CHAPTER 9

APPENDIX

9.1 BOX 1. CASSAVA – BASED ETHANOL INNOVATIVE PROJECT

Colombia is highlighted in the LAC region by its efforts in cassava processing. Since 2005 two Colombian firms De Sargo and Central Sicarare have set a common plant located in Codazzi (Department of Cesar, North West of Colombia) being the pioneer to transform cassava starch into ethanol. Clayuca and CIAT have just inaugurated, on July 22 nd of 2, a new cassava–based ethanol processing plant, located in Palmira (on the Cauca Valley).

This project is still in an intermediate stage because, albeit all the facilities are ready to be used, it is a small scale pilot that will be studied in order to be implemented in different localities of the country. It is characterized by its low costs and flexibility, because it is able to operate with sorghum and yam (or sweet potato).

By now, this is a "Social Ethanol" proposal intended to become a development vector for sustainable energy for rural populations that lack connection to the electricity distribution grid and that have a high degree of dependence on fossil fuels.

Financial support came, in the initial stage, from the Colombian Ministry of Agriculture, however the final technical developments were carried out by the Brazilian entities: Universidad Federal de Rio Grande do Sul and Usinas Sociales Inteligentes (Social Intelligent Large Factories). The production capacity of this plant is between 400 and 500 liters of hydrated ethanol per day. This sort of ethanol allows operating a power generator to produce electricity at 110 and 220 volts. It requires 4 liters to generate one hour of electricity.

Despite firewood use being not very extensive among Colombia territory, it is still an important energy source for isolated rural areas, so the project tries to encourage its reduction, and consequently deforestation and offers cooking alternatives in ethanol-based stoves, diminishing smoke indoors. Some other production efforts are attractive around cassava: The firms Desaro and Petrotesting from Colombia are doing research since 2003 in order to use cassava as feedstock for ethanol production. They started using 25 different kind of cassava and finally selected the 5 most productive, with a yield of 30 tons/ha however the goal is to get 40 tons/ha. Having in account that the yield interval is between 180 and 200 liter per ton it will produce approximately 8 thousand liters per year in the best scenario.

Note: Clayuca is a consortium dedicated to support research and development related with cassava (known as yucca in some countries) applications in LAC region. It has 13 country members: Colombia, United States, Venezuela, Ecuador, Peru, Mexico, Nicaragua, Costa Rica, Haiti, Cuba, Nigeria, South Africa and Ghana. For further information see: www.clayuca.org. (See: El Pais Newspaper, 2009; Eneas, 2006)

9.2 BOX 2. US – COLOMBIA BIOFUELS TRADE THROUGH A FTA: A TEMPORARILY OBSTRUCTED POSSIBILITY

Mathew Rooney, Director of US Economic Policy of State Department explained that his country is expected to consume 36 billion gallons of biofuels by 2022, which is based on possible imports from producer countries like Brazil or Colombia(Guzman, 2009).

Colombia government was highly interested in building commercial bridges with the US so the pursuit of a Free Trade Agreement (FTA) became a priority under Uribe Vélez administration. The final document was written in 2006 and approved in the same year by Colombian Senate, nonetheless some concerns related with HHRR violations delayed the approval from the ongoing US Senate, and so the agreement had not come into force.

For biofuel dynamics, a bilateral accord between Colombia and US in a is a possibility of improvement for both countries, because it represents, for the former, a great opportunity to expand international demand, based on "20 in 10" policy established under G.W. Bush administration and it means, for the latter, additional supply of ethanol and biodiesel which allows to reduce the amount of oil imported form Middle East and Venezuela.

However, there are several arguments that have darkened the implementation of such a pact, despite it has been finally approved: as is seen as a threat to food security. In previous agreements as The Andean trade preference program in 1991 the trend was to export food rather than to provide for local markets (Camastra, 2008); b. It is designed to open markets but in an unfair way: The FTA requires that Colombian agriculture remove tariffs and subsides, while US agriculture remains heavily subsidized (Carnoval, 2009); c. Some indigenous and African-Colombian communities are endangered if FTA is enacted. Democrats in the US senate considered disapproving the FTA with Colombia based on information that accuses Multinationals and Large landholders to use paramilitaries forces, under government indifference, to threat and displace rural population in order to establish some development projects. This was added to the fact of the murders of indigenous, Union and co-ops leaders (Camastra, 2008; Carnoval, 2009); d. Biofuels in particular have not been not part of the discussed agreement: Energy is not part of the executive summary in the proposed document (Hopkins, 2008); the closest approach to bioenergy would be just agricultural commodities without added value.

Note: In 2007 U.S. president G.W Bush gave a new proposal to cut U.S. gasoline usage by "20% in 10 years", to be accomplished primarily by mandating higher proportions of alternative fuels and increasing the fuel efficiency standards for cars and light trucks. (Oxford Analytica, 2007)

9.3 BOX 3. EVICTION PROCESSES: RECENT HISTORY IN COLOMBIA

Some lands left behind by displaced population are currently abandoned. Others contrarily, are occupied by third parties, that could be people that have acted in good faith, as displaced peasants from other regions; but there is presence of bad faith occupants, as paramilitary groups, straw men, and some agribusiness companies. Some hectares have changed their owners due to illegal pressures or fraudulent administrative procedures, and now belong to straw men or have been sold to third parties.

According with Ministry of Agriculture there are several kinds of dispossess that have been identified in the country: Forced transfer of the ownership, fake sales, administrative caducity, forced displacement of the owner, and force displacement of occupants and landholders.

This situation has been facilitated by a high informality in the land tenure in Colombia. This is result of both a slow action from the government to allocate uncultivated land to settlers and generalized practice of no registering property documents in The Register of Public Instruments, in order to shun administrative costs or simply because of the discrete role of paper and bureaucracy culture among rural areas.

Just 18% of total displaced population is officially recognized as a formal owner of the abandoned land.

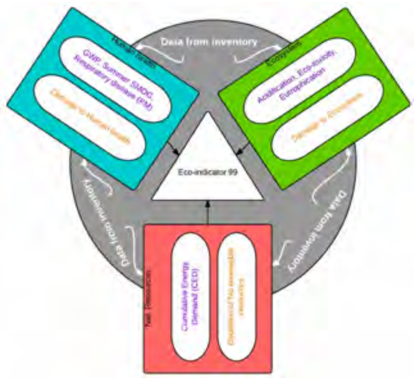
The rest of them do not have a legal ownership, so are catalogued as occupants or landholders. With this background, it turns to be quite complex to advocate for reallocation of land or relocation of population if legal documentation is not in order.

"We are small farmers without land and we see how common savannas that we worked in are fenced off and packed with palm oil and livestock. These lands that allegedly could not be entitled to farmers and fishermen, were now allocated to palm oil producers".

Macro-projects have influenced the loss of collective territories, according to Colombian General Lawyer's Office report, and argue that indigenous people have loss territory because of natural resources exploitation projects that have been implemented without consultation. This institution also reports that illegal armed groups threaten, intimidate, murder and displace managers, leaders and other members of small communal councils and indigenous reservations who oppose illegal crops (coca, poppy and marihuana) or development projects in collective territories.

9.4 ENDPOINT AND MIDPOINT INDICATORS

In order to assess the impact of a particular product on the environment, some midpoint indicators are quantified; i.e. eutrophication, acidification, summer smog and eco-toxicity. Later on these categories are related to endpoint-oriented, such as Human health, Ecosystem and Natural Resources.



Purple font corresponds to midpoint indicators and orange font to endpoint indicators

Regarding ISO 14040, LCIA (Life cycle impact assessment) is developed though two mandatory steps (classification and characterization) and two optional steps (normalization and weighting). In a first step were selected those indicators that are relevant for this study. Category selection must reflect a set of environmental aspects related with the studied production system, taking into account target and scope. Impacts created by biofuels are not limited to potential global warming effects, but also include impact on the ecosystems, on humans and on resources (Searchinger et al., 2008). For this particular study were selected those indicators (endpoint and midpoint) more employed by the scientific community (See figure above).

Classification results as an exercise of evaluating the contribution of every substance to each environmental problem. Afterwards, through a characterization mechanism emission impacts are modelled. Cause-effect mechanism is based on models of destination, exposure and effect. Impact is expressed as an assessment of impact in a common unit to all the contributors to the impact category (e.g. kgCO2 equivalent per GHG that contributes to CC category) through the implementation of characterization factors. A characterisation factor is a specific factor of a substance calculated with a characterization model to express the impact of the elemental flow (expressed in terms of the common unit mentioned above).

