Energy for Sustainable Development 20 (2014) 11–20

Contents lists available at ScienceDirect

Energy for Sustainable Development

System dynamics modeling for renewable energy and CO_2 emissions: A case study of Ecuador

A. Robalino-López [a,b], A. Mena-Nieto [b], J.E. García-Ramos [a,*]

[a] Department of Applied Physics, University of Huelva, 21071 Huelva, Spain
[b] Department of Engineering Design and Projects, University of Huelva, 21071 Huelva, Spain

ARTICLE INFO

Article history:
Received 25 January 2013
Revised 5 February 2014
Accepted 5 February 2014
Available online 6 March 2014

Keywords:
CO_2 emissions
System dynamics
Kaya identity
Ecuador

ABSTRACT

It is clear that renewable energy plays a crucial role in achieving a reduction of greenhouse gas emissions. This paper presents a model approach of CO_2 emissions in Ecuador in the upcoming years, up to 2020. The main goal of this work is to study in detail the way the changes in the energy matrix and in the Gross Domestic Product (GDP) will affect the CO_2 emissions of the country. In particular, we will pay special attention to the effect of a reduction of the share of fossil energy, as well as of an improvement in the efficiency of the fossil energy use. We have developed a system dynamics model based on a relationship, which is a variation of the Kaya identity, and on a GDP that depends on renewable energy, which introduces a feedback mechanism in the model. The main conclusion is that it is possible to control the CO_2 emissions even under a scenario of continuous increase of the GDP, if it is combined with an increase of the use of renewable energy, with an improvement of the productive sectoral structure and with the use of a more efficient fossil fuel technology. This study offers useful lessons for developing countries, and it could be used as a policy-making tool because it is easily transferable to any other time period or region.

© 2014 International Energy Initiative. Published by Elsevier Inc. All rights reserved.

Introduction

Globally, CO_2 is by far the main contributor to anthropogenic greenhouse gas (GHG) emissions ((IPCC, 2007), Fig. 2.1): CO_2 represents 76.7% of the GHG emissions (approximately 56.6% is from fossil fuels, 17.3% from deforestation, and 2.8% from other sources). Ecuador has a relatively low level of CO_2 emissions (2.1 tonnes per capita per year) while Qatar, the world's largest CO_2 emitter per capita in 2009, emitted 44 tonnes per capita. At the same time Venezuela, the largest CO_2 emitter in Latin America (LA), emitted annually 6.5 tonnes per capita (World Bank, 2011). It is expected that social and economic development in the coming years could significantly increase Ecuador's emissions. Observations show that global CO_2 emissions, far from stabilizing, have experienced significant growth in recent years.

Several international organizations, notably, the Intergovernmental Panel on Climate Change (IPCC), are warning about the need of stabilizing CO_2 and other anthropogenic GHG emissions in order to avoid a catastrophic warming of the climatic system during this century (IPCC, 2007). The IPCC has developed several methods to estimate GHG emissions, such as the *Reference method*[1] (IPCC, 2006), which is a top-down technique that uses data from the country's energy supply (mainly from the burning of fossil fuels), land use, and deforestation rate, among others, to calculate CO_2 emissions. It is a straightforward method that can be applied on the basis of the available energy supply statistics (IPCC, 2006). However, the problem when it is necessary to conduct more detailed studies and find the driving forces that are behind the emissions arises, but the data is not available or is not sufficiently disaggregated.

In Fig. 1 Ecuador CO_2 emissions for the period 1980–2010 are depicted (World Bank, 2011).[2] These data only correspond to energy CO_2 emissions and do not include the contribution from deforestation. Clearly, one observes an increasing trend which is related to the growth of economic activity. This growth is due to greater prosperity of the inhabitants and to an increase of the population. There are multiple factors that influence the level of CO_2 emissions, such as economic development, population growth, technological change, resource endowments, institutional structures, transport models, lifestyles, and international trade (Alcántara and Padilla, 2005). The identification of the kind of sources of CO_2 emissions and of its magnitude is essential information for economic planning and decision makers.

