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Brazilian potential for CCS for negative balance emission of CO_2 from biomass energy

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Abstract

In this work is assessed the Brazilian potential for Carbon Capture and Geological Storage (CCS) through CO_2 capture from biomass sources with focus on bioethanol production facilities. In the present document their geographic distribution is associated with localization of the sedimentary basins as well as the potential geologic reservoirs for CCS is presented, thus providing concrete basis to define and optimize longer term goals, consistent with Brazil´s volunteer commitment to help mitigate the effects of global climate change.
It was found that USA, England, Canada, Australia, Germany, France, Netherlands and Japan not only are quite active in the research and technologic development, but also have strong relationships between them, owning several joint products.
Historic data point out an increase in ethanol annual production in the last years, being produced mainly by Sao Paulo (61% of the domestic production). The CO_2 emissions were estimated for each Brazilian state based on the ethanol production and the CO_2 emissions due to the fermentation process. There were 26,959,209 m^3 of total ethanol produced, corresponding to about 11.2 billion m^3 of CO_2 emissions at 20ºC and 1 atm, and to about 29 million m^3 of CO_2 in reservoir conditions.
The CCS scenarios were built considering porosity in the range from 18% to 24%, using the average of the Brazilian basins for oil production. The Paraná Basin should receive over twenty million m^3 of CO_2, encompassing eight Brazilian states, which requires from 110 to 147 million m^3 of rock. Other Basins, such as Ceará, Marajó or Maranhão, Pelotas, Potiguar, Recôncavo or SEAL, and Tacutu require from 12 to 10,861 thousand m^3 of rock, having each one a specific requirement. In all scenarios, the rock volumes are smaller than the real Basins volume, thus a very favorable negative balance can be achieved for bioethanol.

Keywords: CO_2 capture, geologic sotorage, CCS, bioethanol, CO_2 negative balanc

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1. Introduction

CO_2 emission sources vary widely. It is currently considered to be a huge technical challenge the production of an accurate and reliable tool for mapping and quantifying each relevant contribution, being it of anthropogenic origin or not.

It is also well known that important sources such as chemical, petrochemical, oil production and refining facilities contribute to CO_2 emissions through operational facilities as well as through the life cycle of their products.

The urge to curb CO_2 emissions has reinforced the need to invest in the so called “greener fuels” and this scenario has strengthened the market for renewables.

As part of the commitments assumed by the Brazilian Government while participating in the Carbon Sequestration Leadership Forum (CSLF) and also in order to provide a response to a direct demand from the Brazilian National Science and Technology Ministry (MCT), PETROBRAS, the Brazilian Oil Company, has been leading since 2004 the construction of the CCS Roadmap in Brazil, with support by the local academy. By 2011 the final version is due to submission to the Federal Government for appreciation and further publication.

In the present paper we focus on the production of ethanol from the fermentation of sugarcane and also map the Brazilian potential for CCS for negative balance emission of CO_2 from biomass energy focusing on ethanol produced through fermentation in the Brazilian Ethanol Industrial Park.

2. CO_2 production of the Brazilian Ethanol Industrial Park

As previously mentioned, ethanol production facilities are important CO_2 sources. As shown in Figure 1, this activity has been growing steadily in Brazil in the last years. The 2009-2010 production encompasses June 2010 and we may estimate a production of about 34 million m^3 of ethanol for this period.

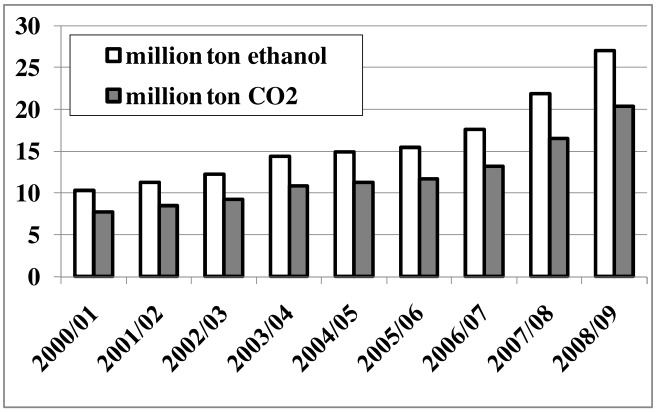

Figure 1: Production of total ethanol and respective CO_2 emissions in Brazil from 2001 to 2009 (Source MAPA).

