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Article

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Analysis of Energy Demand Scenarios in Ecuador: National Government Policy Perspectives and Global Trend to Reduce CO_2 Emissions

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ABSTRACT

The structure of Ecuador's energy matrix over the past 15 years has varied, but in general, the three dominant sources of energy in the country are: Oil, hydroelectricity and biomass. In recent years, hydro energy has had a great boost with the construction of important hydroelectric projects, which has allowed to achieve important generation of energy from renewable sources. A system dynamics model evaluates the scenarios of Ecuador's energy model. The analysis describes the relationship between dynamic factors, such as policies, energy dependence and demand. National governmental political scenarios and global trends mark the way forward in search of reduction of energy consumption, energy efficiency and CO_2 emissions mitigation. The results forecast future scenarios and trends in the supply and demand of energy and CO_2 emissions projected until 2030.

Keywords: CO_2, Emissions, Energy Demand, Energy Policies
JEL Classifications: Q48, Q58, O100

1. INTRODUCTION

Global warming is the term used to describe a gradual increase in the average temperature of the Earth's atmosphere and its oceans. Climatic scientists who look at the data and facts agree that the planet is warming up, the scientific consensus on climate changes related to global warming is that the average temperature of the Earth has increased between 0.4 and 0.8°C in the last 100 years.

Scientists who carry out research on global warming have recently predicted that average global temperatures could rise between 1.4 and 5.8°C by 2100. Changes resulting from global warming may include sea level rise due to polar ice melting, as well as an increase in the occurrence and severity of storms, and other severe weather events.

Global warming is one of the most important challenges that the world is facing today. The adverse impacts of global warming can be catastrophic and a potential threat to the existence of humanity (Mahmood Freij et al., 2017). Earth's climate has changed throughout history. Only in the last 650,000 years there were seven cycles of glacial advance and retreat, with the abrupt end of the last ice age about 7000 years ago, that marked the beginning of the era of the modern climate - and human civilization (NASA, 2018).

Anthropogenic emissions of greenhouse gases have increased since the pre-industrial era, driven largely by economic and demographic growth, now they are higher than ever. This has led to atmospheric concentrations of carbon dioxide, methane and nitrous oxide that are unprecedented and are very likely the dominant cause of warming observed since the mid-twentieth century (Figure 1), (Intergovernmental Panel on Climate Change, 2014).

Increase in energy consumption, as well as CO_2 emissions, cause great concern in the world. The global energy demand grew by 2.1% in 2017, according to preliminary estimates of the

International Energy Agency (IEA), more than double the growth rate in 2016. The global energy demand in 2017 reached an estimated 14050 million tons of oil equivalent (Mtoe), compared to 10035 Mtoe in 2000.

Fossil fuels covered 70% of the growth in energy demand worldwide. Demand for natural gas increased more, reaching a record 22% share of total energy demand. Renewable energies also grew strongly, accounting for about a quarter of the world's energy demand growth, while nuclear use accounted for 2% of growth (International Energy Agency, 2018).

The overall share of fossil fuels in global energy demand in 2017 remained at 81%, a level that has remained stable for more than three decades despite the solid growth of renewable energies.

Improvements in global energy efficiency slowed down. The rate of decline in global energy intensity, defined as the energy consumed per unit of economic production, decreased to only 1.6% in 2017, well below the 2.0% improvement observed in 2016.

The growth in global energy demand was concentrated in Asia, where China and India together represent more than 40% of the increase. The demand for energy in all advanced economies contributed more than 20% of the growth in global energy demand, although its share in total energy use continued to decline. Significant growth was also recorded in Southeast Asia (which accounted for 8% of the growth in world energy demand) and Africa (6%), although the use of energy per capita in these regions remains well below the world average.

Global CO_2 emissions related to energy increased by 1.4% in 2017, an increase of 460 million tons (Mt), and reached a historical maximum of 32.5 Gt. Last year's growth came after three years of flat emissions and contrasts with the sharp reduction needed to meet the Paris Agreement targets on climate change (International Energy Agency, 2018).

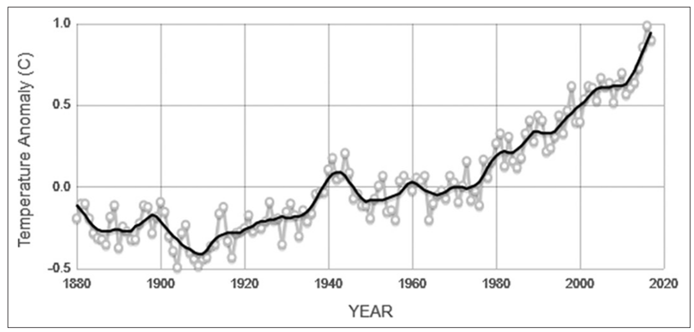
The increase in carbon emissions, equivalent to the emissions of 170 million additional cars, was the result of a solid global economic growth of 3.7%, lower fossil fuel prices and weaker energy efficiency efforts. These three factors contributed to boost global energy demand by 2.1% in 2017 as shown in Figure 2 (International Energy Agency, 2018).

The trend of increasing emissions was not universal. The largest decrease came from the United States, where emissions decreased by 0.5%, or 25 Mt, to 4810 Mt of CO_2, the change from coal to gas played a key role in reducing emissions in previous years, last year the fall was the result of a greater generation of electricity from renewable energies and a decrease in the demand for electricity (International Energy Agency, 2018). The share of renewable energies in electricity generation reached a record level of 17%, while the share of nuclear energy remained stable at 20%.

On the other hand, Asian economies accounted for two thirds of the global increase in carbon emissions (International Energy Agency, 2018). The Chinese economy grew by almost 7% last year, but emissions increased by only 1.7% (or 150 Mt) thanks to the continuous deployment of renewable energies and the faster change from coal to gas. China's carbon dioxide emissions in 2017 reached 9.1 Gt, almost 1% more than in 2014. In India, economic growth boosted the increase in energy demand and continued to promote emissions; last year the emissions per capita in India were 1.7 tCO2, well below the world average per capita of 4.3 tCO2. Emissions in the European Union grew 1.5%, adding almost 50 Mt of CO2, reversing part of the progress made in recent years, mainly due to the strong growth in the use of oil and gas (Figure 3) (International Energy Agency, 2018).

