Bioenergy and mobility; cooperation between Japan and Brazil within a low carbon world

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Abstract

Promoting the use of renewable energy sources is fundamental to maintain a low carbon world. One challenge is finding appropriate low carbon technologies to fuel the mobility needs of our society. Although, the capacity of biofuels, as a carbon mitigation option, depends on various factors, the potential of sugarcane ethanol as a greenhouse gas reduction option is already established. This brief assessment shows that the current sugarcane cropped area for ethanol production in Brazil is enough to power the combined car fleet of Japan and Brazil. The optimization of the energy throughput of 1 ha of sugarcane to provide for the mobility needs of the 2 countries depends on the adoption of state of the art technologies, which are cost competitive. The maximization of the environmental benefits, which include both carbon dioxide and ancillary local pollution reduction, depends on the trade between the 2 countries in order to enable access to products which are part of the intrinsic vocation of the industry in each one. In order to balance the flows of capital between the 2 countries it is possible to trade electric vehicles for ethanol. If a company (sugar mill) in Brazil imports and leases electric vehicles and guarantees that they are charged with bioelectricity, the use of these vehicles will enhance global and local air quality. The monetary value of ethanol imported by Japan, which are based on 3.9 million ha of sugarcane in Brazil are comparable to the value of 583,000 EVs. This fleet of EVs correspond to 3% of the fleet that can be potentially powered by 2,1 million ha of sugarcane, which is enough to fuel the Brazilian car fleet of 33 million vehicles. Over 5 years, emission savings on one ha basis, combining the effect of the use of one electric vehicle in Brazil and the substitution of ethanol for gasoline in Japan equals to 113 metric tons of CO_2.

Introduction

Japan and Brazil have been good commercial partners, and in 2010 $14 billion were traded between the two countries in a reasonably balanced fashion (FIESP 2011). Current efforts promoting an increase in the volume traded between the two countries are underway.

According to the Sao Paulo State Sugarcane Industry Association (UNICA), up to 500 million liters of ethanol are expected to be annually consumed in Japan up to 2017, and currently, Brazil ethanol exports to Japan amount to 264 million liters per year, which corresponds to only 2% of the Brazilian production (UNICA, 2011). In Japan, up to 3% of ethanol can be mixed to gasoline. This demonstrates the existence of a collaborative relationship between Japan and Brazil based on the adoption of biomass energy to cope with a low carbon society. In Brazil, conventional gasoline vehicles, including imported vehicles, run on a 24% ethanol blended gasoline (E25). In addition flex fuel vehicles manufactured in Brazil, including major Japanese brands, can run with 100% ethanol (E100).

Under this arrangement, a private company in Brazil produces and sells ethanol and emission savings are credited to the users of ethanol in Japan. Indeed, the potential of sugarcane based biomass as a source that reduces carbon emissions has been already established (Macedo, Seabra, and Silva 2008; Pacca and Jose R. Moreira 2009). According to a recent directive of the European Union, the use of sugarcane based ethanol usually saves 71% of the greenhouse gas emissions if compared to gasoline on an energy basis (EU 2009). Nevertheless, the potential of sugarcane biomass might increase if more sugarcane based bioelectricity is produced and displaces fossil fuels.

Figure 1. Bagasse stockpile and power generation facility in a sugar mill
Cortesia UNICA/ Foto: Niels Andreas

Currently, existing biorefineries in Brazil produce ethanol and electricity from bagasse (Pacca & Moreira 2009; Macedo et al. 2008; Michael Wang et al. 2010). Because the amount of primary energy contained in the fibers of the sugarcane plant (leaves and stalks) is twice the amount of energy contained as sugar, the amount of surplus electricity that can be supplied to the grid depends uniquely on the efficiency of the boiler that is installed in the sugar mill. The higher the pressure and the temperature supported by the boiler, the greater is the mass of steam produced (Kamate and Gangavati 2009). The substitution of old boilers by high efficient ones in Brazilian sugar mills has been supported by clean development mechanism (CDM) projects (Hultman et al. 2010). Figure 1 shows a stock pile of bagasse in a sugar mill and the boiler where its combustion takes place to produce steam and bioelectricity.

