Assessment of greenhouse gas emissions in the production and use of fuel ethanol in Brazil

GOVERNMENT OF THE STATE OF SÃO PAULO

SECRETARIAT OF THE ENVIRONMENT

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Abbreviations		Units	
BEN	Balanço Energético Nacional (National Energy Balance)	**cv**	Metric horsepower (1cv = 0,7355 kW)
CMA	Controle Mútuo Agrícola (Agricultural Benchmark Program)	**GJ**	Gigajoule
CMI	Controle Mútuo Industrial (Industrial Benchmark Program)	**ha**	Hectare
CTC	Centro de Tecnologia Copersucar (Copersucar Technology Center)	**h**	Hour
C-S	Center-South region (Brazil)	**kcal**	Kilocalorie
IPCC	Intergovernmental Panel on Climate Change	**kg**	Kilogram
NIPE	Núcleo Interdisciplinar de Planejamento Energético – UNICAMP (Interdisciplinary Nucleus of Energy Planning – UNICAMP)	**kWh**	Kilowatt hour
PAMPA	Programa de Acompanhamento Mensal de Performance Agrícola (Agricultural Monthly Performance Follow up Program)	**l**	Liter
SP	São Paulo State	**MJ**	Megajoule
UNICAMP	Universidade de Campinas (University of Campinas)	**Pol**	Polarization (sucrose content)
GHG	Greenhouse gases	**t**	Metric ton
GWP	Global warming potential	**TC**	Metric ton of cane
HHV	Higher heating value	**TCH**	Metric ton of cane per hour
LHV	Lower heating value		
RS	Reducing sugars		

Chemical compounds

CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
H_2SO_4	Sulfuric acid
K_2O	Potassium fertilizers
N	Nitrogen
NH_4	Ammonium radical
N_2O	Nitrous oxide
NO_x	Nitrogen oxides
P_2O_5	Phosphate fertilizers

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Preface

One of the main tasks of the Secretariat of the Environment of the State of São Paulo is the improvement of air quality in the State's urban areas. The addition to gasoline of 20-25% of ethanol is an important contribution to this end.

The substitution of gasoline by alcohol has another important consequence: the reduction of greenhouse gas emission (principally CO_2) provided that in the production of the ethanol, the fossil fuel contribution is minimized. This contribution stems from the energy needed to produce the raw materials used in farming and in the industrial process (fertilizers, lime, sulfuric acid, lubricants etc.) as well as electricity and fuels acquired by the producer (direct energy consumptions).

To consider ethanol as a renewable (or an "almost renewable") fuel, it is essential that the production fossil fuels' contribution is small, just as with the emission of greenhouse gases not directly associated with the use of fossil fuels in the entire cycle of production and usage.

Along the years evaluations of this contribution have been made by various groups of specialists, with highly encouraging results.

With the increase in the numbers of ethanol production units and with the advances of technology, the Secretariat of the Environment felt it to be necessary to seek from University of Campinas (UNICAMP) an updating of these evaluations. This update was carried out with data obtained also from the Copersucar Technology Center (CTC/Copersucar). This report is the result of this work.

Prof. José Goldemberg

Secretary of the Environment

Sugar cane energy products, ethanol and bagasse, have made a significant contribution to the reduction of greenhouse gas (GHG) emissions in Brazil, substituting fossil fuels, gasoline and fuel oil, respectively.

However, fossil fuels are used in the operations of planting, harvesting, transportation and processing of the sugar cane, resulting in GHG emissions. Energy and GHG balances are required to evaluate the net effects during the complete well-to-wheel cycle of ethanol, i.e. ethanol production from sugar cane and its use as fuel in the transport sector. To facilitate the comparison with other studies, the GHG data are presented as CO_2 equivalent emissions (CO_2eq.).

In the energy balance three levels of energy flows are considered, making it easier to compare with other energy balances.

Level 1 – Only the direct consumption of external fuels and electricity (direct energy inputs) is considered.

Level 2 – This is the additional energy required for the production of chemicals and materials used in the agricultural and industrial processes (fertilizers, lime, seeds, herbicides, sulfuric acid, lubricants etc.).

Level 3 – This is the additional energy necessary for the manufacture, construction and maintenance of equipment and buildings.

Due to the diversity of the database for the technical parameters related to the sugar cane and ethanol production in Brazil, a limited but reliable database was prepared using the information available at Copersucar. This database has the advantage of traceability and consistent references.

Two cases have been considered in the evaluation of energy flows: Scenario 1 based on the average values of energy and material consumption and Scenario 2 based on the best values being practiced in the sugar cane sector (minimum consumption with the use of the best technology in use in the sector). In both Scenarios the balance is referred to one metric ton of cane (TC).

Under these conditions, the results obtained for energy consumption were: 48,208 kcal/TC and 45,861 kcal/TC in the agricultural sector for Scenarios 1 and 2, respectively, and 11,800 kcal/TC and 9,510 kcal/TC in the industrial sector for Scenarios 1 and 2, respectively. The total energy consumptions for Scenario 1, 60,008 kcal/TC, and Scenario 2, 55,371 kcal/TC, compare very favorably with the total energy production (ethanol and surplus bagasse) of 499,400 kcal/TC and 565,700 kcal/TC, for Scenarios 1 and 2, respectively. The ratios of output energy (renewable) to input energy (fossil) are 8.3 and 10.2, for Scenarios 1 and 2, respectively.

In the GHG balance the emissions have been divided into two groups: emissions derived from the use of non renewable energy (diesel and fuel oil) and emissions from other sources (cane trash burning, fertilizer decomposition).

