group. Specifically, the project used the so-called Cooke method, because it provides a more comprehensive treatment of conditionalization and dependence.

[23] More information about the Cooke method can be found in: The 'Cooke Method': A Route to More Reliable Expert Advice: www.rff.org/Documents/Features/294-295%20Opinion%20-%20Aspinall%20pr.pdf

The final outcomes of this exercise in terms of the economic growth consisted in a range of GDP rates of growth for each one of three scenarios (high, medium and low) for the 2014-2020 and 2021-2030 periods, as shown in Figure 6.

Figure 6. Range of GDP growth rate (%) for three scenarios (A high, B medium and C low) for two periods 2014-2020 and 2021-2030.

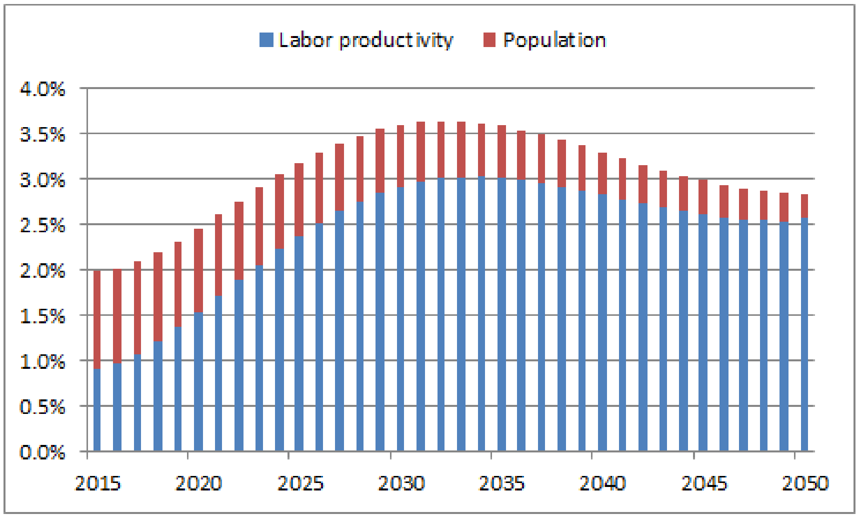


Source: Mexico's FIRM Project, (INECC, 2014c)

For the purposes of this work it was decided to use the low scenario for both periods. It is worth mentioning that this low scenario assumes that important macroeconomic variables for the Mexican economy keep an observed historical trend: between 3.0 to 3.5 for the Mexican interest rate; between 5.0 to 5.4 for unemployment; between 3.0 to 3.5 for the inflation rate and; between 2.8 to 3.3 for the US GDP rate of growth.

Population data is collected from demographic projections (2010-2050) of CONAPO. The projection for labor productivity is derived from the two previously mentioned series and it is calculated as the GDP per capita. Assumptions on population and productivity are not sufficient for the simulation to reproduce the targeted GDP because of the dynamic of the model and because the demand side should also be coherent with this target. Using a solver, the trends of public expenditure and external demand were calibrated so as to reproduce our GDP target. This way, the evolution of the baseline GDP follows its long term determinant and grows at a rate equal to the sum of the growth rate of the population and of labor productivity (See Figure 7).

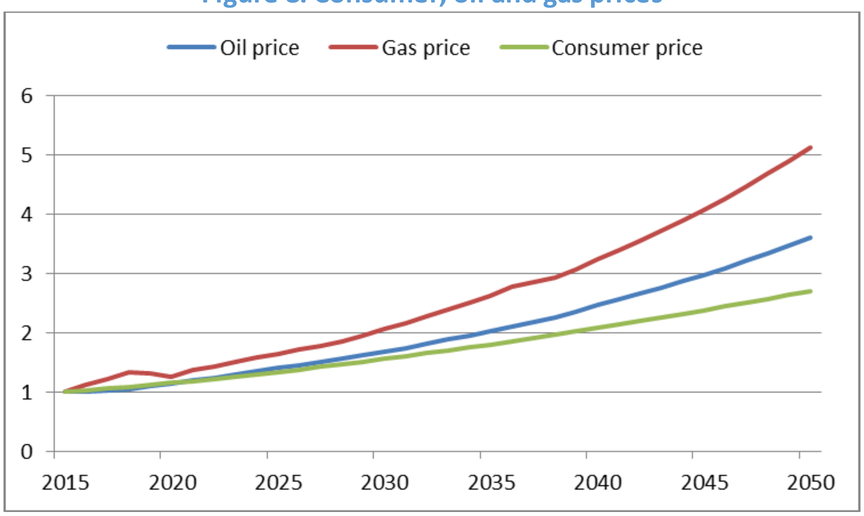
Figure 7. Contribution to the GDP



Source: own estimation

Regarding the international oil and gas prices, we use the projection of the US Energy Information Administration[24]. Oil and gas prices increase respectively by 3.7% and 4.7% per year between 2015 and 2050 (see Figure 8). The consumer price (derived endogenously) increases by 2.9% per year.

Figure 8. Consumer, oil and gas prices



Source: US Energy Information Administration and own estimation

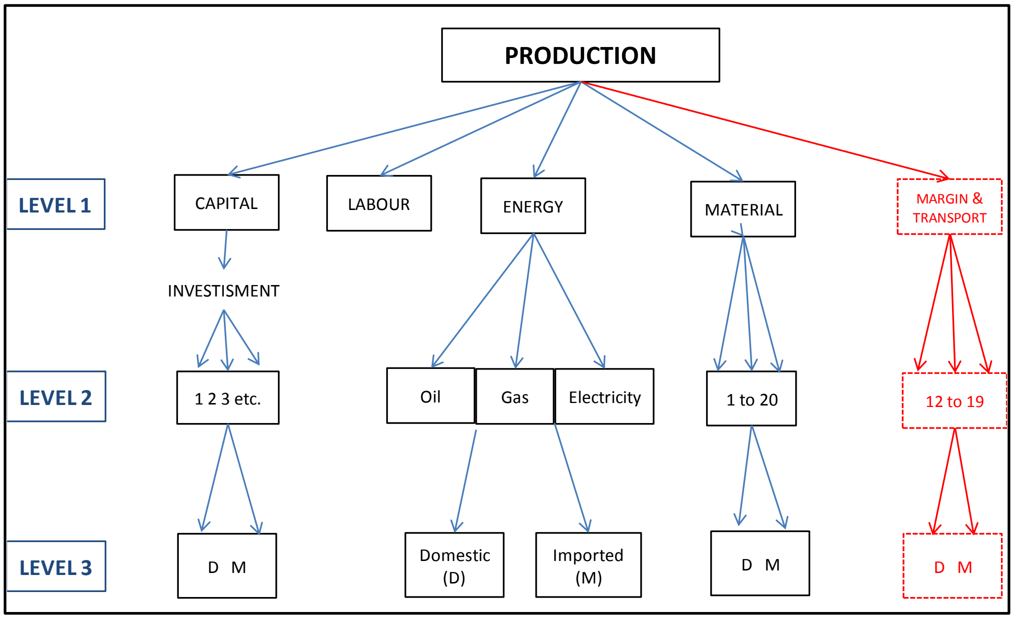
The baseline scenario is also characterized by certain key underlying hypothesis summarized below:

- Energy efficiency increases exogenously by 1% on average per year for production sectors and 0.5% for households (see section 3.2.1). No exogenous trend for the price of energy technology was considered.
- The rate of subsidies on the volume of energy consumed is assumed constant whereas the tax rates on energy quantities increase at the same rhythm as inflation.

[24] http://www.eia.gov/

- Conservative elasticities of substitution have been used in the model that assumes a production structure decomposed into three levels (see Figure 9). The level of elasticity used in each level is presented in Table 6. The first level assumes a technology with four production factors (capital, labor, energy and material), using a Variable Output Elasticities Cobb-Douglas function. This function is a generalization of the constant elasticity of substitution function that allows integrating different values of elasticity between each couple of production factors (OFCE/ADEME/TNO, 2013). The first level has a fifth element: the transport and commercial margins. *Stricto sensus*, they cannot be considered as production factors since they intervene after the production process. Thus, they are not substitutable with the production factors. But they are closely related to the level of production since once a good has been processed, it has to be transported and commercialized. At the second level, the investment, energy, material and margins aggregates are further decomposed. Elasticities of substitution between energies (oil-coal refining, gas and electricity) are assumed equal to 0.6. The same value is assumed for transport margin whereas there is no substitution possible between material goods and between investment goods. We consider that the substitution between some modes of transport is not possible, that is the case between pipeline and the other type of transport and between trucking and passenger transport. At the third level, the demand for each factor is either imported or produced domestically for each type of uses (such intermediary consumption, investment, final consumption and public investment). In all cases, we assume an Armington elasticity of substitution of 0.8.
- Endogenous energy efficiency is taken into account by assuming that the elasticity between capital and energy depends on their relative prices: an increase of the energy price relative to the price of capital leads to a higher level of elasticity of substitution. The elasticity between the elasticity of substitution and relative prices is 1.5. In addition, we assume that this effect is irreversible so that a decrease of the price of energy relative to the one of capital does not lead to decrease of the elasticity of substitution. In the baseline these elasticities are relatively stable since the relative price between capital and energy is quite stable. This is not the case in the policy scenarios that include a carbon tax.

