Cooking fuels in Haiti

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Environmental, economic and social assessment of cooking fuels in Haiti for the Global Alliance for Clean Cookstoves.

This report has been prepared to support the Global Alliance for Clean Cookstoves in the development of a multi-year strategy for clean cooking fuels in Haiti for the Government of Canada. The authors' views expressed in this publication do not necessarily reflect the views of the Global Alliance for Clean Cookstoves, the Government of Canada, the United Nations Foundation, or its partners.

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EXECUTIVE SUMMARY

In partnership with the Government of Canada, the Global Alliance for Clean Cookstoves (Alliance) is developing a comprehensive strategy and national action plan for catalyzing the market for clean and efficient cookstoves in Haiti. Following a preliminary market study, the Alliance decided to extend the sector overview with six consultancies, including the present study. The study assesses 7 alternative fuels to charcoal and firewood: improved charcoal, charbriquettes, non-carbonized briquettes, pellets, ethanol, LPG and solar electricity. Comparison between fuels is carried out through an assessment of local biomass resources, a Life Cycle Assessment (LCA) of the environmental and health impacts, economics and social impacts.

Biofuels locally produced in Haiti are environmentally sound for a clean fuel strategy. However, local biomass resources suited to produce biofuels are limited compared to the cooking energy demand of the country.

The LCA of the biofuel options assessed demonstrate their high CO_2 emission reduction potential if substituted for traditional charcoal (2.5 to 3 $kgCO_2/MJ_{delivered}$). However, the resource assessment shows a limited potential to scale with locally produced biofuels due to the low and variable production of biomass from agricultural activities in Haiti. The scenarios developed indicate that 27 to 51% of the urban households' demand for cooking energy could be theoretically served with biofuels. Charbriquettes, ethanol and pellets are the most promising biofuels identified while non-carbonized briquettes can be produced in limited volumes and solar electricity is not cost competitive for cooking purposes.

The development of clean fuels in Haiti is expected to improve the social and economic wellbeing of end-users but may have a negative impact on jobs along the value chain.

The use of cleaner and more efficient fuels will benefit end-users thanks to time savings in cooking and thanks to a reduced exposure to smoke and particulates. However, charcoal-making is a significant source of jobs and income for farmers possibly threatened by the development of alternative fuels. Developing improved charcoal production techniques and biofuels locally produced are the best options to develop the clean fuels sector while creating local value partly oriented towards farmers.

ENEA recommends the Alliance build a strategy based on four pillars to be conducted in parallel:

- reduce kiln emissions and wood withdrawal with improved charcoal production kilns,
- reduce the demand for charcoal with improved cooking stoves,
- reduce the demand for charcoal with alternative fuels already proven (charbriquettes and LPG),
- investigate the potential of innovative fuels (ethanol locally produced and pellets) for large scale deployment.

Limitations in the availability of local biomass prevent a strategy based on local biofuels from having a significant impact on the cooking sector in Haiti. The improvement of charcoal production techniques is a key lever to reduce the demand for wood and the emission of greenhouse gases of the sector. The combined use of improved cookstoves is key to reduce the demand for charcoal.

In parallel, alternative fuels should be developed, starting with the most promising among those already proven: charbriquettes and LPG. LPG is an attractive option but still requires consumer finance services and political intervention to regulate the market. Ethanol and pellets have a high potential but should first be demonstrated at pilot scale to prove their competitiveness and market adoption. Moreover, in-depth surveys and analyses on land use and agricultural practices in Haiti are required to precisely assess the extent to which energy crops can be grown and existing agricultural residues can be recovered without damage on preexisting agricultural activities or on soil fertility.

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ACRONYMS

BC: Black carbon

CRI: Carbon Roots International

ENPA: Enquête Nationale sur la Production Agricole (National Survey on Agricultural Production)

f_{NRB}: Fraction of non-renewable biomass

GHG: Greenhouse Gas

GSB: Green Social Bioethanol

LCA: Life Cycle Analysis

LCOE: Levelized Cost of Energy

M&E : Monitoring and Evaluation

PaP: Port-au-Prince

PM : Particulate matter

SLCP: Short-lived climate pollutants

1 INTRODUCTION

1.1 Context

Haïti suffers from high levels of poverty and limited economic growth; its development has been strongly impacted by the recent natural disasters such as the 2010 earthquake or Hurricane Matthew in October 2016. Firewood and wood charcoal are still massively used for cooking in the country, which has a very detrimental effect on environment and household health. Clean cooking markets must be developed in order to offer alternatives to traditional charcoal. The Government of Canada partnered with the Global Alliance for Clean Cookstoves (also called "the Alliance") to develop clean cooking markets with a five-year clean cooking program launched in mid-2016.

The Alliance initiated this program with a preliminary market study, and decided to extend the market overview with six consultations, among which the present study was included. It provides an assessment of potential alternative cooking fuels in order to target the most relevant pathways in terms of environment and economic impacts for the Alliance clean cooking program.

1.2 Objectives

The objective of the study is to identify the most promising fuels in terms of potential environmental and social impacts. Comparison between fuels is carried out through an evaluation of:

- Available feedstock in Haïti in order to assess the scalability of locally produced biofuels
- Environmental impacts for each fuel based on a Life Cycle Assessment
- The overall cost of cooking options (cost of fuel and stove), based on the Levelized Cost of Energy
- Social impacts, with a qualitative analysis based on the Alliance M&E framework

1.3 Scope and method

ENEA was the lead consultant for the study and partnered with Quantis and local Haitian partner, Palmis Enèji (Entrepreneur du Monde), to respectively provide the LCA model and conduct the field interviews. Input data for the analyses was collected through extensive literature review and field interviews (see Appendix §8.1).

The study focuses on fuels and does not analyze the impact of improved cooking stoves. However, each fuel had to be modeled in combination with a stove and a given efficiency. The fuel pathways assessed in the present study are:

- Firewood used in three stone fire (stove efficiency: 14.3%)
- Charcoal produced from traditional kilns (kiln energy efficiency: 22% minimum, 44% maximum) and used in conventional charcoal stoves (stove efficiency: 22.2%)
- Charcoal produced from improved kilns (kiln energy efficiency: 44% minimum, 59% maximum) and used in conventional charcoal stoves (stove efficiency: 22.2%)
- Carbonized briquettes – from agricultural residues and bagasse, used in conventional charcoal stoves (stove efficiency: 22.2%)
- Non carbonized briquettes – from waste paper and sawdust, used in forced draft gasifier stoves (stove efficiency: 40.0%)
- Pellets – from sugarcane and sweet sorghum, used in conventional briquette stoves (stove efficiency: 40.0%)
- Liquefied Petroleum Gas (LPG) used in conventional LPG stoves (stove efficiency: 52.5%)
- Ethanol (1st generation) – from sugarcane and sweet sorghum, used in conventional ethanol stoves (stove efficiency: 52.5%)

The resource assessment only reviews the potential for locally produced biofuels: ethanol, carbonized briquettes, pellets and non-carbonized briquettes.

Environmental impacts are evaluated with the Life Cycle Assessment methodology through six indicators:

- Global climate change potential
- Black carbon and short lived climate pollutants
- Total energy demand
- Fossil fuel depletion
- Water withdrawal
- Particulate matter (PM2.5) formation

The economic analysis is also based on a life cycle approach including a calculation of the Levelized Cost of Energy for life cycle stages involving capital costs (raw material processing and stove).

The social impacts review qualitatively assesses the expected impacts of a switch from a traditional fuel (firewood or charcoal) to a alternative fuel (e.g. charbriquettes, LPG…), based on a qualitative ranking of each fuel for a series of categories of impacts listed in the Alliance's M&E framework.

1.4 Description of fuels & value chains

This section gives an overview of the value chain of traditional fuels used in Haïti and the possible alternative fuels covered in this study.

Traditional fuels are:

- Firewood, mainly used by rural households. Wood is collected in nearby forests and used close to the collection site.
- Traditional charcoal, mainly used by urban households. Wood is collected in forests and carbonized in poor-quality kilns (earth mound kilns typically). Charcoal is then transported to wholesalers and sold to consumers by retailer.

Alternative fuels are:

- **Improved charcoal**, similar to traditional charcoal except that wood is carbonized in improved kilns with higher mass yields and lower emissions of unburnt gases (kilns made of bricks and cement typically). This value chain does not exist in Haiti currently.
- **Carbonized briquettes** or **charbriquettes**, made from carbonized agricultural residues (stems, leaves, cobs or straws) left on the fields, or bagasse, the by-product of sugar cane juice extraction. Only one company produces charbriquettes in Haiti currently (Carbon Roots International).
- **Non-carbonized briquettes**, made from a mix of sawdust and compacted waste paper and cardboard. Only one company produces non-carbonized briquettes in Haiti currently (El Fuego del Sol).
- **Pellets**, made from shredded and high-pressure compacted non-carbonized bagasse. This value chain does not exist in Haiti currently.
- **Ethanol**, locally produced from sugarcane juice fermentation and distillation process. Sweet sorghum is also a possible feedstock for ethanol production. This value chain does not exist in Haiti currently, however, a market uptake phase has been launched with imported ethanol produced in the US (Novogaz in Haiti and POET in the US).
- **LPG**, imported from the U.S. and sold by retailers in re-usable cylinders. This value chain has been emerging in Haiti for a decade with two authorized importers (TOTAL and Sodigaz) and with several formal retailers as well as informal retailers, mostly active in Port-au-Prince (PaP).
- **Electricity** from a solar based microgrid equipped with solar panels and batteries. A pilot of a hybrid microgrid (solar and diesel genset) is currently operated by the company EarthSpark in Haiti but does not comprise cooking services.

Bloc diagrams of the different fuel value chains are provided in Appendix (see §8.2). Figure 1 presents the feedstock needed for the production of each fuel considered in the study.

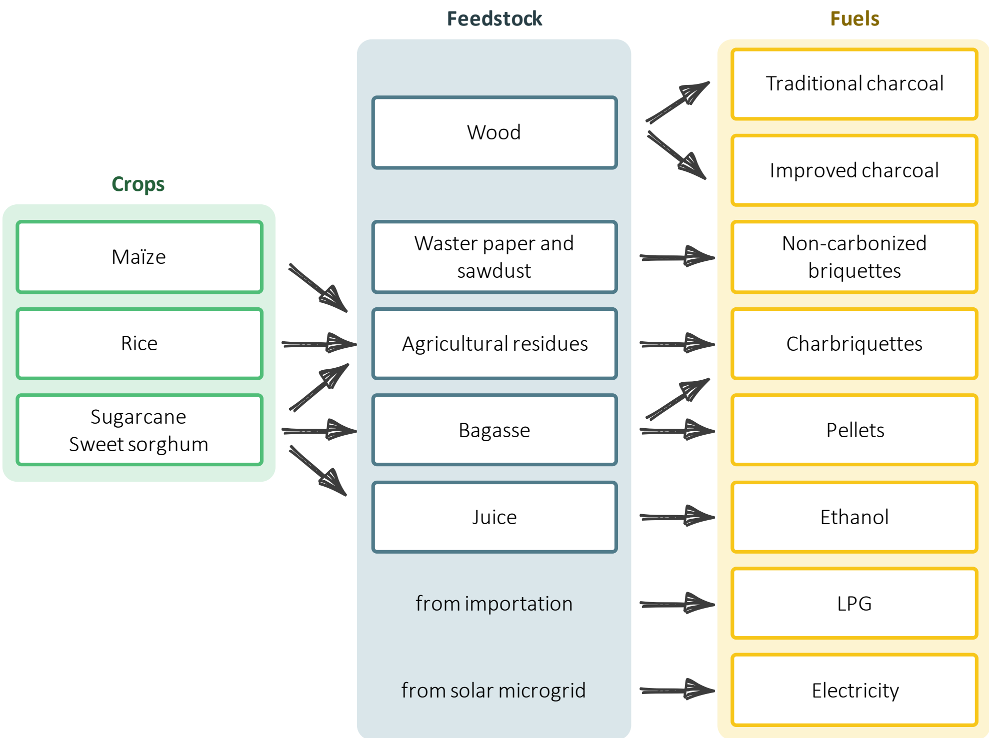

Figure 1 – Fuels and feedstock covered in the study

This study covers the full value chain of fuels (see Figure 2) and thus differentiates the following value chain segments:

- Raw material supply: raw material is collected from production sites, such as crop fields where agricultural residues are collected, or the distilleries where bagasse is a by-product of alcohol production. Feedstock is then transported to processing sites.
- Processing: the raw materials are transformed with dedicated equipment, with possible need for energy input and capital investments in equipments.
- Distribution and sales: the fuel is packaged and transported to wholesalers, then transported and sold to retailers with a possible second packaging step and then sold to the end-user.
- End-use: the fuel is consumed in a dedicated stove by a household[1] for cooking purpose.

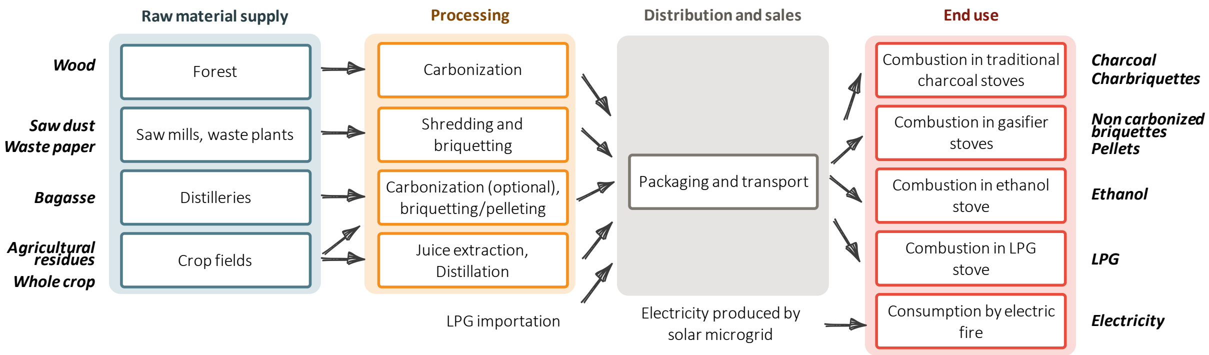

Figure 2 – Stages of fuels value chain

[1] The market of restaurants and institutions (e.g. schools) is not the focus of this study but represents a non negligible share of cooking uses in Haiti.

2 RESOURCE ASSESSMENT

Among the alternative fuels described in §1.4, a number are based on local resources: charbriquettes are based on agricultural residues or byproducts, pellets and ethanol are based on sugarcane processing or sweet sorghum, and non-carbonized briquettes on waste paper. This section aims at assessing the available resources in Haïti to estimate the number of households that can be reached by alternative fuels if they are produced in Haïti.

2.1 Method

2.1.1 Approach

Charbriquettes, pellets and ethanol are based on maize, rice, sorghum and sugarcane productions. Agricultural production figures are from the National Survey on Agricultural Production (Enquête Nationale de la Production Agricole) or ENPA) 2014 [1], a national survey conducted by the Ministry of Agriculture that records production figures by type of crop and by season and in every of the 10 Haïtian departments(see Figure 3).

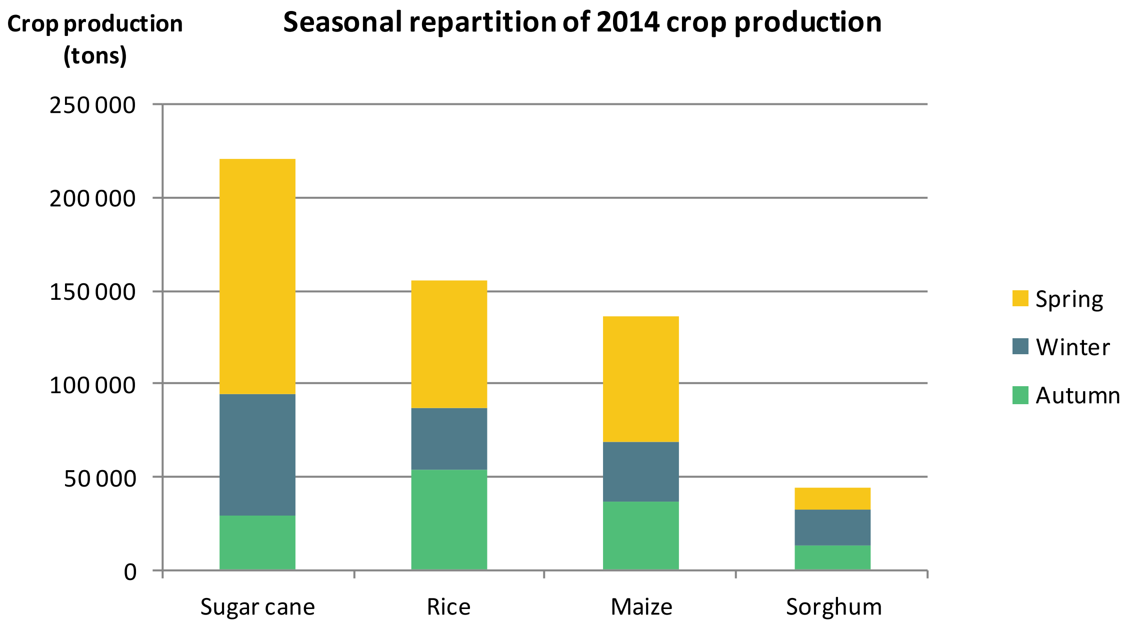

Figure 3 –2014 harvest of primary crops producing raw materials for the alternative fuels

Ideally, data from surveys conducted in other years should have been used for comparison with the ENPA 2014 but such data are not available. In the past decade, crop production fluctuated significantly from year to year because of weather variability, natural disasters, decreasing yields due to degradation of soil and irrigation infrastructure and variable access to fertilizers [2]. For instance, the year 2014 can be considered as a "low production" year, with cereals[2] production reaching half of the production of the year 2013[3] [2]. For some

[2] "Cereals" include rice, maize and sorghum.

[3] 2013 achieves a high crop yields thanks to favourable climatic conditions and availability of fertilizers [46].

specific crops such as sugar cane, lands harvested also decreased since the 80's because of the higher competitiveness of imported products (i.e. sugar in the case of the sugar cane sector).

Waste paper resource is calculated based on the importations of cardboard and paper in Haiti (18.25 Mt in 2009) [3]. This figure does not take into account the additional resource from cardboard packaging, but takes into account the quantity of paper that cannot be recycled (toilet paper…). These quantities are assumed to balance each other [3].

The resource assessment for locally produced fuels is based on a historical scenario and three prospective scenarios designed to explore a theoretical evolution in crop production, taking into consideration the variability of agricultural production (see §2.1.2).

The quantity of agricultural residues produced in Haiti is calculated with the 2014 crop production at a national level and the mass ratio between crop and residue (e.g. mass of maize stem, leaves and stover produced for one ton of maize grain). Losses of feedstock during the fuel processing step are also taken into account. For each fuel, we calculated the chemical energy of combustion per mass unit (Lower Heating Value) and the final energy delivered to the cooking pot (cooking energy) based on the efficiency of the stove.