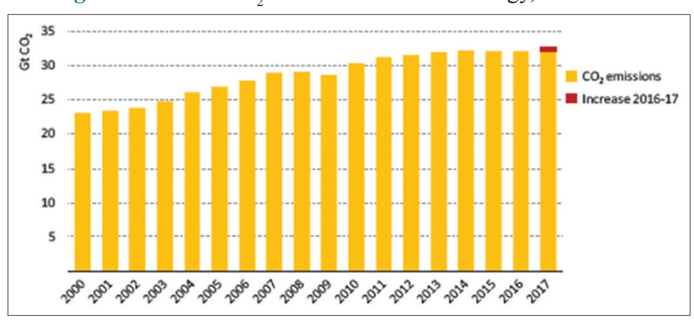
The rate of improvement of the energy intensity was reduced to 0.5%, below the 1.3% of the previous year (International Energy Agency, 2018). The economies of Southeast Asia also contributed to the increase in emissions, and Indonesia leads this growth with an increase of 4.5% comparing to 2016.

Figure 1: Global land-ocean temperature index



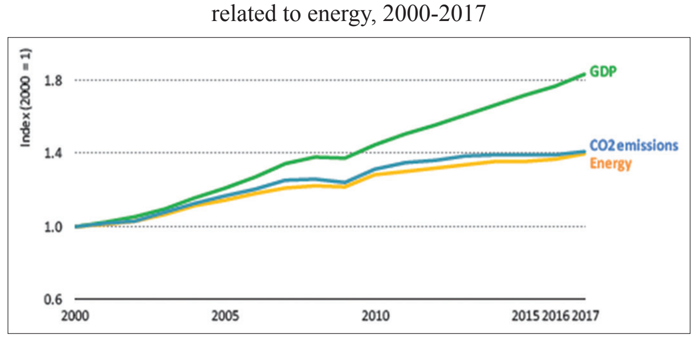
Source: (NASA, 2018)

Figure 2: Global CO_2 emissions related to energy, 2000-2017



Source: (International Energy Agency, 2018)

Figure 3: World GDP, energy demand and carbon dioxide emissions related to energy, 2000-2017



Source: (International Energy Agency, 2018)

Ecuador is a country that has some important aspects when analyzing the energy sector: A remote oil producing region, limited financial resources and lack of infrastructure are just some of the great challenges that must be faced when exploring its natural resources, and at the same time Ecuador must preserve its diverse and unique Amazonian ecosystem.

According to global standards, Ecuador's oil industry is relatively modest. The proven oil reserves are approximately 8,000 million barrels (BP, 2017). Despite this modest classification, the oil sector plays a prominent role in the country's politics and economic well-being, accounting for about 50% of Ecuador's export earnings and about a third of its all fiscal revenues.

Ecuador's main oilfields are in the Amazon region, where biodiversity and fragile ecosystems are admired around the world. Due to technical and economic challenges, natural gas associated with oil production was vented and burned instead of used, releasing significant amounts of CO_2 and other pollutants into the atmosphere. According to the National Oceanic and Atmospheric Administration of the United States, in 2011, Ecuador poured and burned more than 400 million cubic meters of natural gas.

Global warming presents tangible evidence in Ecuador. In recent years, according to specialists, there is a reduction of around 40% of the glaciers of the Chimborazo, Cotopaxi, Carihuairazo and Antisana volcanoes. To face this problem, since 2012 the 'Climate Change Strategy' developed by the Ministry of the Environment (MEE) and socialized with the municipalities has been implemented. The plan includes three aspects: Adaptation, mitigation and reduction of emissions due to deforestation (Sosa, 2017).

2. MATERIALS AND METHODS

The basic methodology of the integrated assessment models is to define all the relationships within and between the key components of the model, a reference scenario is developed using a set of assumptions about the key parameters (Rana and Morita, 2000).

Access to modern energy supports income generation activities and the national development agenda through the improvement of education, the reduction of indoor air pollution and the guarantee of environmental sustainability (Mondal et al., 2018). Having access to modern energy sources is essential for economic development and improvement of livelihoods, it is vital for the government to carry out socially responsible mechanisms that would benefit vulnerable and low-income consumers, so we need to know the variables, actors and indicators involved and their interdependent dynamic interactions to control and guide them better (Reddy, 2015).

Environmental problems must integrate scientific principles with the impacts of technology and politics (Deaton and Winebrake, 2000).

A primary objective of the dynamic modelling of the use of natural resources in economics is to develop an integrated quantitative model that effectively addresses the inherent uncertainty in these complex systems. For more than 3 decades, dynamic models have been used to assess the suitability of natural resources to meet human needs (Ruth and Hannon, 2012). Dynamic Energy Management is an innovative approach to manage the load on the demand side (Parmenter et al., 2008). It incorporates the principles of conventional energy use management represented in the demand side management, demand response and distributed energy resource programs and fuses them into an integrated framework that simultaneously addresses permanent energy savings, permanent demand reductions and temporary reductions of peak load.

The dynamics of the system (DS) was developed in the late 1950s by Jay Forrester and a group of researchers from the Massachusetts Institute of Technology (MIT) under the name of "industrial dynamics." In 1969, Forrester expanded the DS applications to include major socio-economic problems, such as urban modeling. Later, in 1972, Meadows and others presented the revolutionary bestseller "The Limits to Growth" for which they used systemic thinking and DS concepts to explain how short-term development policies can lead to "overflow and collapse" behavior of socio-ecological systems. "The Limits to Growth" has exemplified SD's potential as a tool to help understand complex socio-ecological systems and is still considered a valuable resource for thinking about sustainable futures (Turner, 2012). DS provides a set of conceptual and quantitative methods that can be used to represent, explore and simulate complex comments and non-linear interactions between elements of the system, management actions and performance measures. In DS, a problem is represented as a network of cause-effect and feedback loops, with state variables represented by "stocks" and the rate of change in stocks represented by "flows." Usually DS models are not used to look for steady-state solutions like many other modeling paradigms, but are used to simulate dynamic behavior over time (Elsawah et al., 2017). They (re) create a dynamic behavior by tracking the change in values of stocks and flows over time, and explicitly map information transfers between stocks and flows to model feedback interactions (Sterman, 2000). This explicit representation of the causal relationships that derive the problematic behavior (that is, known as the structure of the problem) makes DS especially suitable to improve the understanding of the system and to explore the unexpected effects that can appear when these causal relationships follow their course.

Predicting the future or building it according to some perspectives is not a simple task. Methods such as qualitative and quantitative forecasts, prospective studies, simulation, causal models, futurology; among others, they provide the indications of what could happen tomorrow with the aim of reducing uncertainty (Vergara et al., 2010). Scenario planning is considered as part of strategic planning, related to tools and technologies to handle uncertainty about the future. A scenario is a set formed by the description of a future situation and a path of events that allow us to move from an original situation to a future one (Godet, 2000).