Figure 9. Production structure



Source: OFCE/ADEME/TNO, 2013

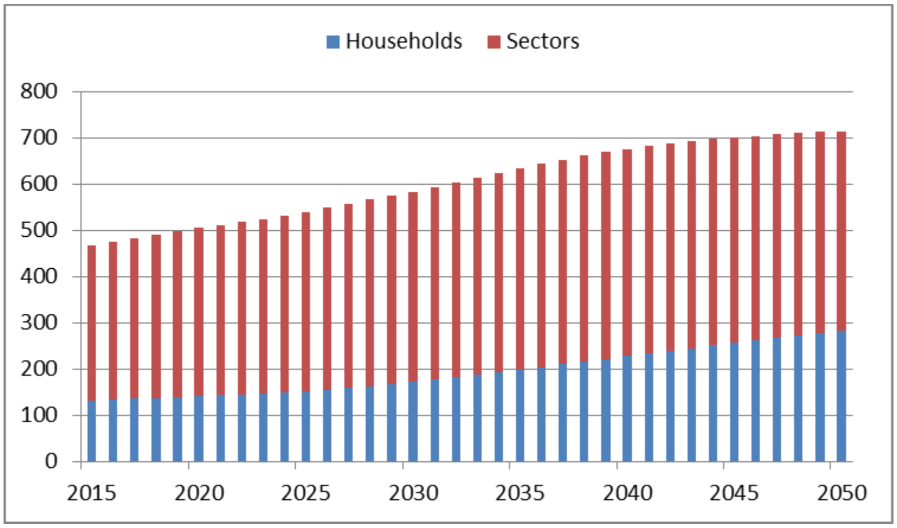
Table 6. Value of elasticity of substitution

Description	Value
Level 1: KLEM Elasticity	
Between Capital and labor in all sectors	0.5
Between Capital and Energy[25]	0.6
Between Labor and Energy in non-energy sectors	0.3
Between Labor and Energy in energy sectors	0
Between Capital and materials, Labor and materials and Energy and materials in all sectors	0
Level 2	
Between energy intermediate input in all sectors	0.6
Between transport margins	0.6
Between investment goods and between material goods	0
Level 3	
Armington elasticity of substitution between domestic and foreign goods	0.8
Between final consumption godos	1
Elasticity of exports	0.6

All hypotheses listed above lead to a total CO_2 emission from energy uses of 715 millions of tons by 2050. The model considers two main emitting segments in the economy: households and productive sectors. These segments respectively contribute by 283 (40%) and 432 (60%) millions of tons (see Figure 10). Households include transport for domestic use only (private light-duty fleet) and residential emissions. Among sectors, electric power, transport for commercial services and industry represent respectively 13%, 17% and 17% of the total emissions.

[25] This elasticity is endogenous; it depends on their relative price. The value of 0.6 corresponds to the calibration for the base year 2008.

Figure 10. CO2 emissions from energy consumption (in millions of tons)



Source: own estimation

4.1.1. Soft link with POLES for the power sector

INECC, in cooperation with the Danish Energy Agency and ENERDATA, used the POLES[26] model in order to establish the baseline generation of electricity, as well as the desired electricity matrix to set the GHG mitigation goal for 2050. The outcomes of this project were useful to have a more specific disaggregation at a technological level, benefiting from a model with a strong engineering background. The ThreeME model needed as input the percentages by technology generation per year, but as it is an exogenous variable, it was necessary to have a solid foundation to strengthen the projection of technologies given the time horizon of the projection.

The most important characteristics for the electricity sector modelling were:

- Same macroeconomic variables taken into account in ThreeME: GDP growth and population.
- Fuel efficiencies & merit order calibrated on historical data.
- Simulates future capacities development by technology on a cost-based competition, including endogenous technology learning ("learning by searching", "learning by doing")[27].
- Different sources of limitations for the development of renewables: Geographical constraints and technical limitations.
- The power production is differentiated for: "must-run" technologies (technologies with a small or negligible) variable cost, and "merit order" technologies (technologies with an important variable production cost).

Assumptions for the development of the baseline:

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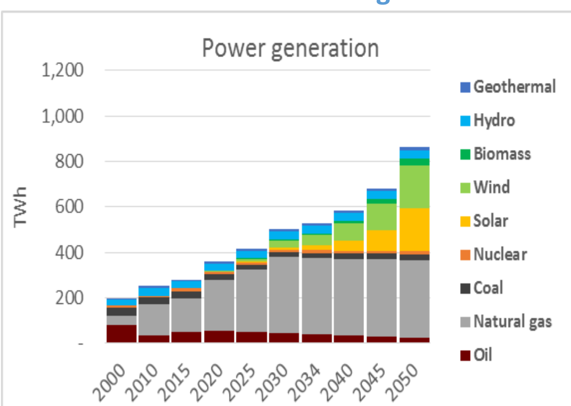
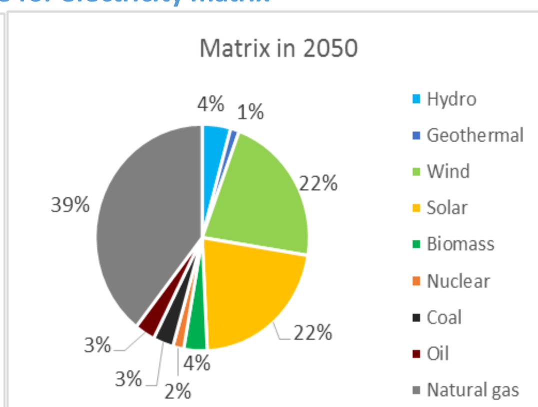
[26] More information on the POLES model can be found in: http://www.enerdata.net/enerdatauk/solutions/energy-models/poles-model.php

[27] IEA World Energy Outlook database available at: http://www.worldenergyoutlook.org/weomodel/investmentcosts/

- For the 2013- 2027 period, incorporation of the capacities and technology mix from SENER[28] forecast (an attempt to match the expected generation was made). It was difficult to reconcile capacities and generation due to differences in technology costs, efficiencies and merit order, but scenarios are in the same order of proportion of technologies. For the 2028-2050 period, the model runs by itself, taking into account all the characteristics mentioned above.
- There is a substitution between gas technologies and oil due to higher oil prices projected up to 2030. Given Mexico's characteristics, this means the phase-out of fuel oil combustion.
- There is an important penetration of renewables between 2030 and 2050. It is important to highlight that the share of clean energy in the electricity matrix is 50% by 2050. Although this might seem as a mitigation scenario, POLES forecasts that renewable energy will be competitive against fossil fuels, where the Levelized Cost of Electricity (LCOE) in terms of \$/kwh becomes equivalent in the year 2030 for both sources. This is due mainly to trends of: 1) higher fossil fuel prices; 2) decrease on technological costs and; 3) rates of learning by doing for renewables (for example, for solar power plants, CSP + PV power plant is 10%, for distributed photovoltaics is 18% and wind onshore 5%).

Figure 11. Baseline for electricity matrix





Source: own estimation based on POLES

4.2. Alternative scenarios

To test the impact of specific policies, we simulate alternative scenarios that we are able to compare to the baseline scenario. The policies considered are shown in table 7. We consider three policies. The first one is the implementation of a carbon tax (PCO2TAX). The second one is the elimination of energy subsidies (PSUB). Finally, the third one is the redistribution of revenues from the carbon tax and from the elimination of the energy subsidies (PREDIS).

[28] Ministry of Energy, Prospective of the electricity sector 2027-2013

Table 7. Policies

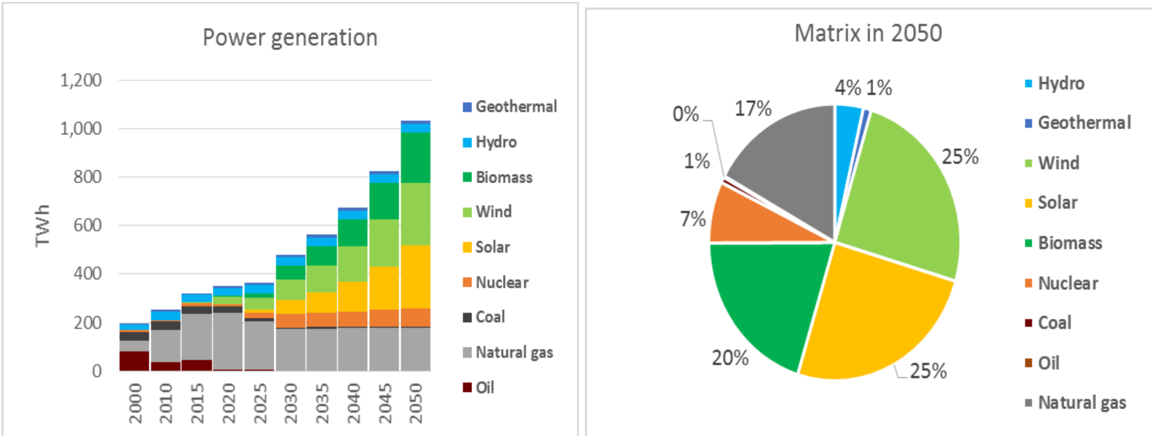
PCO2TAX	Implementation of a carbon tax
PSUB	Elimination of energy subsidies ● All energy subsidies are phased out in 10 years (by 2024)
PREDIS	Redistribution of all revenues from carbon tax collection and from the removal of energy subsidies ● Revenues from the removal of energy subsidies are redistributed through a reduction of the income tax for households. ● Revenues from the carbon tax are redistributed through a reduction of the income tax for households and of the payroll tax for sectors. The carbon tax paid by households is fully reimbursed to households. The carbon tax paid by sectors is fully reimbursed to sectors by a reduction of the average payroll tax rate. This means that high (resp. low) intensive energy sectors receive less (resp. more) than their contribution to the tax.