The average cooking energy demand by urban households is estimated based on the average charcoal consumption in PaP (2.3 kg/household/day) [4] and the urban population (1,218,242 households) [5]. Finally, the cooking energy potentially delivered by a fuel, given the raw material produced in a year, is compared to the annual cooking energy demand of urban households in order to estimate the number of urban households whose cooking energy demand could be fully covered by the fuel. The rural market is not considered for this analysis.

$$Potential\ delivered\ energy_{feedstock} = Crop\ (t) * Residue\ ratio\ \left(\frac{kg_{residue}}{kg_{crop}}\right) * Processing\ yield\ \left(\frac{kg_{fuel}}{kg_{residue}}\right) * LHV\ \left(\frac{MJ_{potential}}{kg_{residue}}\right) * Stove\ efficiency\ (\frac{MJ_{delivered}}{MJ_{potential}})$$

$$Number\ of\ households\ able\ to\ replace\ charcoal = \frac{Household\ yearly\ charcoal\ consumption * LHV_{charcoal} * Stove\ efficiency_{charcoal}}{Potential\ delivered\ energy_{feedstock}}$$

2.1.2 Scenarios

A “historical” scenario illustrates current situation of the agriculture sector using 2014 figures based on historically low productivity. Two scenarios called "Theoretical potential - conservative" and "Theoretical potential – middle" aim at representing a near term situation (i.e. in 3 to 5 years) with same areas harvested than the ones harvested in 2014 for all crops except sugar cane for which we assume a reasonable increase of the area harvested (enabling the production of ethanol on top of the current production of alcoholic beverage) and taking into account the high variability of crop production in Haiti. The third scenario called "Theoretical potential - aggressive" aims at representing a longer term and very ambitious ethanol-based scenario. For each scenario, the results in terms of production potential must be taken as a **maximum theoretical value** because calculations assume that all the raw materials produced are used for fuel production while this biomass is not necessarily available (there are competitive uses), nor accessible (biomass available in remote locations). Table 1 summarizes the assumptions used in the three scenarios and the numbers of households that can be reached accordingly.

<table>
<tr><td></td><td colspan="4">Assumptions</td></tr>
<tr><td>Scenarios</td><td>Maize and Rice assumption</td><td>Sugarcane assumption</td><td>Sweet Sorghum</td><td>Maximum households (HHs) reached</td></tr>
<tr><td>2014 (Historically Low Productivity”</td><td>Same as 2014 production</td><td>Same as 2014 production: entirely dedicated to alcoholic production; 100% of bagasse for solid fuel</td><td>None</td><td></td></tr>
<tr><td>Theoretical Potential – Conservative</td><td>Same as 2014 production</td><td>Twice 2014 production:
• Same as 2014 production left for alcohol beverage market; 100% of bagasse for solid fuel
• Same as 2014 production dedicated to ethanol cooking fuel; 37% of bagasse for solid fuel</td><td rowspan="3">• Provides the same amount of grain than 2014 conventional sorghum grain production
• 2014 equivalent production dedicated to ethanol fuel[4]
• 37% of by-product bagasse dedicated to solid fuel</td><td>Fuel mix 1 (pellets) :497 5 09 HHs

Fuel mix 2 (CB): 333 746 HHs</td></tr>
<tr><td>Theoretical Potential - Middle</td><td>Twice 2014 production</td><td>Four times 2014 production:
• Twice 2014 production left for alcohol beverage market; 100% of bagasse for solid fuel
• Twice 2014 production dedicated to ethanol cooking fuel; 37% of bagasse for solid fuel</td><td>Fuel mix 1 (pellets) :
618 138 HHs

Fuel mix 2 (CB): 436 012 HHs</td></tr>
<tr><td>Theoretical Potential - Aggressive</td><td>Twice 2014 production</td><td>10.6 times 2014 production:
• Twice 2014 production left for alcohol beverage market; 100% of bagasse for solid fuel
• 8.6 times 2014 production dedicated to ethanol cooking fuel; 37% of bagasse for solid fuel</td><td>Fuel mix 1 (pellets) :
1 089 887 HHs

Fuel mix 2 (CB): 785 339 HHs</td></tr>
<tr><td>Common Assumptions</td><td colspan="4">• Stems, cobs and leaves are collected from maize fields
• Rice straws are collected from rice fields
• Stems and leaves are collected from sugarcane and sweet sorghum fields
• Ethanol is produced from dedicated sugarcane and sweet sorghum cane
• 100% of by-product bagasse is collected from sugarcane alcoholic beverage production
• 37% of bagasse is collected from sweet sorghum and sugarcane ethanol fuel production</td></tr>
<tr><td>Fuel Mix Assumptions</td><td colspan="4">CB scenario: all bagasse from sugarcane and sweet sorghum is used in charbriquettes
Pellets scenario: all bagasse from sugarcane and sweet sorghum is used in pellets</td></tr>
</table>

Table 1 – Assumptions for resource assessment scenarios

[4] Sweet sorghum whole crop provides simultaneously the equivalent of conventional sorghum grain and the sweet sorghum cane that can be used to produce ethanol

Common assumptions across all three scenarios

- In all scenarios, sweet sorghum is assumed to fully replace conventional sorghum[5] and is harvested in order to provide the equivalent of 2014 levels of sorghum grain production[6]. This is an optimistic assumption regarding ethanol and bagasse resource assessments because sweet sorghum is still in an experimental pilot status in Haiti and its development in the coming years is not guaranteed. However, the benefit of sweet sorghum is that it produces additional by-products: sweet sorghum juice that can be transformed in ethanol or sugar similarly to sugarcane, and sweet sorghum bagasse that can be transformed into ethanol or charbriquettes. Sweet sorghum stems and leaves are deemed not abundant enough to be used for charbriquettes, as it is a crop selected to maximize grain yield and minimize residue.
- National sugarcane is currently processed to produce “clairin”, a local alcoholic beverage. If the sugarcane were used to produce ethanol, it would compete with sugar cane use for clairin. Economics and current demand for clairin tend to play in favor of this market compared to ethanol. Therefore, for the purposes of this modeling, it was assumed that current production of sugar cane for the clairin market would remain steady and that additional lands for sugar cane must be harvested to give a chance for the ethanol market to develop.
- Sugarcane processing in distilleries dedicated to alcoholic beverage production generates surplus bagasse after juice extraction. Even though the distilleries need fuel to operate, they cannot use the surplus bagasse because of technical limitations. The totality of by-product bagasse from alcoholic beverage sector is assumed to be used in pellets or charbriquettes.
- Sugarcane and sweet sorghum processing in distilleries dedicated to ethanol fuel production also generates surplus bagasse. These potential distilleries are more technologically advanced than alcoholic beverage distilleries: they can burn a part of the by-product bagasse to supply their energy needs. 3.6 tons of bagasse are consumed per ton of ethanol in distilleries [6], which leaves 37% of bagasse surplus to be used in charbriquettes or pellets.

Scenario “2014 (Historically low productivity)” assumptions

- Yields and areas harvested are the same than those observed in 2014, for maize, rice and sugarcane.
- Farmers only grow conventional sorghum; sweet sorghum is still at the pilot project stage.
- There is no ethanol production as harvested sugarcane is entirely dedicated to the alcoholic beverage sector, but bagasse by-product from this sector is available for alternative fuel production.

Scenario “Theoretical Potential - Conservative” assumptions

- For maize and rice, crop production is assumed to be identical to 2014 production [1]
- For sugar cane, lands harvested are assumed to be doubled compared to 2014: 30,000 ha instead of 15,000 ha [7], which is deemed realistic if the ethanol market is economically attractive for farmers. Sugarcane farming would then produce the same quantity of alcoholic beverage as 2014 production levels and would produce ethanol cooking fuel from the 15,000 additional hectares. The yield for sugar cane harvesting is considered similar to that of the year 2014 (15 t/ha) [7, 1].

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[5] Sweet sorghum is very close to conventional sorghum: it provides the same type of grain. However, the cane of sweet sorghum is different from conventional sorghum cane as it is high in sugar and provide juice that can distillated into ethanol fuel.

[6] Sorghum production is decreasing sharply because of aphids infestation. A solution to maintain current production levels would be to replace sorghum by sweet sorghum, a crop selected for robustness and higher grain yield.[23]

Scenario “Theoretical Potential - Middle” assumptions

- The yields of all crops except sweet sorghum[7] are doubled compared to the “Theoretical Potential - conservative” scenario. This assumption represents the variability of production observed in the cereal sector [2].
- As in the “Theoretical – conservative” scenario, land harvested for sugarcane is double that of 2014, half for alcohol production, half for ethanol cooking fuel production.

Scenario “Theoretical Potential - Aggressive” assumptions

- Yields and areas harvested are equivalent to that of the “Theoretical potential - middle” scenario except for areas of sugar cane harvested.
- Sugar cane is assumed to be harvested on the same amount of land area as the historical peak of the sector in the 1980's: 80,000 ha [7] which is an optimistic assumption. 65,000 ha of that quantity is assumed to be dedicated to ethanol in order to maintain 15,000 dedicated to the current alcoholic beverage market.

The feasibility of such scenarios remains uncertain due to competitive uses of arable lands. A large scale use of sugar cane (65,000 ha) would represent a non negligible share (12%) of the total arable land in Haiti (560,000 ha) [8]. Farming plots in Haiti represent approximately 1 million hectares and more than 95% of them were used for agriculture in 2012 [9]. No clear statement can be made on the feasibility of growing additional lands of sugar cane in Haiti without jeopardizing other crops, with the public data currently available. Doubling the areas of sugarcane harvested in the "Theoretical potential - conservative" and "Theoretical potential - middle" scenarios is deemed more feasible but this still requires to be confirmed with in-depth analysis of the agricultural sector and land use in Haiti.

[7] Sweet sorghum yield is already optimized with adapted agricultural practices and crop selection.

Fuel mix assumptions

Alternative fuels based on agricultural feedstock can be developed simultaneously[8], with the exception of pellets and charbriquettes both using bagasse from sugarcane and sweet sorghum[9]. Two pathways are illustrated in the calculations:

- 1. The bagasse in the scenarios is entirely dedicated to pellet production. Charbriquettes are made from rice husks, maize stems, cobs and leaves and sugarcane stems and leaves.
- 2. The bagasse is entirely dedicated to producing charbriquettes. Charbriquettes are made from rice husks, maize stems, cobs, leaves and sugarcane stems and leaves, as well as bagasse from sugarcane and sweet sorghum. There is no production of pellets.

2.2 Results

2.2.1 Potential

Figure 4 shows the share of the total number of urban households in Haiti[10] that can fully substitute traditional charcoal with an alternative fuel, based on 2014 annual crop productions and yields [1] and the scenarios described in §2.1.2.

[8] Maize, rice, sugarcane and sorghum can be harvested simultaneously in the three scen arios described. Stems and leaves, bagasse and ethanol from sugarcane can also be exploited simultaneously.

[9] If produced simultaneously, pellets and charbriquettes from bagasse will compete for the feedstock supply. The two pathways presented illustrate two extreme scenarios: bagasse is entirely used for pellets or entirely used for charbriquettes. In practice, both could be developed simultaneously, depending on the market demand.

[10] Urban households mainly cook with charcoal whereas rural households would rather use firewood. As charcoals is more expensive than firewood, urban consumers should be the privileged target of a fuel switching campaign.

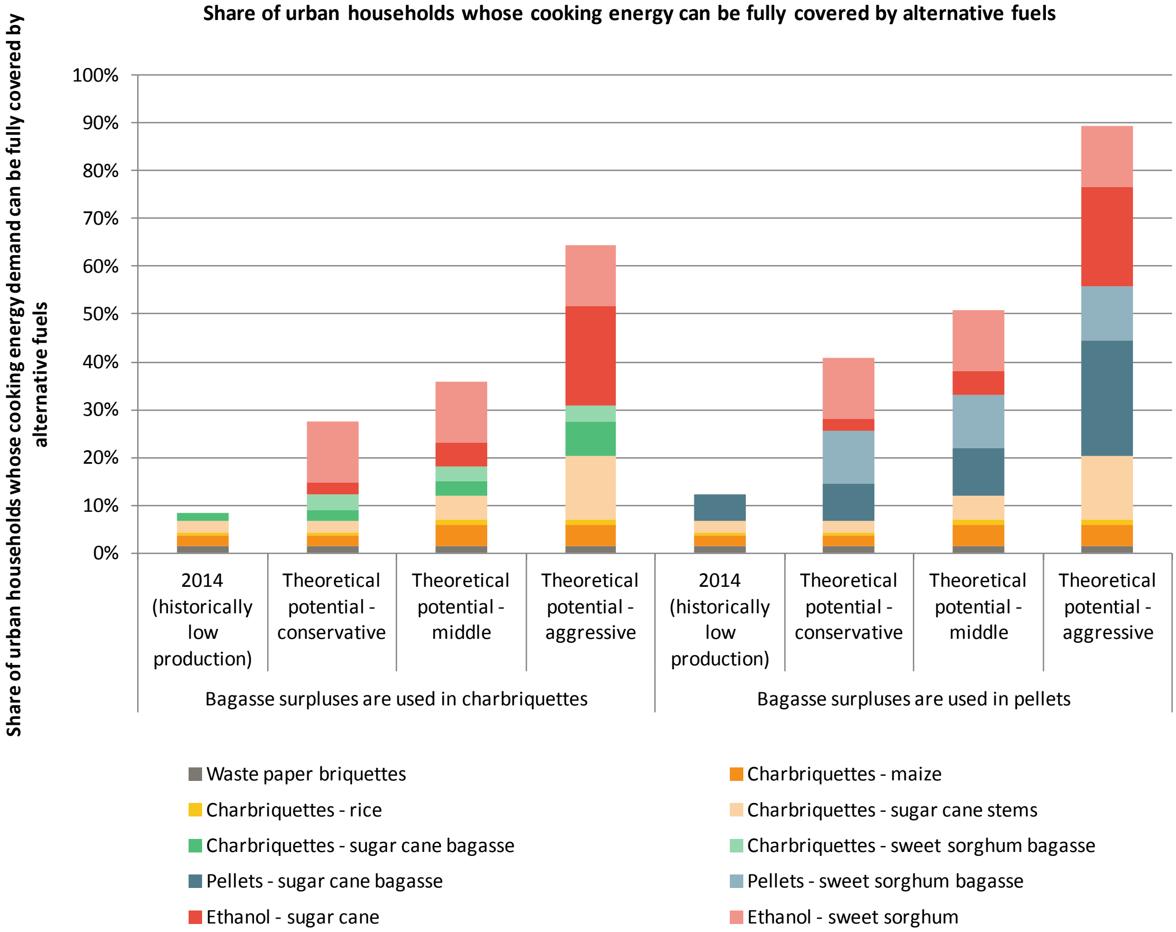

Figure 4 – Share of urban households whose cooking energy demand can be fully covered by alternative fuels according to three scenarios and two paths of fuel mix

In the "2014 (Historically low productivity)" scenario, 8 to 12% of urban households – about 100 000 to 150 000 – could replace charcoal with locally produced fuels. In the "theoretical potential - conservative" and "theoretical potential - middle" scenarios, 27% to 51% of the urban households – between 333 746 and 618 138 households – could be served on a cooking energy basis if all the raw material produced in the current situation were collected and converted into cooking fuels. These results must be considered as a maximum theoretical potential for biomass-based fuels locally produced in Haiti. The actual potential is necessarily lower than estimated in Figure 4 when taking into consideration the actual availability and accessibility of raw materials in the country.

Charbriquettes is the local biofuel most exposed to the risk in terms of raw materials. Agricultural residues contribute the most potential for charbriquettes but their collection in field is challenging compared to collection of centralized bagasse in distilleries:

- Feedstock is dispersed over several small and remote farming sites
- Transport of feedstock is costly as non-processed feedstock has little energy density
- On-site processing requires qualified workforce
- A part of agricultural residues is already used for compost or animal feeding. However, the share of raw agricultural residues with competitive uses cannot be estimated at this stage[11].

Bagasse resources for charbriquettes or pellet production is available at processing mills and thus more easily accessible than agricultural residues left on the field. Figures provided on the potential of bagasse in this study account for the self-consumption of the bagasse as a fuel in ethanol distilleries. However, the surpluses of bagasse could also be used for other energy purposes such as fuel in bakeries or industrial kilns. Even though there is currently very little local production of ethanol for cooking uses, the value chain of ethanol as a fuel should not be difficult to implement, as it very similar to the value chain of alcoholic beverage production.

Overall, the potential for biomass-based fuels locally produced in Haiti in the “2014”, or even the "theoretical - conservative” and "theoretical - middle" scenarios is relatively low. A combination of fuels including at least charbriquettes and ethanol is required to cover a significant share of the cooking energy demand of urban households. Bagasse conversion into pellets instead of charbriquettes is a possible path to increase[12] the cooking energy delivered by the overall fuel mix, thanks to the higher energy efficiency of pellets compared to charbriquettes[13] on a raw biomass to final energy basis.

The “Theoretical potential - aggressive” scenario offers a significant increase in the share of urban households reached thanks to the combined increase of ethanol and solid fuels produced from bagasse. The cooking energy possibly delivered by the fuel mixes in this scenario reaches the equivalent of 64% to 89% of the urban households needs – 785 339 to 1 089 887 households. The development of an extensive sugar cane sector dedicated to energy could thus enable local fuels to play a significant role in the cooking sector.

2.2.2 Seasonality

Figure 5 and Figure 6 display the fuel production by season for the "theoretical - conservative" scenario in order to represent seasonal variations due to agricultural seasonality. The national survey on agriculture (ENPA) reports data on three seasons of different duration: autumn (4 months, August-November), winter (3 months, December-February) and spring (5 months, March-July).

Whatever the fuel, about a half of the production takes place during spring and the remaining production is relatively balanced between winter and autumn. This seasonal variability must be balanced with the longer duration of the spring season and is not deemed to be a significant challenge for the steady supply of customers, if is anticipated by the value chain stakeholders with sufficient storage capacities.

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[11] This estimation would require a significant work of survey to observe agricultural practices in Haiti and uses of agricultural residues.

[12] With bagasse processed into pellets instead of charbriquettes, the number of households covered is increased by 34% to 40% in the "Theoretical - conservative" and "Theoretical - middle" scenarios respectively.