As alternative, different characterized impact assessments are related to a common reference in a process of normalisation. For instance the common reference can be the impacts caused by a person during a year, and this would ease the comparison between categories. A weighting of these environmental impact categories is applied, unveiling the importance of those impacts considered within the study.

In this document were used the following midpoint categories, given their international acceptance and wide implementation: (CML (Centre of environmental Science)(Guinée, 2001), Eco-indicator 99 (Goedkoop & Spriensma, 2007), CED (Cumulative Energy Demand) (Hischier et al., 2010)).

Methodology for Impact assessment CML
Explanation for those categories used in this section is found in this link
http://media.leidenuniv.nl/legacy/new-dutch-lca-guide-part-2a.pdf.

Characterisation values are listed in
http://media.leidenuniv.nl/legacy/new-dutch-lca-guide-part-2b.pdf

Indicator	Abreviation	Units	Comments	Reference
Eutrophication	EUTRO	Kg PO4 eq	It includes all impacts due to excesive levels of macronutrients within the environment caused by emission of nutrients to the air, water and soil	CML
Acidification	ACID	Kg SO4 eq	It includes a great deal of impacts in soil, aboveground and underground water, ecosystems and materials	CML
Eco–toxicity	ETOX	PAF m2yr	Potentially affected fraction (PAF). It is assessed based on toxicity data of terrestrial and water organisms (it covers microorganisms, plants, algae, amphibians, worms, mollusc, crustacean and fish)	EI99
Photochemical Oxidation	SMOG	kg C2H4 eq	Formation of reactive substances (particularly ozone), which turn to be hazardous to human health, environment and crops.	CML
Respiratory diseases	MP	DALY (disability adjusted life years)	Inclusion of PM10,PM22, PST, NOx, CO, VOCs and Sox	EI99

Midpoint indicators were calculated by use of models relatively robust, hence there is less uncertainty in comparison to endpoint methods. In contrast, endpoint indicators draw the relative importance of extraction and emission from LCA inventory and that sort of information is easy to process by decision–makers.

Methodology for Impact assessment Eco-indicator 99
All the explanation regarding classification of impact categories (midpoint)in terms of effect on human health, ecosystems and resources and its corresponding normalisation and weighting until a final point (Environmental impact point) are located in http://www.pre.nl/content/reports.

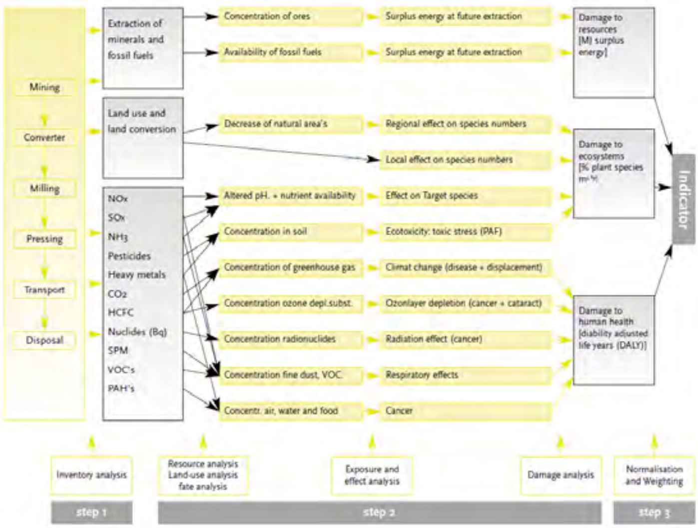
The goal of the Eco-indicator 99 is to provide a holistic evaluation of the impact on the environment based on a broken down perspective. Thus, the starting point was to define "environment". This was carried out with a panel of European scholars, experts in LCA, where there were identified three protection areas (Human health, ecosystem and natural resources); which are described as follows:

Human health: this category includes the number and duration of diseases and losses of labour days due to premature death due to environmental issues. The damage to human health is expressed in DALY (disability adjusted life years) and the effects that are taken into account are: CC, ozone layer depletion, carcinogenic effects, respiratory effects and ionizing radiation.

Ecosystem quality: under this category is covered diversity of species, particular vascular plants and inferior organisms. Deterioration of the ecosystem quality is expressed as a percentage of disappeared species in a particular area due to the environmental burden and the effects of eco-toxicity, acidification, eutrophication and land use.

Natural resources: this category contemplates the excess of required energy in the future in orter to achieve minerals and fossil fuels of a minor quality. Damage is assessed as the extra energy required for future extractions. Depletion of agricultural resources and bushels of sand and gravel are included in land use.

The figure below presents an explanation of the damage model



Source: (Ministry of Housing & environment, 2000)

As it is indicated in the figure above, these three protection areas can be weighted among them to obtain a single added score. Weighting factors employed in the Eco-indicator 99 come from a panel of experts in LCA. There are some other endpoint methodologies (such as EPS 2000, and ecological scarcity), nevertheless; eco-indicator 99 is widely accepted between scholars internationally. Result indicate that members of the panel found that the damage on human health is as important as the one caused to the ecosystem, whereas damage of natural resources possess a an mid level importance.

Weighting of protection areas depend on personal preferences and therefore it is not representative. Furthermore, mechanisms to assess damage are adapted to European environmental conditions and might not be suitable for Colombian conditions. Nonetheless, the advantage in the Eco-indicator is that all results are summarized in one single score, which eases decision-making process. Therefore, the implementation of the Eco-indicator 99 with several midpoint indicators is fully justified if results are discussed and analysed properly. LCA calculations were carried out with Simapro v7.2 (PRé Consultant, 2010).

Limitations of the study

Assessment of environmental impacts in the life cycle usually requires of a great deal of information and assumptions in the model. Through real data collection in field for every stage of the life cycle and based on the state of the art in the emission models was tried to achieve maximum precision in the numbers.

Notwithstanding, this methodological approach has limitations, given that there is no LCA adapted for the Colombian conditions. By default in this exercise were used the indicator standardized for the European case and it is expected to implement adjustments in future research endeavours, given that current results of total environmental impact might be indicative but need to be analysed critically.

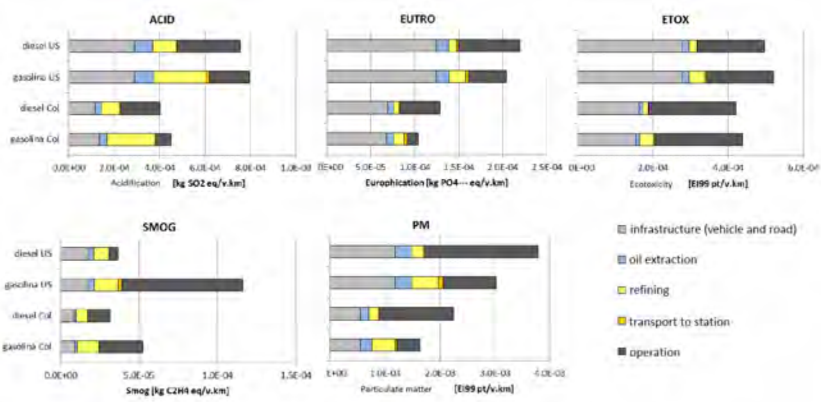
Results of endpoint and midpoint indicators are presented for fossil fuels, sugarcane-based ethanol and palm oil-based biodiesel:

Fossil fuels

Midpoint indicators

The figure below shows environmental impacts for a standard vehicle for Colombia and California. In general the LCA indicates a higher impact in the Californian case, given that usually the life span of these vehicles in Colombia is longer, creating a lesser effect on the infrastructure aspect (grey bar).

Figure 9.1. Comparison between standard vehicles (California vs Colombia)

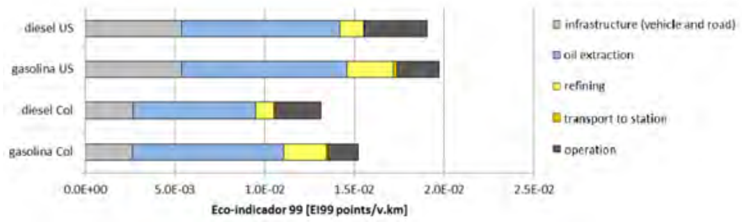


If gasoline and diesel are employed in a similar vehicle, impacts do not differ significantly, except for PM and SMOG. In general, vehicles that are powered with diesel create a higher amount of emissions that those powered with gasoline, due to an incomplete combustion. SMOG results are due mainly to carbon monoxide. Given those uncertainties in the Eco-invent inventory for international data, impact of diesel in the American case seem to be underestimated. In the case of Colombia, data have been verified and adapted for this study and results are reliable.