The strategic energy prospective consists of the determination and analysis of the most probable future scenarios for a given energy system and constitutes an indispensable tool to elaborate the most appropriate strategic options that provide meaning and coherence in specific actions and allow to mobilize the set of actors involved in the system (Foresight and energy planning, s.f). The projections of demand and composition of energy in the future have implications for policy decisions such as investments in large infrastructure projects. The experience of many developing countries shows that energy demand is likely to increase rapidly with economic growth (Mondal et al., 2018). Energy system models are important methods that are used to generate a range of knowledge and analysis about the supply and demand of energy. Regardless of how the modeling of energy systems is developed, policymakers and the analysts who support them should focus on understanding the assumptions that are included in any modeling result (Pfenninger et al., 2014). This is essential to ensure that the policy implications are sound.

2.1. Analysis of Scenarios

To analyze the future consumption of energy, production of CO_2 emissions, and to evaluate the benefits of energy matrix change policies in order to mitigate carbon emissions, three scenarios were analyzed in this study: The Business As Usual (BAU) scenario, the scenario of national government policies (SCENARIO1) and the world trends scenario (SCENARIO2). These scenarios are governed mainly by four factors: Economic growth, population growth, structure of economy and energy structure.

The BAU scenario is a case of high economic growth, which assumes that past trends will continue in the future and new policies for energy saving and environmental protection will not be implemented. The BAU scenario does not take into account the policies that have been published, but have not yet been implemented (Li et al., 2010).

For the BAU scenario, a predictive mathematical model is used to predict the effect of one variable on another, both quantitative.

$$Y_t=\beta_1+\beta_2X_t+u_t \tag{1}$$

$\beta_1 y\ \beta_2$ are the parameters of the model. u_t is a random variable, called error, that explains the variability in Y that cannot be explained by the linear relationship between X and Y.

Errors, u_t, are considered independent random variables normally distributed with zero average and standard deviation σ. This implies that the average value or expected value of Y, denoted by $E(Y_t/X_t)$, is equal to $\beta_1+\beta_2X_t$.

Some of the series are not stationary. To adjust a non-stationary series, it is necessary to eliminate the strong non-stationary variation through an autoregressive, integrated and mobile measurement process (ARIMA). Its algebraic expression is:

$$X_t^d=\Phi+\Phi_1X_{t-1}^d+\cdots+\Phi_pX_{t-p}^d+\theta_1\varepsilon_{t-1}^d+\theta_2\varepsilon_{t-2}^d+\cdots+\theta_q\varepsilon_{t-q}^d+\varepsilon_t^d \tag{2}$$

Expressed in the form of the delay operator polynomial, the model *ARIMA(p,d,q)* is:

$$\Phi(L)\ (1-L)^dX_t=c+\Theta(L)\varepsilon_t \tag{3}$$

Where X_t^d is the series of the difference of order d, μ_t^d is a process of white noise, and c, $\Phi_1.,\Phi p,\theta 1.,\theta q$ are the parameters of the model.

Scenario 1 reflects a shift towards a cleaner energy route that is carried out through policies and measures designed to replace the type of energy consumed. The basis of Scenario 1 are the planned government policies and measures that have not yet been implemented, but which will be enacted or adopted by the end of 2030 in contrast to the most recent trends.

Scenario 2 implies adopting measures or policies established worldwide on mitigation of climate change. It seeks decarbonization of the economy, energy efficiency, achieving the maximum integration of renewable energies, efficient use of resources, all this in search of a new sustainable energy model.

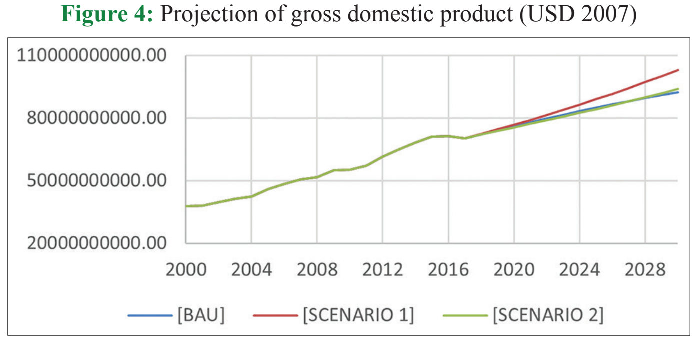
2.2. Economic Development

The economic analysis of Ecuador is carried out in two periods (2000-2006) and (2007-2016). The first period begins with the substitution of the national currency, the sucre, for the American dollar, after a strong economic crisis. This measure allows stability of inflation and economic growth. Ecuador was favored in this period by an increase in oil prices in the world market and an increase in the national oil production, ratifying the dependence of Ecuador on the behavior of the oil sector. In that period Ecuador experienced serious political problems and anticipated change of government.

For the period 2007-2016, the economy of Ecuador suffered only a slight recession during the global crisis of 2008-2009. During the last 10 years, Ecuador has enjoyed positive GDP growth, the average annual growth was 3.74%, being the best years 2004 and 2011, when the growth reached 8%, while in 2016 the gross domestic product (GDP) decreased 1.6%. The last year when the Ecuadorian economy showed a decrease in GDP was 1999, the year of the "bank holiday" and the dollarization of the Ecuadorian economy. In Figure 4, we can see the projections of each of the scenarios for the GDP.

We can see from the simulation of the scenarios that the SCENARIO 1 is the one that projects a better economic growth. The economic policies proposed by the government propose an average growth of 3%, sustained mainly in the increase of oil production, substitution to clean energies, reduction of expenses in hydrocarbon

Figure 4: Projection of gross domestic product (USD 2007)



Source: Own elaboration (VENSIM)

imports, targeting of liquid fuel subsidies and support for a change of the productive matrix. The BAU and the SCENARIO 2, the mathematical model and the regional growth average show a very similar projection, growth of the economy is maintained.

2.3. Population Growth

Population growth can affect the size and composition of energy demand, directly and through its impact on economic growth and development (Li et al., 2010). The growth of the Ecuadorian population considers two fundamental factors: Births and deaths, net migrations have not had an important effect, according to the Latin American Development Center (CELADE) having negligible values. According to current estimates, Ecuador currently has a population of over 16 million people, the average annual growth of the population continues to decline, in 2000 the population of Ecuador grew by 2.14% while in 2016 it only grew by 1.41%.

If the population growth characteristics of the world are taken into account, the projection of the number of inhabitants of Ecuador would decrease notably reaching 17.29 million people, a value below the projections of the BAU and SCENARIO 1, where the population reaches more than 19.2 million (Figure 5).