[13] In the model used, the cooking to biomass energy ratio of bagasse pellets is 3.4 time higher than for bagasse charbriquettes. This is the result of the energy losses during the carbonization process and the lower efficiency of the stove used for charbriquettes (charcoal stove with 22% efficiency) compared to the pellet stove (40% efficiency)

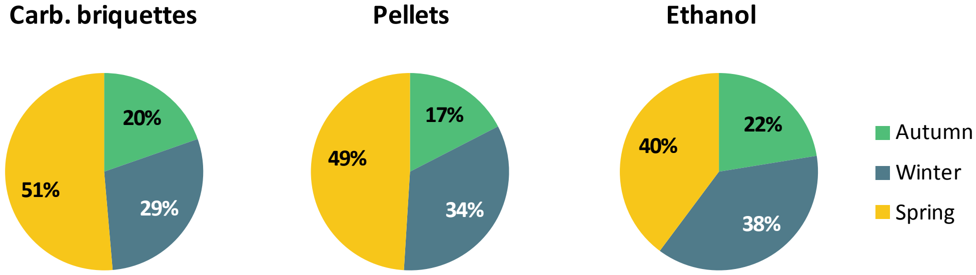

Figure 5 – Distribution of feedstock production (on an energy delivered basis) by fuels and by season in the "theoretical potential - conservative" scenario

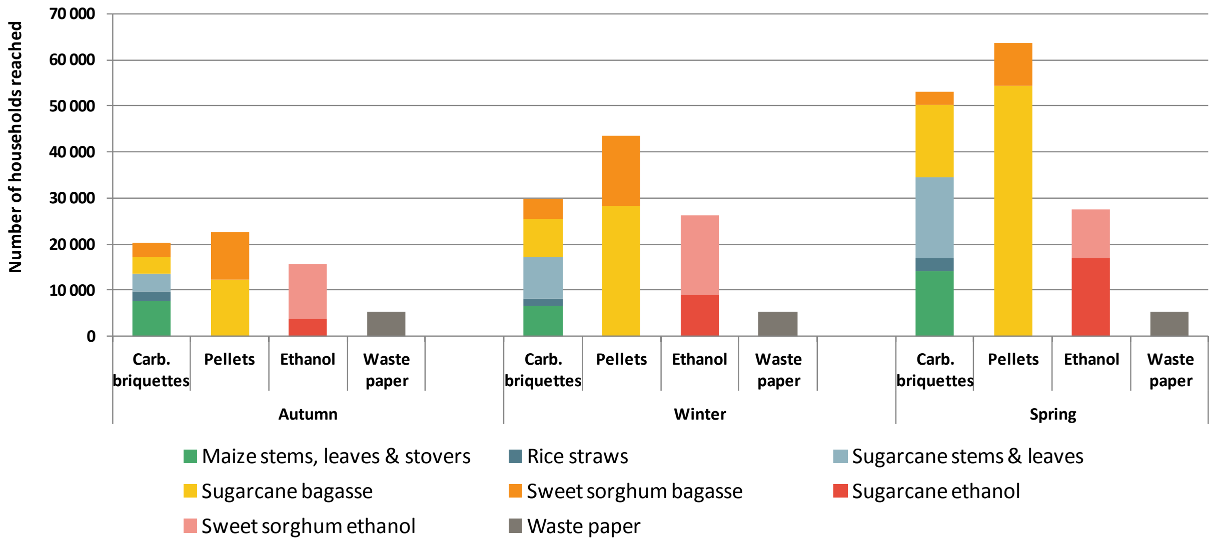

Figure 6 - Distribution of feedstock production (on an energy delivered basis) by season and by fuel in the "theoretical potential - conservative" scenario

2.2.3 Geographical distribution

Transport does not represent a major issue to the development of fuels from agricultural production. According to resource assessment per Haitian department with "Theoretical potential – conservative" scenario, feedstock production is close to main urban areas. Figure 7 shows that fuel production would be mainly concentrated in the central western part of Haiti, close to the three main cities of the country, Port-au-Prince (2.3 million inhabitants), Cap-Haïtien and Gonaïves (both between 200,000 and 350,000 inhabitants) [5]. Transport of fuels locally produced would still be required to address the most paramount urban market of the country: Port-au-Prince.

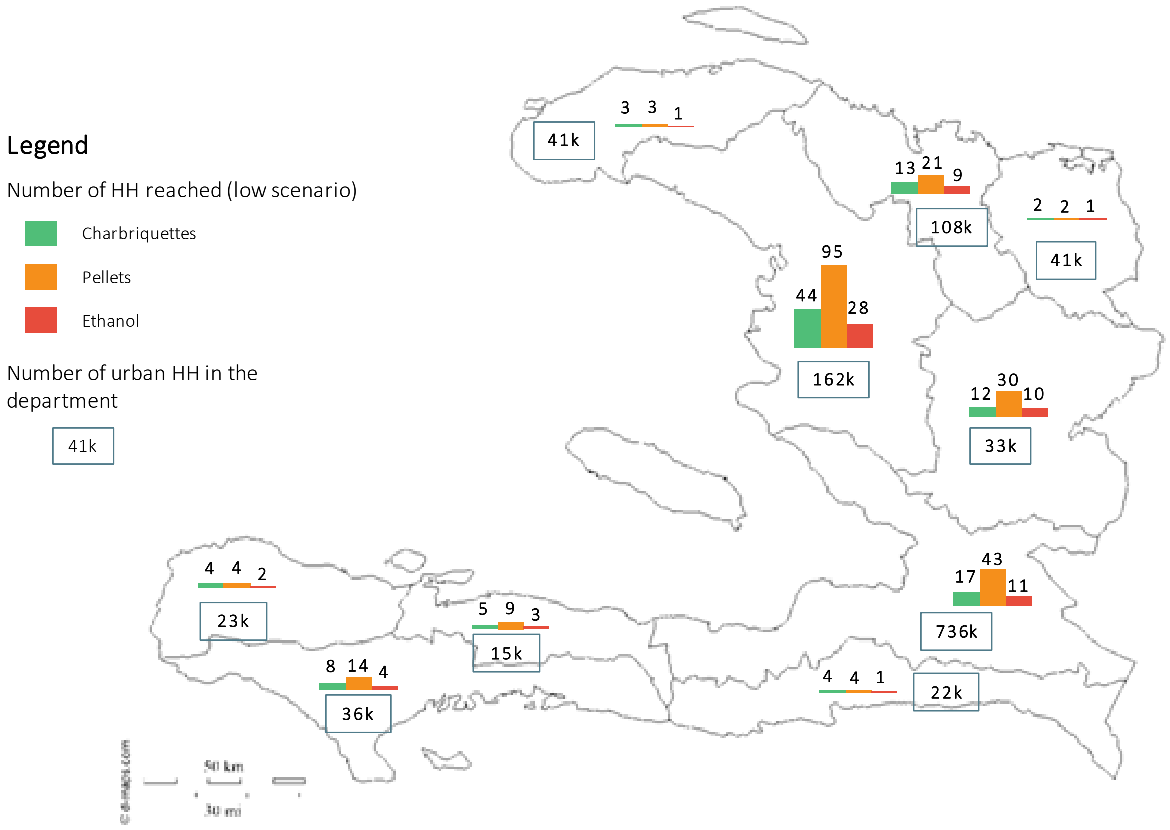

Figure 7 - Distribution of feedstock production (on an energy delivered basis) by department and by fuel in the "theoretical - conservative" scenario

3 ENVIRONMENTAL IMPACTS

This section compares the environmental impacts of the different fuels pathways, based on a Life Cycle Analysis (LCA). LCA takes into account environmental impacts over the entire life cycle of a fuel: in addition to the fuel combustion phase, it screens all the upstream phases such as fuel sourcing, production and distribution. Thus the different fuels can be compared on an equal basis. LCA methodology is based on a framework with worldwide shared standards, and should be undertaken by experts – such as Quantis in the present study – to ensure reliable and relevant information. LCA results offer a comparison between the reviewed fuels based on a set of indicators: it can be a tool to exclude or favor a fuel in order to limit a specific type of environmental impact. It also gives insight on which life cycle stage is the most harmful to the environment and should be addressed in priority to limit environmental impacts.

3.1 Method

The functional unit for the comparison of the various fuel pathways is 1MJ of heat delivered for cooking in Haiti. The indicators used for the assessment are the following:

- **Global Climate change Potential:** emission factors are from IPCC 2013. This indicator evaluates the global warming potential due to greenhouse gases emissions released during the life cycle of the reviewed fuel.
- **Black carbon (BC) and Short-Lives Climate Pollutants (SLCP):** calculated from emission factors provided by The Gold Standard. This indicator takes into account particulate matter and gases with a short term impact on climate change.
- **Total energy demand:** all the energy (renewable and non-renewable) required during the life cycle
- **Fossil fuel depletion:** only the fossil energy required during the life cycle, which points out if a non-fossil fuel use fossil fuel during its life cycle.
- **Water consumption:** direct and indirect water consumed (excludes sustainable water withdrawal), an important indicator in regions that can be affected by drought, or have difficult access to drinking water.
- **Particulate matter:** emissions of PM2.5, air pollutants detrimental to human health

The life cycle stages considered are the following:

- **Land transformation:** impacts from land conversion from forest to non-forest. It takes into account the carbon release from the soil and the roots of cut trees but not the release from the above ground part of the trees.
- **Sourcing and processing:** impacts from raw material sourcing (harvesting, fossil fuel withdrawal, materials and manufacturing of solar panels and batteries) and impacts from raw material processing into fuel (carbonization, fermentation and distillation).
- **Packaging**: impacts from the bottles or bags used to transport and retail fuels.
- **Transport:** impacts from transport (before processing and after processing).
- **Cooking device:** impacts of materials and processes used to manufacture the cookstoves.
- **Combustion**: impacts of fuel combustion based on average stove efficiencies. For LPG, CO_2 emissions from combustion are accounted in the "sourcing and processing" phase[14]).

Data used to build the model and input parameters were collected from interviews in Haiti, literature, GACC FACIT tool [10], Ecoinvent database and ENEA internal data. The main assumptions used to build the LCA model are described in Appendix §8.3 and input data are listed in Appendix §8.5.

[14] In LCA methodology, fossil fuel CO_2 emissions are accounted for as soon as fuel is extracted from underground fossil reserves.

3.2 Results

3.2.1 Global climate change potential

Figure 8 represents the impacts of each life cycle stage on the fuel's potential to impact climate change potential. The indicator is given in kgCO2-eq on a 100 year lifetime basis[15].

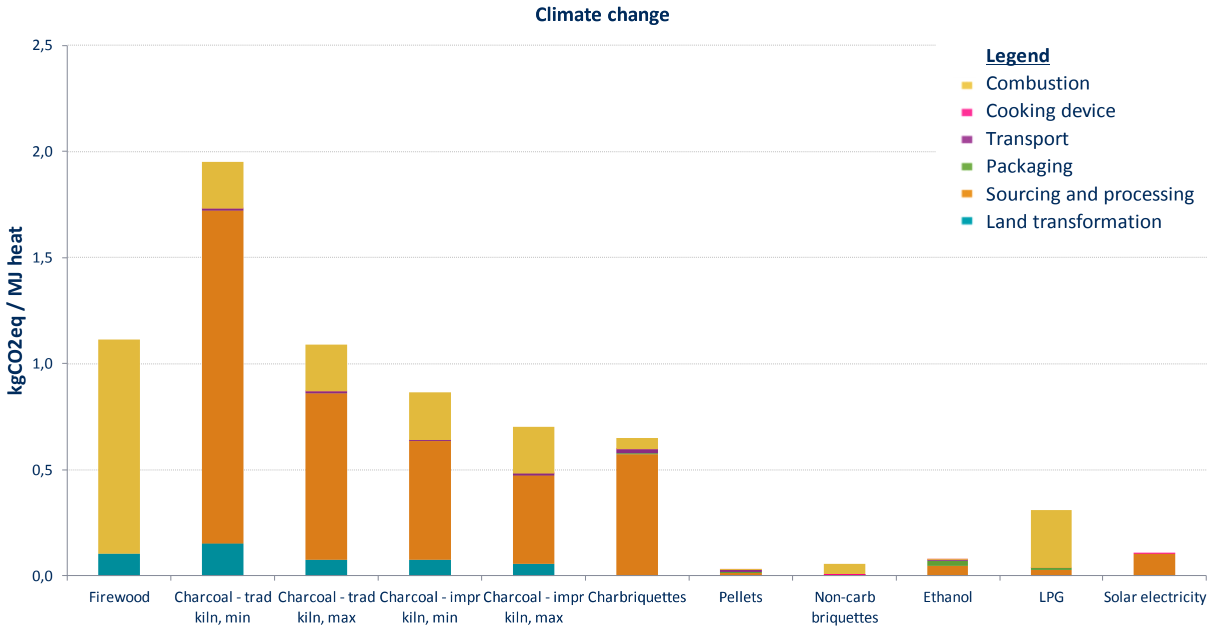

Figure 8 – LCA results on the global climate change potential of fuels

Charcoal is the traditional fuel with the highest climate change potential by far. For charcoal, most of the emissions are related to the carbonization stage. Switching to less-emitting carbonization kilns allows reducing this potential by 0.9 to 1.25 kg $CO_2/MJ_{delivered}$. Switching to an alternative fuel entails a sharper decrease of 1.3 to 1.9 kg $CO_2/MJ_{delivered}$ (see Figure 9), which is fifty percent more than the reduction potential with improvements on kilns. Improved kilns with high efficiency have about the same potential for climate change emissions abatement than charbriquettes.

[15] Greenhouse gases – such as CO_2, CH_4, N_2O and others – are all responsible for climate change, but they have different global warming potentials. For example, fossil CH_4 is 30 times more harmful than CO2 in terms of global warming over a 100-year horizon. In order to have a consistent climate change indicator, all amount of greenhouse gases are expressed in equivalent amount of CO_2. The conversion factors used are the ones published in the 2013 report of the Intergovernmental Panel on Climate Change (IPCC).

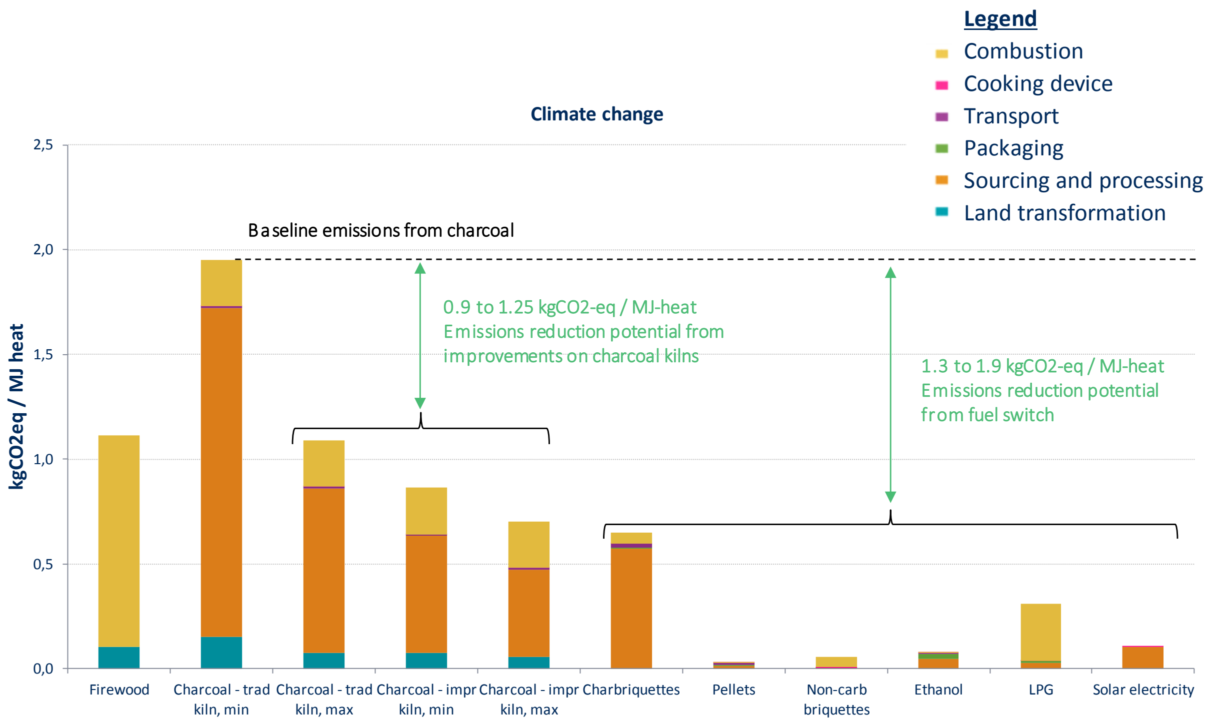

Figure 9 – Climate change reduction potential with two different strategies : switching to less-emitting charcoal pathways or switching to alternative fuels

Figure 10 focuses on non-traditional fuels with low climate change potential compared to charcoal. For fuels based on fully renewable biomass (charbriquettes, pellets and ethanol), emissions are significantly lower because the CO_2 emitted is biogenic[16]. However, other GHG gases also have an impact on climate, which materialize significantly in the carbonization stage for charbriquettes and in the combustion stage of non-carbonized briquettes.

Emissions from agricultural practices (fertilizers and pesticides) used whengrowing sugar cane for ethanol are low despite a conservative scenario[17]. LPG emissions result from the combustion of a fossil fuel. Even though LPG is an imported fuel, greenhouse gases emitted during importation in the country have little weight in total LPG impact because of LPG high energy density. Climate change emissions of the solar electricity path are mostly due to the manufacturing processes of the solar panels and batteries.

[16] CO_2 emissions are considered biogenic when emitted by combustion or decomposition of biologic material. As the CO_2 released to the atmosphere has been previously captured during plant growth, biogenic CO_2 has a neutral impact in environmental assessment. Conversely, CO_2 released from fossil sources was formed over millions of years and is not part of a short-term biological cycle. It thus has a negative impact on global warming.

[17] The LCA model for ethanol considers agricultural practices observed in Brazil supposed to be more intensive on fertilizers and pesticides than in Haiti.

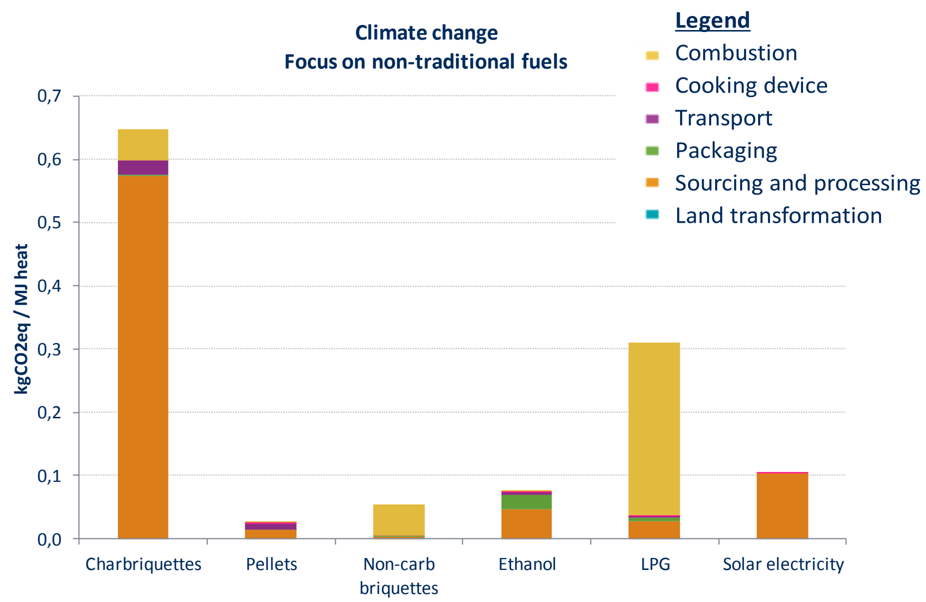

Figure 10 – LCA results on the global climate change potential of non-traditional fuels

3.2.2 Black carbon and short lived climate pollutants

Figure 11 represents the impacts of each life cycle stage on black carbon (BC) and the short-lived climate pollutants (SLCPs) emitted by the different fuels. The indicator is given in kgCO2-eq on a 20 year lifetime basis. Similarly to climate change potential results, switching from traditional charcoal practices to improved kilns results in a decrease of BC and SLCP emissions. The decrease is even more significant when switching to an alternative fuel. Pellets and non-carbonized briquettes show reduced emissions thanks to the absence of a carbonization step. However, these two fuels differ on the combustion emissions, with very low emissions for pellets and high emissions for non-carbonized briquettes due to the difference in fuel combustion quality.