Aggregated environmental impact

Total environmental impact (assessed with the eco indicator 99) is larger (per driven km) in US than in Colombia (145% for diesel and 130% for gasoline). As it was previously discussed an explanation is the lifespan of the vehicles and that fuel consumption and emission flows are more favorable in the Colombian case[I] (in comparison with the international fleet).

Figure 9.2. Total environmental impact. Comparison between vehicles in California and Colombia



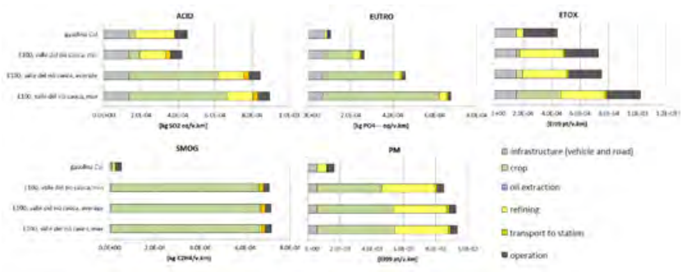
As is it shown in the chart above, this higher environmental impact is due to extraction of crude oil by depletion of non-renewable resources. The higher impact on oil refining is related to a higher consumption og energy per MJ of fuel compared to diesel.

Results of sugarcane-based ethanol and palm oil biodiesel

Midpoint indicators

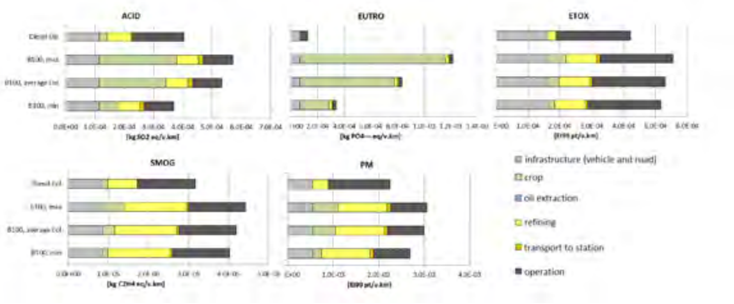
If GW is left aside, both Et-Oh and biodiesel exhibit a higher level of impact in comparison to its fossil counterparts, in terms of environmental indicators. Most of them take place in cultivation stage.

Figure 9.3. Environmental impacts for ethanol



[I] RenaultLogancomplieswiththeEuropeanemissionstandardsEURO4.

Figure 9.4. Environmental impacts for biodiesel



Impact in acidification and eutrophication is caused mainly by emission in the crop by use of fertilizers (ammonia and phosphates). Eco-toxicity is due to heavy metals employed in fertilizers, burnt fuel and tires' wearing (mainly zinc), causing soil and atmospheric pollution.

Summer smog and respiratory diseases can be caused by a frequent practice in sugarcane cultivation which is the pre-harvesting burning process (in the case of palm oil this phenomenon come from the production and use stages). For ET-OH there is no consensus on the net effect of such practice on human health: while some studies show indicate that there is no significant effect on the local population (Jose Goldemberg, 2007), whereas some other studies unveil negative effects on children and elderly people, due to respiratory diseases (Nicolella & Belluzzo, 2011). Within this study the PM effect due to pre-harvesting burning task is assumed in low density areas in terms of population. In ethanol production stage is possible to assume that the biggest impact is given by PM and NOx due to bagasse combustion (for ethanol) and cogeneration (for biodiesel).

Environmental aggregated impact

As it is observed in the figures below, the impact of ethanol and biodiesel (in environmental terms) is higher than fossil fuel (141% and 143% correspondingly). Cultivation stage is the major contributor to global environmental impact and it is caused by impact on human health (caused by PM in the pre-harvesting burning) (35% of the Eco-indicator). In addition some land does not allow natural vegetation regeneration, contributing to 50% and 70% to the global impact (for ethanol and biodiesel respectively).

For biodiesel, the remaining impact is created by heavy metal emissions (close to 10 to 20%) and fertilizers production (approx. 10%).

For ethanol the main environmental burden can be explained by NOx and PM emissions by bagasse combustion. In the case of biodiesel fiber and shells combustion is the cause of the aforementioned.

Figure 9.5. Total environmental impact (Eco-indicator 99) for sugarcane-based ethanol

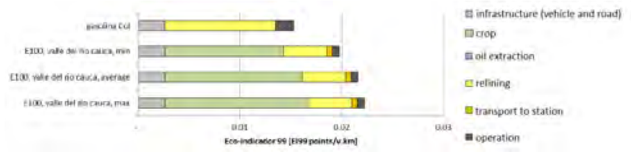
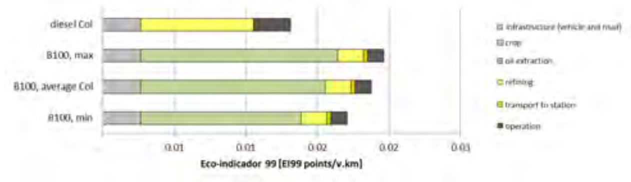


Figure 9.6. Total environmental impact (Eco-indicator 99) for palm oil-based biodiesel

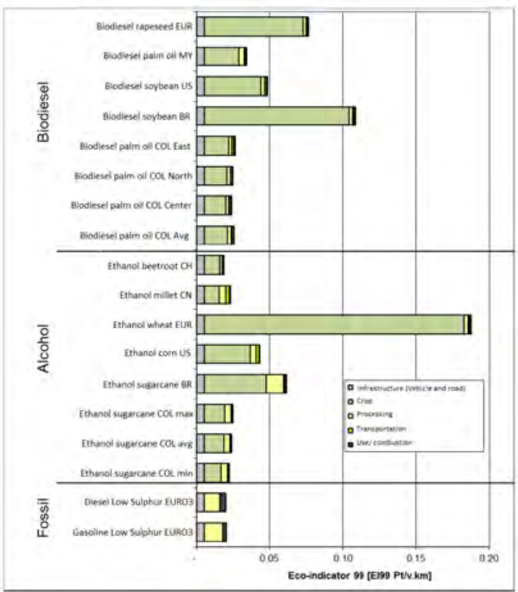


Impact values

Values for the information presented formerly for both bioethanol and biodiesel indicators are related below:

Table 9.1. Midpoint and End point indicators for sugarcane-based ethanol and palm oil biodiesel

	Indicator	ACID	EUTRO	ETOX	SMOG	MP	EI99
Gasoline	Units	kg SO2eq/v.km	kg PO4-eq/v.km	PAF*m2yr/v.km	kg C2H4eq/v.km	DALY/v.km	EI99 points/v.km
	E100 Col, max	8.94E-04	6.79E-04	7.72E-01	7.16E-04	3.55E-08	2.22E-02
	E100 Col, avr	8.44E-04	4.59E-04	3.20E-01	7.15E-04	1.42E-08	2.15E-02
	E100 Col, min	4.22E-04	2.63E-04	2.18E-01	7.07E-04	1.16E-08	1.97E-02
	Gasoline	4.49E-04	1.04E-04	1.44E-01	5.25E-05	8.06E-09	1.52E-02
Diesel	Indicator	ACID	EUTRO	ETOX	SMOG	MP	EI99
	Units	kg SO2eq/v.km	kg PO4-eq/v.km	PAF*m2yr/v.km	kg C2H4eq/v.km	DALY/v.km	EI99 points/v.km
	B100 min	3.69E-04	3.41E-04	7.47E-02	4.02E-05	9.16E-09	1.71E-02
	B100 avg	5.35E-04	8.34E-04	1.46E-01	4.19E-05	1.09E-08	1.88E-02
	B100 max	5.72E-04	1.22E-03	2.00E-01	4.43E-05	1.12E-08	1.96E-02
	Diesel Col	4.04E-04	1.29E-04	1.42E-01	3.17E-05	8.27E-09	1.31E-02



While the Colombian vehicles were adapted to the EcoInvent inventory standard vehicle, the other biofuels were taken from Zah et.al. (Zah et al., 2007).

The main goal of a LCA is providing an assessment of the environmental impact of the more important biofuels within the Colombian context (sugarcane ethanol and palm oil biodiesel). Likewise is very important to build a comparison in reference to traditional fossil fuels (gasoline and diesel). The average environmental impact was compared to international sustainability standards, which provide a first approach on the potential of the Colombian biofuels as a good for international trade. In addition, critical and sensitive factors which take part in the environmental performance are defined and assessed in order to create plans of action and improvement.