2.4. Energy Structure

The primary energy matrix of Ecuador has historically been dominated by oil production. The oil production in Ecuador has played a very important role to generate important economic income for the country and consequently its development. The oil sector accounted for 41% of export earnings in 2016 (Coordinating Ministry of Strategic Sectors, 2017). It should also be noted that historically, renewable energies have not had a greater participation in the primary energy matrix. However, the production of hydro energy has increased by 72% between 2000 and 2015, while the production of other primary sources, such as wind and photovoltaic energy, began in 2007 (Coordinating Ministry of Strategic Sectors, 2017). The Figure 6 shows the evolution of primary energy production in Ecuador, since 2006 there has been a decrease in energy production due to the fact that the Organization of Petroleum Exporting Countries (OPEC) assigned to the country a decrease of 4.5% in its daily production, adding the global crisis of 2008-2009.

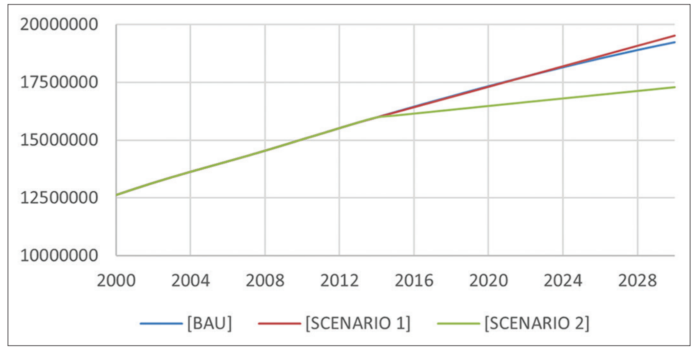
As indicated above, Ecuador's energy matrix is based on oil production. The Figure 7 shows that oil represents more than 90% of total primary energy production. In the last two years, hydro energy has increased its production mainly due to the operation of the new hydroelectric plants.

The Figure 8 shows the evolution of secondary energy production in Ecuador. The total production of secondary energy has remained at levels close to 71 million KBOE between 2000 and 2016, being Fuel Oil the main secondary energy produced in the country, followed by diesel until 2011. In 2012 the electricity becomes the second most-produced source of secondary energy in Ecuador and its generation grows mainly due to the start-up of new projects of hydroelectric plants.

2.5. Demand for Energy

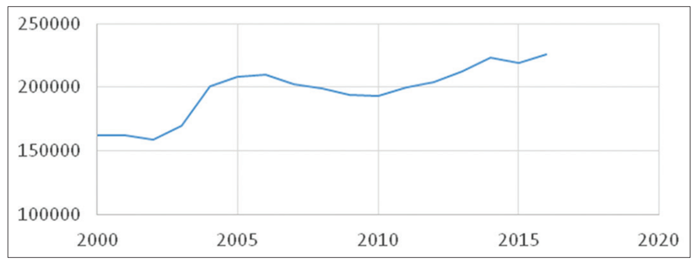
Regarding the demand for energy in the country, it increased from 66 KBOE in 2000 to 95 KBOE in 2016, which represents

Figure 5: Population projection Ecuador



Source: Own elaboration (VENSIM)

Figure 6: Primary energy production (KBOE)



Source: (Coordinating Ministry of Strategic Sectors, 2014) (Coordinating Ministry of Strategic Sectors, 2015) (Coordinating Ministry of Strategic Sectors, 2016) (Coordinating Ministry of Strategic Sectors, 2017)

an increase of 44%. Historically, the transport sector has been the largest energy source, with an average share of 41% during the studied period. The next sector with the highest energy demand in Ecuador has been the industry, with a share of around 18% between 2000 and 2016. Finally, the third sector with the greatest demand for energy has been the residential one, as shown in Figure 9.

In 2015, diesel accounted for 31% of the energy consumed in the country, gasolines accounted for 27%, while electricity and LPG accounted for 15% and 9% respectively. In addition, the Figure 10 shows the percentage variation in the demand for energy by source, where lower consumption of several fossil fuels is notorious, such as diesel, fuel oil and LPG. In the case of diesel, this fact can be attributed to the lower demand in the industry.

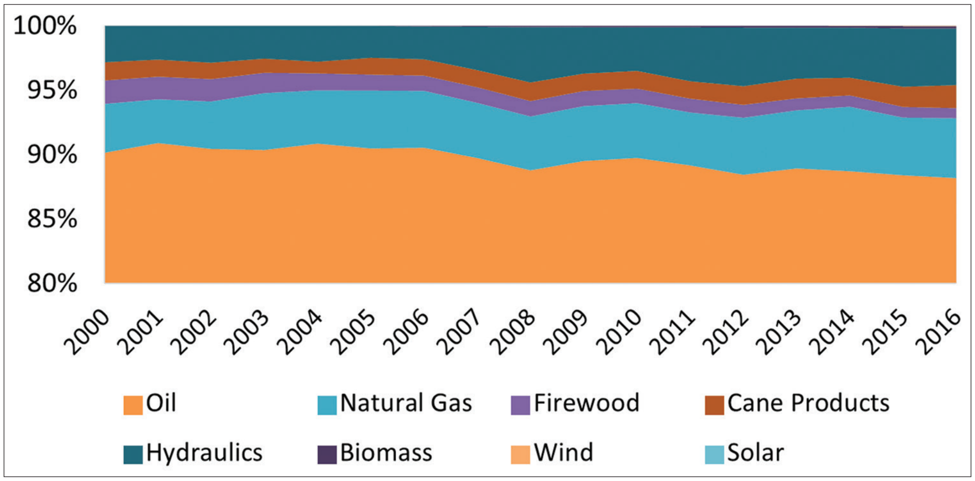
In the case of fuel oil, the greatest reduction corresponds to the substitution of this fuel for hydro energy, for electricity generation. Finally, as regards LPG, this reduction could be related to the Efficient Cooking Program, which until December 2015 had already installed 250,000 induction cookers nationwide (Coordinating Ministry of Strategic Sectors, 2017).

