TECHNICAL AND ECONOMIC ASSESSMENT OF CARBON DIOXIDE CAPTURE FROM ETHANOL PRODUCTION PLANTS FOR HYDROMETHANE PRODUCTION IN PARAGUAY

Marcelo Barboza Torres[a],

Advisors: Dr. Gustavo Riveros[b], M.SC. Ing. Aldo Mendieta[c]

[a]Universidad Católica "Nuestra Señora de la Asunción" - Campus Alto Paraná, Facultad de Ciencias y Tecnología

[b] Centro de Innovación en automatización y Control – FPTI Paraguay

[c] Universidad Nacional de Asunción, Facultad de Ingeniería

marcelobarbozatorres@gmail.com, gustavo.riveros@pti.org.py, aldomendietaa@hotmail.com

Introduction

This research was developed within the project Hydromethane (ETEPHM) faced by FPTI-Paraguay, where the main topic being the CO2 capture from sugar-distilleries plants distributed throughout the Paraguay.

The viability study is presented considering the capture of the carbon dioxide from generated during the fermentation in the ethanol production process from a technical and an economic point of view, and then use the CO2 to synthesize methane , following the principle of the Sabatier reaction, reacting hydrogen and the captured carbon dioxide at high temperatures and pressures to transform them, using a catalyst, into water and methane. (the hydrogen required is obtained by water electrolysis). Experimental tests conducted by [1] found a final composition of 64% CH4, 29 % H2 and 7% CO2 in volume terms. Whereby the resultant methane can be described as hydromethane, due to the presence of hydrogen gas. H2 content should not exceed 30%, to avoid problems both in the transport and combustion.

Objective

The main objective was to evaluate the technical and economic viability of capturing the CO2 emitted during the fermentation of sugar cane distilleries plants in Paraguay as an input to be used in the synthesis of a potential fuel capable of replacing the natural gas called hydromethane (mixture of hydrogen and methane), referencing certain scenarios developed under the current situation of the department of Alto Paraná, Paraguay.

Methodology

Different CO2 capture systems were found in the literature, being chosen the system shown in the Figure 1, referencing [2], it includes the necessary data to perform the technical and economic analysis.

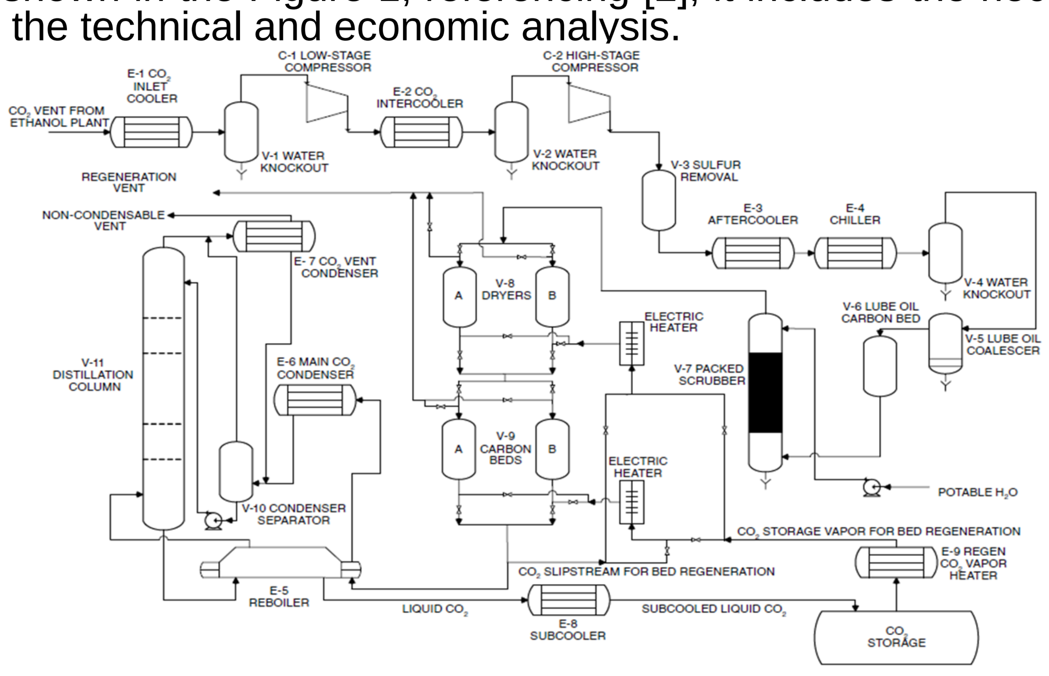

Figure 1. Schematic of the CO2 capture plant considered in this work
Source: [2] (Illinois State Geological Survey, 2006)

The stoichiometric reaction for the conversion of glucose into ethanol yields 0.511 grams of ethanol and 0.489 grams of carbon dioxide per gram of glucose, from which it can be deduced the amount of CO2 generated for every liter of ethanol. However industrial performance normally reach about 87% of efficiency. **In this paper the proportion that each liter of ethanol produced, is considerer in 0.55 kg of CO2 per liter of ethanol**.

