Executive Summary of the Project:

Sustainability of sugarcane-derived renewable jet fuel: life cycle GHG emissions and benchmark of major sustainability standards[1]

Presentation

The global concern with climate change, combined to the world dependence on fossil fuels, the higher prices volatility and the increasing uncertainties of oil supply, have motivated a growing interest for renewable energy sources, more particularly in the form of biofuels. This can be extended to the aviation sector, which faces few alternatives to the conventional fuels due to its dependence on liquid fuels with high energy density. According to IPCC (2007), estimates of CO_2 emissions from global aviation increased by a factor of about 1.5, from 330 $MtCO_2$/yr in 1990 to 480 $MtCO_2$/yr in 2000, and accounted for about 2% of total anthropogenic CO_2 emissions. As aviation CO_2 emissions are projected to continue to grow strongly, the use of biofuels has been encouraged, among other options, as a way to reduce the impacts on the climate.

Not differently from other industry initiatives for the adoption of biofuels in liquid fuel markets, an assessment of the GHG reduction potential and of the capacity of the supply chain to comply with sustainability standards are two concerns raised by the aviation industry. Biofuel producers are also strongly interested in both issues, like the aviation industry.

Sugarcane, which is one of the agricultural feedstock most extensively used in the fuel market, is probably the most efficient plant currently available in scale production capable of converting solar energy into biofuels. It is also the most fast paced agricultural-based feedstock in adopting sustainability requirements and with the highest GHG emissions reduction compared to fossil fuels. As a reference, the production facility considered in this study, capable of delivering approximately 90 million liters of renewable aviation kerosene (2 million tons of sugarcane crush), would support roughly 3% of São Paulo state's aviation kerosene demand, which in 2011 reached roughly 2,8 billion liters.

The results summarized in this document refer to the (i) first step of calculations on carbon footprint of biojet fuel derived from sugarcane according to Amyris process' parameters and to the (ii) benchmark of the three major sustainability standards available in the biofuels market and an analysis of the existing gaps in the sugarcane industry (sugar, ethanol and energy) to comply with the standards' principles and criteria.

Life cycle GHG emissions of biojet fuel produced from sugarcane sugars

This study has two general goals: to improve the scientific knowledge on the carbon footprint of a biojet fuel derived from sugarcane according to Amyris process' parameters and to disseminate the results for public debate with stakeholders interested in the issue of agricultural-based biojet fuel and biofuels sustainability.

Given that the methodologies to measure biofuels GHG emissions are still being improved, this project is tackling this issue in two steps. In the first step, for which the results are summarized here, the EPA approach (2010 Regulatory Impact Analysis, U.S. Environmental Protection Agency) is adopted as the main methodology. In the second step, GHG emissions will be calculated based on the CARB approach (2009 Low Carbon Fuel Standard, California Air Resources Board).

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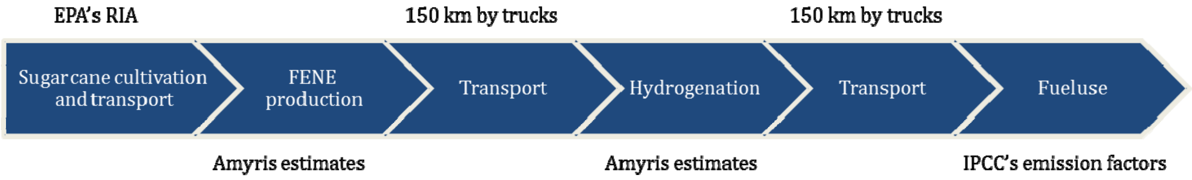
The results presented refer to the life cycle GHG emissions (in g CO_2eq/MJ) associated with the production of the Amyris biojet fuel, which is intended to be compliant with Jet A/A-1 fuel specifications. A cradle-to-grave approach was adopted, comprising direct and indirect emissions associated with cane production and fuel processing, distribution and use for a projected 2022 scenario, according to Amyris estimates provided for this study. Since detailed values for sugarcane production in Brazil are available in the EPA 2010 RIA, which already incorporates the direct and indirect effects of cane production, the emissions per tonne of cane were maintained for the purpose of this analysis.