3. RESULTS

3.1. Energy Structure Projection

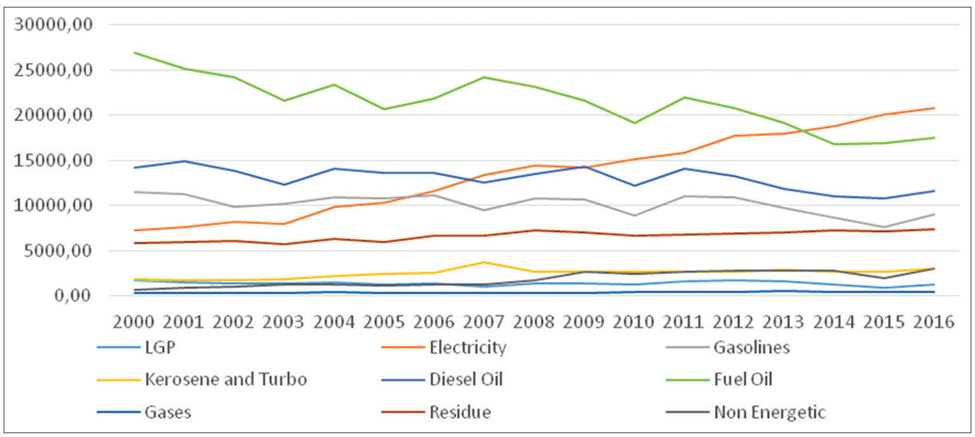
The projection of energy production for the three scenarios generated in VENSIM is shown in the Figure 11. The projection is made until 2030. The projected production in the SCENARIO 1 is the one with the highest growth compared to 2000; by 2030 the

Figure 7: Primary energy production structure (%)



Source: (Coordinating Ministry of Strategic Sectors, 2014) (Coordinating Ministry of Strategic Sectors, 2015) (Coordinating Ministry of Strategic Sectors, 2016) (Coordinating Ministry of Strategic Sectors, 2017)

Figure 8: Secondary energy production (KBOE)



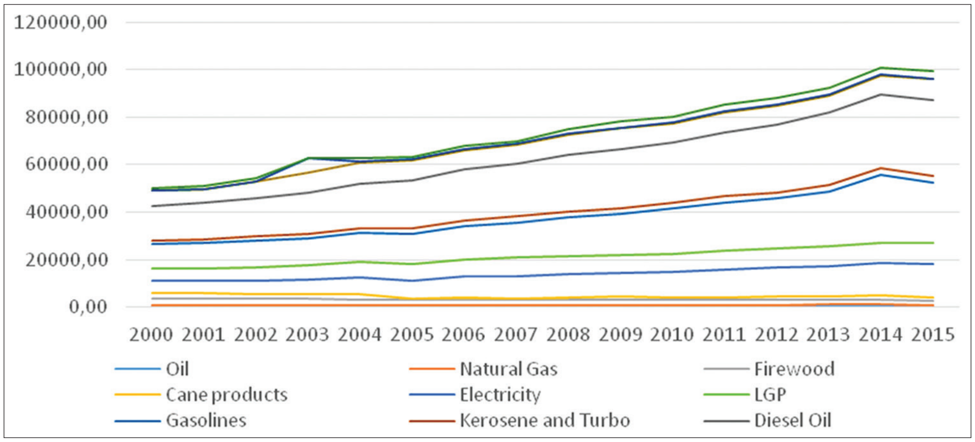
Source: (Coordinating Ministry of Strategic Sectors, 2014) (Coordinating Ministry of Strategic Sectors, 2015) (Coordinating Ministry of Strategic Sectors, 2016) (Coordinating Ministry of Strategic Sectors, 2017)

Figure 9: Energy demand by sector (KBOE)

Source: (Coordinating Ministry of Strategic Sectors, 2014) (Coordinating Ministry of Strategic Sectors, 2015) (Coordinating Ministry of Strategic Sectors, 2016) (Coordinating Ministry of Strategic Sectors, 2017)

energy production will be 291,500 KBOE, an increase close to 80%, this increase is based on hydroelectric plants construction projects and the great hydroelectric potential that exists in the country. In order to promote a cleaner, safer and more affordable

Figure 10: Energy demand by type (KBOE)



Source: (Coordinating Ministry of Strategic Sectors, 2014) (Coordinating Ministry of Strategic Sectors, 2015) (Coordinating Ministry of Strategic Sectors, 2016) (Coordinating Ministry of Strategic Sectors, 2017)

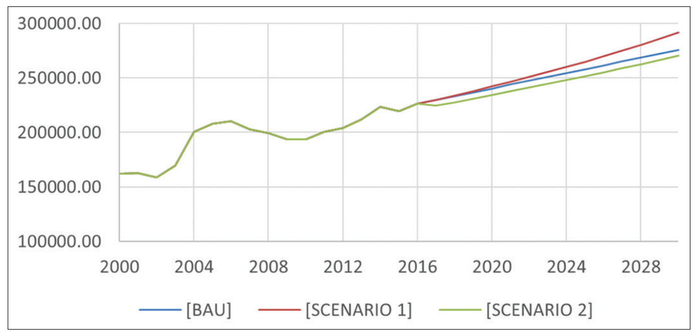
generation matrix, the hydroelectric potential that the country has will be exploited in a sustained manner, in such a way that the participation of hydro energy will be the main source of electricity generation (Coordinating Ministry of Strategic Sectors, 2016b). Hydro energy production will increase almost six fold compared to 2000, becoming the main source of renewable energy in the country.

The development of exploratory activities will be encouraged with the purpose of having sufficient oil and natural gas reserves to satisfy the national demand, as well as increasing the exportable balances of both crude oil and petroleum derivatives. The Ministry of Hydrocarbons will promote the use of efficient, effective and timely technologies for the exploitation of hydrocarbon resources, protecting the ecosystems. In this sense, the exploitation of hydrocarbons will be promoted through investment, both private and public, in projects that prioritize the use of this type of technology, as well as improved recovery techniques, making it possible to extend the useful life of oil and gas fields in the country (Coordinating Ministry of Strategic Sectors, 2016b).

Achieving self-sufficiency in fuels will encourage investment in sustainable productive capacity of petroleum derivatives, a comprehensive policy of energy security will be promoted, especially focused on the development and optimization of the productive infrastructure and refining of crude oil, allowing to satisfy the national demand for petroleum derivatives with quality products, the use of biofuels will be promoted at the national level (Coordinating Ministry of Strategic Sectors, 2016b).

The BAU scenario and the SCENARIO 2 have a very similar growth reaching 275,600 KBOE and 270,400 KBOE; respectively, the mathematical projection of the BAU takes historical data and leaves aside the new policies that may be proposed in the future. The SCENARIO 2 proposes policies focused on the use and infrastructure of renewable energies that in case of Ecuador cannot be widely applied, and only since 2007 the production of wind and photovoltaic energy began, with a very low bet, while globally these energies and other types of energy have a great

Figure 11: Primary energy production scenarios (KBOE)



Source: Own elaboration (VENSIM)

impulse. Hydro energy is the renewable energy that has been mostly used in Ecuador, due to all the factors mentioned above and the projections position it as the main renewable source.