The use of ethanol as automotive fuel was a Brazilian solution for the oil crisis that happened in the 70´s and the goal was to reduce the country´s dependence on imported fossil fuels at the time. In order to encourage the use of ethanol as an alternative to motor gasoline, the National Government created in 1975 the National Ethanol Program (PROALCOOL, as the acronym in Portuguese). Among the initiatives sponsored by PROALCOOL, taxation benefits and incentives were made available for the production of ethanol powered vehicles, which increased substantially the market for motor ethanol. In less than five years the domestic production raised from 300.000 m^3 to 11 Million m^3 of ethanol.

Environmental benefits from ethanol derive mainly from its renewable nature, as compared to fossil derived fuels. Another important positive feature is the contribution to mitigate the greenhouse gas effect, bearing in mind that the fixation of CO_2 by photosynthesis is greater than the release to the environment during the production of ethanol. An assessment made by the Copersucar Technology Center (CTC) (Plet *et al.,* 2007) shows that for each ton of sugar cane the net effect is fixation of 694.7 Kg de CO_2, encompassing all the steps ranging from cane cultivation to the final use of ethanol (Paula *et al*, 2010). Additionally according to that work, the emission of 206.8 Kg CO_2 / ton sugarcane is avoided when ethanol is used instead of gasoline.

According to Plec *et al.*, 2007, the main emission sources occurring in the production of ethanol are the burning of straw in the manual harvesting, the use of diesel as fuel throughout the production cycle, the sugar fermentation process, the bagasse burning and finally the use of ethanol as motor fuel.

Also according to the literature, considering the burning of 80% of the cane tips and leaves during the manual harvesting process, approximately 198 Kg of CO_2 are released per ton of cane. Since 2002, the Brazilian Federal Law 11,241 has encouraged a gradual substitution of manual by mechanical technology in the cane harvest. It is also important to mention that substantial increase in the productivity, the mechanical harvest may not be possible to extend to all the productive lands in Brazil especially because of terrain aspects as well as economic issues.

For each ton of sugar cane, about 38.1 Kg of CO_2 are released in the ethanol production process (Plec *et al.*, 2007). In the fermentation reactions, 0.755 Kg of CO_2 are produced for each liter of ethanol. Based upon these figures it is possible to calculate CO_2 emission for the last two harvests in Brazil, as shown in Figure 1.

The industrial production process of ethanol is described as follows:

$$C_6H_{12}O_6\,(aq) \xrightarrow[\text{Zymase}]{\text{Fermentation}} 2C_2H_5OH\,(aq) + 2CO_2$$

Although the production process of ethanol is already positive in the total emission of CO_2 206.8 Kg / ton sugarcane processed (Plec *et al.*, 2007), it may be even more positive with the adoption of some technologies in the process ethanol production. With the replacement of burnt by the mechanized harvesting, may be avoid the release of 198 Kg CO_2/ton sugarcane. With the capture of CO_2 in the fermentation process may be avoided the release of 38.1 Kg of CO_2/ton sugarcane. Thus, it is possible that the production process of industrial ethanol is still more positive of 442.9 Kg CO_2/ton of sugarcane.

Table 1 shows the total ethanol production (anhydrous plus that in the hydrated ethanol) in Brazil for the years 2008/2009, per state, according to the official Government information.

Figure 2 shows the overlapping of the Brazilian map, the spatial distribution of the geological basins with good potential for CO_2 storage together with the location of the main ethanol plants, as documented by the Ministry of Agriculture Livestock and Supply of Brazil (MAPA). It also highlights the massive concentration of ethanol plants in the state of São Paulo, as well as the fact that the geological basins are located in the same areas where ethanol plants are installed; in fact there is roughly 98% of spatial coverage throughout the country.

Table 2 presents the location of the plants for each Basin as well as the injected CO_2 volume at the reservoir conditions. The calculations performed were based upon an average reservoir porosity ranging from 18% to 24%, assuming siliciclastic reservoirs.

Considering that still don't have an adequate amount of studies to give a safety margin, they were not considerate variations as the possibility of larger storage if it is an aquifer, the residual CO_2 trapping, the dissolution of CO_2 in native formation fluids (including oil and brine during the injection phase, and the part of CO_2 that interact with the reservoir rock. However all these phenomena would reduce the amount of rock volume requested, being, therefore both used sceneries, considered critical. Consequently the amount of rock volume requested should be inferior of both used sceneries.