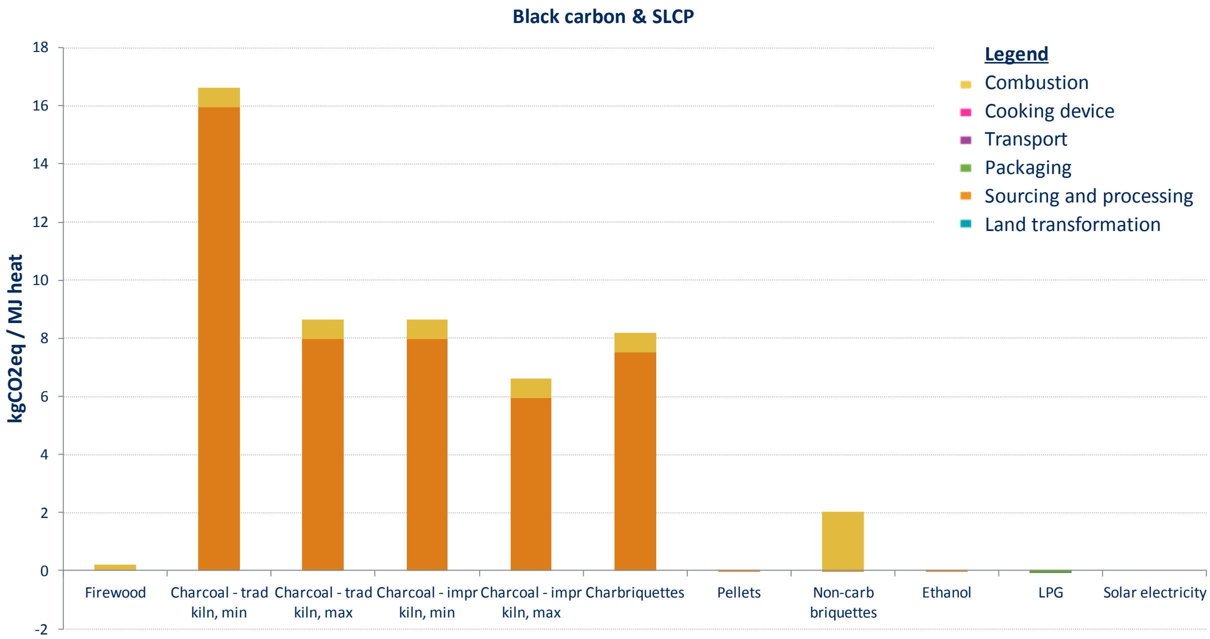

Figure 11 – LCA results on the black carbon and the SLCP emissions of fuels

3.2.3 Total energy demand

Figure 12 represents the impacts of each life cycle stage on total energy required by the different fuels to fulfill the functional unit. Fuels based on primary biomass products, such as firewood, charcoal and ethanol, have a higher demand in energy than fuels based on residues: charbriquettes, pellets and non-carbonized briquettes whose energy content is virtually reduced by the allocation factor[18] applied on the residues. Solar electricity demand in energy is relatively high (equivalent to improved charcoal pathways), due to the energy demand in solar panel and battery manufacturing processes[19].

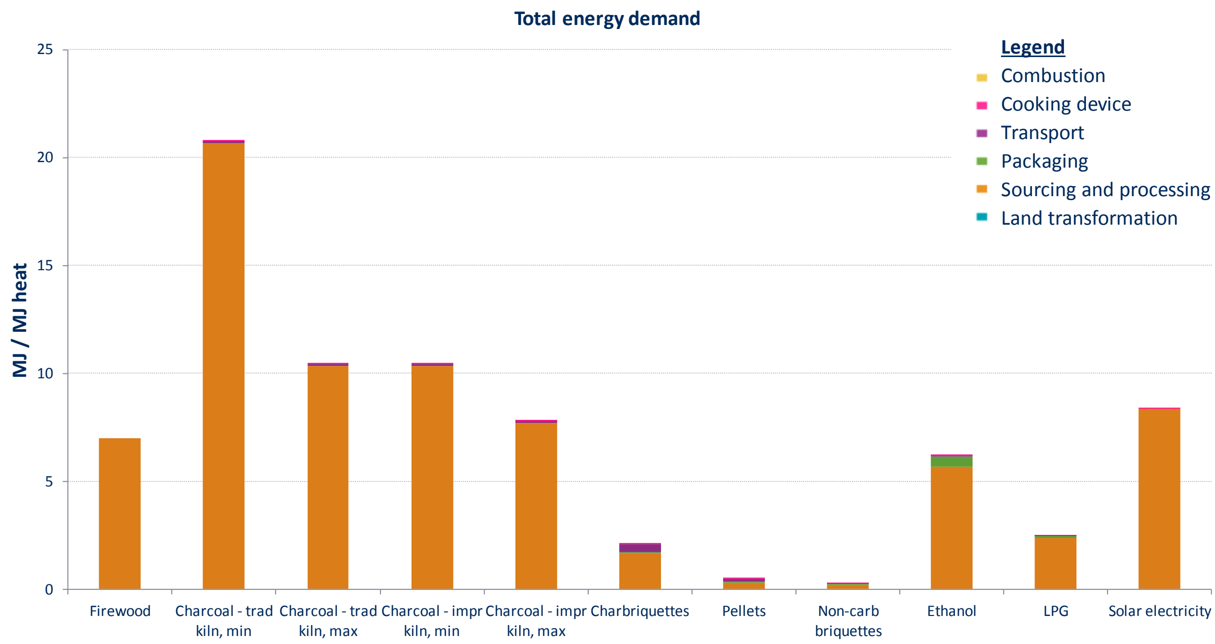

Figure 12 – LCA results on the total energy demand required by fuels

3.2.4 Fossil fuel depletion

Figure 13 represents the impacts of each life cycle stage on fossil fuel depletion entailed by the life cycles of the different fuels. Even though most reviewed fuels are not fossil, they indirectly consume fossil fuels through upstream life cycle stages (e.g. transport). Alternative fuels tend to require more fossil energy than conventional fuels. Fuels based on agricultural residues and by-products consume fossil energy at the processing factory and for packaging. Solar electricity uses fossil energy to manufacture solar panels and batteries. LPG is responsible for the highest fossil fuel depletion, almost entirely due to fossil fuel extraction directly transformed into LPG.

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[18] The harvested crop can be broken down into high added-value products, such as the grain or the juice, and low value by-products, such as the residues: stems, leaves, bagasse… In the LCA methodology, the impacts due to plant cultivation should be broken down similarly. As the primary purpose of plant growing is to produce high value parts, a higher share of the impacts should be attributed to the grain. The remaining share of the impacts is allocated to the residues. This latter ratio is named the "allocation factor" of the residues, and is based on an economic ratio between high value product and residues pricing.

[19] Note than the renewable solar energy captured by solar panel during their lifetime is not included in the indicator.

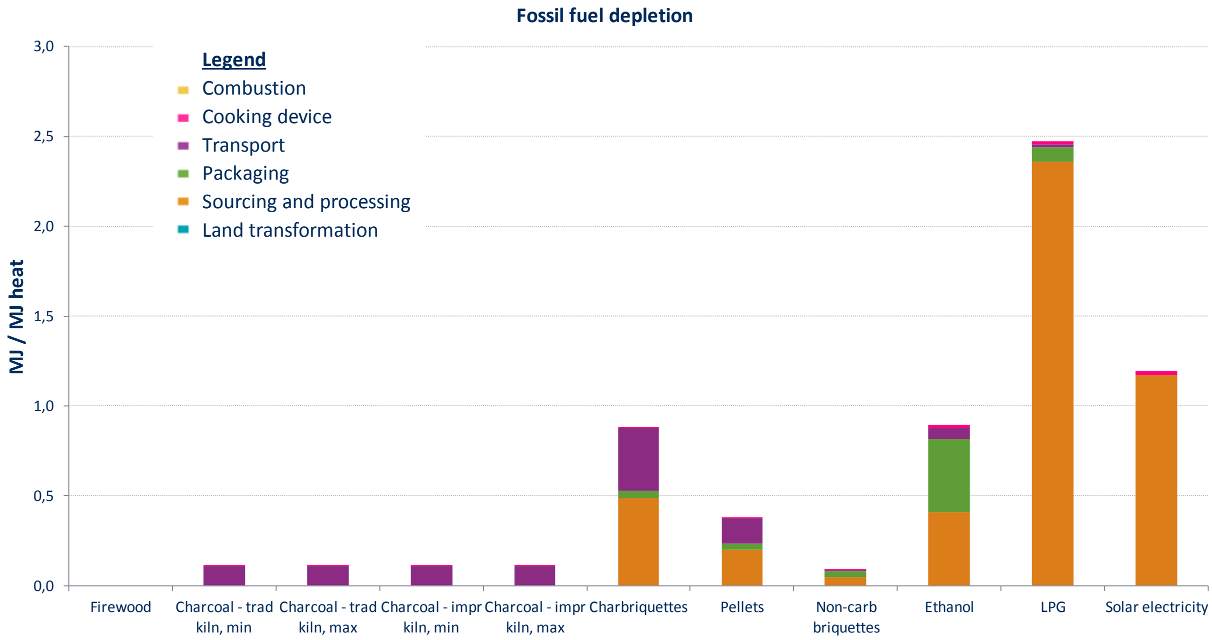

Figure 13 – LCA results on the fossil fuel depletion entailed by each fuel

3.2.5 Water consumption

Figure 14 represents the impacts of each life cycle stage on the water consumed by the different fuels. Except for ethanol, charbriquettes and electricity, water consumption is negligible. Charbriquettes and ethanol are impacted by the water requirements during farming. Ethanol is the most sensitive to water consumption from farming because its economic ratio for impact allocation is higher than charbriquettes produced from agricultural residues or byproducts. Water consumption in the solar electricity path is due to equipment manufacturing.

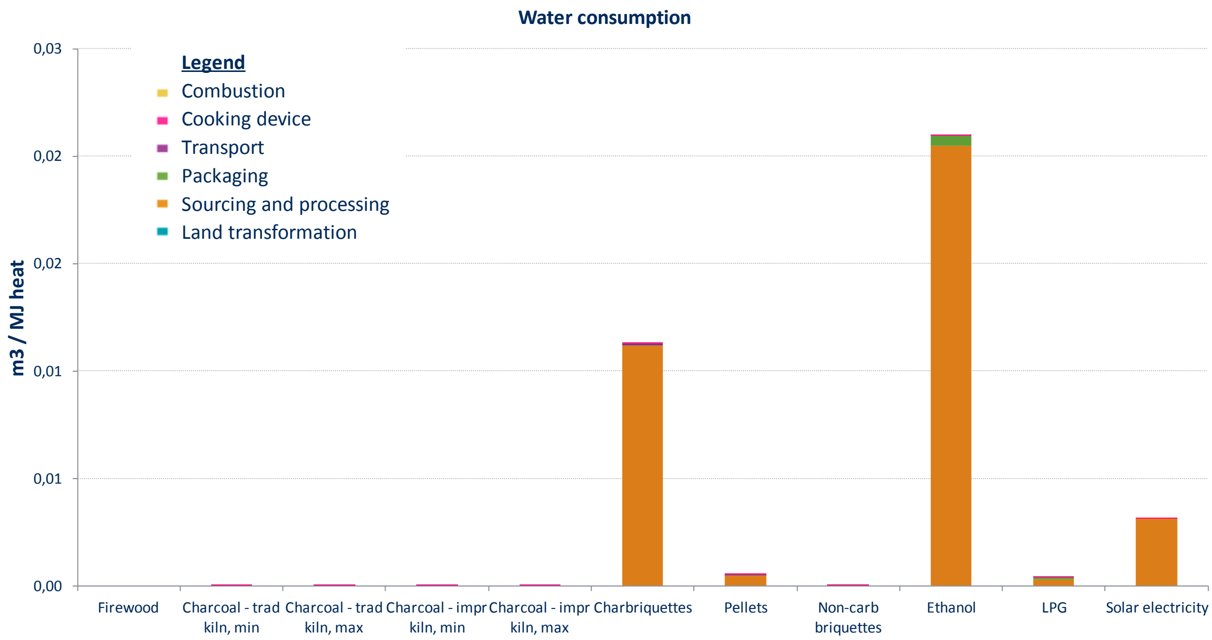

Figure 14 – LCA results on the water consumed by each fuel

3.2.6 Particulate matter formation

Figure 15 represents the impacts of each life cycle stage on particulate matter formed by the different fuels. Except for charbriquettes, switching from charcoal to any alternative fuel decreases particulate matter emissions sharply. In Figure 15, the combustion phase is placed at the bottom of the bar to enable the comparison of the end-user exposure to PM2.5 with the different fuel options. For solid fuels, PM2.5 emissions are highly depending on the type of stove. The LCA model considers conventional stoves for charcoal and charbriquettes and a forced draft gasifier stove for pellets which explains the high difference between these two types of fuels. Data on non-carbonized briquettes is not available but relatively high emissions can be expected from this fuel known for its poor quality for combustion (i.e. comparable to charcoal emissions or even higher) [11]. Ethanol, LPG and electricity emit negligible or no PM2.5 in the use phase.

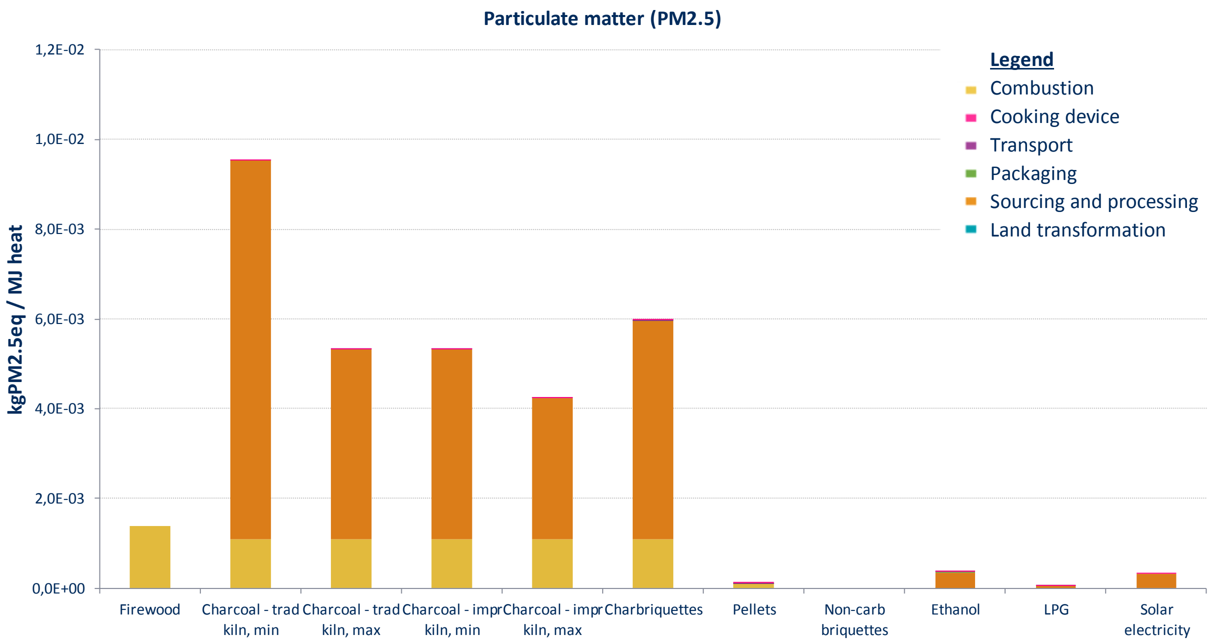

Figure 15 – LCA results on the particulate matter emissions entailed by each fuel

4 COST OF FUELS

The present section aims at comparing the cost of production and delivery of the different fuels to end-users, including the cooking device, based on a life cycle approach. The final cost of cooking is calculated as the sum of the cost of each stage of the value chain (raw material, transport, processing, retail, cooking device) and used the metric of the Levelized Cost of Energy for stages involving significant capital (i.e. processing and cooking device). This cost does not include margins and taxes along the value chain except for the retail margin used as a proxy of the retail cost. Data available in Haiti on the economics of fuels covered in this study are often associated with significant uncertainties or even not accessible. The model used to calculate the costs thus comprise assumptions and input parameters with values associated with significant uncertainties. It should therefore be used as a preliminary analysis of trends rather than an accurate and detailed analysis. Market values of fuels currently sold in Haiti are used as a reference in the analysis, in order to be compared with the calculated cost. Input data and calculations can be found in Figure 51, Figure 52 and Figure 53 in Appendix §**Error! Reference source not found.**

4.1 Method

4.1.1 Scenarios

Market values are derived from stove and fuel market prices observed or taken from the literature. They are given within a range with minimum and maximum values collected from the fuel producers or retailers [12][13][14][15][16][11]. Calculated costs are based on data collected in the field or compiled from the literature. It builds the cost breakdown along the value chain. Market prices and costs are given in **USD/MJ-delivered**: it represents the cost of useful energy and includes the cost of the fuel and the stove, taking into account the energy efficiency of the stove (see values of stove efficiency used in the study in §7).

The target market is Port-au-Prince and costs calculated are intended to be representative of the final breakeven cost to address the domestic market in PaP.

There is no local production of ethanol in Haiti yet. The assessment of the economics related to the processing step is highly uncertain with no feedback available on CAPEX and load factor mainly. The cost analysis on ethanol is thus based on two scenarios aimed at representing the range of cost variability due to uncertainties on the processing step. The minimum scenario is relatively optimistic on the CAPEX and load factor[20] while the maximum scenario is pessimistic[21] on these two parameters.

4.1.2 Cost breakdown

Firewood is assumed to be collected free of charge. The breakdown of LPG costs is not available because the cost of LPG at importation is not disclosed by stakehold; uiers. No data is available in Haiti on the cost of electricity from microgrid. However, the breakeven cost of benchmark microgrids in Africa can be used as a proxy. For the other fuels the cost breakdown is carried out on the following components of the value chain:

[20] CAPEX estimates of Green Social Bioethanol (GSB): 690,000 USD for a 3,500 L/day distillery; Load factor of 240 days/year (8 months full time).

[21] CAPEX doubled compared to GSB estimates: 1,380,000 USD for a 3,500 L/day distillery; Load factor of 120 days/year (4 months full time).

raw materials, binder, processing, transport, retailer margin (as a proxy of the retail cost), and final price of stove.

Raw materials cost

The purchasing cost of the different raw materials is based on the following data and assumptions:

- Firewood: the price of a woody land area in Haiti for charcoal [12]
- Bagasse: The current purchasing price of bagasse to farmers for charbriquettes production [16]
- Sugarcane: Income increase observed for farmers in Haiti thanks to bagasse sales in addition to sugarcane [16]
- Waste paper, rice and maize residues: assumed free of charge [11]

Binder

Binder is needed for charbriquettes processing only. In Haiti, the least expensive binder is imported starch, but its cost is still high compared to the remaining of raw materials [16]. Binder cost could have been included in the "raw materials" category but it is shown separately to highlight its higher cost compared to the other stages of the value chain.