Different studies have assessed the use of electricity and its carbon balance as a transportation option (Lemoine et al. 2010; J. E. Campbell et al. 2009). Consequently, it is possible to enhance the CO_2 mitigation potential per area of planted sugarcane if ethanol and electricity are jointly produced and the final use of both energy carriers is allocated to transportation. Nowadays, both energy carriers can be used to power personal vehicles. A hybrid vehicle contains an internal combustion engine, which consumes liquid fuel, and an electric motor powered by electricity. It is also possible to find in the market flex fuel vehicles that run on ethanol and gasoline, and electric plug in vehicles fully powered by electricity (EV).

In addition to curb climate change, the implementation of policies to reduce greenhouse gas emissions also help improving local air quality in urban areas (Bell et al. 2008; Nemet, Holloway, and Meier 2010). This is the case of most transportation technologies that rely on renewable energy sources, especially when electricity is used as the energy carrier (van Vliet et al. 2011). Therefore, the use of bioelectricity in private cars, especially in large urban areas, is beneficial to local environmental quality.

Nevertheless, every energy source causes negative environmental impacts and the use of biomass has some drawbacks as well. One issue that is still contentious is increasing land footprint to produce biofuels, and several models have been sought to clarify this dilemma (Rathmann, Szklo, and Schaeffer 2010; Nassar et al. 2011). Part of the problem is also due to the effect of indirect land use changes on the overall carbon balance of biofuels (Fargione et al. 2008; Searchinger et al. 2009). Although this dispute is intertwined with complex issues and views, increasing the energy throughput per unit of area of cropped biomass is part of the solution to this question.

Objective

This research note evaluates resources required and the benefits of a complementary business plan involving the trade of ethanol and electric cars between Japan and Brazil. The analysis is based on currently available data, the use of sugarcane ethanol and electricity as energy carriers to power private cars, and virtually cost competitive technology.

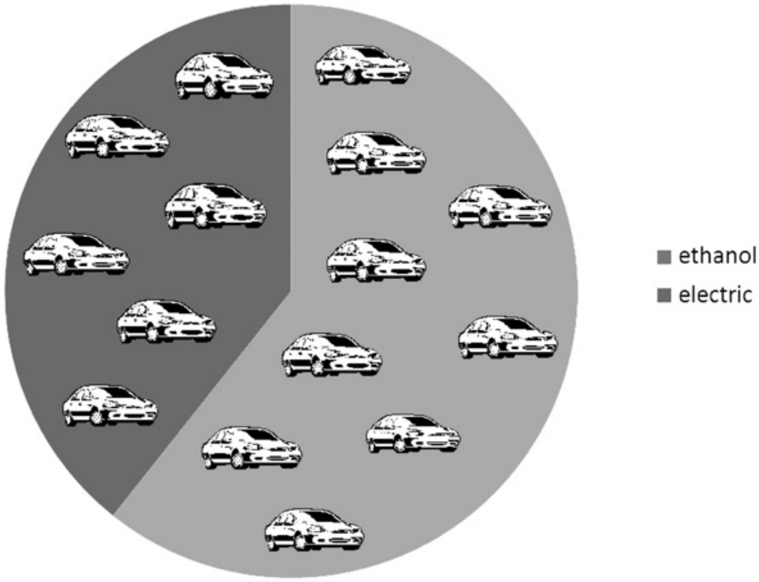

Figure 2. Share of ethanol fueled and electricity powered cars based on one hectare of sugarcane products, and 12,000 km annual driven distance.

Methods

The analysis is based on typical values that represent yield, emission factors, and energy conversion efficiencies. It takes into account a state of the art sugar cane mill, a hybrid car consuming ethanol (15km/liter) [1], and an electric car (6.5km/kWh) [2]. It is assumed that the annual distance driven by each driver in Japan and Brazil is 12,000 km. Therefore 798 liters of ethanol and 1,846 kWh are required to respectively power the hybrid and the electric car over one year.