3.2. Energy Demand Projection

For the sectoral analysis of energy demand, it has been classified into the following sectors: Transport, industry, residential, commercial, agro-fishing-mining sectors, construction and others; additionally, own consumption is considered, which is the energy consumed by the energy sector itself.

From the projections made it can be seen in the Figure 12 how the demand for energy will grow by 2030. The energy demand by 2030 in the BAU scenario is 132,720 KBOE, this is the highest value projected in the three scenarios. Maintaining the current characteristics of energy consumption in the different sectors projects a high and inefficient consumption. The SCENARIO 1 and the SCENARIO 2 raise a demand of 115,407 KBOE and 104,550 KBOE, respectively. The variation is mainly due to the policies of substitution of energy sources and the improvement of energy efficiency. National policies propose the implementation of mechanisms necessary to disseminate and raise awareness of the virtues of energy saving and rational use of energy, considering the particularities of the sectors, actors and age groups to which it is addressed, prioritizing the use of renewable energies and an intelligent consumption.

3.3. Residential Sector

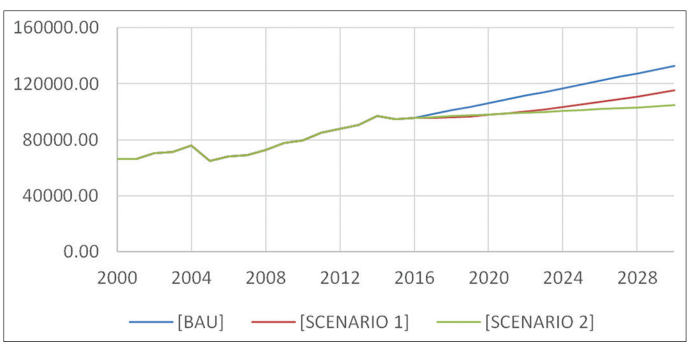
The Figure 13 shows a very similar projection of energy demand in the three sectors. By 2030, the BAU scenario and the SCENARIO 2 project a demand of 14,839 KBOE and 14,828 KBOE. With regard to the SCENARIO 1, there is a decrease in consumption of 92 KBOE of the mathematical projection, this decrease is based on government plans and policies focused mainly on the use of renewable energies and energy efficiency. There are following propositions: Massive introduction of intelligent lighting in homes, technological reconversion in residential lighting, replacement of inefficient basic and high-consumption electrical equipment in homes, labeling used devices in homes, replacement of LPG liquefied petroleum gas with electricity and incorporation of induction cookers that replace kitchens that use LGP, substitution of LGP by electricity for the heating of water for sanitary use in the residential sector, all these changes are to be supported or financed by state credits. The state has established incentives to promote migration to electricity (Ministry of Electricity and Renewable Energy, 2017).

3.4. Commercial Section

The Figure 14 shows the projections of energy demand in the commercial sector tripling the values of 2000. The SCENARIO 1 projects the highest demand of 9433 KBOE, the increase is mainly due to expansion policies and improvements in the distribution in the country. The proposed policies are: Energy efficiency for the sector, optimization of consumption, improvement in energy efficiency in public buildings and agencies, efficient and intelligent public lighting, change of inefficient refrigerators and freezers, as well as air conditioning devices and mainly prioritizing the use of renewable energies.

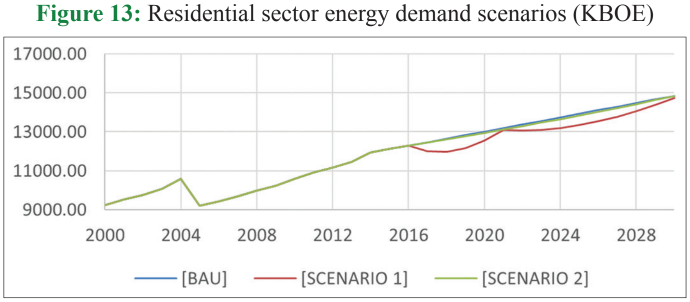
The projection of the BAU scenario reaches a demand of 8884 KBOE characterized by an energy mix made up of non-renewable energies that produce high emissions. Finally, the SCENARIO 2 is the scenario that projects a lower demand, 8029 KBOE, the global trends focus on the use of renewable energies, energy efficiency and development of new technologies.

Figure 12: Energy demand scenarios (KBOE)



Source: Own elaboration (VENSIM)

Figure 13: Residential sector energy demand scenarios (KBOE)



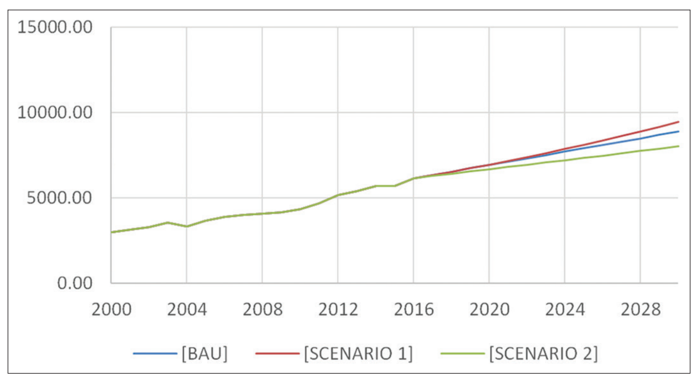
Source: Own elaboration (VENSIM)

3.5. Transport Sector

The transport sector represents more than 50% of the energy consumption matrix. The transport sector has been characterized as the most inefficient sector in the use of energy due to the use of hydrocarbons in great measure, which has caused this inefficiency. The projection of the BAU scenario shows a growth of 132% by 2030, as shown in the Figure 15.

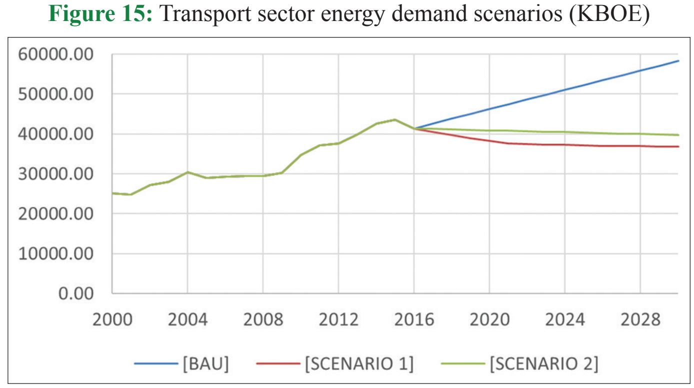
The government policies proposed in the SCENARIO 1 show a considerable reduction, compared to the projection of the BAU, reaching 36,857 KBOE, which is a 47% growth in the demand of the sector. To achieve this growth, the use of biofuels and the use of electricity in the mass passenger transportation, mainly in the largest cities of Ecuador, have been proposed among other policies. The use of electric vehicles and the renovation plan for heavy and public transport vehicles are promoted in order to have more efficient and less polluting units. Improve the efficiency of private transport by introducing hybrid vehicles. Introduce the use of biodiesel in heavy transport (trucks and vans). Optimize the infrastructure for transport circulation and operation, contributing to the reduction of fuel consumption. Implement integral mobility systems that allow the planning and control of vehicular flow in an intelligent way in the cities.