Processing

The Levelized Cost of Energy (LCOE) gathers the sum of discounted cash flows over the lifetime of the processing factory: capital cost of equipments, operational costs of labor, maintenance and energy (see definition of the LCOE in Appendix §8.6).

These costs were calculated based on the information collected with

- Factories currently operated in Haiti to produce carbonized briquettes [16] and non-carbonized briquettes [11]
- Techno-economic data on wood pellet production plants in East Africa for pellets [17]
- Cost estimates from Green Social Bioethanol on a small scale distillery for ethanol [6]
- CAPEX and workforce needed for improved carbonization kilns for improved charcoal [18]

Transport

The low homogeneity and reliability of data available on transport of products in Haiti prevent from building a model able to calculate the cost of transport per distance traveled. Therefore, the cost model considers a cost per kg transported based on the feedback of CRI and thus representative of a travel from Cap-Haitien to Port-au-Prince [16].

Cost of transport from wholesale to retail is not taken into account.

Retailer margin

Retailers buy fuel at wholesale and add an extra cost to the fuel sold to customers. It is assumed to be the same for all alternative fuels, based on CRI's experience [16]. Retailer margin is highly variable for charcoal because of the large and unregulated market. In our model a fixed margin is used for charcoal in and outside of Port-au-Prince based on bulk and retail differences in prices observed [12][13][14]. Eventually, retailer margins for charcoal and alternative fuels are similar independently from the adopted calculation method.

Cooking device

The cooking device may be capital intensive and has a specific lifetime; it is therefore modeled with the calculation of a levelized cost per MJ delivered based on its lifetime and the amount of energy delivered per year.

The lifetime and share of the household energy demand covered by the stove vary depending on the type of stove and fuel [19] [20] [15] [14]:

- Charcoal and charbriquettes: lifetime of 0.75 months, 100% of energy need of the household covered by the fuel
- Non-carbonized briquettes and pellets: lifetime of 2 years, 100% of energy need of the household covered by the fuel
- LPG and ethanol: lifetime of 2 years; 50% of energy need of the household covered by the fuel

4.2 Results

Figure 16 displays the cost breakdown of each cooking path as calculated in the cost model as well as the market values observed in Haiti. Market values are shown for PaP and outside PaP for charcoal. For the other fuels, market values are applicable to PaP only. The calculated costs (bars breakdown) are applicable to PaP only, with a fuel transportation representative of the distance between Cap-Haitien and PaP.

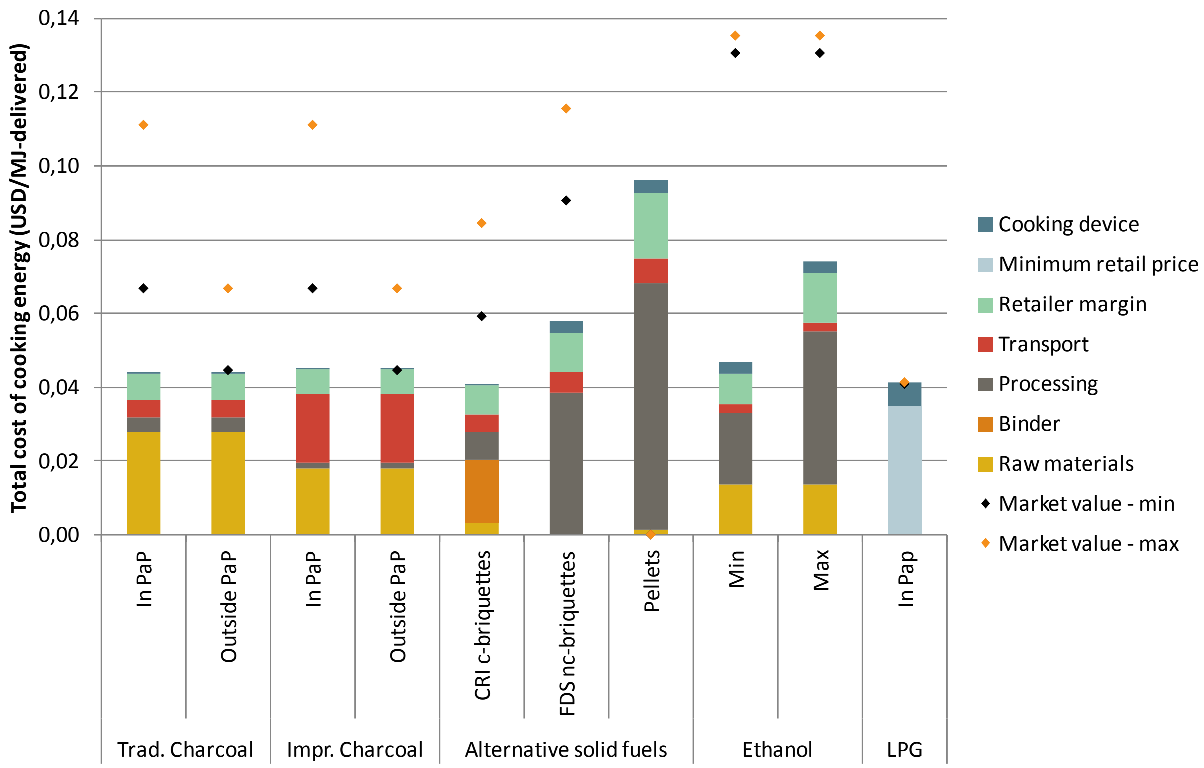

Figure 16 – Overall cooking costs of fuels based on the cost of each stage of the value chain versus minimum and maximum market values

In the results shown in Figure 16, market prices are systematically higher than calculated costs, except for LPG for which the retail price has been directly used and for pellets not yet sold in Haiti. The gap between the calculated cost of fuel and the market values represents the margins on sourcing and production as well as possible taxes along the value chain. Uncertainties on the data collected and assumptions used in the model could also underestimate the calculated cost. Costs of transport in particular may be underestimated in the model. For ethanol, market prices are those of imported ethanol[22] which explains the difference with calculated costs and also shows an economic benefit to develop local production instead of importation. This preliminary analysis thus must be used to define trends and key learnings but would require further work to precisely assess the cost of fuels.

Despite the relatively high uncertainty on the results of cost calculations, several trends or learning can be stated. Improved charcoal[23] cost is in the same range as traditional charcoal. This is the consequence of a balance in cost savings with lower consumption of wood and additional cost expenditures due to wood transport to the improved kiln[24]. CRI charbriquettes seem to compete with charcoal despite a high cost of binder (significant consumption of imported starch). If the binder issue were solved for charbriquettes, this fuel could likely outcompete charcoal. Non-carbonized solid fuels (briquettes, pellets) tend to be more expensive mostly due to the capital investments in the processing factory. Ethanol tends to be more expensive than charcoal but still positions in the same order of magnitude with possible areas of competitiveness if the CAPEX and load factor of the microdistillery are optimum (Min scenario).

The cost of cooking device is negligible for charcoal and has a very low contribution to the total cost of cooking for other fuels, even for pellets, ethanol or LPG requiring expensive stoves. Nevertheless, the high upfront capital cost of stove for these latter fuels might be an obstacle to fuel switch for end-users. This financial entry barrier may be one of the causes of the low penetration of LPG in Haiti despite its affordability when considering the total cost of cooking.

Cooking from electricity is not displayed in the graph due to dramatically higher costs (0.8 USD/MJ-delivered), and have therefore be excluded of the range of fuels screened in the economic analysis.

[22] Prices of imported ethanol are particularly high due to the low quantities imported currently.

[23] "Improved charcoal" refers to improved carbonization techniques but not to the use of improved cooking stove.

[24] Estimates on the cost of wood transport to improved kilns are conservative: the same cost per mass unit has been used for wood transport and for charcoal transport between Cap-Haitien and PaP while distances for wood are expected to be much lower.

5 SOCIAL IMPACTS

Social impacts of a cooking fuel can materialize along the entire value chain, from raw material sourcing to final use of the fuel. The present study does not aim at measuring actual impacts of fuels already used in Haiti but at assessing qualitatively the expected impacts of a switch from a traditional fuel (firewood or charcoal) to a modern fuel (e.g. charbriquettes, LPG…). This section thus provides a theoretical analysis based on facts and figures known *a priori* rather than an evaluation of impacts that have already materialized.

The Alliance developed a Monitoring & Evaluation (M&E) frame for social and economic impacts of cooking options (stoves and fuels) covering the whole value chain with two main domains of impacts applicable to the theoretical analysis proposed in this report: "Livelihoods" and "Household social and economic wellbeing". The categories of impacts comprised in these domains are listed in appendix (see §0). The M&E of the Alliance includes a third domain called "Social & Economic Empowerment" excluded from the scope of this study.

This section elaborates a qualitative ranking of the different fuel options on Livelihoods (see §5.1) and on Social & Economic Empowerment (see §5.2), for the categories of impact that can be covered with data available currently in Haiti. A preliminary assessment of the impact of fuel switch is then assessed for the different alternative fuel options.

5.1 Livelihoods along the value chain

Impacts of cooking fuels in the domain of livelihoods are related to jobs and income for the stakeholders involved in the value chain except end-users, with a particular attention to gender (see detailed list of categories of impact in appendix in §0). The analysis of the social impacts of livelihoods in the value chain is based on the information collected from field interviews and the literature on the fuels values chains. A synthesis of this information is provided in appendix (see §0).

Figure 17 displays the qualitative ranking of fuel value chains by segment (raw material sourcing, fuel processing, and fuel sales) for three main categories of impacts on livelihoods (jobs and income). A reference is also made to the geographic location of economic activities and to the distribution of roles between women and men. The rationale used to rank the indicators is detailed at the bottom of the figure.

	Job			Income			Geographic location			Gender		
	Sourcing	Processing	Sales	Sourcing	Processing	Sales	Sourcing	Processing	Sales	Sourcing	Processing	Sales
Improved charcoal	High	High	High	Low	Low	Medium	Rural	Rural	Urban	Male	Mixed	Female
Carbonized briquettes	Medium	Medium	High	Medium	High	Medium	Rural	Urban	Urban	Mixed	Male	Female
Non carbonized briquettes	Medium	Medium	High	Medium	High	Medium	Urban	Urban	Urban	Male	Male	Female
Pellets	Medium	Medium	High	Medium	High	Medium	Rural	Urban	Urban	Male	Male	Female
Ethanol	High	Medium	High	Medium	High	Medium	Rural	Rural	Urban	Mixed	Mixed	Female
LPG	Low	Low	High	N/A	N/A	Medium	N/A	N/A	Urban	N/A	N/A	Mixed
Electricity	Low	Low	Low	N/A	N/A	High	N/A	N/A	N/A	N/A	N/A	N/A

Rationale for ranking

Employment - Sourcing
High: raw material production is a dedicated activity
Medium: the raw material is a waste or a byproduct
Low: the raw material is not produced locally

Employment - Processing
High: the processing step is job intensive (the baseline is traditional charcoal)
Medium: the processing phase requires manwork but offers higher productivity than traditional charocal
Low: there is no processing phase

Employment - Sales
High: the fuel is sold in small units to consumers
Medium: the fuel is sold in bulk or wholesales to consumers
Low: the fuel is sold with a grid or is not sold

Wage & Skills
High: the wage is higher than the national minimum wage, the tasks required trained workforce and management
Medium: incomes are increased compared to the baseline and the activity requires no particular skills but possible management
Low: incomes correspond to the minimum salary or basic economic activities (farming, charcoal making)

Geographic location
Rural: operations are mainly located in rural areas
Urban: operations are mainly located in urban areas

Gender
Female: tasks generally handled by women
Male: tasks generally handled by men
Mixed: no specific differentiation of gender in the tasks

Figure 17 - Qualitative ranking of the impacts of fuels value chains on livelihoods

Employment

Firewood implies a very simple value chain with no economic trade and is thus not really suited to a comparison with other fuels on employment.

Traditional charcoal is the baseline and is likely to be the most impacting value chain in terms of employment because it is the less efficient paths on a mass and energy basis, and thus requires higher workforce than the other fuels for the sourcing and processing segments. Improved charcoal will require lower volumes of wood and is thus likely to reduce the need of labor on the sourcing segment. Improved carbonization techniques require labor to build the kilns and operate it. Even though improved kilns are more efficient, it could require the same amount of labor than traditional kilns overall.

Ethanol production from sugar cane or sweet sorghum harvesting is the only path with a level of job intensity equivalent to traditional charcoal because it is a dedicated activity. Other biomass-based fuels (i.e. charbriquettes, pellets) and non-carbonized briquettes valorize wastes or byproduct and thus create jobs for collection but not for its production[25]. Processing technologies for ethanol, briquettes and pellets would be operated locally but with a lower need for workforce compared to charcoal due to more efficient technologies and production organization.

[25] Nevertheless, these fuels can increase the incomes of farmers producing the residues even though it does not materialize as an employment.

LPG and electricity are not based on raw materials or equipments locally sourced or processed locally and thus have a low impact on employment on these two segments of the value chain.

Sales of solid, liquid and gaseous fuels rely on a network of small retailers with a significant impact on employment independently from the type of fuel. Electricity is sold with a grid and is thus less labor intensive.

Income

Firewood collection does not generate incomes. For alternative fuels, local sourcing of raw materials and local processing of the fuels are expected to generate higher incomes than for charcoal because it valorizes wastes or byproducts for the benefit of farmers and the processing steps are operated in factories with wages up to twice higher than the minimum salary (see §0). Incomes from fuel sales are expected to be equivalent from a fuel to another, with similar retail margins. For electricity, most of the activity lies in the distribution and sales of electricity through a grid which could imply higher revenues from this specific segment of the value chain.

Geographic location

Alternative fuels tend to localize the processing step, and its jobs and incomes associated, in urban areas while for charcoal it is located in rural areas. Ethanol would be the only biofuel with a processing step in rural areas, if based on a decentralized model with microdistilleries operated by farmers. Alternative fuels are most likely to be consumed in urban markets where charcoal is prevailing.

Gender

Women are involved in agricultural activities but not in raw material sourcing, except for firewood. Alternative fuels to charcoal tend to exclude women from the processing phase but sales are achieved by women as they systematically operate small shops.

5.2 Household social and economic wellbeing

Impacts of cooking fuels in the domain of Household social and economic wellbeing are related to fuel adoption, household finances, time use, status, safety and protection, and drudgery (see detailed list of categories of impact in appendix in §0). The analysis of social and economic impacts on end-users generally requires field survey. Therefore, the assessment of most of these impacts is not feasible in the frame of this theoretical analysis:

- Adoption: There is no comprehensive study available on the time of use of the different fuels in Haiti. However, it is known that households using modern and fast cooking fuels such as ethanol, LPG and electricity keep using solid fuels such as charcoal for certain meals (e.g. beans that require long periods of cooking).
- Household finances: The cost analysis provided in §4 shows that uncertainties on economics of fuels are still too high to enable a ranking of the fuels, except for electricity that is one order of magnitude more expensive than other fuels.
- Status: The change in status within the family or community due to fuel switch cannot be anticipated before in-field observations.
- Safety and protection: Risks related to burns is often cited by Haitians but should be more precisely assessed on ethanol end-users. Similarly, for other fuels and for the risks related to fuel collection or fuel purchase a field survey on end-users would be required.

However, a preliminary assessment can be done on the categories of time use and drudgery, based on the features of the fuels, known *a priori* thanks to the Tier classification shown in Figure 18.

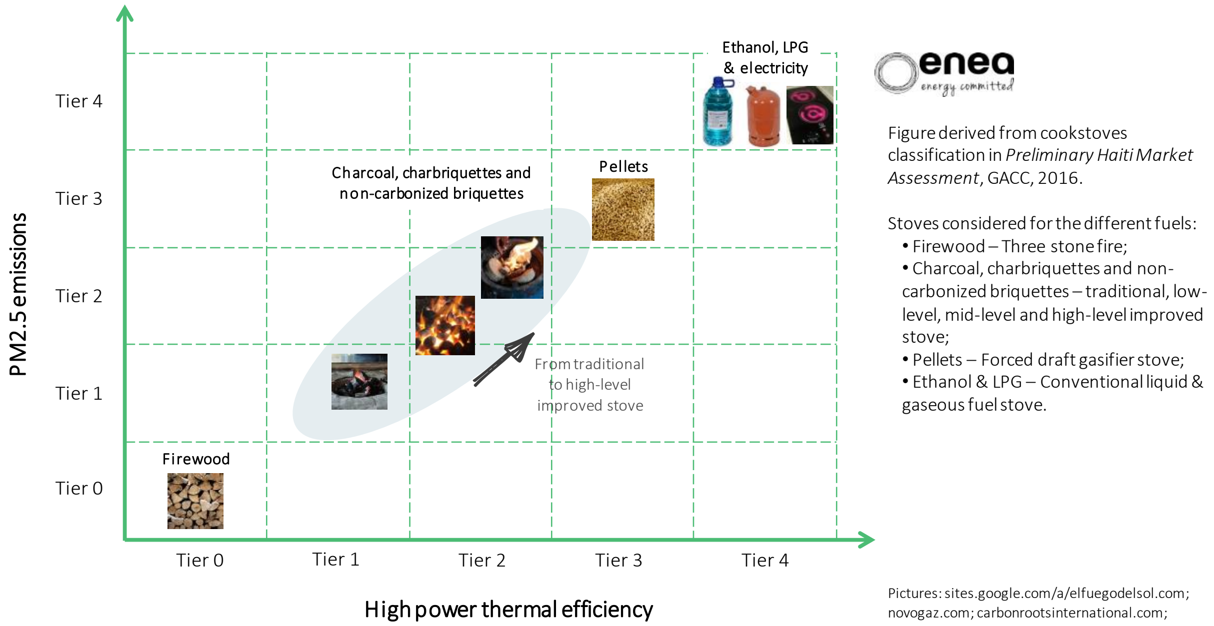

Figure 18 - Tier classification of cooking fuels

Time use & Drudgery

The time spent on fuel collection (or fuel purchase) is not expected to change for urban households who buy their fuels in small retail shops in town (generally called *Madame Sara*). LPG can be sold in larger shops and could thus be less accessible but the energy content of an LPG bottle is higher than volumes of charcoal generally bought by households, thus balancing the time spent on fuel purchase. Finally, urban end-users would not likely benefit from time savings on fuel purchase if switching from charcoal to an alternative fuel. Rural household may save time if switching from firewood collected to an alternative fuel purchased but such a switch is not likely due to economic reasons (i.e. ability and willingness to pay of rural end-users).

Time spent on cooking can be derived from the high thermal efficiency of the fuel (see Figure 18). For solid fuels, this feature depends strongly on the type of stove used. Charcoal, charbriquettes and non-carbonized briquettes have poor performances if used in traditional stoves and can have improved performances as long as a more sophisticated stove is used. A fuel switch from charcoal to charbriquettes or non carbonized briquettes is thus not expected to have an impact on the time spent on cooking.

In the context of Haiti where improved stoves are currently not a common practice, the fuels performances can be assessed assuming that these three fuels are used in traditional stoves (Tier 1) or in low-level or mid-level improved stoves (Tier 2). This enables pellets (Tier 3), ethanol, LPG and electricity (Tier 4) to have a positive impact on time spent on cooking compared to charcoal.