The impact of the above described policies can be explored according to various targets. Table 8 provides a summary of the targets we consider. We define two types of targets. The first one refers to the level of CO_2 emissions from energy consumption (TCO_2). The second type of targets concerns gradual changes in the electricity generation matrix for the period of analysis, this means different changes in the share of the different technologies producing electricity (TMIX). The objective of this exercise is to conduct a **sensitivity analysis** of two different scenarios, and to be able to look at the impacts in terms of carbon tax, emission reduction and macroeconomic variables, to highlight the importance of a clean electricity matrix. For this exercise, the scenarios considered are:

TMIX-RENEW. This target portrays a major potential for renewables. By 2050, 82% of the mix is from clean energy. ThreeME assumes the same scenario as the clean energy scenario undertaken by POLES.

- The POLE's scenario lays out a potential path for Mexico to align with a 2°C global effort: This means that all the assumptions in POLES are aligned with a world that is also carrying out policies in order to align to this target. This assumption has impact in all the variables involved, especially on fossil fuel prices and technology costs for renewables.
- It complies with the 2024 target of 35% of generation based on clean energy stated in LAERFTE.
- Clean power, including wind, solar, biomass, and nuclear, plays a very strong role in decarbonizing Mexico's power sector. Solar power's costs are currently higher than onshore wind, but falling quickly.
- Fossil fuel technologies are still needed to provide both baseload and peak power, but given the time horizon technologies as CCS may be considered to fill this gap.
- The penetration of 82% of clean energy in the matrix represents that the electricity sector has much more potential than other sectors, compensating for the lack of emission reduction or the higher costs of undertaking it. It is important to point out that this scenario involves about 200 additional TWh compared to baseline scenario in 2050, this shows an effect where all the other energy sectors in the economy are switching to electricity. This has a double benefit: other energy sectors switch to electricity leaving behind other alternative sources of energy such as thermal energy based on fossil fuels and they switch to a low emission electricity matrix.

Figure 12. Electricity matrix with carbon tax



Source: own estimation based on POLES

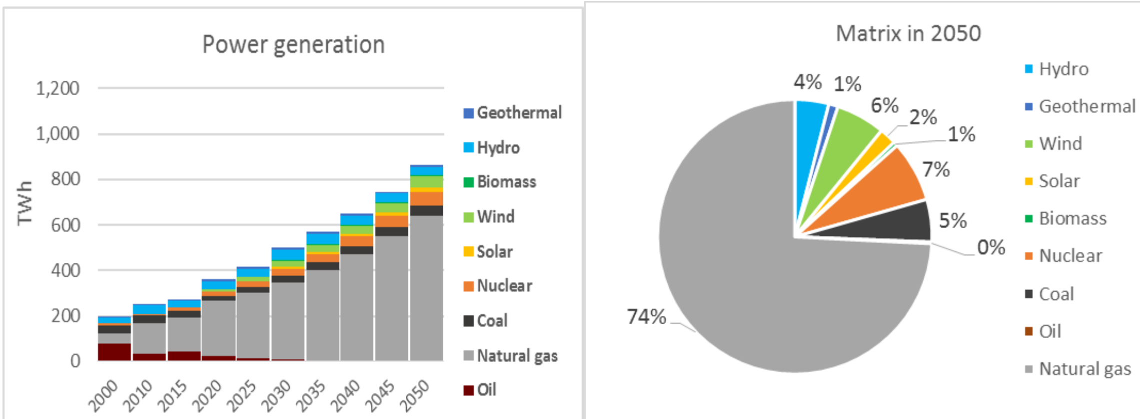
TMIX-FOSSIL. 79% based on fossil fuels: 74% of the mix is from natural gas and 5% from coal by 2050.

In order to perform the sensitivity analysis, a scenario that represents an energy matrix based on fossil fuels was developed, so a wide range of possible impacts could be quantified. However, this scenario could not be seen as economically feasible up to 2050, at least with the high costs forecasts for fossil resources. According to POLES, and assuming this trend, more renewable energy penetration is possible in the coming years; nonetheless, it was considered important to show the impacts of continuing with an investment scheme in fossil fuels. While Mexico has a climate change law, which specifies goals for the power sector, at the same time it is also promoting a major penetration of natural gas. This could delay the transition proposed or make it more expensive in the future, as it is generating important investments in infrastructure that supports the current one at least for the next 20 years.

In this scenario, the share of natural gas in the energy matrix is 74 percent. The fuel oil phasing out policy is kept, since historical data shows it has been decreasing over time (3.4% annual average since 2004, SIE-SENER), and in the next 15 years it looks not economically feasible with the natural gas prices and efficiency given. In the case of coal, CFE forecast to gradually reduce it at an annual average rate of 0.7%, but its use remains as an option considering that plants using it as a primary source constitute a mature technology. Even more, coal is the primary energy with more global reserves and its price has been less volatile compared to other fuels (SENER,2014).

The evolution of the electricity mix is therefore defined exogenously and is not sensitive to the relative prices between energy technologies in ThreeME. This assumption would be strong in a fully deregulated and decentralized electricity market. However, Mexico has just recently begun to deregulate its market, so it is most likely that decisions related to electricity production will still be largely dominated by the state power enterprise CFE.

Figure 13. Electricity matrix based on fossil fuels



Source: own estimation based on POLES

Table 8. Targets for the electricity mix and the level of CO_2 emissions.

TCO2	CO_2 emissions target for emissions from energy consumption, INECC "IDEAL scenario": reduction of emission from energy uses of 55 $MTCO_2$[29] in 2018, by -40% in 2030, compared to the baseline and -50% compared 2000 level in 2050[30] (175 million of ton CO_2 emission).
TMIX	• **TMIX-RENEW**: 35% from clean energy in 2024 and a renewable intensive electricity mix where 82% of the mix is from clean energy by 2050 given the carbon tax imposed to meet the target of 2000 levels in 2050. • **TMIX-FOSSIL**: Fossil intensive electricity mix, that is 74% of the mix is natural gas and 5% coal by 2050

The alternative scenarios that are simulated are constructed by combining the different policies and targets (Table 9). We define three groups of scenarios. The first one concerns fiscal policy without redistribution. It corresponds to an increase of the taxation on fossil energy through the phasing out of energy subsidies (S1A) and the implementation of a carbon tax (S1B). Scenario S2 tests the impact of accompanying measures that are meant to reduce the negative economic impacts of the increase of energy taxation. Scenario S3 tests in addition the effect of changing the electricity mix.

Table 9. Alternative scenarios simulated

Scenarios	Policies	Target mix	Target CO2 emissions
S1. Fiscal policy without redistribution • S1A. Phasing out of energy subsidies • S1B. Phasing out of energy subsidies and implementation of a carbon tax	PSUB PSUB + **PCO2TAX**	TMIX-**RENEW** TMIX-**RENEW**	TCO2
S2. Fiscal policy with redistribution • Phasing out of energy subsidies and implementation of a carbon tax	PSUB + PCO2TAX (S1)+ **PREDIS**	TMIX-**RENEW**	
S3. Changing the electricity mix (& fiscal pol. with redis.) • S3. Fossil intensive electricity mix	PSUB + PCO2TAX (S1) + PREDIS	TMIX-**FOSSIL**	

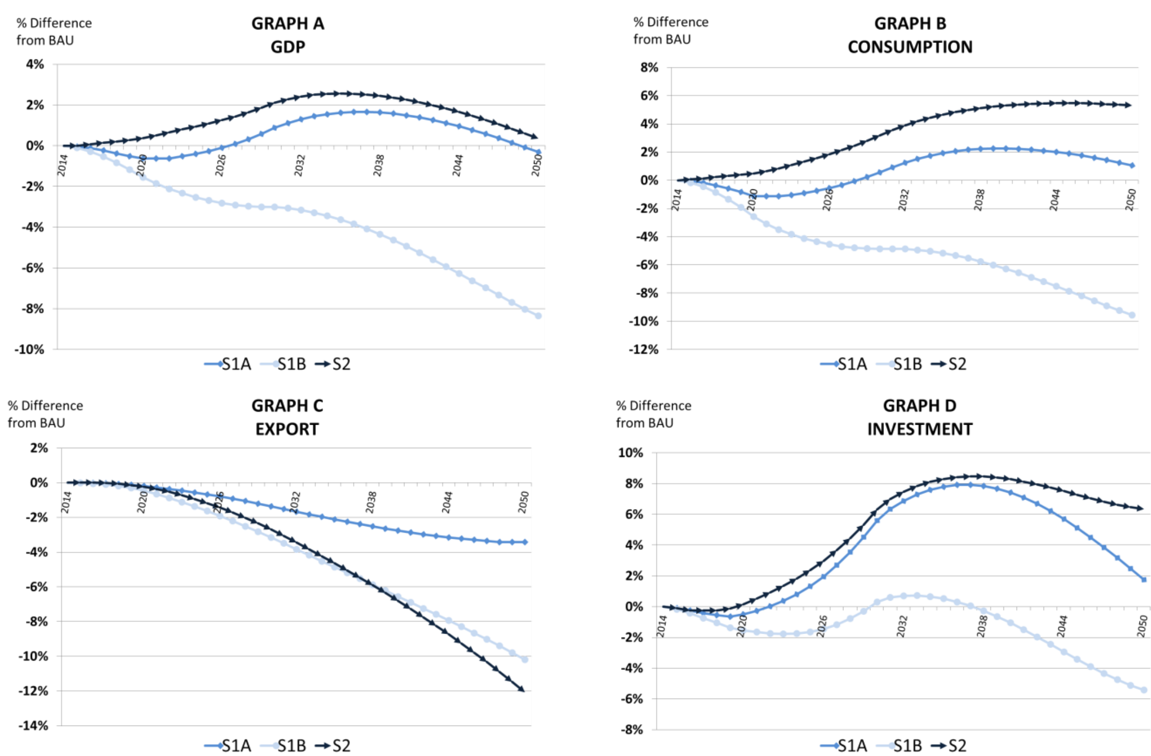
[29] It estimated from GHG emission target (83 MtCO2) stated in the Special Programme of Climate Change 2014-2018 (PECC, 2014). Emissions from energy uses correspond about 66% of total GHG emissions in 2018