For the first group the calculated values were 19.2 kg CO_2eq./TC and 17.7 kg CO_2eq./TC for Scenarios 1 and 2, respectively, while the values determined for the second group were 12.2 kg CO_2eq./TC for both Scenarios.

The emissions avoided due to the substitution of ethanol for gasoline and surplus bagasse for fuel oil, deducting the above values, gives a net result of 2.6 and 2.7 t CO_2eq./m^3 anhydrous ethanol and 1.7 and 1.9 t CO_2eq./m^3 of hydrous ethanol, for Scenarios 1 and 2, respectively.

Introduction

The Brazilian sugar cane agribusiness is an economic activity responsible for 2.2% of GDP, generating an income of over US$ 8 billion and creating approximately one million direct jobs: more than 400,000 in the State of São Paulo alone – the country's largest producer State – as well as fostering the economic development of a large number of municipalities and contributing to the employment of a large number of workers in the rural areas.

The activity has a positive environmental differential that is the efficient production of fuel grade ethanol from sugar cane. The extensive use of fuel ethanol in Brazil, whether as a 25% blend with gasoline (gasohol), or used as a neat fuel in vehicles equipped with dedicated alcohol engines or used in the newly produced flex fuel vehicles, which can operate on neat ethanol, gasohol or any intermediate blend, places Brazil as a leader in carbon emission reduction and Greenhouse Effect mitigation.

The production of ethanol in the 2003/2004 crop season will reach the significant volume of 14.4 billion liters and the Center-South region, which includes São Paulo State, will respond for 89.6% of the total.

In addition to the production of ethanol, the industrial processing of sugar cane generates bagasse, another valuable product. This residue also adds to the industry's positive environmental differential because it has been widely used to replace fossil fuels in the production of industrial heat and electricity in the sugar mills and distilleries thereby boosting the abatement potential of greenhouse gases emission.

The present work is a contribution to a better understanding of the renewable energy value and energy efficiency of this important industrial sector.

Objective

This work presents the life cycle analysis of the GHG emissions in the production and use of ethanol, under the typical conditions found in Brazilian sugar and ethanol mills. It also presents the emissions derived from fossil fuel consumption and those not related to the use of energy.

Data collected in 2002 have been used for the latest update of the analysis of energy consumption in the sugar cane ethanol production at Copersucar mills undertaken in 1985[1], then updated in 1998[2].

The observations made in the first report, especially those concerning the correct definition of the boundaries of the process analysed, remain valid. Some of the parameters defined at that time have been maintained in this report, due to the difficulties found in their updating. However this fact can be considered of little importance since it would have only a very small impact on the energy consumption figures.

The evaluation of the GHG emissions in the production and use of ethanol is also an update and a revision of previous work performed at the Copersucar Technology Center (CTC), whose studies were published in 1992[3] and revised in 1998, with 1996 data[4].

Methodology

The energy flows have been considered in two situations: one (Scenario 1), based on the average values of energy and chemicals' utilizations, and the other (Scenario 2), based on the best existing values (minimum consumption values resulting from the application of the best technology in use by the sector). The use of these scenarios allows not only the characterization of the present situation (Scenario 1) but also the estimation of a situation that may become reality in the medium term (Scenario 2) by the widespread use of good practices already being used in some mills. Technologies that are already developed, or in the process of being developed, but are not used in a significant degree today, have not been considered in this work.

Technologies in the process of gradual introduction, that may have significant impact on the GHG emissions, have been considered at the present degree of utilization. This is the case of mechanically harvested unburned cane, without trash recovery for power generation.

The energy flows have been considered in three levels, to facilitate the comparison with other studies:

Level 1 – Only the direct consumptions of external fuels and electricity (direct energy inputs) are considered.
Level 2 – The energy required for the production of chemicals and materials used in the agricultural and industrial processes (fertilizers, lime, seeds, herbicides, sulfuric acid, lubricants etc.) is added.
Level 3 – The energy necessary for the fabrication, construction and maintenance of equipment and buildings is added.

The parameter values recommended by the Intergovernmental Panel on Climate Change (IPCC)[7] have been used in the GHG emission calculations whenever available.

Database

A complete countrywide database for the sugar cane sector has not yet been fully established, thus the use of a database covering part of the sector but based on reliable and traceable information has been preferred. It is important to point out that this database is representative of the agricultural and industrial practices, especially of the Center-South region, accounting for approximately 85% of the sugar cane production in Brazil.

Under these considerations the following documents have been selected as references for the energy balance of ethanol production in Brazil.

– Copersucar: Agricultural Benchmark Program (26 to 31 mills in the State of São Paulo) – These reports present dozens of performance parameters in the agricultural sector of a group of Copersucar associated mills. They have been prepared for many years, bring monthly and annual averages, and have been fully discussed among the participating mills.
– Copersucar: Industrial Benchmark Program (17 to 22 mills in the State of São Paulo) – These reports present the industrial sector performance parameters (efficiencies, consumption of chemicals etc.) of a selected part of Copersucar member mills. They have been also extensively discussed among the participants, and show the monthly and annual averages.
– Copersucar: Agricultural Monthly Performance Follow up Program (98 mills in the Center-South region) – These reports present the agricultural sector parameters for a larger number of participating mills in the Center-South region. However the traceability of the information and the uniformity of procedures have not the same level of accuracy as in the cases of the two previous sets of documents.

In the cases where weather conditions can have significant impacts on the results (such as the case of sugar cane productivity) the averages for five seasons in sequence (1998/99 to 2002/2003 seasons) have been used. In other cases the 2001/2002 harvesting season has been used as reference for both agricultural and industrial performance data.