Average environmental impact assessment of Colombian biofuels is based on data from those fields where the feedstock is produced. Data was contrasted and complemented by experts and literature review, and the EcoInvent database.

Sugarcane-based ethanol

¿What is the total environmental impact for the Colombian sugarcane-based ethanol?

The aggregated environmental impact of bioethanol- assessed with the Ecoindicator 99–is slightly higher than regular fossil gasoline (141%). Cultivation stage is the major contributor to the total environmental impact and it is mainly caused by the effect on the human health due to emission of particulate matter released by the pre-harvesting burning process (35% of the Ecoindicator 99), and the land use that avoid regeneration of natural species. In comparison with some other biofuel from elsewhere around the world, Colombian biofuels exhibit attractive performance and they are considerably favorable.

Nonetheless, it is important to remark that this indicator was built based on European conditions and the assessment has not been adapted for the Colombian conditions. Thus, this study could work as a comparative reference, but requires a proper fine tuning This could be the start of future research that establish adapted inventories.

¿What is the scope of impact of Colombian ethanol?

Biofuels exhibit some other environmental impacts, which are not shared by traditional energies, as contrarily occurs with GHG's and Non-renewable energy cumulative demand. Extraction of crude oil and further refining are relatively simple and create less impacts regarding eutrophication, acidification in comparison to biofuels.

These impacts of biofuels occur mainly in the cultivation stage, due to the need of large extensions of land and several production factors such as machinery and fertilization. Fertilizer production is energy intensive and the crop itself is accompanied by several emissions (ammonia, nitrates, phosphates, heavy metals), therefore quality of land, air and water are affected (acidification, eutrophication and eco-toxicity).

Additionally, the pre-harvesting burning has a significant impact on the air quality and it might affect the quality of the environment as a whole and of course human health (by smog and particulate matter). Is not conclusive the effect on human health on the nearby population: whereas some authors argue that there is no evidence of harm on the locals (Jose Goldemberg, 2007), some other authors disagree and explain that such practice affects in major extent to elderly people and children due to respiratory diseases (Nicolella & Belluzzo, 2011).

However, these environmental impacts depend highly on the sensibility of the environment and therefore they have a local scope. As there is no impact assessment methodology created specifically for the Colombian case, European models were employed.

Biodiesel

What is the environmental impact of Colombian palm oil based biodiesel? The aggregated environmental impact of Colombian palm oil-based biodiesel –assessed with the EcoIdicator 99— is higher that is fossil equivalent (by 143%). As in the case of ethanol the cultivation stage, of palm oil-based biodiesel is the major contributor to total environmental impact and it is caused by land occupation, which avoids regeneration of natural vegetation (approximately 70% of the impact) and fertilization (approximately 20% of the impact).

As it was mentioned before, the indicator is based on the European environment and the impact assessment has not been adapted to Colombian conditions.

Values are related to reference fossil fuels (which has been valued as 100%). Green area means lesser emissions of GHG and minor impact and minor environmental impact in comparison to gasoline (Biofuels adapted to Ecoinvent standard vehicle, other type of biofuels brought from Zah et al 2007).

¿What is the scope of impact of Colombian biodiesel?

Some other environmental indicators, in addition to GHG emissions and Non-renewable energy cumulative demand, were taken into account, and they showed that biofuels have higher impacts than regular fossil fuels. Production of fertilizers is particularly energy intensive and the emissions that come from the crop (such as ammonia, nitrates, and heavy metals) disturb the quality of air, water and soil (impacts on acidification, eutrophication and eco-toxicity). Summer smog is mainly caused by emissions from biofuels within processing and using stages (COx and SOx). The main impact that emerges from biofuel production regarding PM is associated with NOx from the cogeneration process.

As it was mentioned, these impacts hinge on the sensibility of the environment and therefore they are a reflection of a local phenomenon. As there is no specific methodological approach to assess environmental impact and neither designed for the Colombian conditions, this study is supported on European models. Indicators such as GWP and CED can be used, but some other indicators must be interpreted with caution.

Final conclusions

In addition to GHG and Nonrenewable energy cumulative demand, some other environmental indicators are considered. Based on this information it can be established that biofuels have some impacts that are not present in regular fossil fuels. Impacts on acidification, eutrophication and eco-toxicity are caused mainly by use of fertilizers and pesticides. These negative impacts can be mitigated through the implementation of good agricultural practices and the use of alternative treatments, such as, organic controls of insect and pests. In such sense agricultural research and land management result crucial to achieve better results regarding environmental performance. Cenicaña and Cenipalma, along with the Ministry of Agriculture, have an important role to play within the Colombian context.

Results of the ecoindicator 99 show the midpoint assessment, indicating that biofuels in general create a higher environmental stress in comparison to regular fossil fuels. Even though, the midpoint methodology is not adapted to Colombian conditions, it is important to analyze beyond GWP and Cumulative Energy Demand, and look to other environmental aspects.

9.5 WASTESON LAND (SUGARCANE)

Deposits of heavy metals are calculated as the balance between the input of heavy metals due to fertilization and output due to dirt remotion (Jungbluthetal.,2007). The emission by account of pesticides is presented as follows:

Table 9.2. Residuals to the ground by pesticides and fertilizer application (kg/kg of sugarcane)

Parameter	C001	C002	C003	C004	C005	C006	C007	Averange
Cd	2,30E-10	2,00E-10	3,40E-10	3,50E-10	3,60E-10	3,60E-09	7,30E-09	1,10E-09
Cu	1,70E-08	3,60E-07	6,40E-09	6,20E-09	4,30E-09	1,60E-06	2,30E-06	5,10E-07
Zn	1,60E-07	2,30E-06	8,30E-08	7,50E-08	6,80E-08	9,60E-06	1,20E-05	3,00E-06
Pd	3,70E-09	7,30E-09	4,00E-09	9,10E-10	3,60E-09	5,40E-08	1,20E-07	2,30E-08
Ni	1,30E-08	2,90E-08	6,70E-09	6,30E-09	6,00E-09	1,40E-07	3,20E-07	6,40E-08
Cr	8,90E-09	2,00E-08	4,10E-09	3,80E-09	3,40E-09	1,20E-07	8,40E-06	8,10E-07
Hg	3,40E-18	2,50E-09	0,00E+00	0,00E+00	0,00E+00	1,30E-08	1,60E-08	3,90E-09
Glyphosate	0,00E+00	2,60E-08	2,70E-08	3,50E-08	2,90E-08	6,00E-08	8,90E-08	8,90E-08
Sulphur	0,00E+00	1,60E-04	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Roundup	0,00E+00	0,00E+00	0,00E+00	1,10E-07	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Ametryn	4,90E-08	4,90E-08	2,70E-08	3,20E-08	2,70E-08	0,00E+00	0,00E+00	0,00E+00
Diuron	1,20E-07	0,00E+00	3,00E-06	1,70E-07	3,00E-06	1,50E-10	1,80E-10	1,80E-10
Terbutryn	5,10E-06	6,20E-06	5,40E-06	6,40E-06	5,40E-06	0,00E+00	0,00E+00	0,00E+00
2,4–D	5,10E-09	4,30E-09	3,70E-09	4,40E-09	3,70E-09	5,50E-09	6,70E-09	6,70E-09
Sodium, hypochlorite	0,00E+00	1,50E-06	0,00E+00	0,00E+00	0,00E+00	2,10E-06	2,50E-06	2,50E-06
Atrazine	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	1,80E-07	2,30E-07	2,30E-07
Hydrocarbons, aliphatic, chlorinated, alkanes	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	2,30E-07	2,80E-07	2,80E-07
Fluazifop	0,00E+00	0,00E+00	4,60E-08	6,00E-08	5,00E-08	0,00E+00	0,00E+00	0,00E+00