[30] (LGCC, 2012)

4.3. Macroeconomic results

All results, except when it is indicated otherwise, are reported as a difference from baseline expressed as a percentage. The main macroeconomic results are shown in Figure 14 and Figure 15. The two fiscal policy scenarios without redistribution (S1A and S1B) have similar effects since they both increase the energy price. However, they have two main differences. The first one concerns the base of the fiscal instrument. Whereas the carbon tax is based exclusively on fossil energy, 16 percent of the energy subsidies are spent on electricity. Even if the share of fossil energy in electricity production goes from 46% to 18% in these scenarios, a large part of the subsidy on electricity can be seen as a subsidy on fossil energy. The main difference between S1A and S1B concerns the order of magnitude of the shock: the carbon tax (S1B) leads to a stronger increase in energy prices that comes and amplifies the phasing out of energy subsidies (S1A). Whereas the GDP marginally decreases in S1A until 2025, it drops by more than 4% after 2040 in S1B. The positive effect in the S1A after 2025 is allowed thanks to the high penetration of renewable energies in the electric mix. In the same way, electric mix limits the negative effect of GDP between 2025 and 2040 in S2 (see Figure 14.A). The level of the carbon tax is chosen such that we reach a target of 353 and 175 millions of tons of CO_2 respectively in 2030 and in 2050 (see TCO2 in Table 8). This requires a carbon tax at 1500 MX$2015 (US$100) in 2030 and 10500 MX$2015 (US$ 700) in 2050 (see Figure 16D). Compared to the baseline scenario, this corresponds to a 40% decrease in CO2 emissions from energy consumption in 2030 and 75% in 2050 (see Figure 15.D).

Figure 14. GDP, Consumption, Export and Investment

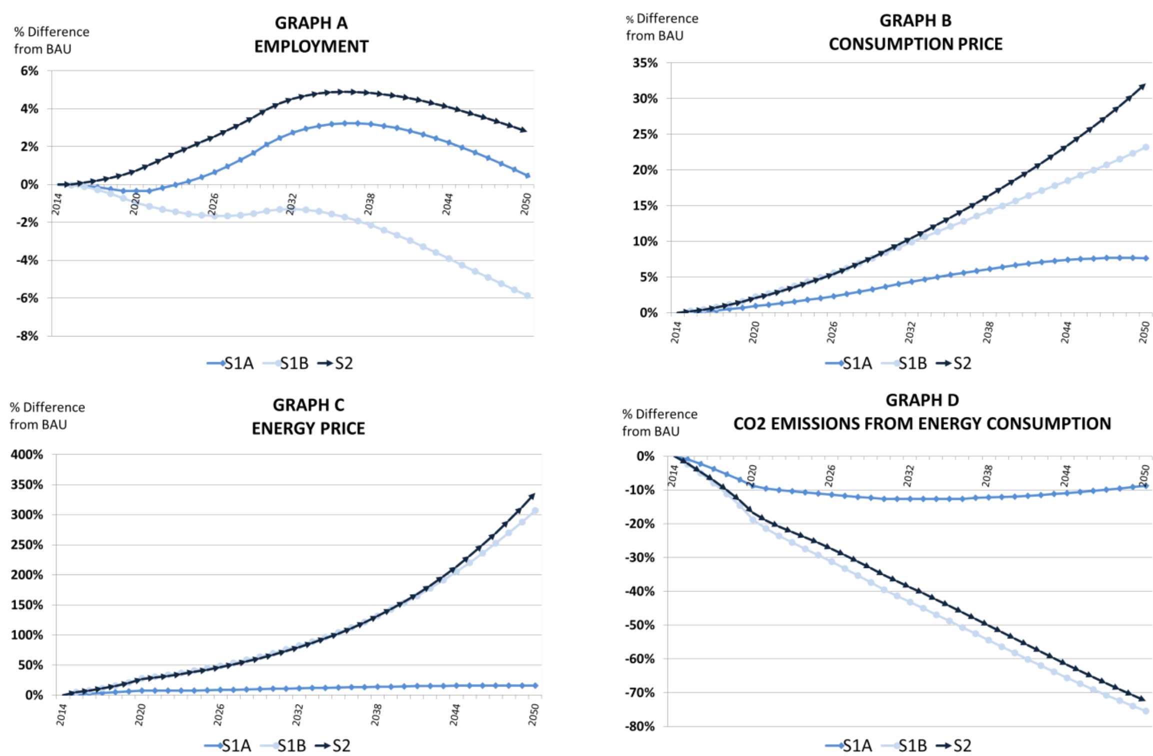


The strong GDP decrease in S1B comes from the recessionary shock caused by the implementation of the carbon tax. The carbon tax increases the energy price by more than 300% by 2050 (see Figure

15.C) which results in higher overall prices. The increase of the consumer price by nearly 25% (see Figure 15.B) has a negative impact on consumption which drops by 10% (see Figure 14.B). Since we assume that the rest of the world does not follow a similar policy, the Mexican economy suffers from a loss of competitiveness due to higher production costs and therefore higher prices. This leads to a decrease of exports by 8% after 2040 (see Figure 14.C). As a consequence of the negative multipliers effects, the recession is reinforced by the decrease in investment that drops by 4% by 2040 (see Figure 14.D). A noticeable difference with consumption is that investment starts to increase between 2030 and 2035 (see Figure 14.B&D) because of the substitution from energy to capital. But this substitution effect is insufficient to compensate the recessionary effect.

As expected, the GDP decrease in S1B leads to a decrease in employment which drops by more than 4% by 2040 (see Figure 15.A). This limits the progression of wages and explains why inflation tends to stabilize at the end of the period. This explains also why the consumer price is lower than in S2 where GDP increase (see Figure 15.B), whereas the price of energy still continues to strongly increase in both cases (see Figure 15.C). Because of the substitution effects, CO_2 emissions decrease by more than 75% by 2050 (see Figure 15.D). But this environmental dividend appears at the cost of a recession. This makes this policy difficult to accept politically at least in the short run.

Figure 15. Employment, Consumption Price, Energy Price and CO2 Emissions

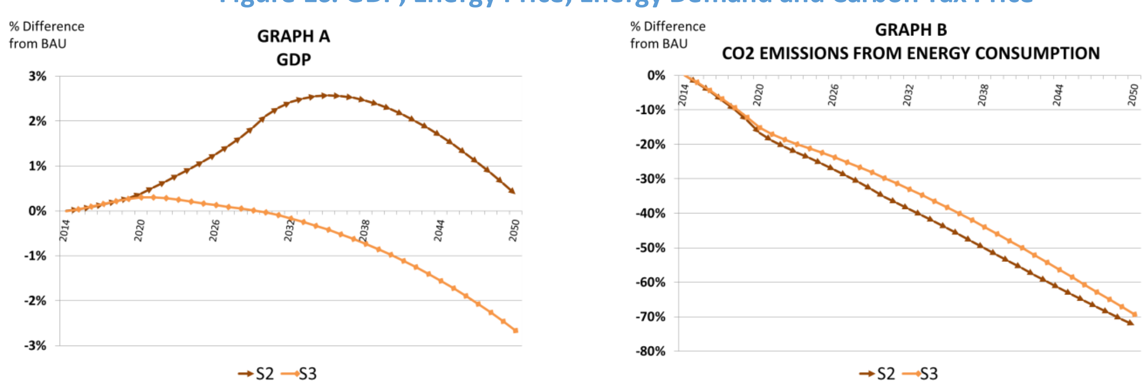


By contrast, the implementation of the carbon tax with the full redistribution (by reducing income tax for households and the payroll tax for sectors) of the tax revenue (S2) appears as a way to reconcile environmental and economic objectives: the effect on GDP is indeed positive (see Figure 14.A), whereas the decrease in emissions is only a bit smaller than in S1B (see Figure 15.D).