The results revealed net life cycle emissions of around 15 g CO_2eq/MJ, which leads to mitigation around 82% of the GHG emissions considering fossil kerosene.

Farnesane is the molecule that will compose this biojet fuel. The technology pathway comprises the fermentation of cane sugars (to be available in a high concentration must) into farnesene (a hydrocarbon) using genetically engineered yeasts. The farnesene (FENE) forms a separate phase on the top of the fermentation broth, thus facilitating the subsequent recovery and purification. The FENE produced at the sugarcane mill is then transported to a hydrogenation plant where it is converted to farnesane, which is later transported to the airport fuel tanks. The figure below shows a schematic representation of the life cycle stages under study and the main assumptions.



Life cycle stages and assumptions

In the projected scenario all the energy required for FENE production would be supplied by the bagasse fueled cogeneration plant. Additionally, it was assumed that the biogas from vinasse biodigestion and 40% of the cane trash (as in the EPA's 2010 RIA) produced in the field would be used as fuels supplementary to bagasse in the cogeneration plant. For the cogeneration plant, a similar configuration to the current state-of-the-art high pressure systems was adopted, as these are equipping all new sugarcane mills in Brazil and several retrofitted units.

In the hydrogenation plant, H_2 provided from natural gas reforming is employed for the hydrogenation of FENE into farnesane. The reforming process involves an exothermic reaction whereby reactor cooling raises steam at 40 bar that is used to produce power in a steam turbine. The excess H_2 supplied to the FENE hydrogenation process is subsequently combusted in other processes, providing additional energy. Once converted, the farnesane-based fuel is ready for final transport/distribution and use.

The GHG emissions associated with sugarcane production and transport are largely dominated by farm inputs and (mainly) emissions of N_2O from the soil, as they account for more than 80% of the approximately 84 kg CO_2eq (~50.7 g CO_2eq/MJ of farnesane) that are emitted in the production of 1 tonne of cane. Practically the same applies to the biojet fuel – the avoided emissions due to the co-production of electricity at the FENE production stage accounts for about 46 g CO_2eq/MJ of farnesane, which leads to net life cycle emissions of around 15 g CO_2eq/MJ. Though the co-production of yeast also leads to emissions avoidance, its contribution is very small.

The sugarcane derived biojet fuel presents a substantial potential to mitigate the GHG emissions of the aviation sector considering the displacement of fossil kerosene. Based on EPA and Ecoinvent parameters, the biojet fuel would be able to mitigate around 82% of the GHG emissions, assuming that there will be no change on the jet engine technology.

Uncertainties associated to the estimations both on the sugarcane production and refining process naturally exist, especially because the study relies on projected performances for future scenarios. For sugarcane production the uncertainties are related to N_2O emissions and indirect land use effects. EPA evaluated the emissions derived from crop residues using the IPCC approach and assuming perennial grasses as a surrogate for cane (since the latter was not available in the IPCC guidelines). However, there is a substantial difference between the sugarcane and perennial grasses roots shoot ratios, which has possibly led to an overestimation of N_2O emissions from cane residues.

On the indirect land use effects, uncertainties are related to the several assumptions and parameters that are part of the economic models used: elasticities that govern land competition among agricultural uses, land supply elasticities driving the expansion of the agricultural frontier and native land conversion, intensification capacity especially in the case of pasture-fed cattle production, yields response to price changes and methods applied to estimate GHG emissions from land use changes.

In the refining process the amount of electricity surplus from FENE production also deserve attention. The electricity surplus from FENE production plays a special role in the biojet fuel life cycle and any variation in power generation leads to a substantial impact on the net emissions. It must be noted that the conditions assumed in this study are optimistic (but aligned with EPA considerations – e.g. 40% of residue collection) in terms of electricity exports, so lower power levels could be expected even with the adoption of advanced cogeneration systems.