This paper considers the catalytic hydrogenation of the captured CO2 (also known as the Sabatier reaction) to synthetize methane, the Sabatier reaction states that it is necessary 5.5 kg of CO2 for each kg of H2 in order to obtain the stoichiometric composition of methane [2], or in other words, **in order to produce each kg of CH4 it is necessary 0.5 kg of H2 and 2.75 kg of CO2**.

In order to estimate the viability from the economic point of view, the unit cost of CO2 capture per ton is calculated, this cost is directly related to the equipment installation and operation costs, as shown in the Equation

$$C_{CO2} = \frac{C_{ACO2}}{P_{ACO2}}$$

C_{CO2}=unit cost of CO2 capture (US$/ton); C_{ACO2}=annual cost of CO2 capture (US$/year)
P_{ACO2}= Annual CO2 generation in the ethano plant (ton/year)

The annual carbon capture cost is given by:

$$C_{ACO2} = C_i + C_{OM} + C_{ins} + C_{GGE}$$

C_i=Annual investment cost (US$/year); C_{OM}=Annual operation&maintenance cost (US$/year)
C_{GGE} = Greenhose Gas Emissions costs (US$/year); C_{ins}=Inputs cost (US$/year)

The study assumes CDE (Ciudad del Este, Paraguay) as the impact area and includes 25% and 50% of all gasoline-fueled vehicles (about 29,800 vehicles) scenarios A and B respectively. Table 1 shows the data taken into account for the analysis of each scenario according to the Sabatier Reaction, which states that for each kg of CH4 are needed 2.75 kg of CO2.

Table 1. Data for each scenario
Source: Own Elaboration

Scenario	CO2 (kg/year)	Hydromethane (kg/year)[1]	Vehicles
A	24.591.050	8.942.200	14.904
B	12.295.525	4.471.100	7.452

[1]Considering an average consumption of 4 kg/day hydromethane, with an average consumption of 600 kg of hydromethane/year by vehicle

Another project that uses the same concept proposed in this work for the synthesis of hydromethane is the E-Gas project from Audi. The Company is establishing a portfolio of sustainable energy sources by producing a sustainable fuel, the E-Gas (synthetic methane) [3], in which it is proposed to use renewable electricity (generated by wind or solar), water and carbon dioxide to synthesize the E-Gas. The plant produces the E-Gas in two stages, electrolysis and methanation, as shown in Figure 2 In the first stage, the electrolyser separates water into hydrogen and oxygen. In the second stage of the process, hydrogen is reacted with the CO2 to produce synthetic methane. The carbon dioxide used by Audi gas plant comes from the exhaust of a biomethane plant adjacent, although this scheme is represented by CO2 emissions from human activities, such as transport and housing.