The cooking drudgery mostly lies in smoke and particulate emissions and in cooking speed. The Tier performance can thus be used as a preliminary proxy to assess cooking drudgery, with PM2.5 emissions as an indicator of cooking emissions and with high power thermal efficiency as an indicator of cooking speed. Finally, a common ranking of fuels can be proposed to assess the time spent on cooking and cooking drudgery in Haiti:

- High: Firewood in three stone fire (Tier 0)
- Medium: Charocoal, charbriquettes or non-carbonized briquettes used in traditional stove or low-level to mid-level improved stoves (Tier 1 to Tier 2)
- Low: Pellets used in forced draft gasifier stoves, ethanol, LPG or electricity

5.3 Impact of fuel switch

The impact of alternative fuels will be the change resulting from the switch from a traditional fuel. Urban households using charcoal are the most likely to operate this switch[26]. Therefore, the assessment of the impact of fuel switch proposed below is built on a baseline with charcoal used as a traditional fuel in cities.

The assessment of the impact of fuel switch is based on the qualitative ranking (low, medium, high) for the three main categories that can be covered in this study: employment, income, time spent, drudgery. The impact is calculated as the spread of the ranking level of the alternative fuel and the baseline fuel (i.e. traditional charcoal).

Finally, the impact is qualified as:

- "**Very positive**" if the ranking of the alternative fuel is two levels above the baseline (i.e. high vs low)
- "**Positive**" if the ranking of the alternative fuel is one level above the baseline (i.e. high vs medium or medium vs low)
- "**Null**"if the ranking of the the two fuels are similar
- "**Negative**" if the ranking of the alternative fuel is one level below the baseline (i.e. medium vs high or low vs medium)
- "**Very negative**" if the ranking of the alternative fuel is two levels below the baseline (i.e. low vs high)
- "**N/A**" if one of ranking of at least one of the fuel was not feasible

Figure 19 displays the qualitative assessment of the social impacts of a fuel switch from traditional charcoal to alternative fuel.

	Job			Income			Time spent	Drudgery
	Sourcing	Processing	Sales	Sourcing	Processing	Sales	End-user	End-user
Improved charcoal	Null	Null	Null	Null	Null	Null	Null	Null
Carbonized briquettes	Negative	Negative	Null	Positive	Very positive	Null	Null	Null
Non carbonized briquettes	Negative	Negative	Null	Positive	Very positive	Null	Null	Null
Pellets	Negative	Negative	Null	Positive	Very positive	Null	Positive	Positive
Ethanol	Null	Negative	Null	Positive	Very positive	Null	Positive	Positive
LPG	Very negative	Very negative	Null	N/A	N/A	Null	Positive	Positive
Electricity	Very negative	Very negative	Very negative	N/A	N/A	Positive	Positive	Positive

Figure 19 - Qualitative assessment of the impacts of a fuel switch from traditional charcoal to an alternative fuel

Switching from traditional charcoal to improved charcoal (with the same cooking stove) is not expected to generate a significant change in social impacts, neither on the value chain (job, income) nor on end-users (time spent, drudgery).

[26] Past experiences in context similar to that of Haiti (sub-Saharan Africa) show that households cooking on free collected firewood are reluctant to switch to a paying fuel.

The fuel switch to an alternative solid fuel (carbonized briquettes, non-carbonized briquettes, pellets), is likely to have a negative impact on jobs, due to the lower need for labor on sourcing and processing steps but should increase the incomes of stakeholders of the value chain. Pellets are the only solid fuel able to procure a significant change in the time spent on cooking and the cooking drudgery, if used in a proper stove (forced draft gasifier) while other solid fuels are used in less efficient stoves.

The impacts of ethanol on job could be slightly negative on the processing step with distilleries operated more efficiently than current traditional charcoal making. However, this fuel can increase incomes thanks to the creation of a demand for a cash crop and the operation of distilleries. End-users should also benefit from the switch to ethanol with savings on time spent on cooking and a reduced exposure to smoke (drudgery).

Finally, the two most modern fuels, LPG and electricity, have a very negative impact on job with no local employment on the sourcing and processing segments of the value chain. Electricity is also likely to destroy jobs on sales due to the low requirement for sales agents when distributing electricity with a microgrid. However, the jobs required to manage the microgrid an electricity sales are likely to be better paid than conventional retail jobs. On the end-user side, both LPG and electricity are expected to generate a positive impact with savings in time spent on cooking and reductions in smoke exposure.

6 CONCLUSIONS AND RECOMMENDATIONS

Biofuels locally produced in Haiti are environmentally sound for a clean fuel strategy.

The Life Cycle Analysis of charbriquettes, non-carbonized briquettes, pellets and ethanol demonstrate their significant CO_2 emission reduction potential if substituted for traditional charcoal (1.3 to 1.9 $kgCO_2/MJ_{delivered}$). Among these clean fuels, charbriquettes are the most emitting (based on CO_2, BC & SLCPs and PM2.5). Along their lifecycle, biofuels tend to consume more water and fossil energy than charcoal due to harvesting practices and fuel processing input. Overall, switching from charcoal to biofuels offer a great potential of positive impact on the environment and on end-user exposure to PM2.5.

However local biomass resources suited to produce biofuels in Haiti are limited compared to the cooking energy demand of the country: it could theoretically cover up to 50% of the urban household demand.

The resource assessment shows a limited potential in Haiti for biomass based fuels due to the low production of this biomass from agricultural activities. Moreover volumes produced each year are highly variable and not necessarily available (competition in uses) nor accessible (remote areas). The scenarios developed in this study indicate that based on the current national production of biomass suited to cooking fuels (maize, rice, sorghum, sugar cane) and with realistic efforts dedicated to the development of ethanol crops (i.e. sugar cane and sweet sorghum), 27% to 51% of the urban households demand for cooking energy could be theoretically served.

The development of a biofuel sector at larger scale would mean developing pellets and ethanol and is expected to face various challenges that must be investigated before building a more ambitious strategy on local biofuels.

In-depth surveys and analyses on land use, land availability and agricultural practices in Haiti are required to precisely assess the extent to which energy crops can be grown and existing agricultural residues can be recovered without damage to preexisting agricultural activities or on soil fertility.

A large scale development of biofuels in Haiti for cooking purposes would imply a high penetration of ethanol and pellets in urban markets. However, the competitiveness and the market adoption of these two fuels is still to be proven. The preliminary analysis of production cost of fuels highlights higher costs for pellets and ethanol compared to charbriquettes and charcoal due to CAPEX intensive processing equipments. No experience has yet been identified on pellets in Haiti (neither on wood nor bagasse pellets). Despite the high energy efficiency of this fuel and its very low emission of smoke and particulate, market adoption of pellets is known to be challenging in other developing countries, notably due to the high upfront cost of the required stove. Novogaz is currently working on the market uptake of ethanol but social and political acceptance of ethanol is still challenging in Haiti. Distrust on ethanol is observed at several levels of the value chain: farmers and politicians can fear the ethanol sector as it is not related to a food market and may jeopardize the food security of the country, while end-users and politicians are sensitive to rumors on the risks related to the use of ethanol (fire and adulterated alcohol beverage).

Non-carbonized briquettes and electricity have a low potential and should be excluded from further considerations on fuels.

Local resource to produce non-carbonized briquettes (saw dust, waste paper) are too limited to make it a candidate for a fuel strategy aiming to reach more than 1% of the household urban demand. The production cost of clean electricity is too high to make cooking on electricity an affordable option for households in Haiti.

LPG is an attractive option to develop clean fuels in Haiti but requires the development of consumer finance services and political intervention to regulate the market.

LPG offers good performances in terms of environmental and health impacts despite its fossil origin and is cost competitive with charcoal on a cost of energy basis. However its market uptake in Haiti is still limited due to the high upfront cost of LPG cylinders and stoves due to a lack of regulation of LPG retail activities in Haiti.

To overcome these barriers, it is recommended on one hand to enforce safety standards and the protection of cylinder ownership as well as supporting marketer investment in new LPG cylinders through the creation of an organization in charge of the management of cylinders and the removal of damaged cylinders from the market. On the second hand, developing consumer finance to provide credits or leasing solutions for cylinders and stoves acquisition for end-users would help reducing the upfront cost and make LPG an affordable cooking option for most urban households.

The development of clean fuels in Haiti is expected to improve the social and economic wellbeing of end-users but may have a negative impact on jobs along the value chain.

The use of cleaner and more efficient fuels will benefit to end-users thanks to time savings in cooking and thanks to a reduced exposure to smoke and particulate. Nevertheless, charcoal making is a significant source of job an income for farmers possibly threatened by the development of alternative fuels. Developing improved charcoal production techniques and biofuels locally produced are the best options to develop the clean fuels sector while creating local value partly oriented towards farmers.

ENEA recommends the Alliance to build a strategy based on four pillars to be conducted in parallel:

- reduce kiln emissions and wood withdrawal with improved charcoal production kilns,
- reduce the consumption of charcoal with improved cooking stoves,
- reduce the consumption of charchoal with alternative fuels already proven (charbriquettes and LPG),
- investigate the potential of innovative fuels (ethanol locally produced and pellets) for large scale deployment.

Limitations in the availability of local biomass prevent a strategy based on local biofuels from having a significant impact on the cooking sector in Haiti. The improvement of charcoal production techniques is a key lever to reduce the demand for wood and the emission of greenhouse gases of the sector. The adoption of fixed kilns by charcoal makers may be a challenge due to the requirement for wood transport. Nevertheless, improvement margins should exist on charcoal production with mud kilns and should be identified and targeted. The combined used of improved cooking stoves will reduce the demand for charcoal.

In parallel, alternative fuels should be developed, starting with the most promising among those already proven: charbriquettes and LPG. Ethanol and pellets have a high potential but should first be demonstrated at pilot scale to prove their competitiveness and market adoption.

Figure 20 illustrates the impact on climate change of a fuel strategy with an example of objectives deemed realistic in Haiti and based on the pillars above-mentioned.

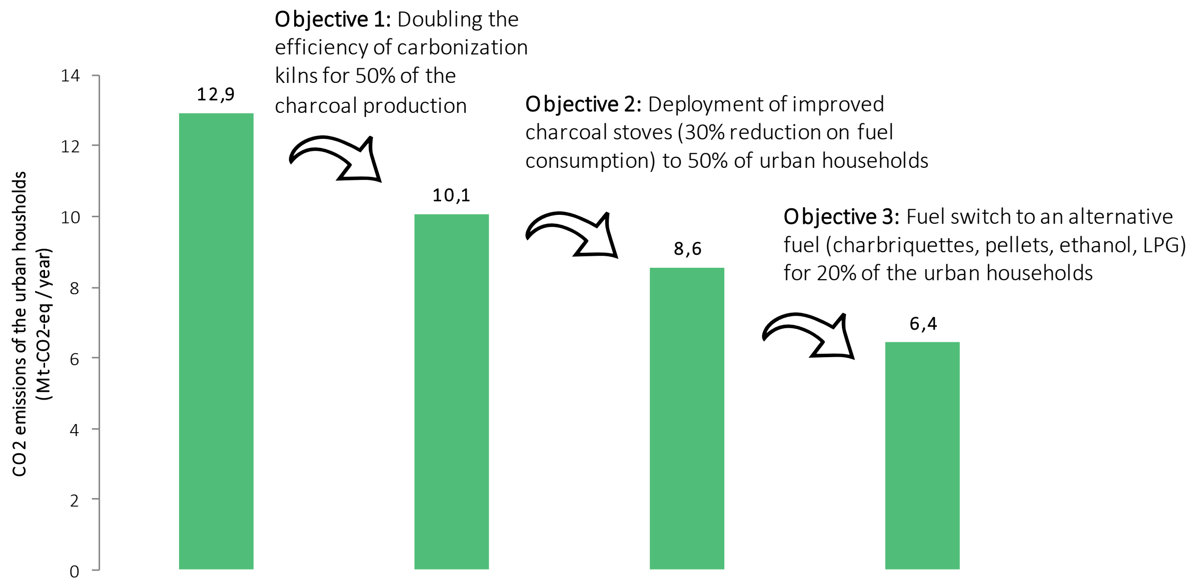

Figure 20 - Example of a multi objectives strategy on climate change (based on charcoal consumption of urban households) with three objectives to be achieved concurrently

7 RESEARCH GAPS

Findings that have emerged from the assessments carried out in the present study are challenged by the various uncertainties regarding input data. Further work should refine data collected within fieldwork or in literature through in-depth field analysis and effective pilot projects. This section presents the most important areas that should be investigated in order to reduce uncertainties and provide more accurate results.

Prospective pathways

In the present study, data related to prospective pathways contains more uncertainty that existing pathways investigated during fieldwork. There is no pilot project in Haïti on charcoal from in improved kilns, pellets, or ethanol fuels. Data on technical aspects, economics, social impacts and customer adoption is thus limited and was extrapolated from literature or existing projects from other countries. The implementation and follow-up of pilot projects on these new fuel pathways would produce more reliable data.

Technical data on sourcing and processing

Available resource and environmental impact assessments are based on technical data collected from different sources, such as field interviews or literature. Key parameters should be carefully assessed as they strongly impact end results:

- Residue to whole crop mass ratio
- Carbonization kiln efficiency
- Heating value of prospective fuels
- Inputs and yield for sugarcane farming (LCA inputs only)
- Black carbon and PM emissions for the reviewed fuels

On-site measurements would provide improved accuracy on the assessment of these parameters for the Haïtian context.

The present study only presents the maximum potential feedstock that can be produced in Haïti. The estimation of feedstock really available for collection should be carried out. It would take into account the amount of agricultural residues and bagasse dedicated to competitive uses, the amount that cannot be collected because of scattered production sites or lack of transportation, and possible opportunities such as onsite carbonization by farmers. A detailed survey on a large sample of farms would provide insights on these aspects.

Prospective scenarios for the resource assessment

The resource assessment include a realistic scenario, and three prospective scenarios. A review of crop production and harvested land data over the last decades and an in-depth analysis of the agricultural sector should estimate:

- The available land for extension of the sugarcane currently harvested land area
- The possible variations of crop yield over the next few years with minimum and maximum range

This would provide insights on whether the adopted scenarios are likely to occur, and in which time frame. The occurrence of these scenarios may also be limited by farmers' adoption of new agricultural practices, especially for large scale replacement of conventional sorghum by sweet sorghum.

Economics

As specified earlier, cost of non-existing fuels in Haïti should be based on existing Haïtian projects to limit uncertainty. Cost of infrastructure and associated business plan, such as improved carbonization kilns and briquette factories, have a major impact on final cost of fuel. Stoves dedicated to pellets and non-carbonized briquettes are not commercialized for households yet and their price is still uncertain.

Apart from high uncertainties for prospective fuels (charcoal with improved kilns, pellets, ethanol), cost of transport is difficult to estimate. It highly depends on the distance covered, on the type of transportation, and the type of roads.

Social impacts and market assessment for customer adoption

A customer survey should be carried out on fuel end-users in order to assess their cooking practices, the objective and the perceived qualities of each fuel. This is especially true for fuels that are not yet offered on the Haïtian market.

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8 APPENDIX

8.1 List of interviewees

In person interviews conducted by Entrepreneur du Monde in Haiti

Interviewee	Position	Organization	Date
Pierre Kenol Thys	Manager - Energy	BID - Haiti	05/09/16
Marie Bonnard	Country Coordinator	AVSF Haiti	06/10/16
Patrice Dion	Professor	Université de Laval - Faculty of Science, Agriculture and Food	26/09/16
Rachèle Lexidort	Project coordinator	Akosaa - Haiti	26/09/16
Gael Pressoir	Executive Director	Chibas Energie - Haiti	10/10/16
Jean-François Hibbert	Executive Director	Novogaz	29/09/16
Jean-François Lambert	Stock Unit Manager	Total Haiti	07/10/16
Victor Munet	Sustainable Development Manager	Total Haiti	07/10/16
Andrew Tarter	PhD	Antropologist - Haiti	29/09/16
René Jean Jumeau	Founder and Executive Director	Former Ministry of Energy - Haitian Energy Institute	30/09/16
Jean-Robert Altidor	Energy Ressources Director	Bureau des Mines et de l'Energie	10/10/16
Claude Preptit	Executive Director	Bureau des Mines et de l'Energie	10/10/16
Yann François	Monitoring and Evaluation Manager	GERES - Cambodia	18/10/16
Yves André Wainwright	Energy and Environment specialist	UNDP	07/10/16

Eric Sorensen **Ryan Delanay**	CEO COO	Carbon Roots International - Chabon boul Haiti	28/09/16
Philipp Villedrouin	Executive Director	Chabon Ticadaie	27/09/16
Kevin Adair	Executive Director	Fuego del Sol	05/10/16
Joaneson Lacour	Executive Director	Wastek Haitian Energy Institute	30/09/16

Phone and mail interviews/contacts by Entrepreneur du Monde

Interviewee	Position	Organization
Jean Tisserat	Technical Assistant	AVSF Haiti
Carmille Joseph	Pwofipann Coordinator	AVSF Haiti
Wiggens Petiton	ENPA Manager	MARNDR

Phone and mail interviews/contacts by ENEA

Interviewee	Position	Organization
Allison Archambault	President	Earth Spark
Gaston Kramer, Bruno Mallman	N.C	Green Social Bioethanol
Nick Moses	R&D Engineer	InStove
Dan Sweeney	Lead researcher for the D-Lab Biomass Fuel & Cookstoves Group	MIT
Megan Rapp	Africa Team Leader USAID Development Credit Authority	USAID
Luceno Brady	Director, POET Clean Cooking	POET