Figure 14: Business sector energy demand scenarios (KBOE)



Source: Own elaboration (VENSIM)

Figure 15: Transport sector energy demand scenarios (KBOE)



Source: Own elaboration (VENSIM)

Generate alternatives, strengthen planning and implement regulation for energy use in transportation. Analyze the feasibility of implementing an electric freight train that generates energy efficiency in the heavy and light cargo transport in the country, this will reduce diesel consumption (National Electrification Council, 2013).

With regard to public transport, two projects with significant progress are being developed: The Metro of Quito and the Tramway in Cuenca. Sustainable mobility projects have been proposed, such as the Monorail project that will connect the Chillos Valley with M. D. Quito, this mass transportation system is implemented with a set of electric trains that travel on their own way on a high concrete structure without occupying the current road spaces, which would improve the circulation of private vehicles (Hora, 2012). Several cableway projects of "Mono Cable" type have been proposed, which is an alternative mass transportation system.

The projection of the SCENARIO2 shows an energy demand of 39,732 KBOE by 2030, it is an increase of 58% comparing to 2000. The global trends pose a scenario of sustainable mobility and mainly of energy efficiency in the sector, concerned about a reduction in emissions into the environment. The use of renewable energies in this sector is increasingly noticeable, research projects aim to reduce the environmental impact of such an important sector for the development of nations.

3.6. Industrial Sector

The industry is the second sector with the highest participation, after transportation, in the total consumption matrix. It recorded a consumption of 11,477 KBOE in the base year. Among the sources used, diesel has a 42% share, followed by electricity with 29% and fuel oil with 12%; the first of the aforementioned energy sources reached 47% of total petroleum derivatives imports in 2013. Although diesel consumption is mostly used in the transport sector, the industry has a 25% share, which is why it is necessary to take energy efficiency measures and substitute intermediate petroleum derivatives, such as diesel.

The projection of the BAU scenario and the SCENARIO 1 achieves an energy demand of 27,631 KBOE and 27,105 KBOE respectively, Figure 16. The mathematical projection and the scenario under government policies project a similar demand by 2030, the difference lies in the type of energy to be used.

Public policy in the industrial sector is aimed at changing the productive matrix. Promote energy efficiency as a tool to improve competitive advantage. This sector focuses on the efficient use of resources, implementing cogeneration projects. Inefficient equipment renovation projects are developed, such as pumps, motors, boilers and water heaters. The ISO 50001 standard is adopted in the energy-intensive industries (Ministry of Electricity and Renewable Energy, 2017b).

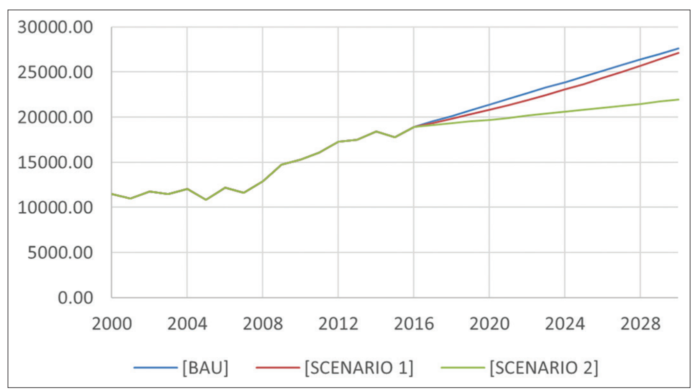
The SCENARIO 2 projects a demand of 21948 KBOE, a lower demand than the other two scenarios. The policies and plans focus on the constant penetration of electricity, reducing the use of coal and biomass, mainly in industrialized and developing countries. Although the oil share exists, environmental improvement policies propose its limited use, while, on the other hand, an accelerated growth of renewable energies is proposed.

3.7. Agricultural, Fishing and Mining Sectors

The National Energy Balance quantifies the consumption of agricultural sector along with fishing and mining sectors. In the seventies, Ecuador was considered an agricultural country and its economy was largely based on the export of basic foods. Since the discovery of oil, the country leaves the agriculture aside and bases its economy on the export of oil; on the other hand, the fishing sector is an important global player in the tuna industry, artisanal fishing also has an important place in the sector, making Ecuador one of the main producers of various types of fish, shrimp, lobsters, etc. The mining sector in Ecuador is in the process of development, large-scale mining projects have been proposed, such as: Mirador, Fruta del Norte, Panantza-San Carlos, Río Blanco and Quimsacocha.

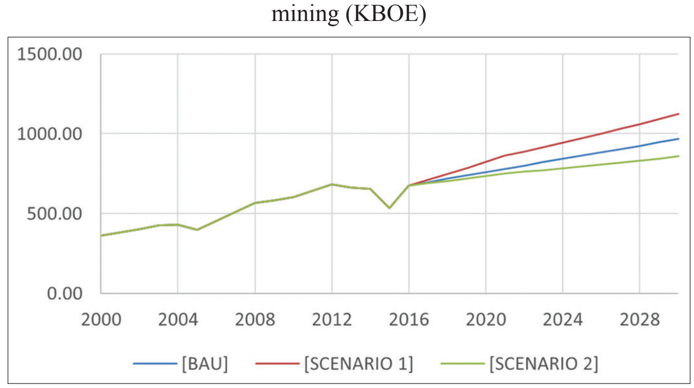
In the Figure 17, the projections of the three scenarios show a projection of 967 KBOE for the BAU, 1126 KBOE for the SCENARIO 1 and 857 KBOE for the SCENARIO 2. Efficiency improvement and substitution by sources of clean and efficient energy raised in global trends produce significant savings in energy demand: By 2030 there will be a 23% decrease in the energy demand, according to the BAU scenario. The growth of demand in the SCENARIO 1 is mainly due to large-scale mining projects that are intended to be implemented in the country and will require more energy and an impulse to the agricultural and fishing sectors projected in the productive matrix change.