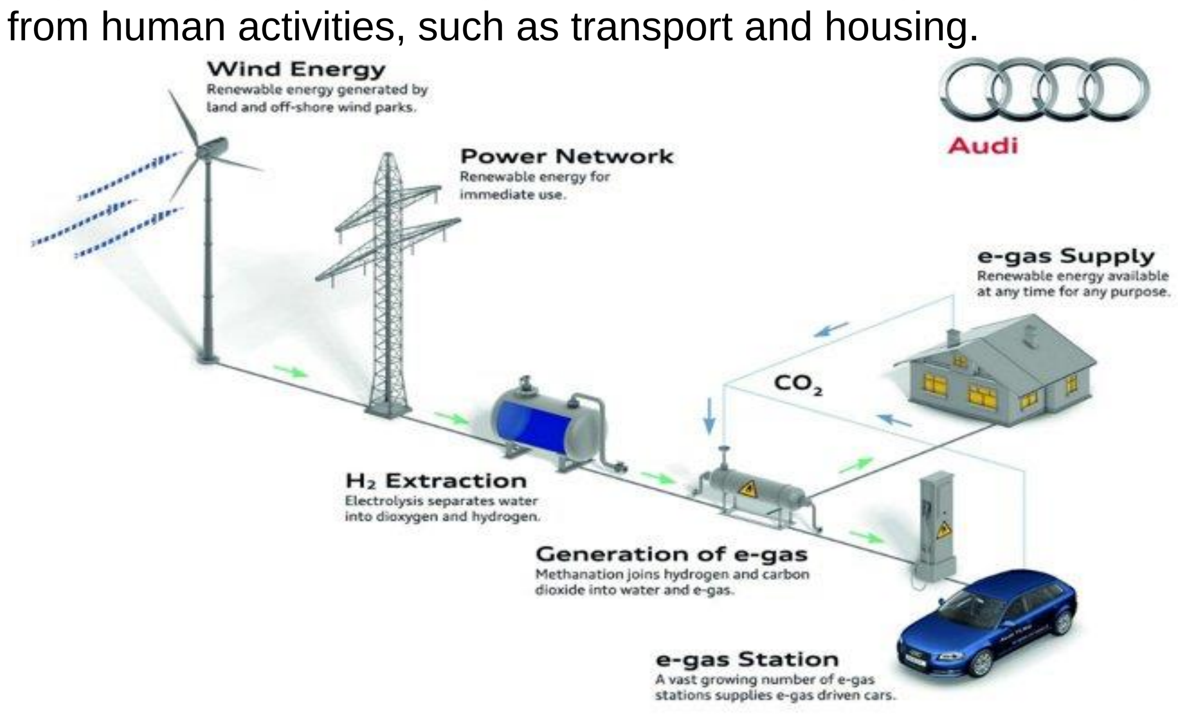

Figure 2. Schematic of the production process of the E-Gas
Source: [3] (Audi e-gas project, 2014)

Results and Conclusions

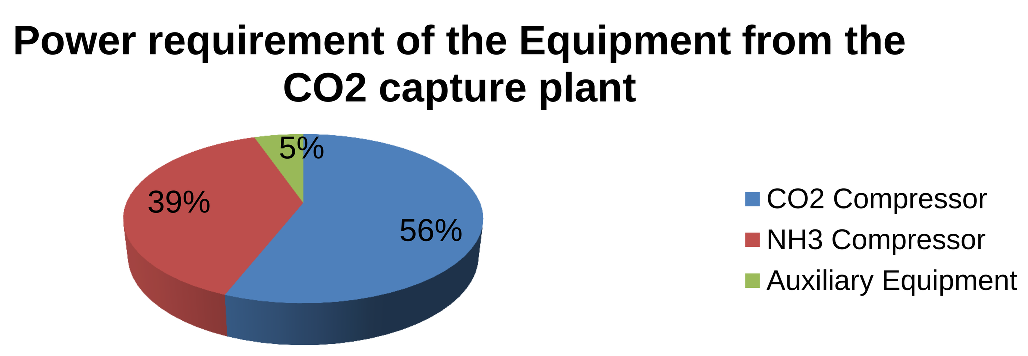

Figure 3. Schematic of the CO2 capture plant considered in this work
Source: [2] (Illinois State Geological Survey, 2006)

1. As shown in Figure 3 the equipment with the highest energy impact (hence economic) in the capture system is the CO2, so **it can be concluded that in order to optimize the capture process is necessary to optimize the operation of the compressors.**
2. The main result of this paper expresses a capture cost of 15.49 US$/ton and 30.98 US$/ton for scenarios A and B respectively, **demonstrating technical feasibility but not necessarily an economic viability, simply because the cost of CO2 capture found in both scenarios it is not within the range of the reference capture costs found in the literature[4-6]**, as shown in Figure 4
3. **Yet it is important to note that when considering a larger amount of CO2 the capture cost decreases, making the proposal more interesting. Proving that it is viable when considering the economy of scale.**