8.2 Bloc flow diagrams of fuels value chain

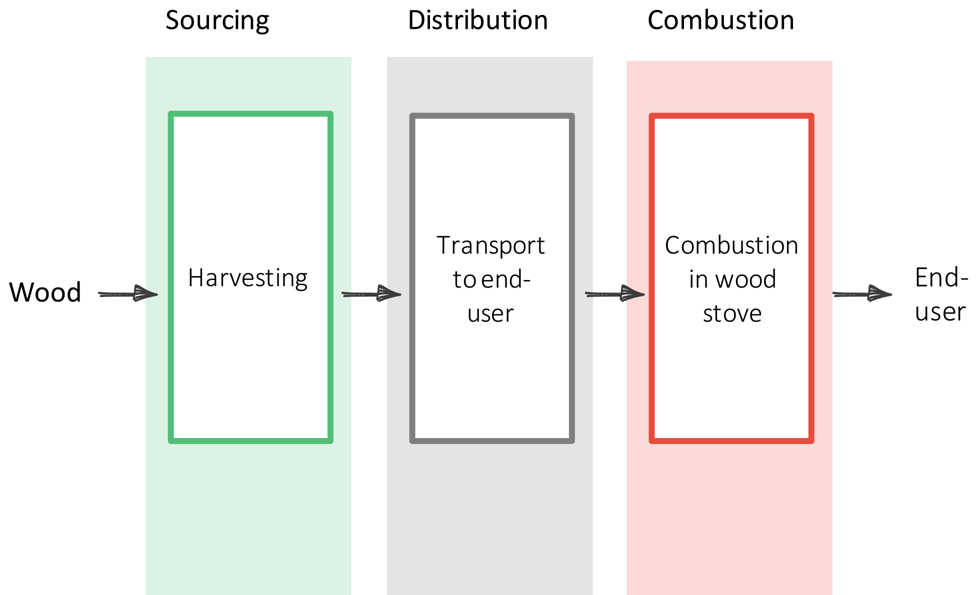

Figure 21 – Value chain of firewood

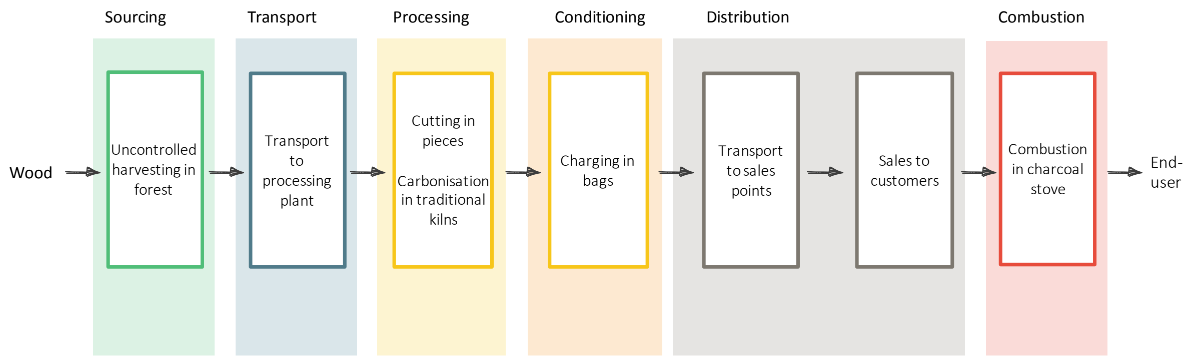

Figure 22 – Value chain of charcoal with traditional kilns

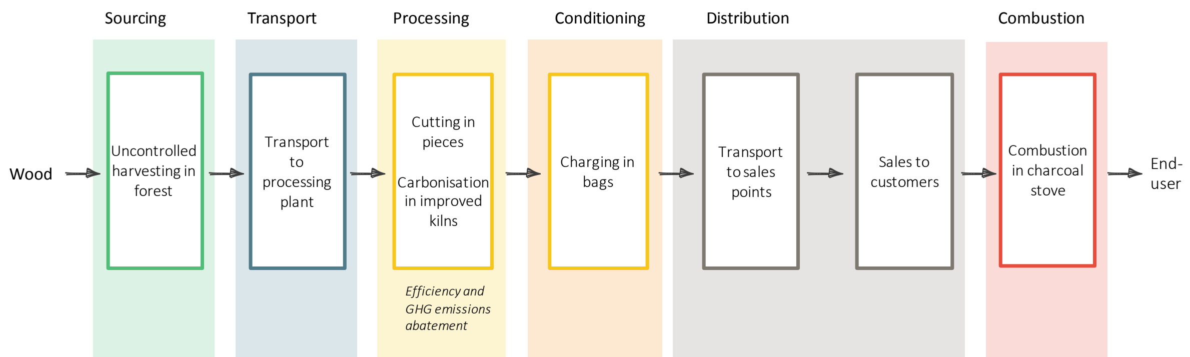

Figure 23 – Value chain of charcoal with improved kilns

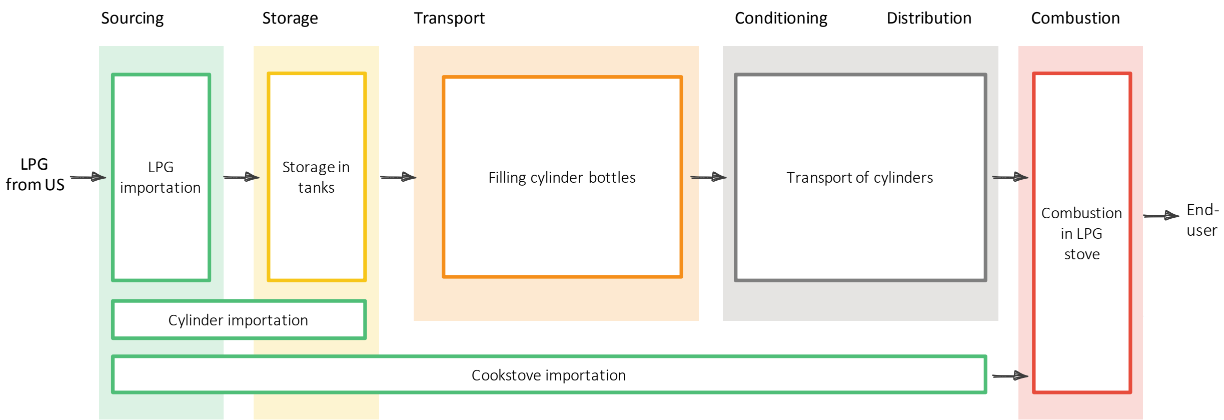

Figure 24 – Value chain of LPG

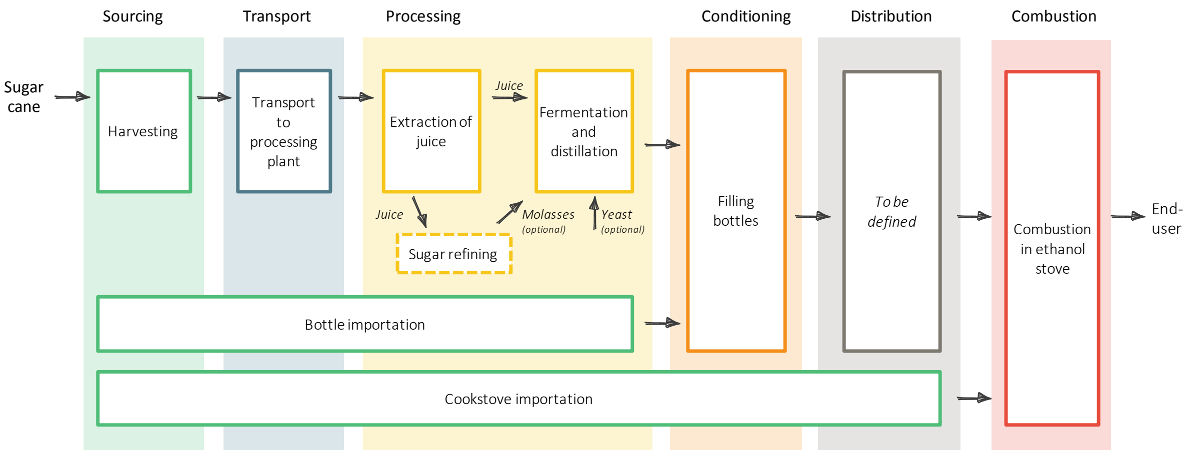

Figure 25 – Value chain of ethanol

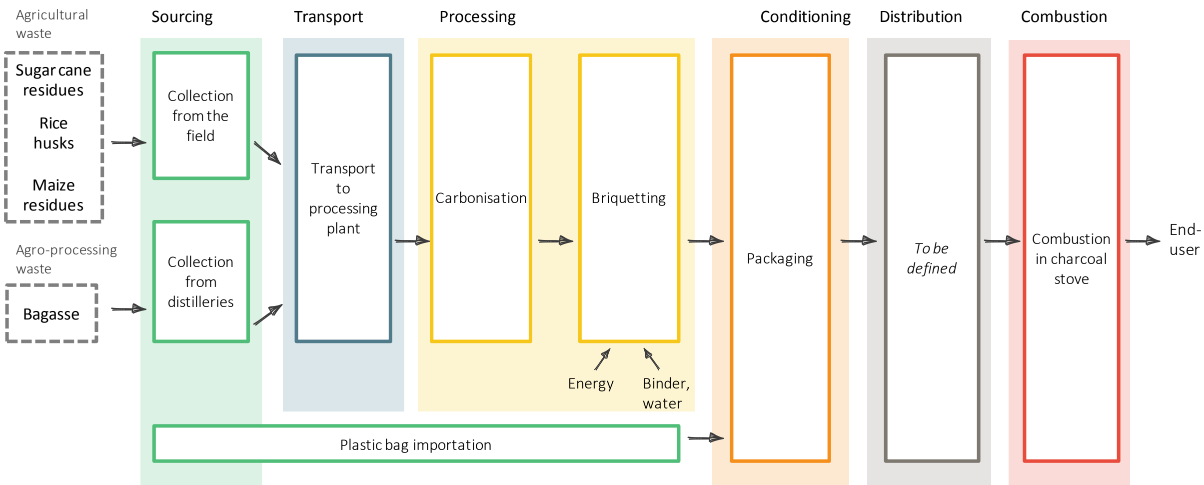

Figure 26 – Value chain of charbriquettes

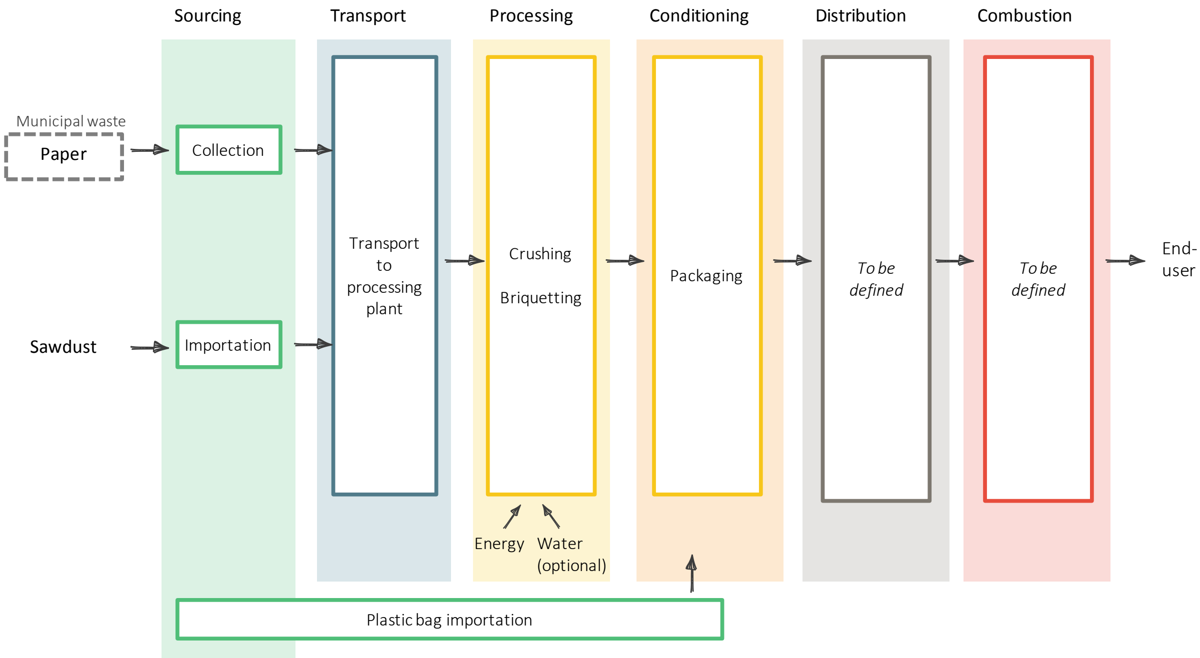

Figure 27 – Value chain of non-carbonized briquettes

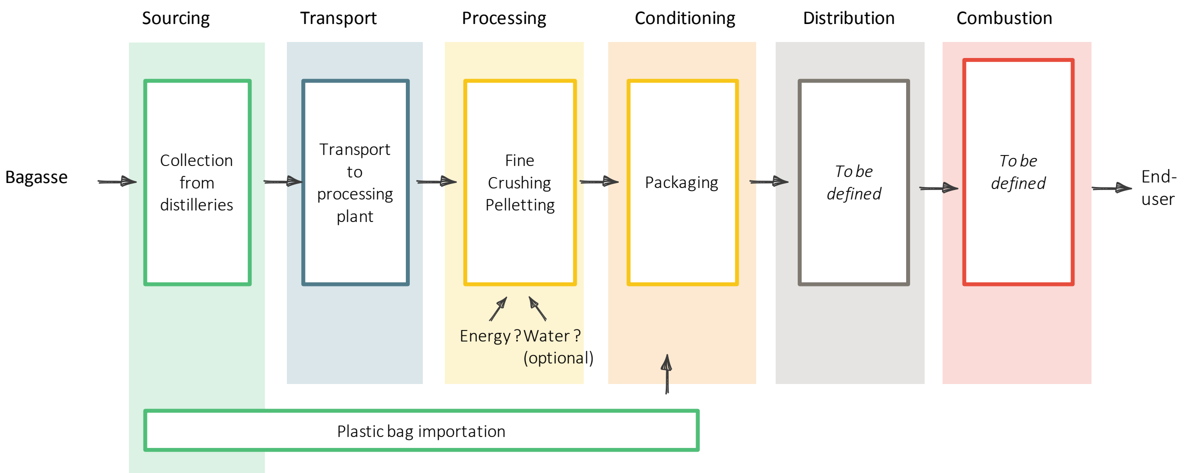

Figure 28 – Value chain of pellets

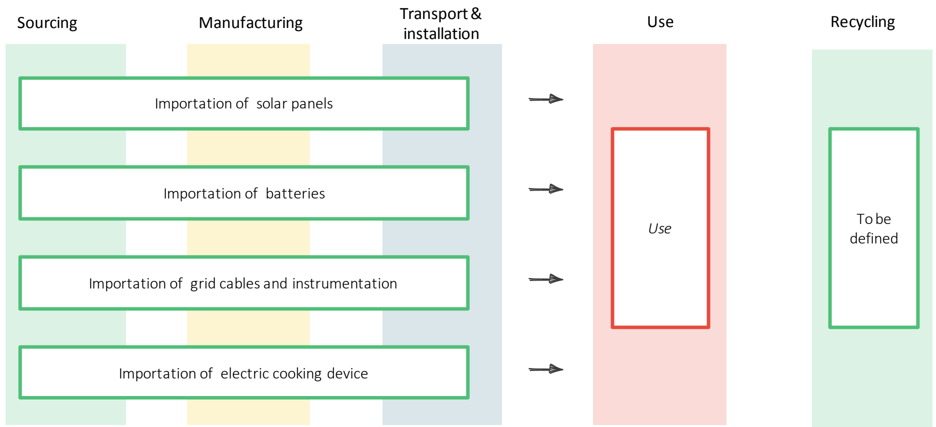

Figure 29 – Value chain of electricity from solar microgrid

8.3 Resource assessment results

	Bagasse surpluses are used in charbriquettes			
	2014 (historically low productivity)	Theoretical potential		
		Conservative	Middle	Aggressive
Waste paper briquettes	16 138	16 138	16 138	16 138
Charbriquettes - maize	28 343	28 343	56 686	56 686
Charbriquettes - rice	6 228	6 228	12 456	12 456
Charbriquettes - sugar cane stems	30 591	30 591	61 181	163 150
Charbriquettes - sugar cane bagasse	20 190	27 785	35 380	86 015
Charbriquettes - sweet sorghum bagasse	0	39 948	39 948	39 948
Pellets - sugar cane bagasse	0	0	0	0
Pellets - sweet sorghum bagasse	0	0	0	0
Ethanol - sugar cane	0	29 508	59 017	255 740
Ethanol - sweet sorghum	0	155 205	155 205	155 205
Total number of households able to replace charcoal by alternative fuel	**101 489**	**333 746**	**436 012**	**785 339**
Total number of urban households	**1 218 242**			

Figure 30 – Number of households able to replace charcoal by an alternative fuel in the four resource assessment scenarios if bagasse is entirely used for charbriquettes production

	Bagasse surpluses are used in charbriquettes			
	2014 (historically low	Theoretical potential		
		Conservative	Middle	Aggressive
Waste paper briquettes	16 138	16 138	16 138	16 138
Charbriquettes - maize	28 343	28 343	56 686	56 686
Charbriquettes - rice	6 228	6 228	12 456	12 456
Charbriquettes - sugar cane stems	30 591	30 591	61 181	163 150
Charbriquettes - sugar cane bagasse	0	0	0	0
Charbriquettes - sweet sorghum bagasse	0	0	0	0
Pellets - sugar cane bagasse	69 004	94 962	120 921	293 978
Pellets - sweet sorghum bagasse	0	136 534	136 534	136 534
Ethanol - sugar cane	0	29 508	59 017	255 740
Ethanol - sweet sorghum	0	155 205	155 205	155 205
Total number of households able to replace charcoal by alternative fuel	**150 303**	**497 509**	**618 138**	**1 089 887**
Total number of urban households	**1 218 242**			

Figure 31 –Number of households able to replace charcoal by an alternative fuel in the four resource assessment scenarios if bagasse is entirely used for pellets production

8.4 Main assumptions in the LCA model

General assumptions

The nominal value on the fraction of non-renewable biomass (f_{NRB}) used in models is 30%, in accordance to the results of the Stockholm Environmental Institute (SEI) conducted in parallel with the present study.

Impact from land transformation on Climate Change are the result of carbon release from the soil and roots in areas deforested (i.e. for applicable to the f_{NRB} fraction of wood only). The following assumptions were made for the calculation of the carbon release due to land transformation:

- Carbon dioxide release due to roots degradation:
  - The carbon content of roots is similar to the carbon content of above-ground biomass (49% of dry mass share)
  - The mass ratio of below-ground biomass to above-ground biomass is 0.37 tonne of dry root/tonne of dry shoot ([21] table 4.4)
- Carbon dioxide release due to soil degradation: it has to be estimated from the difference in soil organic carbon content. The following default values are suggested:
  - Soil organic carbon content before deforestation = 19.4 kg/m² (mean value for a secondary forest in alfisols, inceptisols, oxisols, ultisols and vertisols that are the types of soils relevant for energy access project areas in the world [22])
  - Soil organic carbon loss due to deforestation = 36% (corresponding to the change from secondary forest to grass land [22]

Transport is modeled using Ecoinvent data with vehicles compliant with the EURO3 norms which entail little restriction on transport emissions in order to be as close as possible to Haiti standards for trucks.

The three-stone fire used for firewood is the only stove that is not modeled: it has no impact as it does not require directly any processed material such as metal. All the other cooking devices are made with steel. The ethanol stoves and the rice cooker for electric cooking are the only ones that also contain another material than steel, respectively aluminum or polypropylene (PP). Steel, aluminum and PP are modeled with generic world data from the Ecoinvent database. The model accounts for lifetime and annual consumption of a family.

Combustion emissions, as well as black carbon (BC) and short-lived climate pollutants (SLCP) are taken from data related to similar processes in the GACC FACIT tool [10]. If several countries are considered, the country the closest geographically to Haiti (often Guatemala) is selected.

Firewood

The energy content corresponds to the energy contained in the wood. It does not take into account the photosynthetic efficiency. It is hence related to the cooking efficiency.

No packaging is needed for the scenario.

No transport is considered, since the firewood is considered harvested close to the place of use.

Except for CO_2 the combustion emissions are related to the combustion of firewood in a traditional mud stove in Ghana [10]. The emissions of Black carbon and SLCP at combustion are Guatemala data [10]. Since no emissions of PM2.5 were given by this source, emissions of PM2.5 were taken from the emissions related to the combustion of brushwood in brick stove with flue in China [10].

Charcoal

Data for carbonization emissions is based on carbonization data in an earth mound kilns in Kenya [23], while data for BC & SLCP emissions are taken from charcoal production data in Guatemala [10]. They are both combined with charcoal yield, directly related to the efficiency of the carbonization kiln. Four scenarios are modeled to take into consideration the variability of the carbonization impact that depends on the kiln characteristics. The parameters listed in Table 2 are the only inputs that differ between the four charcoal scenarios.