Benchmark of cane-derived renewable jet fuel against major sustainability standards

This study was developed in order to understand the differences in the requirements of major sustainability standards for the production of biofuels and to understand the main challenges in the implementation of these standards in Brazil. The analyzed initiatives are Bonsucro, the Roundtable on Sustainable Biofuels (RSB), the International Sustainability and Carbon Certification (ISCC) and the Inter-American Development Bank Biofuels Sustainability Scorecard (IDB Scorecard), although the latter is a self-assessment tool rather than a certification. The assessment of the scorecard, therefore, was related to identifying the topics that it includes compared to the certification standards. The principles and criteria in the analyzed standards are mainly focused on environmental issues, such as GHG emissions, land use change and biodiversity conservation; and social issues, such as labor and worker health and safety. Some standards also have principles and criteria related to economic issues, such as production and processing efficiency. Throughout the process of developing this study, representatives from these initiatives were invited to provide feedback and suggestions on the analysis and methodology used.

The benchmark was carried out for the production and chain of custody standards, as well as for governance and system operations (including conformity and risk assessments) of the initiatives. The main differences were found to be in the way that each standard requires proof of compliance (evidence) with criteria, as well as in the governance structures, scope of the standards and system operations. The differences among governance structures are important, since they are related to the standard setting process and transparency protocol adopted by the standards and, therefore, to their legitimacy. Bonsucro and RSB are part of the ISEAL Alliance and follow the

ISEAL code of good standard setting processes, which should ensure that the standard setting process is transparent and involves multiple and relevant stakeholders. ISCC is not an ISEAL member and there are no public records of the standard setting process adopted. Although it was initiated by the German government, it is now managed by a multi-stakeholder process.

The criteria in the standards are generally similar. There are differences, however, in additional criteria included in RSB - related to GMOs, food security and ILUC - and in ISCC – related to food security. There are also important differences in the criteria and definitions related to high conservation value areas (HCVA) in the standards.

The gap analysis was carried out for Bonsucro, RSB and ISCC; although the last two have not been implemented in Brazil for sugarcane based biofuels production yet. ISCC only has chain of custody certifications for sugarcane based biofuels in Brazil. Interviewed groups included sugarcane mills already certified or in the process of becoming certified by one of these initiatives, intermediary companies and certifying companies. Both production and chain of custody standards were assessed to identify the existing gaps between the standards and current practices adopted along the supply chain, as well as the challenges in implementing these standards in Brazil.

The gap analysis revealed that the main bottlenecks for certification are related to its expansion. The implementation of sugarcane biofuel certification in Brazil has taken place so far only in producer-owned/managed areas and in companies/mills with established management programs, which facilitated the process. The expansion of certification to smaller producers and third party supplier areas will be a much greater challenge. Although the gaps vary among the standards, there is a very important gap that is common to all related to compliance with some points of the Brazilian legislation, especially environmental (Forest Code), labor (overtime, shifts and breaks) and worker health and safety (NR-31). This problem is common to the entire agricultural sector in Brazil. Many producers are in the process of becoming compliant with the law, which is an important first step that is generally accepted by the certifications. Another important gap identified, also related to compliance with the law, is that of necessary structural adaptations, especially in mills with older plant configuration.

There are other gaps that go beyond the law, especially related to the interpretation and implementation of certain criteria, such as HCVA, ILUC and food security. The requirements of these criteria are not clear and there is uncertainty regarding how they will be implemented in Brazil. Other gaps, such as formal communication with stakeholders are less complicated and more a matter of organization.

The main difference among the standards is that the Bonsucro production standard has already been implemented in Brazil for sugarcane based biofuels, while RSB and ISCC have not. Therefore, while Bonsucro's gap is for the expansion of certification, the others are for the implementation of the certifications.

In addition to identifying gaps between the contents of a standard, it is critical to choose a standard based on good governance. Not all standards are governed or audited in an equal fashion. A quality standard is created through a transparent, multi-stakeholder process representing the full value chain and civil society. After such a credible standard setting process, the auditing process must be rigorous and capable of demonstrating thorough analyses of the relevant processes and data as well as thorough interviews with relevant stakeholders, such as field laborers. Currently, not all standards in the marketplace fulfill the credibility criteria of multi-stakeholder development processes and robust auditing. ISEAL is a good reference point to determine such credibility.