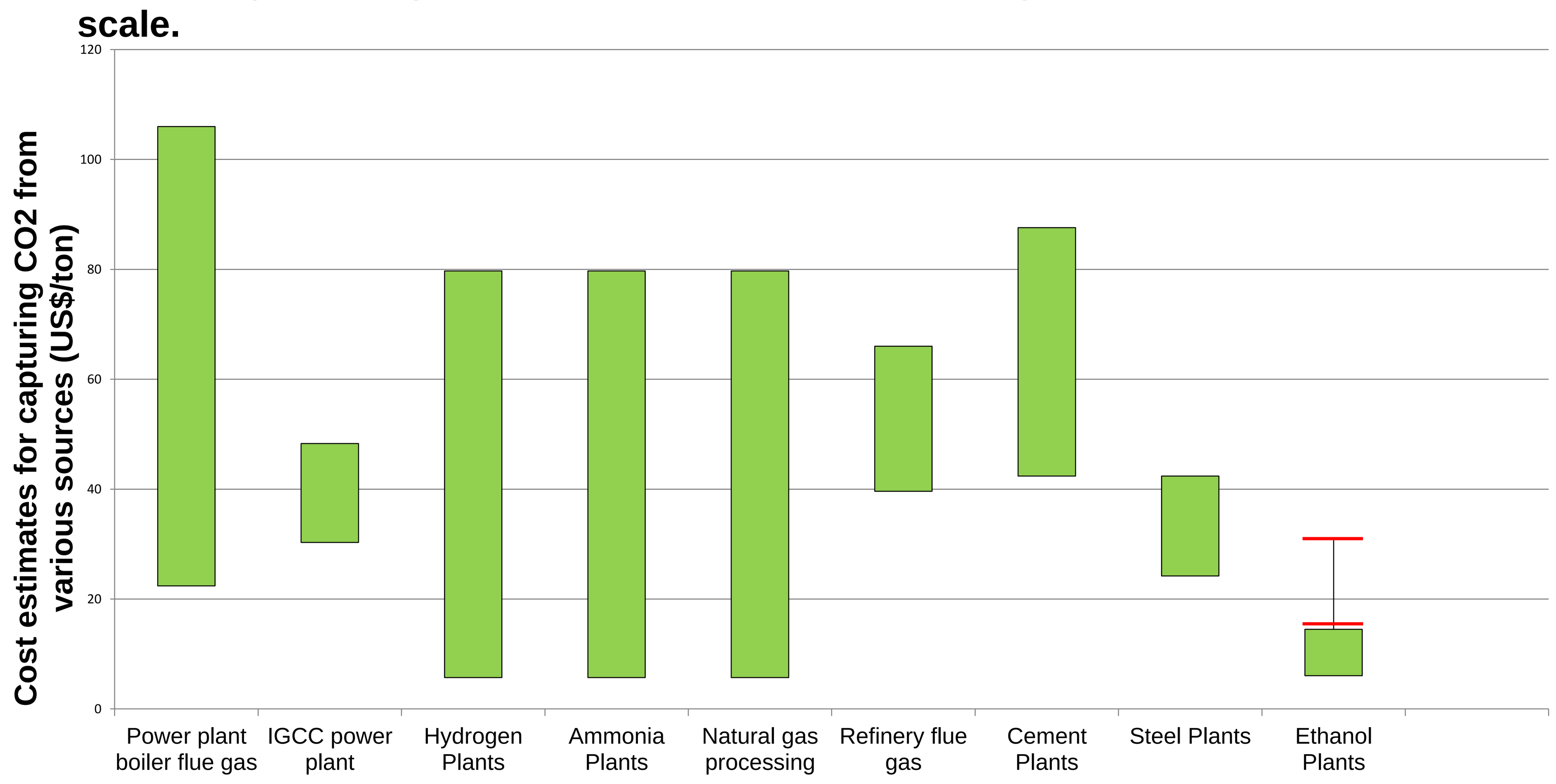

Figure 3. CO2 capture costs from various sources
Source: Own Elaboration

References

[1] Barbarossa, V., Capriccioli, A., Sardella, B., & Tosti, S. (2009). Carbon dioxide utilisation for methane production by renewable energy sources. *S4FE–sustainable fossil fuel for future energy*. Rome, 8th–11th July; 2009.

[2] Illinois State Geological Survey. (2006). Evaluation of CO2 Capture options from Ethanol Plants. Illinois, USA.

[3] Audi e-gas project. (26 de Agosto de 2014). Obtenido de sitio web oficial de Audi: http://www.audi.com/com/brand/en/vorsprung_durch_technik/content/2013/10/energy-turnaround-in-the-tank.html#vdt-button-enrich

[4] Xu, Y., Isom, L., & Hanna, M. (2010). Adding value to carbon dioxide from ethanol fermentations. Bioresource technology, 101(10), 3311-3319.

[5] Electric Power Research; WorleyParsons Services Pty Ltd; Global CCS Institute. (2009). Strategic Analysis. Report 4: Existing Carbon Capture and Storage Research.

[6] Carbon Capture and Storage. (s.f.). Recuperado el 15 de Junio de 2014, de Center for Climate and Energy Solutions: http://www.c2es.org/technology/factsheet/CCS