Figure 16: Energy sector demand scenarios (KBOE)



Source: Own elaboration (VENSIM)

Figure 17: Energy demand scenarios for agriculture, fishing and mining (KBOE)



Source: Own elaboration (VENSIM)

3.8. Construction Sector and Others

Construction is one of the productive sectors that provides the greatest wealth to society, due to its participation in the number of companies specialized in construction and related activities. In 2007-2014, the Ecuadorian government invested a large part of the income obtained as a result of the increase in the price of oil, in the infrastructure. This meant that the construction gave a great impulse to the national economy. In 2013, the industry reached its peak, representing 10.46% of the national GDP, according to the Ministry of Finance (Dura, 2017).

In mid-2015, construction in Ecuador experienced a fall of 1.7%, which deepened during 2016 with another drop of 8.9%, and for this year a new contraction is expected, this time of 7.3%. This occurs as a consequence of the fall in the price of oil and new policies implemented such as the Added Value Law (Organic Law to Avoid Speculation on the Value of Land), which did not benefit the sector that was in crisis (Dura, 2017).

When comparing the projections of the three scenarios we can see in the Figure 18 that the SCENARIO1 is the one that shows the fastest growth, demanding 22117 KBOE for the year 2030, the BAU shows a demand of 18305 KBOE and the SCENARIO 2, 14772 KBOE; the decrease in the demand for energy is due to energy efficiency, the use of renewable energies and the penetration of technology with greater efficiency.

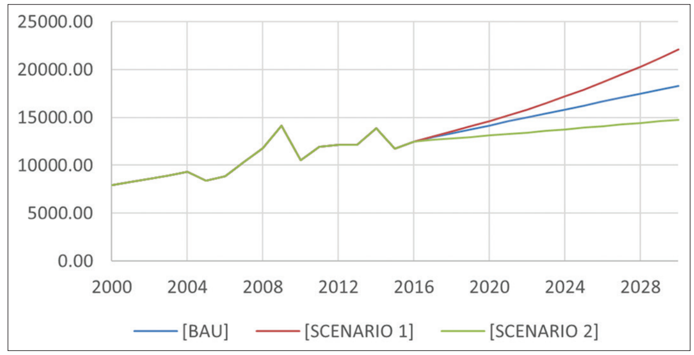
3.9. CO_2 Emissions

Although Ecuador generates a small part of emissions of gases that cause climate change to the atmosphere, it has demonstrated to the international community its real commitment to face this challenge. In this way, in 1992 Ecuador signed the United Nations Framework Convention on Climate Change; in 1999, the Kyoto Protocol; in 2016, the Paris Agreement and, consequently, actively participates in international negotiation processes on climate change and generates a regulatory and institutional framework that allows the country to meet the objectives established in the Convention (Ministry of the Environment, 2017).

In the base year, CO_2 emissions were 27682 $KTCO_2$, in 2016 they increased by 30% reaching 35,913 $KTCO_2$ and by 2030 the BAU SCENARIO projects 48,129 $KTCO_2$, an increase of 74% compared to the base year. This accelerated growth is mainly due to the use of highly polluting and inefficient non-renewable energy and the increase in energy production to satisfy the demand that has also grown in the last 15 years. The sector with the highest emissions is transport, which is justified since it is the main energy seeker, and because this energy comes from fossil sources. Other sectors with significant emissions have been power plants and the industrial sector.

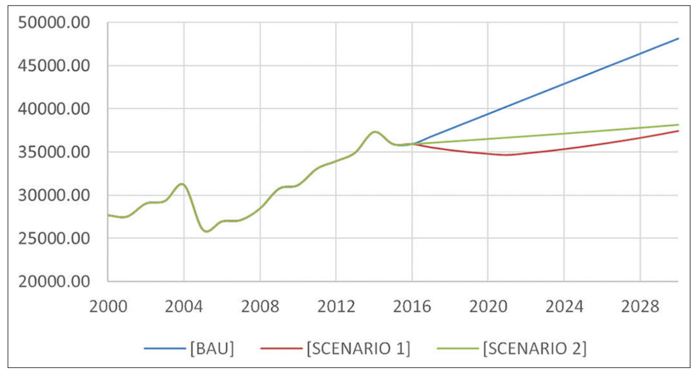
In the Figure 19, when comparing the SCENARIO 1 and the SCENARIO 2 with the BAU scenario, a significant decrease in CO_2 emissions can be seen, which, starting in 2018, start to be strongly noticeable, thanks to new technologies of substitution and efficiency and to the changes in the energy matrix that will contribute to the mitigation of CO_2 emissions in approximately 10 MM of tons of CO_2.

Figure 18: Construction sector and other sectors energy demand scenarios (KBOE)



Source: Own elaboration (VENSIM)

Figure 19: CO_2 emission scenarios ($KTCO_2$)



Source: Own elaboration (VENSIM)

National policies have reflected these concerns, one of them being the gradual replacement of energy sources based on fuel combustion, by hydraulic generation. The reduction of fossil fuel consumption leads to a reduction in emissions of combustion gases that negatively affect the environment (National Electrification Council, 2013).

4. CONCLUSIONS

The dynamics of systems allow modeling the supply, demand and CO_2 emissions scenarios by 2030 in Ecuador, the results obtained will serve as a basis for proposals for future energy policies aimed at mitigating emissions, energy efficiency and a sustainable energy matrix.

Ecuador is a country with an important water potential of approximately 22,500 MW. The goal is to maintain at least 70% of the hydro energy share of the total electricity produced annually in the national interconnected system at the end of the analyzed period. Its diversity, the development of technologies and incentives for the use of renewable energies, together with actions towards energy efficiency, allow it to improve its energy matrix, considerably reducing CO_2 emissions.

The BAU Scenario shows the dependence of Ecuador on the use of petroleum derivatives, a continuous increase of consumption of the derivatives is expected, with serious implications for the environment; for this reason, it is important for the country to take energy efficiency and mitigation measures that are even more profound and more exhaustive than those proposed up to now. International cooperation in this area is crucial not only for funding reasons, but also in terms of technology transfer and training.

The Ecuadorian government and the private sector must join efforts to amplify the projects aimed at energy efficiency and an increase in financing of renewable energy sources such as wind, biomass, solar energy and especially in hydro energy. In this way, it will be possible to reduce the energy demand by 13% according to the SCENARIO 1 and by 21% according to the SCENARIO2 in 2030.

Decisions taken in the coming years on energy issues can play a key role for the economic development of Ecuador, the petroleum derivatives import, low energy efficiency of the transport and industrial sectors, excessive subsidies for fuels and a rapid growth in the final demand for energy oblige to design a more efficient energy model, which is why we must accelerate on issues of technological innovation, improve the development of low-carbon energy, and transform consumption patterns in search of sustainable development.

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