Source: CUE based on emission models

9.6 DESCRIPTION OF THE STAGES IN THE SUGAR PRODUCTION PROCESS IN THE SUGAR MILL (INGENIO)

Process	Description
Receipt and preparation of sugarcane	Arriving sugarcane is weighted and led to the loading place, where cranes put it into wagons or baskets, to be further directed to the preparation zone
Preparation and milling	Sugarcane is led by a system of conveyor belts to the cutters and fiber-breaking machines. This equipment works by the power of steam turbines or electricity, and it have high speed spinning knives, and under them it is a layer of sugarcane, which is fractioned in Preparation and order to ease juice extraction. Prepared sugarcane arrives to the milling tandem, which is milling formed by 6 crushers of 3 or 4 weights each. Such weights are metal rollers and the sugarcane layer passes through them, and by use of pressure juice is extracted. These crushers can be driven by steam turbines or electricity. Water is added to sugarcane along the way, hence sucrose is extracted from the fibers.
Steam generation	Resulting bagasse, which comes from the last milling section is fed to the boilers and it is used as fuel for creating high-pressure steam. This steam is employed in the turbines and in the preparation equipment, as well as in the turbo-generators used for electricity generation to feed the processing facilities (surplus is sold to public energy grid). Exhaust steam is employed in evaporation and juice heating processes. Heating and juice clarification The juice extracted from mills is weighted on scales. Subsequently it is sulphatized, and lime is added, in order to put contaminants away, and it is heated with vegetable steam in interchangers up to 102-105°C. Once the juice is alkalized it goes through a tank where some gases (non-condensable) are released. Afterwards juice is fed to clarificators, where insoluble solids are separated from the juice, in a decanting process, with a mud like substance as the output product.
Filtration	Muds go through a sucrose recovery process by way of filtration. Resulting juice is returned to the process and it is mixed with the juice that comes directly from the mill.
Evaporation	Clarified juice is received in the evaporators, with a content of solids (15° degrees brix), it is concentrated up to 60°-70° brix. This concentrated juice is called "meladura" (honey like kind of substance). Evaporation station has between 4 and 6 stages where juice is reduced to sucrose content as the process progresses. This substance goes through a "meladura" clarification process as well.
Crystallization and centrifugation	The sucrose embedded in the meladura is crystallized, and it is oversaturated, by effect of the evaporation process. Resulting material has a liquid part (honey) and a solid part (sugar crystals) called "cooked mass". Crystals are separated from honey by centrifuges. During the centrifugation process, sugar is washed with hot water or steam to remove the honey layer that covers these crystals and afterwards honey is taken to dryers. This process is applied three times and only then an exhausted honey is obtained (called "Honey C" or "Miel C"), which is used for animal fodder. In those sugar mills associated with ethanol processing plants, only two crystallizations take place and the by-product (Honey B or Miel B) is sent to the distillery as raw material for alcohol fuel production.
Drying	During the drying process the excess of moisture is taken away by way of hot air, with the purpose of complying with international quality standards. Right after, sugar is packed.
Sugar refinery	Refined sugar manufacture requires raw sugar to feed the process. Raw sugar is dissolved in water, making a syrup-like substance, which is filtered in DSM sieves in order to take away insoluble residuals. Later on, it goes through a clarification process, and afterwards it undergoes a de-coloration by using active carbon. Clarified and discolored syrup goes through crystallization, centrifugation and drying process, obtaining refined sugar
Transportation from the sugar mill to ethanol production plant	Transportation of the honey B is carried out by use of pipelines between the sugar mill and the ethanol distillery facilities.

Source: Cenicaña website

9.7 TRANSPORTATION DISTANCES PER EVERY 100 TONS OF SUGARCANE

Item	Transport by truck > 28t(km)	Quantity (tons per 100 of sugarcane)
Sugarcane	23,27	100
Lime	493,7	0,08
Flocculant	33,3	0
Sulfuric acid	184,7	
Sulphur	448,3	0,01
Water	0	57,55
NaOH, Sodium hydroxide	30	0,02
Biocides	620	0
Surfactant	620	0
Charcoal	24	1,4
Total	2405.6 ton–km	

Source: CUE based on data field

9.8 EMISSIONS PER 1 KG OF BAGASSE COMBUSTION AND PER EVERY 100 TONS OF SUGARCANE (KG UNLESS INDICATED OTHERWISE)

Substance	Quantity per 100 ton	Quantity per kg of bagasse
Residual heat (MJ)	1000000	5,8
Carbon dioxide	120000	0,71
Nitrogen oxide	4900	0,0002
Particles, < 25 µm	2500	0,0001
Biogenic carbon monoxide	390	0,000016
Biogenic methane	24	0,00000018
NMVOC, different methane compounds of volatile organic, no specified origin	34	0,0000014
Sulphur dioxide	140	0,0000056
Monoxide of di-nitrogen	130	0,0000052
Acetaldehyde	3,4	0,00000014
Aliphatic hydrocarbons to alkanes, unspecified	51	0,0000021
Aliphatic hydrocarbons, unsaturated	170	0,000007
Arsenic	0,056	2,3E-09
Benzo(a)pyrene	0,028	1,1E-09
Benzene	51	0,0000021
Br	3,3	0,00000014
Ca	330	0,000013
Cd	0,039	1,6E-09
Cl	10	0,00000041
Cr	0,22	8,9E-09
Cr VI	0,0022	9E-11
Cu	1,2	0,00000005
Dioxins, assessed as 3, 7, 8 tetrachlorodibenzodioxin-p-dioxin	0,0000017	7E-14
Ethyl benzene	1,7	0,000000068
F	2,8	0,00000011
Formaldehyde	7,2	0,00000029
Hexachlorobenzene	0,0000004	1,6E-14
Hg	0,017	6,8E-10
K	1300	0,000053
Mg	20	0,00000081
Mn	9,5	0,00000039
Na	72	0,0000029
Ammonium	97	0,0000039
Ni	0,33	0,000000014
P	17	0,00000068
Polycyclic aromatic hydrocarbon	0,61	0,000000025
Pb	1,4	0,000000056
Pentachlorophenol	0,00045	1,8E-11
Toluene	17	0,00000068
m–xileno	6,7	0,00000027
Zinc	17	0,00000068

Source: CUE based on data field

9.9 DESCRIPTION OF THE ETHANOL MANUFACTURE PROCESS

Process	Description
Raw materials	Raw materials for alcohol manufacture are clarified juice, honey B or “miel B” and “melaza”, and they all come from the sugar refinery
Fermentation	Fermentation for producing sugarcane-based ethanol is a microbiologic process, in which the sugar embedded in the raw materials are turned, by way of yeast application, into ethanol and carbonic gas (CO2). Fermented “must” or wine that comes from the final fermentation equipment is taken to a sedimentation tank where yeast decants, goes out from the bottom and goes to the yeast activation tank, whereas the liquid known as wine is sent to distillation process.
Distillation	This type of wine has alcohol diluted in water and some other impurities that must be separated from the alcohol through distillation process. This process takes advantage of the boiling temperature of ethanol that is below the boiling temperature of water, hence those vapors of alcohol leave from the upper part of the must column, whereas the lower part releases vinasses, which is residual made out water and some contaminants. Those vapors, in the first column, contain near to 45% alcohol and they are sent to a rectification column, to get 95% alcohol in the upper part. In the lower part is left a residual called ”flemaza”, which has some alcohol traces.
Dehydration	Ratified alcohol in distillation has 95% v/v ethanol and 5% v/v water. It is necessary to reduce the amount of water from this mix in order to be used as fuel, therefore a molecular sieve is used and through a synthetic resin retains water contained in the rectified alcohol, up to a concentration of 99.5% and a minimum quantity of water, reaching established standards of alcohol fuel.
Vinasse concentration	One fraction of vinasse that goes out from the must column is reused in the fermenting process and the rest is led to flubex evaporators, in which water is taken away in form of steam in order to concentrate vinasse, reduce the amount of it and ease further treatment.
Storage and delivery	Finally the product is sent to storage area, which is permitted to keep 20 days of production to cover market demand.
Compost	Industrial–size compost plant transform organic residuals created in the sugar and ethanol production processes, such as cachaza, ashes, agricultural wastes, concentrated vinasse. These residuals are turned into a stable and hygienic product that can be applied in agricultural practices as organic fertilizer and soil booster.
Water treatment	Residual water treatment plant (RWTP) receives all flemazas and some other residuals (condensed) of vinasse concentration.

Source: Cenicaña website

9.10 WATER TREATMENT MASS BALANCE

n the next 2 tables are presented the flow of residual water and its composition. Water flow was analyzed from the location object understudy, whereas data of composition were found in the literature (Hampannavar & Shivayogimath, 2010).

Table 9.3. Entry of residual waters and the production of 100 tons of sugarcane (ton/100 tons of sugarcane)

Substance	Quantity
Input	
Flemazas	7,32
Condensed	6,88
Total	14,2
Output	
Treated water	12,7
Mud	2,1

Source: CUE based on data field

The total flow of muds within the pools system (250 m3/h) was close to 11% of the water input (Dilek, Yetis, & Gökçay, 2003).