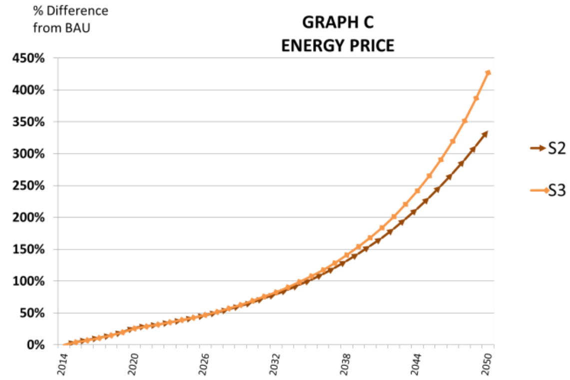
There are several reasons explaining why the redistribution allows for a positive effect on the GDP. First, the average real revenue remains more or less stable since the revenue of the tax is given back to households[31]. Second, the redistribution also limits the increase of the production costs especially for labor-intensive industries. By penalizing energy intensive sectors - which also happens to be less labor-intensive (see the sectorial results of Section 4.4- the level of employment, and therefore of consumption increases). Third, the Keynesian multipliers effects play the other way around compared to the case without redistribution. They generate a virtuous cycle for growth: more economic activity leads to more employment, consumption and investment which lead in return to more economic activity. This virtuous cycle can be maintained as long as inflationary pressures are not too high.

Higher GDP means more employment (see Figure 15.A) which leads to higher wages increases. This increase in production cost leads to more inflation. This explains why the consumer and the energy price are higher in S2 than in S1B (see Figure 15.B & C). With GDP being higher in S2 compared to S1B, CO2 emissions are logically higher when the revenue of the tax is redistributed (see Figure 15.D). This is a classic example of a rebound effect: more economic activity means more production and more households' consumption which means more energy consumption. But this rebound effect is quite small since the increase in CO2 emission is relatively limited. This result is quite interesting. It shows that it is possible to implement a carbon tax in a way that is acceptable economically (and therefore politically) without renouncing much to the potential of the tax in terms of environmental dividend. In other words, the model shows that the substitution effects due to the changes in relative prices can have more effects on energy consumption than the revenue effect (caused by the fiscal revenue transfers). Of course, this result depends on the capacity of the economy to adapt to the change in energy prices that is on the level of elasticity of substitution assumed in the simulation. Therefore, we investigate in the sensitivity analysis (Section 4.5) how these results are altered when we retain alternative levels of substitution.

Figure 16. GDP, Energy Price, Energy Demand and Carbon Tax Price



[31] Actually the average real revenue slightly decreases because the basis of the tax decreases with the substitution of fossil energy to other commodities. Therefore the amount redistributed becomes smaller while the substitution is not important enough to compensate the increase of the energy prices (unless we assume that commodities are perfectly substitutable to each other, that is a level of elasticity of substitution tending to infinity).



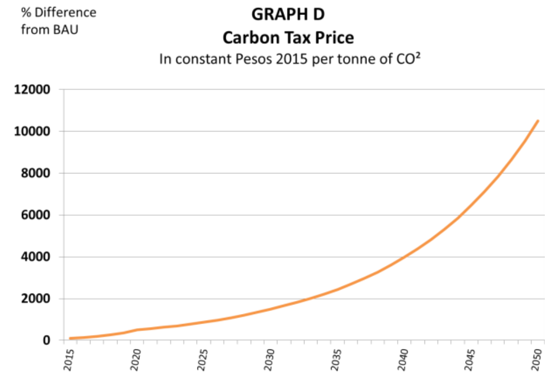
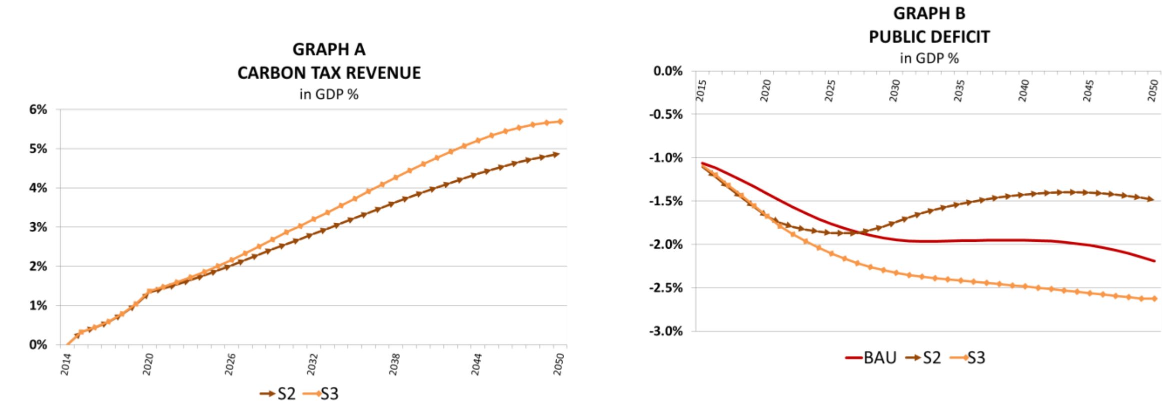


Figure 16 shows the impact of a change in the energy mix by comparing scenarios S3 to S2. As for S2, scenarios S3 assume the full redistribution of tax revenues and the same carbon tax level (see Table 8). As summarized in Table 7, S2 assumes a renewable intensive electricity mix where 75% of the mix is from renewable by 2050 (TMIX-RENEW). By contrast Scenario S3 retains the fossil intensive electricity mix where 75% of the mix is from natural gas by 2050 (TMIX-FOSSIL). The renewable intensive scenario S2 leads to a higher GDP (see Figure 12.A) and lower CO_2 emissions compared to the fossil intensive scenario S3[32] (see Figure 16.B). This result is logical. On one hand, more renewable (resp. fossil) energy in the electricity mix means a reduction (resp. increase) of CO_2 emissions from the electricity sector, which for a given aggregate electricity demand leads to less (resp. more) CO_2 emissions at the aggregate level. On the other hand, more renewable energy in the electricity mix in the context of an increase of the price of fossil energy (because of the carbon tax) leads to a lower energy price in S2 compared to S3 (see Figure 16.C). This has a positive effect on the purchasing power of consumers and on the competitiveness economic sectors. This explains why the economic activity is more favorable in S2. Of course, higher economic activity means also more energy consumption which plays as a rebound effect. This can be observed in Figure 16.B where the decrease in the energy consumption is smaller in S2 than in S3. But this rebound effect is too small to reverse the reduction of CO_2 emission allowed by a higher penetration of renewable energy: emissions are still lower in S2 compared to S3. This result suggests that, in the context of higher fossil energy prices, efforts in improving the penetration of renewable energy are more efficient both economically and environmentally.

The carbon tax revenue of S2 and S3 represents between 5% and 6% of the GDP in 2050 (See Figure 17.A), while the value added tax revenue represents in the same period 3.7% of GDP. The revenue of the tax is higher in S3 compared to S2 because of higher emission due to an intensive use of natural gas in the electricity mix. Recalling that in those scenarios the carbon tax revenue is redistributed through the decrease of others taxes. Ex ante, payroll tax and income tax are reduced to keep total tax collection at the initial level. Ex post, any change in the public deficit is due to endogenous adjustment and depends of the policy effect on other variables. The difference in evolution regarding the public deficit in S2 and S3 mainly comes from the evolution of the GDP: in S2, GDP improves compare to the baseline scenario whereas the contrary is true for S3.

[32] All scenarios produce the same results until 2020 because the mix is almost the same across all scenarios until this date.

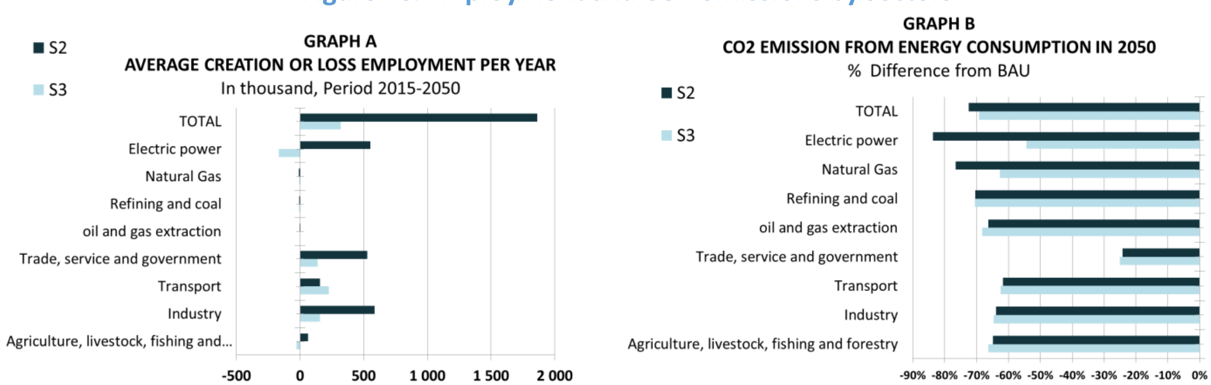
Figure 17. Carbon tax revenue and Public Deficit, in % of GDP