It is observed that the rock volume requested is much smaller than the available in each Basin, still allowing choosing the sites where the seal rocks are more reliable and where the monitoring has better cost benefit rate.

As resumed in Figure 3, the publication of scientific articles in the area of CCS has shown an exponential increase, is consistent with the profile of an emerging theme. Additionally it is clearly shown that the collaboration among the countries is widespread and at substantial levels, thus reinforcing the international nature of this issue.

The most active countries, both in terms of individual production as well as cooperation initiatives are USA, England, Canada, France, Australia, Germany, Norway, Nederland, Japan and Italy.

Table 1: 2008/2009 Ethanol Harvest, CO_2 emissions at normal and reservoir conditions (Source: MAPA)

UFs	Ethanol (m^3)	Ethanol (%)	Vol CO_2 (m^3) [20ºC, 1atm]	Vol CO_2 (m^3) [reservoir]
Alagoas	825,683	3.1%	342,726,604	890,199
Amazonas	7,644	0.028%	3,173,091	8,242
Bahia	139,363	0.5%	57,847,124	150,252
Ceará	8,896	0.03%	3,692,575	9,591
Espírito Santo	268,938	1.0%	111,631,354	289,952
Goiás	1,673,591	6.2%	694,678,684	1,804,360
Maranhão	179,141	0.66%	74,358,463	193,139
Mato Grosso	876,675	3.3%	363,892,397	945,175
Mato Grosso do Sul	1,049,668	3.9%	435,698,865	1,131,685
Minas Gerais	2,151,002	8.0%	892,843,339	2,319,074
Pará	43,898	0.16%	18,221,180	47,328
Paraíba	382,024	1.4%	158,571,585	411,874
Paraná	1,974,173	7.3%	819,444,879	2,128,428
Pernambuco	518,447	1.9%	215,198,449	558,957
Piauí	44,096	0.16%	18,303,616	47,542
Rio de Janeiro	122,865	0.46%	50,999,274	132,466
Rio Grande do Norte	112,164	0.42%	46,557,326	120,928
Rio Grande do Sul	6,065	0.022%	2,517,592	6,539
Roraima	6,935	0.026%	2,878,614	7,477
São Paulo	16,478,116	61%	6,839,779,342	17,765,661
Sergipe	87,090	0.32%	36,149,495	93,895
Tocantins	2,734	0.010%	1,134,819	2,948
TOTAL	26,959,209	100	11,190,298,667	29,065,711

Table 2: Porous volume to be filled out with CO_2 and percentile of porous volume that would be filled out by Brazilian states and sedimentary Basins.

UFs	Basins	CO_2 volume (1,000 m^3) [reservoir]	Rock volume (1,000 m^3) [18% porosity]	Rock volume (1,000 m^3) [24% porosity]
GO, MT, MS, MG, PR, SP, ES, RJ	Paraná	26.517	147,316	110,487
AL, PB, PE, SE	Recôncavo or SEAL	1,955	10,861	8,146
MA, PI	Maranhão	241	1,337	1,003
BA	Recôncavo	150	835	626
RN	Potiguar	121	672	504
AM, PA	Marajó or Maranhão	56	309	232
CE	Ceará	10	53	40
RR	Tacutu	7	42	31
RS	Pelotas	7,5	42	31
TO	Paraná or Maranhão	2.9	16	12