Table 9.4. Composition of residual water and treated residual water per m^3 (kg/m^3)

Substance	Input	Output	Removal	Standard
Chemical oxygen demand (COD) as O2	2,5	0,4844	81%	0,25
Biochemical oxygen demand (COD) as O2	0,75	0,07111	91%	0,05
Dissolved organic carbon (DOC) as C	0,0458	0,0075	84%	
Total organic carbon (TOC) as C	0,0673	0,0073	89%	
N	0,0275	0,0203	26%	0,01
P	0,0019	0,0007	63%	0,002

Source: CUE

This process is based on the description of the process reported in Ecoinvent registered as "treatment, residual waters, treatment of residual waters, class $2/m^3$/CH" and the methane emissions were adapted as a function to the composition of input and output material.

Methane is captured in an anaerobic reactor and is burnt. Nonetheless, it assumed a loss of 15% of methane. CH4 emissions were calculated using the factor suggested by IPCC

Table 9.5. Methane emissions during residual water treatment

Parameter	Quantity	Unit
Removed COD	28,6	kg/100 tons of sugarcane
Methane	6,01	kg CH4/100 tons of sugarcane
Released CH4	0,902	kg/100 tons of sugarcane

Source: CUE based on data field

9.11 MASS BALANCE FOR COMPOST STAGE

Below it is shown the material input for compost for "average" and "optimized" scenarios per every 100 tons of sugarcane.

Table 9.6. Material inputs for compost per every 100 tons of sugarcane (tons)

Input	Average	Optimized
Ashes form the boiler	1,6	0,25
Dust from sugarcane residual	0,13	0,13
Sugarcane leaves	0,58	0,58
Muds (RWTP)	2,1	2,1
Mud filtered	4,17	4,17
Vinasse 35%	2,36	2,36
Vinasse 55%	0,24	0,24

CUE: from data field

The next 2 tables display mass balances for compost material. Composition data from different input material were taken from the literature, while compost composition was calculated based on the principles of mass balance.

Table 9.7. Mass and compost balance for every 100 tons of sugarcane (average scenario)

Substance	This study	Humidity	Quantity	Water	Organic material	C	N	P2O5	K2O	C/N
	Ton/100 ton of sugarcane	%	ton (dry weight)	ton	%	%	%	%	%	
Input										
Ashes form the boiler	1,6	5	1,52	0,08				0,87	1,67	
Dust from sugarcane residual	0,13	50	0,07	0,07	74	41	0,15	0,12		273,33
Sugarcane leaves	0,58	50	0,29	0,29	74	41	0,15	0,12		273,33
Muds (RWTP)	2,1	63	0,78	1,32		31,6	4,17	10,34		7,58
Foam and impurity on top of sugarcane juice (cachaza)	4,17	80	0,83	3,33	80	44,4	1,5	1,8	0,3	29,6
Vinasse 35%	2,36	65	0,83	1,53	86,85	52,2	0,58	0,07	5,52	90
Vinasse 55%	0,24	45	0,13	0,11	86,85	52,2	0,58	0,07	5,52	90
Total entry	11,18		4,45	6,73						
Output										
Compost	6,13	27,5	4,44	1,69	26,15	18,73	0,76	1,63	1,2	30,89
Evaporated water	5,05	100		5,05						
N2O	0,00041		0,00019				0			
CH4	0,00004		0,00004							

Emissions of N2O were calculated based on nitrogen inputs, employing a value of 1.222% (IPCC, 2006). Methane emissions are calculated based on the IPCC of 10 g of CH4 per kg of dry matter (IPCC, 2006).

Table 9.8. Mass and compost balance for every 100 tons of sugarcane (optimized scenario)

Substance	This study	Humidity	Quantity	Water	Organic material	C	N	P2O5	K2O	C/N
	Ton/100 ton of sugarcane	%	ton (dry weight)	ton	%	%	%	%	%	
Input										
Ashes form the boiler	0,25	5	0,24	0,01				0,87	1,67	
Dust from sugarcane residual	0,13	50	0,07	0,07	74	41	0,15	0,12		273,33
Sugarcane leaves	0,58	50	0,29	0,29	74	41	0,15	0,12		273,33
Muds (RWTP)	2,1	63	0,78	1,32		31,6	4,17	10,34		
Foam and impurity on top of sugarcane juice (cachaza)	4,17	80	0,83	3,33	80	44,4	1,5	1,8	0,3	29,6
Vinasse 35%	2,36	65	0,83	1,53	86,85	52,2	0,58	0,07	5,52	90
Vinasse 55%	0,24	45	0,13	0,11	86,85	52,2	0,58	0,07	5,52	90
Total entry	9,83		3,17	6,66						
Output										
Compost	4,36	27,5	4,44	1,69	26,15	18,73	0,76	1,63	1,2	30,89
Evaporated water	5,47	100		5,47						
N2O	0,0003						0,0003			
CH4	0,00003		0,00003							

9.12 AGROCHEMICALS EMPLOYED IN DIFFERENT AREAS OF THE PALM OIL CROP (KG/KG FFB)

Agrochemical	E001	E002	E003	N001	N002	N003	N004	C001	C002	C003
Glyphosate	4.40E-05	6.21E-05	1.98E-05	1.50E-04	2.10E-04	6.95E-07	3.75E-04	1.28E-04	1.32E-04	1.28E-04
Bipiridilium compounds	1.88E-05	1.71E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Urea compounds	1.27E-05	1.21E-05	3.35E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ethoxylates alcohols *	1.57E-05	2.21E-05	2.06E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Organophosphate compounds	5.88E-05	5.07E-05	0.00E+00	1.12E-05	1.57E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.13E-06
Acetamide compounds	6.08E-06	1.43E-06	3.08E-05	0.00E+00	0.00E+00	0.00E+00	1.40E-05	0.00E+00	0.00E+00	8.06E-06
Phthalimide compounds	0.00E+00	0.00E+00	0.00E+00	6.49E-07	9.09E-07	1.44E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pyrethroid compounds	0.00E+00	0.00E+00	0.00E+00	7.69E-08	1.08E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Benzimidazole compounds	0.00E+00	0.00E+00	0.00E+00	1.86E-05	2.60E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
N Cyclic compounds	0.00E+00	0.00E+00	0.00E+00	1.00E-06	1.40E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dithiocarbamate compounds	0.00E+00	0.00E+00	0.00E+00	1.35E-06	1.89E-06	0.00E+00	2.24E-04	0.00E+00	0.00E+00	0.00E+00
Triazine compounds	0.00E+00	0.00E+00	0.00E+00	1.14E-06	1.59E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Thiocarbamate compounds	0.00E+00	0.00E+00	0.00E+00	4.98E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Herbicides	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.81E-05	0.00E+00	0.00E+00
Insecticide	5.58E-06	2.86E-06	0.00E+00	5.41E-08	7.57E-08	1.44E-04	0.00E+00	1.17E-04	1.85E-06	1.08E-05
Fungicide	0.00E+00	0.00E+00	0.00E+00	2.85E-07	3.99E-07	0.00E+00	0.00E+00	6.70E-05	0.00E+00	0.00E+00

*All agrochemicals can be accessed in a local shop but this one. Alcohol is obtained directly from the plant

9.13 DESCRIPTION OF THE PALM OIL PROCESS

Process	Description
Loading	FFB are weighted and discharged from the trucks to the wagons of the palm FFB train.
Sterilization	Sterilization is carried out with low pressure steam for about 90 minutes.
Threshing	Fruits are separated from the bunch through a mechanical process. Those bunches, without fruits, are called "tusas" and they are transported by way of conveyors to trucks and after that they are taken back to the field for compost process.
Digestion and crushing	Digestion is the process employed to release the oil from the fruit by breaking those cells that contain the oil. Usually a digester is a cylinder, heated with steam, and attached to a shaker. This shaker hits fruits and makes oil extraction easier.
Clarification and drying	Oil is clarified by gravity, using the difference of densities. Clarified density is stored in tanks. Oil is dried to reduce moisture, through heating in a system of tanks or via atmospheric drying.
Effluents treatment	The water contaminated with oil is a by-product of the clarification process. This water goes through centrifuges with the aim to recover the remaining oil. The rest of the liquid is treated in the Residual Water Treatment Plant (RWTP).
Fiber-breaking and meal extraction	The mix of nuts and fibers is separated. Nutshells are broken and kernel meal is taken aside. Kernel meal goes through the drying silo and it is crushed to extract oil. Palm kernel oil is sold and kernel cake meal is used as fodder. Fibers and shells are picked up and employed as fuel in the boiler.