4.4. Sectorial results

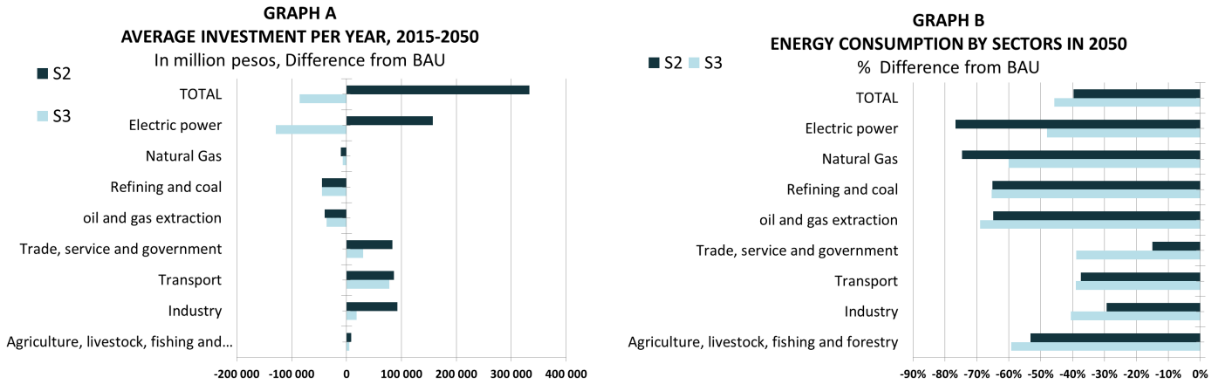
The aforementioned macroeconomic results show that the redistribution of the revenues of the carbon tax has the advantage to lead to a double dividend. In addition both dividends are higher when this fiscal policy is coupled with the development of renewables in the production of electricity. This result can be seen in Figure 18: the average employment creation per year is higher in S2 with more reduction of CO2 emissions. Almost all sectors benefit from the measures, particularly, those labor-intensive ones, such as services, industry and electric power.

Figure 18. Employment and CO2 emissions by sectors



Moreover, the electric power sector that has a high level of renewable is more labor-intensive than fossil fuel sectors. This explains why the loss of employment in fossil fuel sectors is limited with the implementation of a carbon tax (see Figure 18.A), opposite to all energy sectors that are capital intensive. Indeed, the decrease in energy demand penalizes the activity of fossil fuel sectors and therefore their investment (see Figure 19.A). All other sectors benefit from the increase in economic activity resulting from the compensation of households and industry and their investment increases. As the carbon tax is introduced for all sectors, CO_2 emission fall across the whole economy (see Figure18.B). The impact in the aggregate CO_2 emission is higher in S2, even if the reduction of total energy consumption is lower in S2 due to a higher GDP (see Figure 19.B).

Figure 19. Investment and Energy consumption by sectors



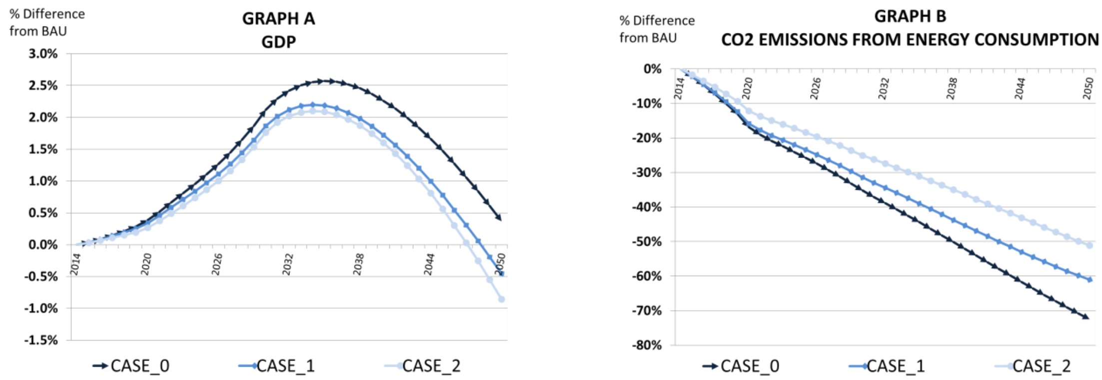
4.5. Sensitivity analysis

For the sensitivity analysis we examine the scenario S2 in all the cases shown in Table 10. The base case (Case 0) considers assumptions and parameters taken into account in section 4.2, 4.3 and 4.4. In case 1, the assumption on endogenous energy efficiency is removed. The sensitivity parameter between "the elasticity of substitution between capital and energy" and their relative price is equal to 1.5 in the base case but to 0 in case 1. The elasticity of substitution between capital and energy remains therefore constant over the all simulation period at 0.6. Case 2 integrates case 1 plus a change in value of the elasticity of substitution between final consumption goods. This elasticity is equal to 1 in case 0 and to 0.5 in case 2. Case 3 provides a sensitivity analysis on elasticity of substitution between domestic and foreign goods for each type of uses (such intermediary consumption, investment, final consumption and public investment). While the base case assumes 0.8, case 3 assumes 1. In case 4, we consider change in competitiveness. In the base case export elasticity is 0.6. In case 4, it is 0.8. Finally, case 5 analyses the sensitivity of wage to unemployment rate. Case 5 adopts an elasticity of 0.3 and case 0 assumes 0.1.

Table 10. Sensitivity analyses: Changes in assumptions

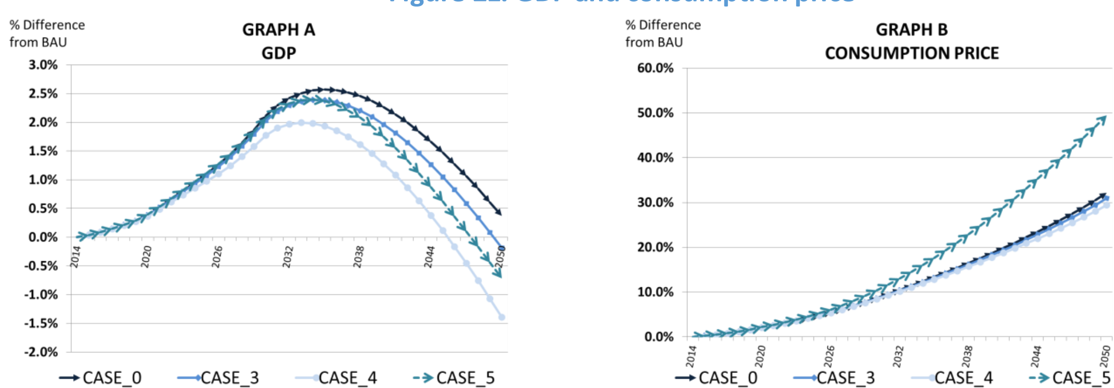
Description		**Value Case 0**	**Value**
Case 0	Base case		
Case 1	Sensitivity to relative price in the elasticity of substitution between capital and energy	1.5	0
Case 2	Case 1 + Elasticity of substitution between final consumptions goods	1	0.5
Case 3	The Armington elasticity of substitution between domestic and foreign goods	0.8	1
Case 4	Exports Elasticity	0.6	0.8
Case 5	Wage elasticity, sensitivity to unemployment rate	0.1	0.3

Figure 20. GDP and CO2 emissions from energy consumption



Results in Figure 20 shows that changes in assumptions of elasticities between capital and energy and between consumption goods affect the double dividend in the medium and long term. In particularly, removing the endogenous energy efficiency (case 1) leads to higher CO_2 emissions compared to case 0. We observe a gap of more than 10% by the end of the period. If we consider case 2, which additionally includes a halving of the elasticity of substitution between final consumption goods, this gap is doubled (See Figure 20.B). The whole economy is less flexible, sectors and households are struggling to adapt to higher energy prices. The impact on GDP is limited until 2045, after that we observe a negative effect caused by the higher cost in terms of energy bill because of a low flexibility. Agents are unable to further reduce their energy consumption. This implies that investment choices made by them forbid deep adaptation to a large shift in relative prices. The rigidity of investment, induced by a constant low elasticity of substitution between capital and energy, is the cause of the loss in activity accompanied with a lower environmental dividend (See Figure 20.A). In the above illustration, we have tested the effect of a less flexible economy. We get the inverse results (not shown for brevity) if we assume a more flexible economy: the GDP and the emission reduction are higher.

Figure 21. GDP and consumption price



Case 3, 4 and 5 have no impact on environmental dividend, reductions in CO_2 emissions from energy consumption remain at the same level than the base case (not show). The explanation is the same as previously mentioned: the substitution effects due to the changes in relative prices have more effects on energy consumption than the revenue effect (here a lower GDP); in other words, rebounds effects are much smaller than substitution effects.

The assumption underlying the Armington elasticity is that domestic goods and imported goods are imperfect substitutes. Higher elasticities in case 3 are equivalent to a decrease in barriers to trade. Because foreign prices are less expensive[33] than domestic ones, agents import more penalizing the national activity. However this negative effect is lower than case 4 and case 5. In case 4, the impact of the relative price between export prices[34] and world prices on the external demand[35] is increased. Since export prices are higher than world prices, external demand decreases more compared to case 0, affecting GDP negatively (See Figure 21). In Case 5, wages are more strongly related to the unemployment rate than in case 0. In the event of less unemployment, bargaining power of trade unions is reinforced leading to higher wage increases that affect production cost and so inflation. That explains why consumption price is higher is case 5 than in base case (see Figure 21.B). Consequently, the inflationary pressure resulting from the taxation policy reverses the economic gain because the Mexican economy is less competitive externally.