Therefore, this work tries to study the driving forces of CO_2 emissions of a given country, particularized to the case of Ecuador, considering doubling the GDP within 10 years, which will approximately correspond to achieve the estimated international average GDP per

* Corresponding author. Tel.: +34 959219791; fax: +34 959219777.
E-mail address: andres.robalino@alu.uhu.es (A. Robalino-López).

[1] http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_6_Ch6_Reference_Approach.pdf.

[2] http://data.worldbank.org/country/ecuador.

http://dx.doi.org/10.1016/j.esd.2014.02.001
0973-0826/© 2014 International Energy Initiative. Published by Elsevier Inc. All rights reserved.

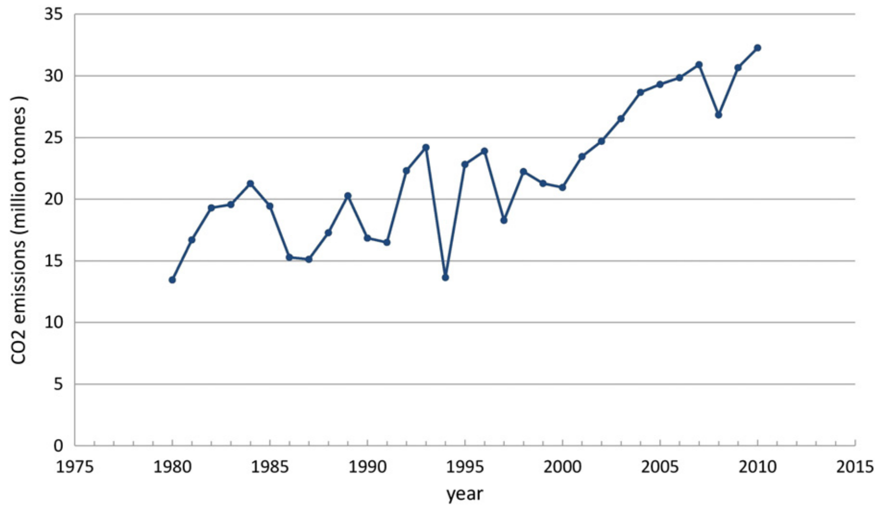

Fig. 1. Ecuador CO_2 emissions (1980–2010). CO_2 emissions are given in million tonnes of CO_2.

capita for 2020 (around 12,000 USD, own estimates based on the World Bank data[3]). In this work the increase of the income will be induced through a process of industrialization of the country (see Scenarios section). Unfortunately, this economic growth, according to the environmental Kuznets curve (EKC), in a first stage will also increase the CO_2 emissions of the country (Pasten and Figueroa, 2012). Within the EKC hypothesis the relationship between income per capita and some types of pollution is approximately an inverted U. This behavior states that as the GDP per capita grows, environmental damage increases, reaches a maximum, and then declines. The Ecuadorian government has, among its goals, the development of strategies to guarantee energy supply, to increase energy cost efficiency, and last, but not least, to minimize the negative impact of economic development on the environment (Mosquera, 2008).

Renewable energy sources could play an important role in the diversification of the energy matrix in Ecuador. In particular, CONELEC-004/11 regulation (CONELEC11, National Council for Electrification (Consejo Nacional de Electrificación), 2011) establishes the conditions for selling electricity to the national grid, which is encouraging new projects. Below we summarize projects that will increase the use of renewable energy in Ecuador in the upcoming years.