An internal combustion engine powered vehicle releases 214 g of CO_2 per km (Ji-Yong Lee et al. 2009). Although sugarcane ethanol is a renewable fuel, a life cycle assessment shows that 1 liter of ethanol releases 417 g of CO_2e (Macedo, Seabra, and Silva 2008). Therefore one ethanol fueled vehicle releases 40 g of CO_2 per km. Consequently, the emission of 174 grams of CO_2 per km is prevented when an ethanol powered car substitutes for a gasoline car. If the gasoline car is displaced by the electric vehicle, emission savings amount to 214 grams of CO_2 per km driven.

In 2007, the car fleet in Japan comprised 61 million vehicles whereas the car fleet in Brazil comprised 33 million vehicles (OPEC 2010). The challenge is optimizing the sugarcane based technology to maximize the mobility of these two fleets constrained by land area. Although this is just a theoretical exercise, it is worthwhile to determine the land footprint required if appropriate technologies are adopted.

It is assumed that a state of the art sugar mill in Brazil produces 85 metric tons of sugarcane per hectare (10,000m^2) and 90 liters of ethanol per metric ton of sugarcane. In addition, the facility produces 135kWh per metric ton of sugarcane (Macedo, Seabra, and Silva 2008). This corresponds to mills operating condensing extraction steam turbine (CEST) at 6.5MPa/480℃, which implies 340kg of steam per metric ton of sugarcane, and relies on the collection and use of 40% of harvesting residues (straw).

Results

Based on the assumptions described in the methods section, it is possible to power almost 16 cars for every hectare cropped with sugarcane. In fact, 10 vehicles are powered with ethanol and 6 with electricity (figure 2). Alternatively it is possible to envision the use of both energy carriers in a hybrid vehicle that over 39% of its driving cycle draws only power from its batteries. The combined effect is that 36 metric tons of CO_2 are saved due to the use of one hectare planted with sugarcane.

If bioelectricity and ethanol are used together, the area required to power the fleet of cars in Japan and Brazil is respectively 3.9 and 2.1 million ha, which is roughly the current sugarcane cropped area in Brazil that is solely dedicated to ethanol production. In 3.9 million ha it is possible to produce 48 billion liters of ethanol and 44 TWh of electricity, whereas in

2.1 million ha it is possible to produce 26 billion liters of ethanol and 24 TWh of electricity. The total demand of the Japanese car fleet is 79 billion liters of ethanol. Therefore the total ethanol produced in 6 million ha is enough to power 93% of the fleet. However, this considers that all cars in Brazil run on electricity and all cars in Japan run on ethanol. A more realistic figure is that 60% of the Japanese fleet is fueled with ethanol, 44 TWh of electricity, which is produced out of 3.9 million ha is consumed in Brazil and displaces natural gas. The displaced natural gas in Brazil is exported to Japan to generate electricity, which is consumed there in plug in hybrid vehicles. Currently, the price of bioelectricity that is sold in the auctions organized by the Brazilian government is ￥8,434/MWh.

On a monetary basis, the importation of 48 billion liters of ethanol corresponds to ￥1,749 billion, which yields ￥1,443 billions of gasoline savings. Fuel prices are based on a trading report prepared by the Brazilian Ministry of Agriculture, and the prices of ethanol and gasoline in 2009 are respectively ￥36.44 and ￥39.08 per liter[3]. In addition we have considered that gasoline vehicles are 30% more efficient than ethanol fueled vehicles. If we consider that the price of each electric vehicle is ￥3,000,000 the expenses with ethanol importation in one year corresponds to 583,081 vehicles or 3% of the EV fleet that can be potentially powered with bioelectricity produced out of 2.1 million ha. The total EV fleet in Brazil corresponds to 12,83 million vehicles.

In addition to the reduction of greenhouse gas emissions, the use of electric vehicles in Brazil contributes to air quality improvements in urbanized areas. However this ancillary effect depends on the availability of electric cars at a competitive price in the Brazilian market or the substitution of the current fleet for plug in hybrid cars that run 39% of the time using electricity.