5. Conclusions

A double dividend is possible. A carbon tax will incentivize the energy transition and a low emission development of the Mexican economy, achieving at the same time higher levels of social welfare through the correct distribution policies of the carbon tax revenues. How large and how fast these benefits can be achieved will depend on the readiness and flexibility of the production and consumption sectors. The sooner Mexico triggers a change of relative prices, by sending explicit atmosphere's scarcity signals, the sooner investments in energy efficiency and in clean energy, followed by wide changes in production and consumption patterns will start. Long-term public policy commitments are needed in order to give clarity and certainty to economic actors to engage in such technological and behavioral changes.

So far Mexico has built the institutional framework to have order in its climate policies. It is a necessary but not sufficient condition. The final step to be truly coherent with its climate goals is to fully start implementing carbon price policies such as an emission trading scheme and a bold carbon tax. Regarding the latter one, this work shows that constant increases to the current carbon tax up to 30 USD/tCO_2 by 2020 and to 100 USD/tCO_2 by 2030 will create the necessary and sufficient conditions to be in the path to a complete decarbonized economy in 2050. In doing so, higher rates of growth in order of annual differences up to 2.5% in reference to the baseline are forecasted by the model. In absolute values, this means that Mexico could finally achieve annual rates of growth beyond 3.9% that would place it out of the middle income trap in the years to come.

Albeit of Mexico's great efforts, the country is running out of time to change its path of development. The next years are critical to make the right investments. Mexico faces a crossroads, either it implements the above mentioned climate policies and sets the conditions for a clean energy industry to grow, or it continues in a business as usual pathway with a soft transition, deferring crucial investments and getting lock in with fossil fuel technologies. The latter choice entails high risks of

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[33] Recall that we assume that the rest of the world not follows a carbon tax policy.

[34] It depends on the production cost and reflects the price competitiveness of domestic products.

[35] Under the assumption of a « small open economy » the external demand and the export price are negatively related for a given world price.

major costs of changing producers and consumers patterns unable to adapt rapidly to a world that implements severe restrictions on carbon emissions in the near future.

Mexico recently presented its Intended Nationally Determined Contributions (INDCs) to the United Nations Framework Convention on Climate Change (UNFCCC). Its proposal states unconditional GHG mitigation of 22% in reference to a baseline by 2030 and conditional mitigation up to 36% for the same year. According to Mexico's INDC proposal, the conditional target is subject to an international agreement on carbon price policies, carbon border adjustments, technical cooperation, access to low cost financial resources, and technology transfer. It is clear that all these conditions are necessary but it is quite unlikely this will be the outcome of COP21. Mexico should not wait for all this to happen to begin its own decisive transition. Even in a world that slowly converges to these international agreements to tackle climate change, these policies are good economics. As it was shown by the results of this work, early actions will reduce emissions with environmental, social and economic benefits for the country that clearly offset the costs of implementation.

5.1. Next steps

There are still important questions that need to be answered. In order to have a more comprehensive work regarding the consequences of the energy and climate policies, INECC has to keep working with the model. One important issue to be solved regards carbon tax predictions in the long run. The model predicts a carbon tax approximately of 700 USD/tCO_2 for the year 2050. The high cost in this case is related, among other variables, to the technology costs face by the industry, as they do not change over time in any scenario. Inclusion of decreasing cost trends must be included in the next exercises. Regarding the foreign sector, the model predicts a loss of competitiveness and a drop in exports. This is related to the assumption of a world committed or not to reduce GHG emissions. In order to have more realistic scenarios, different assumptions on the degrees of commitment of the rest of world should be undertaken. One other issue is that distributional effects are not part of this assessment. Disaggregating households by income is absolutely necessary to see the level of regressivity or progressivity of the carbon tax. Availability of new information such as the new 2012 input-output matrix will update the work to a different base year. The disaggregation of the transport sector is also a must. Just like we did with the electricity sector, exogenous changes to technologies of the on-road fleet will allow us to see the impacts of specific policies such as regulations or government programs that change technologies in the auto fleet. Finally, continuous work to get the right price elasticities that better fit the national context is a non-stop effort that will help to sophisticate the Mexican version of ThreeME.

6. APPENDIX

Table 11. Summary table, Scenario Business as Usual (BAU)

VARIABLE		2008	2013	2015	2020	2030	2040	2050
Real GDP (in million Pesos)	1	12 256 864	13 426 992	13 954 396	15 580 633	21 358 495	30 259 340	40 678 583
Value Added market sector (In million Pesos)	2	10 903 262	11 946 268	12 403 004	13 809 596	18 827 989	26 668 823	35 894 583
Household Consumption (In million Pesos)	3	8 250 896	9 175 204	9 454 943	10 318 826	13 572 980	19 148 618	25 448 829
Investment (In million Pesos)	4	2 830 420	3 096 765	3 201 895	3 515 697	4 720 294	6 897 760	9 730 182
Investment (commercial sectors, in million Pesos)	5	955 531	1 055 986	1 091 231	1 192 694	1 569 538	2 242 917	3 068 145
Exportations (In million Pesos)	6	3 270 613	3 495 892	3 698 733	4 329 766	6 332 385	8 776 865	11 568 147
Importations (In million Pesos)	7	3 600 182	3 953 769	4 107 160	4 576 892	6 164 280	8 556 743	11 256 981
Real Household Income (In million Pesos)	8	9 281 214	10 284 620	10 622 896	11 620 505	15 298 377	21 528 634	28 617 281
Saving rate	9	11%	11%	11%	11%	11%	11%	11%
Household consumption Price	10	1.00	1.15	1.22	1.41	1.89	2.53	3.30
Production Price	11	1.00	1.14	1.21	1.39	1.88	2.51	3.27
Export price	12	1.00	1.15	1.22	1.41	1.90	2.54	3.32
Import Price	13	1.00	1.13	1.20	1.39	1.88	2.55	3.45
Real wage (In million Pesos)	14	0.08	0.09	0.09	0.09	0.12	0.16	0.21
Real Labor Cost (In million Pesos)	15	0.09	0.10	0.10	0.09	0.09	0.10	0.09
Employment	16	47 439 094	50 467 400	51 617 151	54 263 005	58 544 436	61 681 232	64 035 869
Unemployment rate	17	4.16%	4.15%	4.11%	4.07%	4.22%	4.42%	4.36%
Trade Balance (point of GDP)	18	-2.69	-3.08	-2.44	-1.14	1.09	0.57	-0.36
Public Deficit (point of GDP)	19	-1.73	-1.00	-1.06	-1.41	-1.95	-1.95	-2.19
Public Debt (point of GDP)	20	31.07	30.29	29.54	28.69	29.20	30.49	33.88
GDP Index	21	100	110	114	127	174	247	332
CO2 Emissions (MtCO2)	22	415	455	468	505	584	676	715
Sector	23	287	327	338	363	412	448	432
Household	24	128	128	131	142	172	228	283
CO2 Emissions (Index 2008)	25	100	110	113	122	141	163	172

Table 12. Summary table, Scenario 1A

VARIABLE		2015	2020	2030	2040	2050
Real GDP (%difference from BAU)	1	-0.03	-0.61	0.88	1.50	-0.29
Value Added market sector (% difference from BAU)	2	-0.06	-0.78	0.82	1.46	-0.47
Household Consumption (% difference from BAU)	3	-0.04	-1.06	0.58	2.26	1.07
Investment (% difference from BAU)	4	-0.11	-0.52	5.58	7.41	1.75
Investment (Commercial sectors, % difference from BAU)	5	-0.01	-0.55	0.36	2.26	1.37
Exportations (% difference from BAU)	6	0.00	-0.18	-1.34	-2.75	-3.42
Importations (% difference from BAU)	7	-0.07	-0.89	1.13	2.91	1.47
Real Household Income (% difference from BAU)	8	-0.06	-1.10	0.60	2.15	0.97
Saving rate (difference from BAU)	9	-0.02	-0.04	0.01	-0.10	-0.09
Household consumption Price (% difference from BAU)	10	0.05	0.96	3.67	6.66	7.66
Production Price (% difference from BAU)	11	-0.01	0.60	3.53	6.64	7.67
Export price (% difference from BAU)	12	0.00	0.58	2.91	5.25	6.04
Import Price (% difference from BAU)	13	-0.01	0.11	0.31	0.20	0.07
Real wage (% difference from BAU)	14	-0.06	-0.48	2.96	5.60	5.76
Real Labor Cost (% difference from BAU)	15	0.00	-0.13	2.68	5.15	5.43
Employment	16	-9 404	-187 420	1 240 467	1 846 604	311 692
Unemployment rate (Difference from BAU)	17	0.01	0.19	-1.17	-1.51	-0.21
Trade Balance (Difference from BAU in point of GDP)	18	0.02	0.34	-0.01	-0.23	0.25
Public Deficit (Difference from BAU in point of GDP)	19	-0.07	-0.50	-1.07	-1.46	-1.35
Public Debt (Difference from BAU in point of GDP)	20	-0.07	-1.87	-7.95	-15.15	-19.97
GDP (index 2008)	21	114	126	176	251	331
CO2 Emissions (MtCO2)	22	464	461	510	596	652
CO2 Emissions (% difference from BAU)	23	-0.95	-8.80	-12.63	-11.91	-8.76
Sector (% difference from BAU)	24	-1.18	-9.42	-16.00	-17.62	-14.06
Household (% difference from BAU)	25	-0.37	-7.21	-4.52	-0.70	-0.69
CO2 Emissions (Index 2008)	26	112	111	123	143	157
Carbon Tax Value (in Pesos 2008)	27	0.00	0.00	0.00	0.00	0.00
Real Carbon Tax Revenue (In pesos)	28	0.00	0.00	0.00	0.00	0.00
Carbon Tax Revenue (point of GDP)	29	0.00	0.00	0.00	0.00	0.00