9.14 AIR EMISSIONS AS PRODUCT OF THE COMBUSTION OF 1 MJ OF FIBER, 1 MJ OF SHELLS PER EACH 100 TONS OF FFB (KG UNLESS INDICATED OTHERWISE)

Emission	1 MJ of fiber	1 MJ of shell	100 tons of FFB
Residual heat (MJ)	1	1	303209
Carbon dioxide	0.24	0.15	62750
Nitrogen oxides	1.14E-04	1.50E-04	3.88E+01
Particulate matter	5.84E-05	7.68E-05	1.98E+01
Carbon monoxides	9.11E-06	1.20E-05	3.09E+00
Methane	5.65E-07	7.42E-07	1.91E-01
NMVOC, non-methane volatile organic compounds	7.94E-07	1.04E-06	2.69E-01
Sulphur dioxide	3.24E-06	4.26E-06	1.10E+00
Nitrogen monoxide	2.99E-06	3.93E-06	1.01E+00
Acetaldehyde	7.94E-08	1.04E-07	2.69E-02
Aliphatic compounds, alkane, unspecified	1.18E-06	1.56E-06	4.01E-01
Aliphatic compounds, unsaturated	4.03E-06	5.30E-06	1.37E+00
Arsenic	1.30E-09	1.71E-09	4.41E-04
Benzo[a]pyrene	6.50E-10	8.55E-10	2.20E-04
Benzene	1.18E-06	1.56E-06	4.01E-01
Brome	7.81E-08	1.03E-07	2.65E-02
Calcium	7.61E-06	1.00E-05	2.58E+00
Cadmium	9.11E-10	1.20E-09	3.09E-04
Chlorine	2.34E-07	3.08E-07	7.94E-02
Chromium	5.15E-09	6.77E-09	1.75E-03
Chromium VI	5.20E-11	6.84E-11	1.76E-05
Copper	2.86E-08	3.76E-08	9.70E-03
(Dioxins) 2,3,7,8-Tetrachlorodibenzodioxin	4.03E-14	5.30E-14	1.37E-08
Ethyl benzene	3.90E-08	5.13E-08	1.32E-02
Fluorine	6.50E-08	8.55E-08	2.20E-02
Formaldehyde	1.69E-07	2.22E-07	5.73E-02
Hexachlorobenzene	9.37E-15	1.23E-14	3.17E-09
Mercury	3.90E-10	5.13E-10	1.32E-04
Potassium	3.04E-05	4.00E-05	1.03E+01
Magnesium	4.70E-07	6.17E-07	1.59E-01
Manganese	2.22E-07	2.92E-07	7.54E-02
Sodium	1.69E-06	2.22E-06	5.73E-01
Ammonia	2.26E-06	2.97E-06	7.67E-01
Nickel	7.81E-09	1.03E-08	2.65E-03
Phosphorous	3.90E-07	5.13E-07	1.32E-01
PAH, Polycyclic aromatic hydrocarbon	1.43E-08	1.88E-08	4.85E-03
Lead	3.24E-08	4.26E-08	1.10E-02
Pentachlorophenol	1.05E-11	1.38E-11	3.57E-06
Toluene	3.90E-07	5.13E-07	1.32E-01
m-xylene	1.56E-07	2.05E-07	5.29E-02
Zinc	3.90E-07	5.13E-07	1.32E-01

9.15 WASTE WATERS TREATMENT

Most of the waste or residual waters are generated during the oil extraction process in the extraction plant. Residual water has high levels of organic matter and it is treated generally in open pools.

Chemical oxygen demand (COD) of residual waters can be substantially reduced, the treatment system has a great setback due to the fact that it emits high methane concentrations, which is, as it has been mentioned, a potent GHG; therefore federation of palm oil cultivation presented a project design document (PDD) of the Clean Development Mechanism (CDM) of the UNFCCC with the purpose of capturing to some extent such methane and burn it through the use of an close anaerobic reactor (Fedepalma, 2006a). In this study, the future methane capture is taken into account for the "optimized scenario".

In general sense, inventory for this part of the process was based on the process from Ecoinvent called "Treatment, residual waters, from households, for residual water treatment, class 2", whereas the COD, the amount of residual waters and methane emissions were modeled for the Colombian conditions. The functional unit is residual water treated for processing of 100 tons of FFB's.

Entry

The amount of residual waters and the content of COD of waste waters have been taken from different processing plants of FFB's and are condensed in. Main residual or waste waters are created in the extraction process.

Table 9.9. Total residual waters and COD content per 100 tons of treated FFB (tons)

Input	Amount
Total residual waters	106.6
COD content	5.23
Extraction residual water	99.6
COD content	5.19
Refinery residual water	3.92
COD content	0.02
Transesterification residual water	3.08
COD content	0.02

Source: CUE based on data field

Effluents and emissions

After the treatment of waste waters, the treated stream is led to surface waters (mainly rivers). Content of COD is based on assessment, and emissions of methane were calculated based on the elimination of COD (factor of 21%). For the optimized scenario, where 85% of methane is captured and burned, the values registered in the PDD are used.

Table 9.10. Quantity of treated water and methane emissions per 100 tons of FFB (ton)

Output	Average	Optimized
Total residual water	68.69	68.69
COD content	0.32	0.32
COD removal	4.91	4.91
Methane	1.03	0.05

Source: CUE based on data field

9.16 RENAULT

Source: www.renault.com

9.17 SURFACE EXTENSION OF THE CARBON ZONES (KM^2), TYPES OF LAND USE BY VEGETATION ZONES IN COLOMBIA

Cover type	Cover sub-type	Cover name	Main use	Tropical rainforest	Tropical shrub land	Tropical dry forest	Tropical moist deciduous forest	Tropical mountain system
Natural and semi-natural vegetation	Forest	Natural forest (Bn)	Preservation areas, national natural parks, reservoirs and territories for indigenous people and black communities	426'889			861	51'355
		Fragmented natural forest (Bi)	Selective extraction of flora and fauna, crops and pasture lands in forest areas that are being turned into grazing land	72'140		8	5'731	19'661
	Bushes	Natural and/or induced bushes (Ma)	Selective extraction of products as firewood, fibers and fruits, silvopasture uses and fallow lands	2'491	1'174		3'511	5'527
	Other type of vegetation	Herbaceous savannah vegetation (Sl)	Extensive and very extensive livestock farming	28'721			27'298	50
		Wooded savannah vegetation (Sa)	Extensive and very extensive livestock farming	15'485			32'392	12
		Bushy savannah vegetation (Sb)	Sporadic extraction of fauna and flora and very extensive livestock farming	18'667				
		Xerophytic vegetation (Xe)	Semi-nomad livestock farming, species extraction for craftmaking and eco-tourism	265	6'650	158	2'775	391
		Moor vegetation (Vp)	National natural parks, protected areas, grazing of bovine and ovine land and potato cultivation					13'016
		Mangrove vegetation (Vm)	Selective use of fauna and flora; protected areas	3'803	14	202	717	
		Very sparse herbaceous vegetation on rocky land (Pe)	Eco-tourism in areas of National natural parks	8'256			1'400	

9.18 MAP OF NATURAL POTENTIAL VEGETATION

Most uses of Colombian soil are, or can be, potentially turned into natural forest, where biomass carbon would reflect conditions of vegetation zones.

Vegetation zone	AGB (tons of dm/ha)	RS-R	Total biomass (tons of C/ha)
Tropical forest	300	0.37	193.2
Deciduous humid forest	220	0.24	128.2
Dry tropical forest	210	0.28	126.3
Tropical bush	80	0.4	52.6
Tropical mountain system	145	0.27	86.6

Some other uses of Colombian soil include anthropogenic restrictions to potential vegetation in term of soil cover instead to evolve into natural forest. Spatial distribution of potential biomass of the ecosystem is associated with vegetation zones and types of land use, therefore they can

1. potentially evolve in to natural forest or they are forest already; or
2. they can maintain current biomass conditions, due to environmental and human limitations.

Colombian surface (1,114,000 km^2) is broken down in several vegetation regions:

- 42% is occupied with natural forest (480,000 km^2),
- 52% of its territory has the potential to turn into natural forest (590,000 km^2)
- and remaining 6% are occupied by those land use types (bushes, mangroves, waste land, rocky and sparse land) which incur in environmental limitations, keeping biomass levels in their current levels.