Discussion

One barrier to the deployment of the proposed scheme is that the biomass energy source is located in Brazil and most of the energy consumption takes place in Japan. However, it is possible to create a scheme in which the electricity is consumed in Brazil and other fuel such as natural gas or even gasoline is exported to be consumed in Japan. The emissions from the combustion of this fossil fuel in Japan would be neutralized by the generation and consumption of bioelectricity in Brazil and the displacement of fossil fuels. It is hard to imagine that all Brazilian car fleet is going to be displaced by EVs or that all gasoline consumed in Japan is displaced by ethanol. However a small share of penetration of such biomass based energy carriers might significantly improve environmental quality.

It is important to guarantee that bioelectricity is used to charge the electric vehicles. This would be possible if the EVs are leased by a bioelectricity supplier that controls the supply of electricity to the grid and the consumption of the EV's fleet. This is not the first time that electric vehicles are leased because the General Motors EV1 was made available in the 90s based on lease agreements. This scheme also facilitates maintenance and helps the EV to achieve a longer lifetime.

A scheme in which companies balance imports and exports is currently in place in Argentina. The Japanese company Sojitz Corporation has an agreement with the Argentinean government that for each dollar imported in Hyundai vehicles they export $1 worth of biodiesel and other commodities made in Argentina (Valor 2001).

The scheme proposed in this research note entails the use of electric vehicles in Brazil and exporting most of the ethanol to Japan. In this case, one company sells all ethanol produced in one ha (or any multiples of 1ha). The same company leases one electric vehicle and guarantees that all electricity needed to charge it is bioelectricity from bagasse, which results from crushing the sugarcane grown in one ha. Based on this arrangement, the annual value of ethanol exports based on 1 ha of sugarcane corresponds to ￥279,000. If Japan imports ethanol, the value of the avoided gasoline corresponds to ￥230,000. In Brazil, the benefits encompass ethanol and electricity sales, which amount to ￥279,000 and ￥15,600 respectively. In addition, an EV, which costs ￥3,000,000 is exported to Brazil. Over 5 years, which is the typical tenure period of a car by a middle income household in Brazil, emission savings, combining the effect of the use of the electric vehicle in Brazil and the substitution of ethanol, which is produced in one ha, for gasoline in Japan, equals to 113 metric tons of CO_2.

The assumptions required to get to our results also entail the existence of a flex fuel hybrid car, which is not manufactured yet. Nevertheless, this is probably possible, and depends only on the willingness of the companies that detain such technology.

Other assumption is that erase sugar mills will be willing to expand their cogeneration capacity, installing new and more efficient boilers that will increase the secondary bioenergy throughput per hectare. This probably demands policies and incentives.

Finally, this paper demonstrates results of a preliminary assessment, and more comprehensive information on costs and benefits in Japan and Brazil need to be incorporated to render a more robust analysis.

Conclusion

In this assessment it is demonstrated that based on available efficient technology, both for energy production and consumption it is possible to demonstrate that the discourse of lack of land for energy production is a fallacy. If policies promoting the adoption of efficient technologies are adopted and if countries like Japan and Brazil can cooperate and trade products, which their industries have vocation to produce; the challenge of living within a low carbon society is overcome. Nevertheless, policies are needed so that consumption of appropriate technology takes place. This is a preliminary assessment and a more elaborated economic analysis could provide more insights on the underlying business plan of this bilateral GHG mitigation scheme.

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References

Bell, Michelle L, Devra L Davis, Luis A Cifuentes, Alan J Krupnick, Richard D Morgenstern, and George D Thurston. 2008. Ancillary human health benefits of improved air quality resulting from climate change mitigation. *Environmental Health* 7, no. 1: 41. doi:10.1186/1476-069X-7-41.

EU. 2009. *DIRECTIVE 2009/28/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC*. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:140:0016:0062:en:PDF.

Fargione, J., J. Hill, D. Tilman, S. Polasky, and P. Hawthorne. 2008. Land Clearing and the Biofuel Carbon Debt. *Science* 319, no. 5867 (2): 1235-1238. doi:10.1126/science.1152747.

FIESP. 2011. Fiesp promove encontro empresarial entre Brasil e Japão; Iniciativa busca aumentar o fluxo comercial entre as empresas dos dois países. http://www.fiesp.com.br/agencianoticias/2011/02/09/fiesp_encontro_empresarial_brasil_japao.ntc.