Table 13. Summary table, Scenario 1B

VARIABLE		2015	2020	2030	2040	2050
Real GDP (%difference from BAU)	1	-0.10	-1.54	-3.00	-4.94	-8.35
Value Added market sector (% difference from BAU)	2	-0.15	-1.90	-3.61	-5.87	-9.64
Household Consumption (% difference from BAU)	3	-0.16	-2.57	-4.84	-6.27	-9.57
Investment (% difference from BAU)	4	-0.18	-1.55	0.30	-1.06	-5.42
Investment (Commercial sectors, % difference from BAU)	5	-0.04	-1.36	-4.04	-5.60	-8.68
Exportations (% difference from BAU)	6	-0.01	-0.45	-3.15	-6.55	-10.19
Importations (% difference from BAU)	7	-0.18	-2.15	-3.26	-4.14	-6.61
Real Household Income (% difference from BAU)	8	-0.25	-2.73	-4.89	-6.51	-9.94
Saving rate (difference from BAU)	9	-0.08	-0.15	-0.05	-0.23	-0.37
Household consumption Price (% difference from BAU)	10	0.24	2.23	8.42	15.68	23.20
Production Price (% difference from BAU)	11	0.06	1.60	7.94	15.32	23.41
Export price (% difference from BAU)	12	0.05	1.40	6.91	13.59	21.83
Import Price (% difference from BAU)	13	0.01	0.27	0.58	0.45	0.18
Real wage (% difference from BAU)	14	-0.25	-1.35	-0.08	-0.76	-4.79
Real Labor Cost (% difference from BAU)	15	-0.08	-0.73	0.07	-0.71	-5.02
Employment	16	-19 390	-524 952	-817 984	-1 653 862	-3 755 556
Unemployment rate (Difference from BAU)	17	0.03	0.55	0.70	1.45	3.14
Trade Balance (Difference from BAU in point of GDP)	18	0.06	0.81	1.66	2.48	3.99
Public Deficit (Difference from BAU in point of GDP)	19	-0.35	-1.52	-3.04	-4.90	-6.82
Public Debt (Difference from BAU in point of GDP)	20	-0.37	-5.09	-21.10	-43.13	-72.00
GDP (index 2008)	21	114	125	169	235	304
CO2 Emissions (MtCO2)	22	457	410	353	282	175
CO2 Emissions (% difference from BAU)	23	-2.37	-18.80	-39.51	-58.28	-75.47
Sector (% difference from BAU)	24	-2.16	-17.31	-38.08	-55.10	-71.00
Household (% difference from BAU)	25	-2.91	-22.61	-42.94	-64.53	-82.26
CO2 Emissions (Index 2008)	26	110	99	85	68	42
Carbon Tax Value (in Pesos 2008)	27	100	500	1 500	3 969	10 500
Real Carbon Tax Revenue (In pesos)	28	45 585	204 532	523 945	1 098 192	1 795 778
Carbon Tax Revenue (point of GDP)	29	0.33	1.33	2.53	3.82	4.82

Table 14. Summary table, Scenario 2

VARIABLE		2015	2020	2030	2040	2050
Real GDP (%difference from BAU)	1	0.04	0.39	2.12	2.26	0.37
Value Added market sector (% difference from BAU)	2	-0.01	0.11	1.77	1.64	-0.62
Household Consumption (% difference from BAU)	3	0.05	0.47	3.18	5.30	5.29
Investment (% difference from BAU)	4	-0.10	0.15	6.31	8.27	6.33
Investment (Commercial sectors, % difference from BAU)	5	0.05	0.68	3.01	5.38	5.34
Exportations (% difference from BAU)	6	0.01	-0.24	-2.69	-6.81	-12.08
Importations (% difference from BAU)	7	-0.08	-0.38	1.74	3.55	3.68
Real Household Income (% difference from BAU)	8	0.07	0.42	3.11	5.03	4.83
Saving rate (difference from BAU)	9	0.02	-0.04	-0.06	-0.23	-0.39
Household consumption Price (% difference from BAU)	10	0.20	2.11	8.66	18.67	32.14
Production Price (% difference from BAU)	11	0.01	1.37	8.02	18.23	32.58
Export price (% difference from BAU)	12	-0.06	0.80	6.16	14.67	27.41
Import Price (% difference from BAU)	13	0.01	0.26	0.57	0.44	0.19
Real wage (% difference from BAU)	14	-0.20	-0.72	3.47	6.53	6.86
Real Labor Cost (% difference from BAU)	15	-0.66	-2.72	-1.43	-1.03	-3.11
Employment	16	18 568	404 102	2 323 170	2 881 006	1 789 856
Unemployment rate (Difference from BAU)	17	-0.02	-0.43	-2.10	-2.37	-1.42
Trade Balance (Difference from BAU in point of GDP)	18	0.01	0.21	0.17	0.57	1.78
Public Deficit (Difference from BAU in point of GDP)	19	0.04	0.26	-0.21	-0.53	-0.71
Public Debt (Difference from BAU in point of GDP)	20	0.00	0.34	-1.49	-6.11	-10.50
GDP (index 2008)	21	114	128	178	252	333
CO2 Emissions (MtCO2)	22	458	420	378	311	197
CO2 Emissions (% difference from BAU)	23	-2	-17	-35	-54	-72
Sector (% difference from BAU)	24	-2	-15	-34	-51	-68
Household (% difference from BAU)	25	-3	-20	-38	-60	-79
CO2 Emissions (Index 2008)	26	110	101	91	75	47
Carbon Tax Value (in Pesos 2008)	27	100	500	1 500	3 969	10 500
Real Carbon Tax Revenue (In pesos)	28	45 666	209 861	561 216	1 204 463	1 991 931
Carbon Tax Revenue (point of GDP)	29	0.33	1.34	2.57	3.89	4.88

Table 15. Summary table, Scenario 3

VARIABLE		2015	2020	2030	2040	2050
Real GDP (%difference from BAU)	1	0.04	0.30	-0.03	-0.97	-2.66
Value Added market sector (% difference from BAU)	2	0.00	0.04	-0.53	-1.82	-3.94
Household Consumption (% difference from BAU)	3	0.05	0.46	0.75	0.79	-0.21
Investment (% difference from BAU)	4	-0.05	-0.22	-0.81	-2.40	-1.04
Investment (Commercial sectors, % difference from BAU)	5	0.05	0.67	1.08	1.47	2.09
Exportations (% difference from BAU)	6	0.01	-0.21	-1.75	-4.14	-8.84
Importations (% difference from BAU)	7	-0.06	-0.36	-0.66	-0.97	-0.83
Real Household Income (% difference from BAU)	8	0.07	0.41	0.66	0.58	-0.65
Saving rate (difference from BAU)	9	0.02	-0.04	-0.08	-0.18	-0.40
Household consumption Price (% difference from BAU)	10	0.21	1.96	6.44	12.71	25.19
Production Price (% difference from BAU)	11	0.02	1.18	5.68	12.22	26.21
Export price (% difference from BAU)	12	-0.04	0.67	3.80	8.68	20.34
Import Price (% difference from BAU)	13	0.02	0.22	0.38	0.30	0.14
Real wage (% difference from BAU)	14	-0.21	-0.81	-0.27	-0.83	-3.69
Real Labor Cost (% difference from BAU)	15	-0.67	-2.82	-5.45	-9.69	-15.48
Employment	16	21 957	338 786	519 259	342 224	-76 937
Unemployment rate (Difference from BAU)	17	-0.03	-0.35	-0.46	-0.28	0.07
Trade Balance (Difference from BAU in point of GDP)	18	0.01	0.19	0.56	1.18	2.46
Public Deficit (Difference from BAU in point of GDP)	19	0.03	0.26	0.38	0.53	0.43
Public Debt (Difference from BAU in point of GDP)	20	-0.02	0.34	1.86	3.30	2.97
GDP (index 2008)	21	114	128	174	244	323
CO2 Emissions (MtCO2)	22	459	428	410	352	220
CO2 Emissions (% difference from BAU)	23	-2	-15	-30	-48	-69
Sector (% difference from BAU)	24	-2	-13	-26	-41	-62
Household (% difference from BAU)	25	-3	-20	-39	-62	-80
CO2 Emissions (Index 2008)	26	111	103	99	85	53
Carbon Tax Value (in Pesos 2008)	27	100	500	1 500	3 969	10 500
Real Carbon Tax Revenue (In pesos)	28	45 746	213 979	612 034	1 381 017	2 253 422
Carbon Tax Revenue (point of GDP)	29	0.33	1.37	2.87	4.61	5.69

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