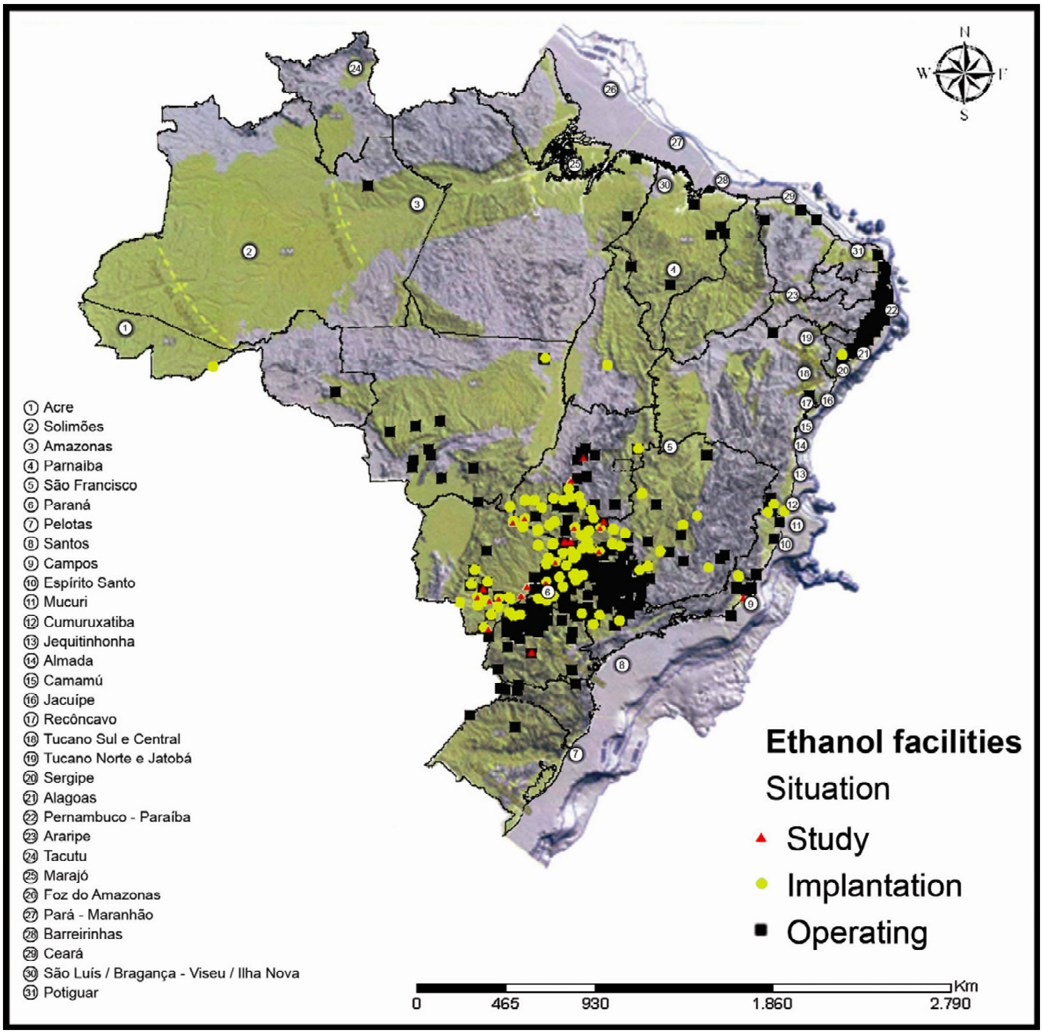

Figure 2: Overlapping the location of ethanol production plants and potential basins for CO_2 injection (Source: Milani, 2007).