9.19 PROSPECTS OF BIOFUELS PRODUCTION IN COLOMBIA BEYOND FIRST GENERATION BIOFUELS

In general sense, it can be said that biomass ethanol can be elaborated from sugars, starches and lignocellulose materials. Colombia has exhibited a prominent behaviour regarding sugarcane yield, according to FAO (108.4 Ton/ha average between 2008-2012) (FAOSTAT, 2014), and therefore the core of this thesis has been biased to this feedstock. However, cassava-based ethanol is also produced in minor proportion in Colombia[2]. Corn has not been considered to produce ethanol in a commercial scale in Colombia due to its low yield (2.28 ton/ha compared to 10.07 ton/ha produced in US). On the other hand, lignocellulose ethanol has counted with some initiatives that so far have been explored on paper, but which have not been deployed properly. In fact most advances have been made focused on conditioning and pre-treatment processes of lignocellulose material, to expose sucrose material with a minor energy consumption, less capital investment and higher efficiency in the use of raw materials (Cardona Alzate, 2009).

During 2009, it was reported an initiative between 3 firms (Inar Ltda, Equitec S.A and G&B) to design, built and manage a processing plant fed with sugarcane bagasse, in a region where sugarcane for panela production is raised (Suarez river basin) (Forero, 2009). The cost of the whole project escalated to 167 million dollars in 2010, and the feedstock was supposed to come from 210 small panela production firms committed to provide approximately 1000 tons of bagasse, which in turn can produce 90.000 l/d (Acuña, 2010). Unfortunately the project has not reported any further results, neither in conventional press nor in academic publications.

Nowadays the panorama is quite blurred for these initiatives, in the Suarez river basin (Hoya del río Suárez) after the bad experience suffered in the past: In 2008 was inaugurated a pilot plant that was built to process nearly 60.000 ha of sugarcane, but after a couple of months later and some tests it was noticed that such infrastructure (with several some disasters in the deployment) was able to process only half ha. Finally the project, with an investment of nearly 3US million, was basically abandoned by the government and left to Universidad Industrial de Santander for academic purposes (Publicaciones Semana, 2010).

Likewise research efforts have been conducted in the development of other feedstock alternatives. For instance, in 2009, it was presented in Mexico the result of an experiment conducted on residues from the palm oil production in order to produce ethanol. The idea consists applying chemical delignification (by using Sodium Hypochlorite in the emptied shells of the palm seeds) to pre-treat the material and reach embedded cellulose. Results support technical feasibility of such treatment, but they do not indicate neither costs nor prospects of implement this technology by the building of a plant (not even in pilot stage) (Piñeros, Rincón, Bourdon, & Velásquez, 2009). Similar work, on the same feedstock, has been documented by researchers of the Univeridad de los

[2]Cantaclaro is a processing plant located in Puerto López and it counts with an installed production capacity of 25000 l/d (reported in 2011). See http://www.fedebiocombustibles.com/v3/nota-web-id-270.htm

Andes, whose experiments are focused on trying with different enzymes (A. F. González, Jiménez, Susa, Restrepo, & Gómez, 2008).

Something similar has happened with the use of timber and wood, in general, as source of lignocellulose for ethanol production in Colombia. Some scholars of the Universidad de Antioquia have conducted some work in order to identify those timber-yielding species that have been used for reforestation and commercial purposes. At first sight it was identified a set of species[3] within Colombia territory that count on high volumetric yield of biomass and short harvesting periods (Gómez, Ríos, & Peña, 2012) which guarantee a continuous and abundant supply of lignocellulose feedstock. It was also found that the species pinus patula is probably the most plentiful within the timber Colombian industry, and it counts with the highest contents of cellulose and hemicellulose and low content of lignin. Nonetheless; there is a technical hindrance given that releasing those sugars is a complex procedure, not only for this species but also to all the broad group of soft woods. However, given its abundance and wide use it has been foreseen that the amount of material can offset the difficulty to process it, providing good chances to use such option for ethanol production.

There is an alternative that has been explored in Medellín in the National University, where banana shell and cassava starch (separately) were used as feedstock to feed a fermentation process for further ethanol production. The result that is particularly interesting here is the one obtained in the experiment on banana shell, given that does not rival directly with the product as food, but it is a by-product that is usually thrown away or used for compost elaboration (Monsalve Gil, Medina de Pérez, & Ruiz Colorado, 2006). Finally, another option for ethanol production is the use of household solid wastes, with pre-treatment via enzymatic reaction and microwave applications. Results indicated, that despite of interesting yields in technical terms, it has had not reached enough competitiveness in the economic aspect to think in funding such alternative (A. F. González et al., 2008).

Regarding biodiesel production, within first generation biofuels feedstock can be found vegetable oils and animal fat. An alternative can be residual oils that have been used in the food industry. Palm oil has been the chosen feedstock for biodiesel production in the case of Colombia. Despite its prominent production (in 2012 was the fourth world producer, with close to 1 million MT, FAOSTAT 2014), it remains far from the global leadership in palm oil production[4]. Nevertheless, the Colombian incursion as biodiesel producer is noteworthy and so far fulfil the needs of diesel blends, dictated by the national government[5].

[3]Within this set are Eucalyptus camaldulensis, pine trees Caribaea, Oocarpa y Tecunumanii and eucaliptos Grandis, Camaldulensis and Tereticornis

[4]In 2012 Indonesia and Malaysia produced 23.6 and 18.7 million MT of palm oil (FAOSTAT, 2014). In addition, thanks to a broad experience these two countries are in the forefront of productivity with average production rates of 6000 l/ha, whereas in Colombia this rate reaches 4.400 l/ha (Cardona Alzate, 2009).

[5]A blending level of 15% biodiesel would require nearly 425 thousand ha by the year 2020, according to Cardona's calculations (Cardona Alzate, 2009).

Regarding alternatives to first generation biodiesel (i.e. 2nd and 3rd Generation), in Colombia have been studied the possibilities of producing it from castor oil seeds and microalgae. An isolated experiment on household solid wastes has been notified as well.

Castor oil biodiesel has been studied in Colombian, since 2004, as an alternative to palm oil biodiesel. All the tests have been conducted at laboratory level (Cardona, C.E., Sanchez, & Rincón, 2007). Within the program of Industrial Chemistry of the Universidad Tecnológica de Pereira, in 2012, was presented a thesis that covers most of the research undertaken regarding a potential castor oil biodiesel production. Basically this document presented a set of tests applied to castor oil seed genetically modified and it was verified that most of technical parameter of regular biodiesel are fulfilled by this option. The genetic modification brings along some advantages like low content of free-fatty acids, therefore it is easier trans-esterification process; low iodine content which guarantees a better oxidative stability and enhancement of engine lubricity. However some nuisances are exhibited as well, like a major ability of corrode the system in comparison to regular biodiesel (Huertas Greco & Sánchez Medina, 2012).

Since 2009, it can be found within the Colombian academic literature some reports and papers on research which presents a different approach to third generation biofuels is the elaboration of biodiesel based on algae use. In particular in the Universidad Industrial de Santander has been conducted some experiments, at laboratory level, on Chlorella vulgaris, Chlorella protothecoides, Nannochloropsis oculata, which are a kind of algae with high oil content. The advantages of these species over traditional terrestrial oily seeds are high growth rates (which doubles size in about 24 hours), high yields (which can be 300 times the yield of terrestrial seeds) and adaptability (given that they can be produced in salt water, residual water and degraded lands not suitable for food production). Despite the appeal of such option it seems that the combination of an absent supply of microalgae in combination with a reduced number of publications regarding transesterification of these species have leaded to a poor support in this front.

Pyrolysis has been applied to household solid wastes, in a temperature range between 450 and 700°C, reaching a liquid product with similar characteristics to commercial diesel 8500cal/g vs 9900 cal/g, and a solid product superior in calorific content, if it compared to regular coal. However, high content of sulphur discourages the use of such products for their environmental performance (A. F. González et al., 2008).

Despite biogas is not direct application of transportation alternative of biofuels, it can be mentioned that hydrogen production from porcine farming wastes has been run on experiments via anaerobic digestion.

It is important to be aware that palm oil and sugarcane processing industries can exert some pressure on the Colombian government given the employment that they both represent and the income reported to the nation's wealth. Additionally there is no evidence that, in Colombia, diversion of feedstocks (sugar and palm oil) threatens food security. Therefore, such fact, combined with isolated efforts on research provide a bleak landscape for second generation biofuels technologies (and beyond) in the near future, but the possibility of using by-product of such industries such as. Colombia remains updated in terms of the technologies that have been studied in the forefront in the field of biofuels, however further investment and infrastructure acquisition is required to develop a mature supply of advanced biofuels.