Hultman, Nathan E., Simone Pulver, Leticia Guimaraes, Ranjit Deshmukh, and Jennifer Kane. 2010. Carbon market risks and rewards: Firm perceptions of CDM investment decisions in Brazil and India. *Energy Policy* (8). doi:10.1016/j.enpol.2010.06.063. http://linkinghub.elsevier.com/retrieve/pii/S0301421510005331.

Kamate, S, and P Gangavati. 2009. Exergy analysis of cogeneration power plants in sugar industries. *Applied Thermal Engineering* 29, no. 5-6 (4): 1187-1194. doi:10.1016/j.applthermaleng.2008.06.016.

Lee, Ji-Yong, Moo-Sang Yu, Kyoung-Hoon Cha, Soo-Yeon Lee, Tae Won Lim, and Tak Hur. 2009. A study on the environmental aspects of hydrogen pathways in Korea. *International Journal of Hydrogen Energy* 34, no. 20 (October): 8455-8467. doi:doi: DOI: 10.1016/j.ijhydene.2009.08.003.

Macedo, Isaias C., Joaquim E.A. Seabra, and Joao E.A.R. Silva. 2008. Green house gases emissions in the production and use of ethanol from sugarcane in Brazil: The 2005/2006 averages and a prediction for 2020. *Biomass and Bioenergy* 32, no. 7 (July): 582-595. doi:doi: DOI: 10.1016/j.biombioe.2007.12.006.

Nassar, Andre M., Leila Harfuch, Luciane C. Bachion, and Marcelo R. Moreira. 2011. Biofuels and land-use changes: searching for the top model. *Interface Focus* 1, no. 2 (April 6): 224 -232. doi:10.1098/rsfs.2010.0043.

Nemet, G F, T Holloway, and P Meier. 2010. Implications of incorporating air-quality co-benefits into climate change policymaking. *Environmental Research Letters* 5, no. 1 (1): 014007. doi:10.1088/1748-9326/5/1/014007.

OPEC. 2010. *World Oil Outlook 2010*. Vienna, Austria: Organization of the Petroleum Exporting Countries. http://www.opec.org/opec_web/static_files_project/media/downloads/publications/WOO_2010.pdf.

Pacca, Sergio, and Jose R. Moreira. 2009. Historical carbon budget of the brazilian ethanol program. *Energy Policy* 37, no. 11 (November): 4863-4873. doi:doi: DOI: 10.1016/j.enpol.2009.06.072.

Rathmann, Régis, Alexandre Szklo, and Roberto Schaeffer. 2010. Land use competition for production of food and liquid biofuels: An analysis of the arguments in the current debate. *Renewable Energy* 35, no. 1 (1): 14-22. doi:10.1016/j.renene.2009.02.025.

Searchinger, T. D., S. P. Hamburg, J. Melillo, W. Chameides, P. Havlik, D. M. Kammen, G. E. Likens, et al. 2009. Fixing a Critical Climate Accounting Error. Science 326, no. 5952 (10): 527-528. doi:10.1126/science.1178797.

UNICA. 2011. UNICA-União da Indústria de Cana-de-açúcar. http://www.unica.com.br/noticias/show.asp?nwsCode={BD256852-25D4-4CDA-BD54-F47DDCD89A6A}.

Valor. 2001. Valor Economico Newspaper. Argentina troca Porsche por vinho. page B1. Monday, June 20 2011.

van Vliet, Oscar, Anne Sjoerd Brouwer, Takeshi Kuramochi, Machteld van den Broek, and André Faaij. 2011. Energy use, cost and CO_2 emissions of electric cars. *Journal of Power Sources* 196, no. 4 (2): 2298-2310. doi:10.1016/j.jpowsour.2010.09.119.

Endnote

[1] Toyota Prius efficiency assuming 19.55 km per liter of gasoline and assuming that ethanol engine efficiency is 75% of that of gasoline powered engine.

[2] Supporting online material for Campbell, JE Lobell, DB Field, CB Science 324(5930): 1055-57 (2009)

[3] http://www.agricultura.gov.br/arq_editor/file/MAIS%20DESTAQUES/IntercambioComercial2010.pdf