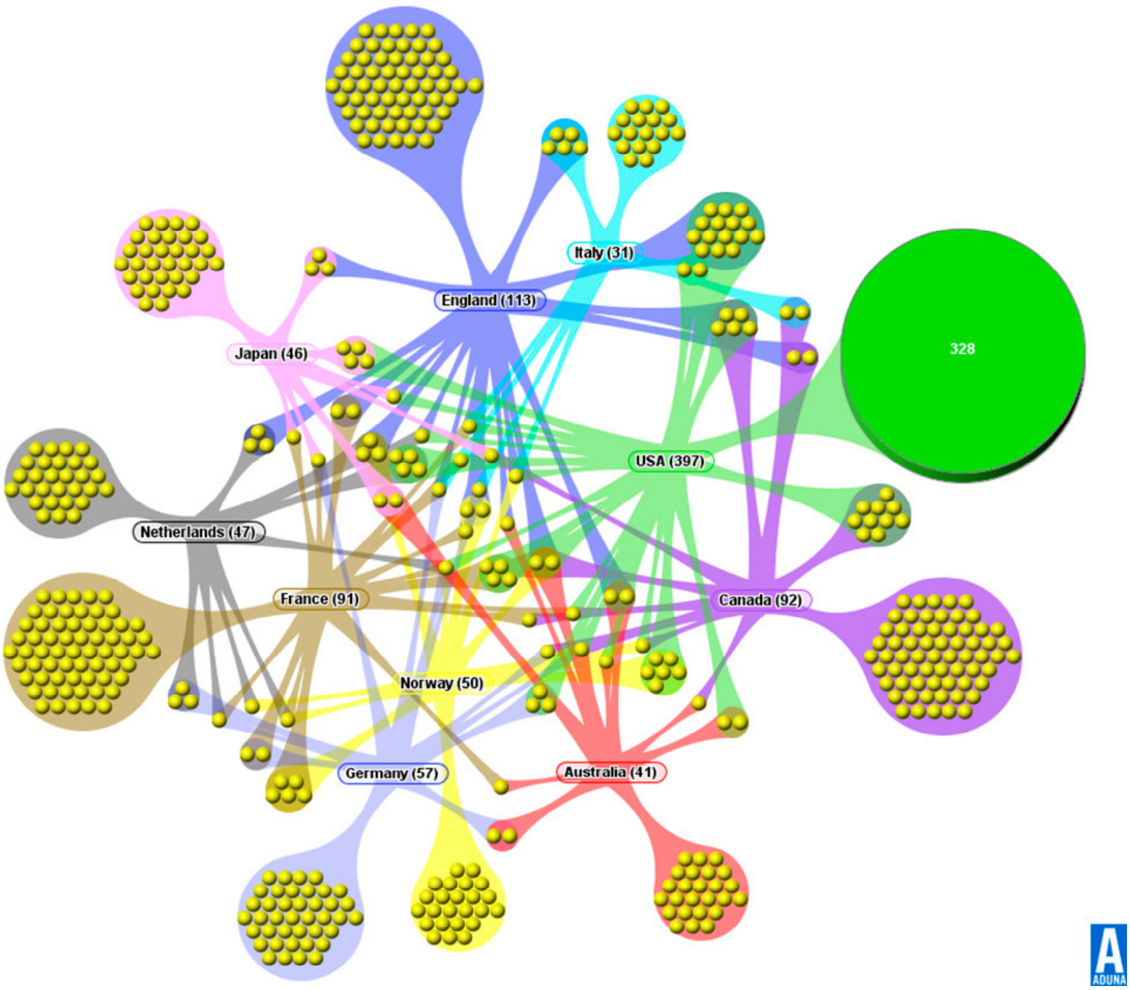

Figure 3: Countries that published more articles concerning CCS showing the relationships between them (june 2010).

3. Conclusion and Perspectives

Although the CCS is becoming a technological route for GHG emissions mitigation, contributing to a quicker and safer stabilization of GHG atmospheric concentration levels and allowing the maintenance of fossil derived fuels within the energy matrix, it still requires that CO_2 is captured from large point sources, such as power plants and oil refineries.

In the last fifty years, Brazil has built a strong technological park dedicated to bioethanol production with an yearly capacity of 25 billion liters (2008). This should be doubled by the year 2017. Considering, as a general rule, that the production of 1.5 million liters of ethanol yields 1.2 thousand tons of CO_2, in the years 2008/2009 alone 20 million tons of CO_2 were produced as a result of ethanol production. In this case, if a wide program of carbon capture and storage is established, it has high feasibility due to the punctual nature of these emissions.

An advantage of the integration of bioethanol production and CCS is the reduction cost of capture due to the high concentration of the CO_2 current. Considering microalgae and gasification, the price of capture technologies becomes a relevant variable for the feasibility of the capture.

Considering the production of bioethanol from sugarcane there is no need for capture processes, once CO_2 emissions occur at roughly 90% purity level, which dramatically reduces injection costs at supercritical levels mainly because the higher the CO_2 purity levels the lower the required injection pressure levels.

As showed previously the net CO_2 balance is negative for the biotehanol plants with the CO_2 injection via CCS, bearing in mind that rock integrity and reliability as well as a robust monitoring program for leakages is granted.

Nevertheless, for CCS to become viable, it is necessary to ensure it can be done at costs and impacts that are economically and environmentally acceptable. However, the CO_2 capture technologies currently available are not economically feasible due to their consumption of large amounts of energy and of the costs of the energy being significantly increased. Thus, the development of CO_2 capture technologies is vital to make CCS viable. Whilst this is not possible, the CO_2 yielded by ethanol production based on fermentation could be easily captured and sequestrated through CCS.

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