1. *Bioenergy*. Ecuador has about 71,000 ha (2009) of sugarcane mostly concentrated in the Coastal Region, near Guayaquil (MAG Ministry of Agriculture, Livestock, Aquaculture and Fisheries of Ecuador (Ministerio de Agricultura, Ganadería, Acuacultura y Pesca del Ecuador), 2011). A fuel ethanol pilot program has been planned in Guayaquil and Quito, initially consisting of 5% ethanol blend with gasoline (MRNRE Ministry of Non-Renewable Natural Resources of Ecuador (Ministerio de Recursos Naturales no Renovables del Ecuador), 2012). If successful, this could set the ground for a nation-wide ethanol fuel program. The use of this kind of fuel will generate savings of about 32 million USD a year, as the country would stop importing about 320,000 barrels of high octane naphtha[4] (15%) (MRNRE Ministry of Non-Renewable Natural Resources of Ecuador (Ministerio de Recursos Naturales no Renovables del Ecuador), 2012). On the other hand, the total area planted with African palm in Ecuador is 240,000 ha, with about 200,000 ha currently being harvested (MAG Ministry of Agriculture, Livestock, Aquaculture and Fisheries of Ecuador (Ministerio de Agricultura, Ganadería, Acuacultura y Pesca del Ecuador), 2011). Ecuador could potentially plant up to 760,000 ha of African palm according to Ecuador's Association of African Palm Growers (ANCUPA, 2013). Based on projections from the sector in terms of production, domestic consumption and export surplus of red oil, the surplus could grow significantly and reach more than 850,000 tonnes of red oil in 2025 (USDA (United States Department of Agriculture), 2011).
2. *Hydroelectricity*. In 2011 Ecuador had 2215 MW of installed hydropower capacity and another 2756 MW under construction (CONELEC13, National Council for Electrification (Consejo Nacional de Electrificación), 2013). The biggest hydroelectric project is called Coca Codo Sinclair and has a capacity of 1500 MW and an estimated cost of 2245 million USD (the overall project progress is 27.4% up to November 2012). Other hydroelectric projects are: Delsitanisagua with 115 MW, Manduriacu with 60 MW, Mazar Dudas with 21 MW, Minas de San Francisco with 270 MW, Quijos with 50 MW, Sopladora with 487 MW, and Toachi Pilatón with 253 MW (MEER Ministry of Electricity and Renewable Energy of Ecuador (Ministerio de Electricidad y Energía Renovable del Ecuador), 2012).
3. *Solar energy*. Through Rural Electrification and Urban Marginal Funds (Fondos de Electrificación Rural y Urbano Marginal — FERUM), Ecuador initiated in 2004 a program of electrification in the countryside using photo-voltaic (PV) generation units. This program started in zones near the border with Peru and in the Amazonian region. Another program using PV panels is executed in the Galapagos Islands to generate a power of 2.1 MW (MEER Ministry of Electricity and Renewable Energy of Ecuador (Ministerio de Electricidad y Energía Renovable del Ecuador), 2012).
4. *Wind energy*. Programs for using wind energy started in 2004. One of the main programs, promoted by the Ministry of Electricity and Renewable Energy (Ministerio de Electricidad y Energía Renovable — MEER), aims at replacing existing thermal generation plant by wind and PV plants in the Galapagos Islands. With the new facilities, 5.7 MW of wind power (plus 2.1 MW of PV power) will substitute most of the 8.8 MW of the thermal generation installed (MEER Ministry of Electricity and Renewable Energy of Ecuador (Ministerio de Electricidad y Energía Renovable del Ecuador), 2012; CONELEC13, National Council for Electrification (Consejo Nacional de Electrificación), 2013). Other projects for using wind energy in the Ecuadorian continental region are being carried out by the MEER as the one called Villonaco, located in the province of Loja in the south of the country, with a cost of 41.8 million USD and a power capacity of 16.5 MW.
5. *Geothermal energy*. The geographical location of Ecuador in one of the zones of largest volcano activity, Andean Mountains, is the reason for having a geothermal potential of 534 MW (CEPAL Comisión Económica para América Latina y el Caribe, 2000), which remains unexploited. The main geothermal project existing in Ecuador (Tufiño-

[3] GDP given in constant 2005 PPP (purchasing power parity) international dollars (USD). Data taken from http://data.worldbank.org/indicator/NY.GDP.PCAP.PP.KD.
[4] Naphtha is used primarily as feedstock for producing high octane gasoline.

Download English Version:

https://daneshyari.com/en/article/1046842

Download Persian Version:

https://daneshyari.com/article/1046842

Daneshyari.com