Scenario		Traditional kiln, minimum efficiency	Traditional kiln, maximum efficiency	Improved kiln, minimum efficiency	Improved kiln, maximum efficiency
Energy efficiency		22[27]%	44[28]%	44[29]%	59[30]%
Charring emissions (g/per kg of carbonized wood)	CO_2, PM2.5	Similar to carbonization in Kenya (earth mound kilns [23])	Similar to carbonization in Kenya (earth mound kilns [23])	Same than traditional kiln, weighted by efficiency	Same than traditional kiln, weighted by efficiency
	BC & SLP	Similar to carbonization in Guatemala[10]	Similar to carbonization in Guatemala[10]	Same than traditional kiln, weighted by efficiency	Same than traditional kiln, weighted by efficiency
	CO, CH_4, NMHC, N_2O and NO_x	Charring emissions similar to carbonization in Kenya (earth mound kilns [23])	Charring missions similar to carbonization in Kenya (earth mound kilns [23])	50% reduction compared to traditional kiln, weighted by efficiency	50% reduction compared to traditional kiln, weighted by efficiency

Table 2 – Variable parameters related to the environmental impacts of carbonization for the four scenarios on charcoal

No packaging is needed for the scenario.

Transport by truck[31] is considered for distribution, modeled with Ecoinvent data.

Except CO_2 emissions, the emissions of combustion are related to the combustion of charcoal in metal stoves in India (and also considered valid for China, Bangladesh and Guatemala) [10]. The combustion emissions of

[27] Earth mound kiln with 15% dry mass yield and 50% moisture content in wood

[28] Earth mound kiln with 30% dry mass yield and 50% moisture content in wood

[29] Adam retort kiln with 30% dry mass yield [17] and 50% moisture content in wood

[30] Adam retort kiln with 40% dry mass yield [17] and 50% moisture content in wood

[31] Transport, freight, lorry 7.5-16 metric ton, EURO3 {RoW}[9]

Black Carbon and SLCP are from Guatemala [10]. Emissions of PM2.5 for charcoal combustion were communicated by the Alliance directly.

Charbriquettes

The feedstock mix in charbriquettes is based on the quantity of available residues estimated in the "Theoretical potential - conservation" resource assessment scenario (see §2). Environmental impacts of the different raw materials are modeled using Ecoinvent data. Economic allocation factors are used to scale the impacts to the specific part of the crop that is used in the charbriquette.

- Maize[32] and rice[33] input data represents world average cropping practices
- Sugarcane[34], input data represent cropping practices in Brazil. Sugarcane cropping practices in Haiti use fewer inputs, but give a lower yield as compared to Brazil. All in all, since no other information could be collected, it is considered that the same ratio of inputs per hectare is needed for sugarcane cultivation in Haiti as compared to Brazil.

Since no specific charring emissions are available for charbriquettes, BC, SLCP and all the other charring emissions are the same than the ones used for charcoal, weighted with the charring yield. The binder (corn starch imported from the US) is modeled with world average coefficients from Ecoinvent database[35]. Electricity for briquetting is modeled using Haiti's electricity mix (80% diesel, 20% hydro [24]).

Packaging is a plastic bag, considered to be made out of Low Density Polyethylene (Ecoinvent data for LDPE world average [25]). The model accounts for bag capacity and number of uses. End of life in landfill is considered (Ecoinvent data for landfilling of PE in Switzerland, the only country with available emissions data [25]).

Transport by minibus (4t) is considered for distribution, modeled with Ecoinvent data[36].

Since no specific combustion emissions and no specific BC & SLCP emissions are available for charbriquettes, combustion emissions and BC & SLCP emissions for charcoal are used. 100% of CO_2 emissions are considered biogenic.

Non-carbonized briquettes

Raw materials considered in the scenario are sawdust, cardboard and paper: the feedstock mix is based on existing Fuego del Sol non-carbonized briquettes business [11].

- Sawdust is modeled using a world average Ecoinvent data[37].
- Waste paper and cardboard are considered with no impact.

[32] Maize grain {GLO}| market for | Alloc Rec, U from Ecoinvent data base [9]

[33] Rice {GLO}| market for | Alloc Rec, U from Ecoinvent data base [9]

[34] Sugarcane {BR}| market for | Alloc Rec, U from Ecoinvent data base [9]

[35] Maize starch {GLO}| market for | Alloc Rec, U from Ecoinvent data base [9]

[36] Transport, freight, lorry 3.5-7.5 metric ton, EURO3 {RoW} from Ecoinvent data base [9]

[37] Saw dust, wet, measured as dry mass {GLO}| market for | Alloc Rec, U from Ecoinvent data base [9]

Assumption on the briquettes production are based on Fuego del Sol process [11].

- Impact of heat production for briquetting is modeled using the world average Ecoinvent data of petrol[38].
- BC & SLCP emissions are similar to crop briquettes processing emissions in Ghana [10].

Packaging is the same as for charbriquettes.

Transport by truck (10t) is considered for distribution, modeled with Ecoinvent data[39]

The combustion emissions considered are the same than the combustion emissions of crop briquettes in India, the only country with available emissions data in the GACC FACIT tool [10]. Since no emissions of PM2.5 were given by this source, and no other source could be found, PM2.5 emissions are not modeled. Hence, no result is given for this scenario on the PM2.5 scenario. All CO_2 emissions are considered biogenic. The emissions of Black carbon and SLCP at combustion are the same than non carbonized briquettes from crop residue emissions [10].

Pellets

Sugarcane is modeled with Ecoinvent data representing cropping practices in Brazil[40]. An economic allocation factor is applied to scale the impacts to bagasse production. Electricity for pelleting is modeled using the Haitian electricity mix. BC & SLCP for pellets processing are modeled using data from saw dust pellets processing in India, the only country with available emissions data in the GACC FACIT tool [10].

Packaging is the same as for charbriquettes.

Transport by minibus (4t) is considered for distribution, modeled using Ecoinvent data[41]

The combustion emissions considered are average emissions related to the combustion of wood pellets [10] as no data for pellets are available. All CO_2 emissions are considered biogenic. The emissions of Black carbon and SLCP at combustion are the same than emissions produced by biomass pellets in India, the only country with available emissions data in the GACC FACIT tool [10].

Ethanol

Ethanol from sugarcane is modeled using the Ecoinvent data[42]. BC & SLPC emissions from ethanol production are similar to the emission related to sugarcane ethanol production in Brazil, the only country with available emissions data in the GACC FACIT tool [10]. Impacts of sweet sorghum harvest cannot be quantified as little data is available, but it is not expected to differ significantly from impacts of sugar cane.

Packaging is a 1L plastic bottle, considered in PET, modeled with Ecoinvent data for PET world average, and for plastic blow moulding. The model accounts for bottle capacity and number of uses. End of life in landfill is considered, based on Ecoinvent data for landfilling of PET in Switzerland [25], the only country with available emissions data.

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[38] Petrol, low-sulfur {RoW}| market for | Alloc Rec, U from Ecoinvent data base [9]

[39] Transport, freight, lorry 7.5-16 metric ton, EURO3 {RoW} from Ecoinvent data base [9]

[40] (Sugarcane {BR}| market for | Alloc Rec, U) from Ecoinvent data base [9]

[41] Transport, freight, lorry 3.5-7.5 metric ton, EURO3 {RoW} from Ecoinvent data base [9]

[42] Ethanol, without water, in 95% solution state, from fermentation {BR}| ethanol production from sugar cane | Alloc Rec, U from Ecoinvent data base [9]

Transport by minibus (4t) is considered for distribution, modeled using Ecoinvent data[43].

The combustion emissions considered are average emissions related to the combustion of sugarcane ethanol in alcohol stove [25]. All CO_2 emissions are considered biogenic. The emissions of Black carbon and SLCP at combustion are the same than emissions related to the heat from ethanol and wood (average for all countries) [10].

LPG

LPG commercialized in Haiti is conventional propane [26]. Production of LPG is modeled using the world average data from Ecoinvent[44]. BC & SLCP emissions for LPG production are the same than emissions in Guatemala [10].

Packaging of LPG is added to the model, using Ecoinvent data for steel and processing of steel. The model accounts for bottle capacity and number of refills. Impacts of the bottling stage are the same than bottling of LPG in India [10]. BC & SLCP emissions associated with the bottling stage are modeled using assumptions from LPG processing in Guatemala [10], chosen for geographic proximity.

Transport by truck (5t) is considered for distribution, and for return trip for refill, modeled using Ecoinvent data[45]

The combustion emissions considered are the emissions related to the combustion of LPG in LPG stove in India [10], the only country with available emissions data. Since no emissions of PM2.5 were given by this source, emissions of PM2.5 were added using GACC online fuels catalog. All CO_2 emissions are considered fossil. The emissions of Black carbon and SLCP at combustion are the same than the ones emitted by the heat from LPG in Guatemala [10].

Solar electricity from mini-grid

The devices for solar electricity production and mini-grid are estimates, and they are modeled using the best proxies possible from the Ecoinvent database. Solar panels and batteries are modeled using Ecoinvent data for PV solar rooftop panels[46] and NaCl batteries[47]. Cables for the mini-grid are modeled using Ecoinvent generic data[48]. The end of life of those devices is not taken into account because of lack of data in available databases.

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[43] Transport, freight, lorry 3.5-7.5 metric ton, EURO3 {RoW} from Ecoinvent data base [9]

[44] Liquefied petroleum gas {RoW}| market for | Alloc Rec, U from Ecoinvent data base [9]

[45] Transport, freight, lorry 3.5-7.5 metric ton, EURO3 {RoW} from Ecoinvent data base [9]

[46] Photovoltaic flat-roof installation, 3kWp, single-Si, on roof {GLO}| market for | Alloc Rec, U from Ecoinvent data base [9]

[47] Battery, NaCl {GLO}| market for | Alloc Rec, U from Ecoinvent data base [9]

[48] Cable, unspecified {GLO}| market for | Alloc Rec, U from Ecoinvent data base [9]

8.5 Input data of the LCA model

Firewood

Element	Value	Unit
Sourcing and production		
LHV wood anhydrous	19	MJ/kg
LHV wood wet (50% moisture)	8,3	MJ/kg
Deforestation		
fNRB	0,66	
Packaging		
N/A		
Transport		
Average distance (one way)	0	km
Cooking device		
3 stone stove	-	
Combustion		
Cooking efficiency	0,143	MJ(out)/MJ(LHV)

Figure 32 – LCA assumptions for firewood

Charcoal

Element	Value	Unit
Sourcing and production		
LHV of charcoal	29	MJ/kg
LHV of input wood wet (50% moisture)	8,7	MJ/kg
Moisture content of input wood	50%	
Efficiency of carbonization kiln - min	22%	
Charring in earth mound kilns - CO2 emissions to air	3822,8	g/kgchar
Charring in earth mound kilns - CO emissions to air	474,3	g/kgchar
Charring in earth mound kilns - CH4 emissions to air	94,7	g/kgchar
Charring in earth mound kilns - NMHC emissions to air	183,7	g/kgchar
Charring in earth mound kilns - N2O emissions to air	0,3	g/kgchar
Charring in earth mound kilns - NOx emissions to air	0,1	g/kgchar
Charring in earth mound kilns - PM2.5 emissions to air	53,9	g/kgchar
Amount of charcoal from wood = charcoal yield	0,07	kg(char)/kg(wood wet)
Amount of charcoal from wood = charcoal yield	0,13	kg(char)/kg(wood dry)
Transport between wood and carbonization distance	0	km
Deforestation		
fNRB	0,66	
Packaging		
NA	-	

Figure 33 – LCA assumptions for charcoal with traditional kiln and minimum efficiency, sourcing to packaging

Transport		
From carbonization to sale point		
Average distance (one way, truck 7,5t)	200	km
From sale point to consumer		
Average distance (one way)	0	km
Cooking device		
Composition		
Steel	100%	
Total weight	1,3	kg
Lifetime	0,75	years
Annual consumption of a family	24451	MJ(LHV)/year
Combustion		
Cooking efficiency	0,22	MJ(out)/MJ(LHV)

Figure 34 – LCA assumptions for charcoal with traditional kiln and minimum efficiency, transport to combustion

Element	Value	Unit
LHV of charcoal	*29*	*MJ/kg*
LHV of input wood wet (50% moisture)	*8,7*	*MJ/kg*
Moisture content of input wood	*50%*	
Efficiency of carbonization kiln - max	44%	
Charring in earth mound kilns - CO2 emissions to air	*1911,4*	*g/kgchar*
Charring in earth mound kilns - CO emissions to air	*237,2*	*g/kgchar*
Charring in earth mound kilns - CH4 emissions to air	*47,3*	*g/kgchar*
Charring in earth mound kilns - NMHC emissions to air	*91,9*	*g/kgchar*
Charring in earth mound kilns - N2O emissions to air	*0,2*	*g/kgchar*
Charring in earth mound kilns - NOx emissions to air	*0,1*	*g/kgchar*
Charring in earth mound kilns - PM2.5 emissions to air	*26,9*	*g/kgchar*
Amount of charcoal from wood = charcoal yield	*0,13*	*kg(char)/kg(wood)*
Amount of charcoal from wood = charcoal yield	*0,26*	*kg(char)/kg(wood dry)*
Transport between wood and carbonization		
distance	*0*	*km*
Deforestation		
fNRB	*0,58*	

Figure 35 – LCA assumptions for charcoal with traditional kiln and maximum efficiency, on emissions

Packaging		
NA	-	
Transport		
From carbonization to sale point		
Average distance (one way, truck 7,5t)	*200*	*km*
From sale point to consumer		
Average distance (one way)	*0*	*km*
Cooking device		
Composition		
Steel	*100%*	*%*
Total weight	*1,3*	*kg*
Lifetime	*0,75*	*years*
Annual consumption of a family	*24451*	*MJ(LHV)/year*
Combustion		
Cooking efficiency	*0,22*	*MJ(out)/MJ(LHV)*

Figure 36 - LCA assumptions for charcoal with traditional kiln and maximum efficiency, from packaging to combustion

Element	***Value***	***Unit***
Sourcing and production		
LHV of charcoal	*29*	*MJ/kg*
LHV of input wood wet (50% moisture)	*8,7*	*MJ/kg*
Moisture content of input wood	*50%*	
Efficiency of carbonization kiln - improved kiln - min	44%	
Carbonization - CO2 emissions to air	*1911,4*	g/kgchar
Carbonization - CO emissions to air	*118,6*	g/kgchar
Carbonization - CH4 emissions to air	*23,7*	g/kgchar
Carbonization - NMHC emissions to air	*45,9*	g/kgchar
Carbonization - N2O emissions to air	*0,1*	g/kgchar
Carbonization - NOx emissions to air	*0,0*	g/kgchar
Carbonization - PM2.5 emissions to air	*26,9*	g/kgchar
Emissions reduction thanks to improved kiln :		
Reduction in CO2 emissions	0%	
Reduction in CO emissions	50%	
Reduction in CH4 emissions	50%	
Reduction in NMHC emissions	50%	
Reduction in N2O emissions	50%	
Reduction in NOx emissions	50%	
Reduction in PM2.5 emissions	0%	
Amount of charcoal from wood	*0,13*	*kg(char)/kg(wood)*
Amount of charcoal from wood = charcoal yield	*0,26*	*kg(char)/kg(wood dry)*
Transport between wood and carbonization		
distance	*0*	*km*

Figure 37 – LCA assumptions for charcoal with improved kiln and minimum efficiency, sourcing and production

Deforestation		
fNRB	*0,66*	
Packaging		
NA	*-*	
Transport		
From carbonization to sale point		
Average distance (one way, truck 7,5t)	*200*	*km*
From sale point to consumer		
Average distance (one way)	*0*	*km*
Cooking device		
Composition		
Steel	*100%*	
Total weight	*1,3*	*kg*
Lifetime	*0,75*	*years*
Annual consumption of a family	*24451*	*MJ(LHV)/year*
Combustion		
Cooking efficiency	*0,22*	*MJ(out)/MJ(LHV)*

Figure 38 – LCA assumptions for charcoal with improved kiln and minimum efficiency, from deforestation to combustion

Element	Value	Unit
Sourcing and production		
LHV of charcoal	*29*	*MJ/kg*
LHV of input wood wet (50% moisture)	*8,7*	*MJ/kg*
Moisture content of input wood	*50%*	
Efficiency of carbonization kiln - improved kiln - max	59%	
Carbonization - CO2 emissions to air	*1425,5*	*g/kgchar*
Carbonization - CO emissions to air	*88,4*	*g/kgchar*
Carbonization - CH4 emissions to air	*17,7*	*g/kgchar*
Carbonization - NMHC emissions to air	*34,3*	*g/kgchar*
Carbonization - N2O emissions to air	*0,1*	*g/kgchar*
Carbonization - NOx emissions to air	*0,0*	*g/kgchar*
Carbonization - PM2.5 emissions to air	*20,1*	*g/kgchar*
Emissions reduction thanks to improved kiln :		
Reduction in CO2 emissions	*0%*	
Reduction in CO emissions	*50%*	
Reduction in CH4 emissions	*50%*	
Reduction in NMHC emissions	*50%*	
Reduction in N2O emissions	*50%*	
Reduction in NOx emissions	*50%*	
Reduction in PM2.5 emissions	*0%*	
Amount of charcoal from wood	*0,18*	*kg(char)/kg(wood)*
Amount of charcoal from wood = charcoal yield	*0,35*	*kg(char)/kg(wood dry)*
Transport between wood and carbonization distance	*0*	*km*

Figure 39 – LCA assumptions for charcoal with improved kiln and maximum efficiency on sourcing and production

Deforestation		
fNRB	*0,66*	
Packaging		
NA	*-*	
Transport		
From carbonization to sale point		
Average distance (one way, truck 7,5t)	*200*	*km*
From sale point to consumer		
Average distance (one way)	*0*	*km*
Cooking device		
Composition		
Steel	*100%*	
Total weight	*1,3*	*kg*
Lifetime	*0,75*	*years*
Annual consumption of a family	*24451*	*MJ(LHV)/year*
Combustion		
Cooking efficiency	*0,22*	*MJ(out)/MJ(LHV)*

Figure 40 – LCA assumptions for charcoal with improved kiln and maximum efficiency from deforestation to combustion

Charbriquettes

Element	Value	Unit
Sourcing and production		
LHV of carbonized briquettes	21	MJ/kg(final charbriquette)
Moisture content of input biomass	15%	
Raw materials for input char		
Sugar cane straws	17%	for 1 kg of char
Sweet sorghum straws	0%	for 1 kg of char
Maize straws & stovers	28%	for 1 kg of char
Sugar cane bagasse	49%	for 1 kg of char
Rice straws	9%	for 1 kg of char
Allocation : annual sales revenue due to the co-product/annual sales revenue due to the whole plant		
Sugar cane straws	10%	
Sweet sorghum straws	10%	
Maize straws & stovers	10%	
Sugar cane bagasse	26%	
Rice straws	10%	
Carbonization		
Charring - CO2 emissions to air	1715,7	g/kgchar
Charring - CO emissions to air	212,9	g/kgchar
Charring - CH4 emissions to air	42,5	g/kgchar
Charring - NMHC emissions to air	82,5	g/kgchar
Charring - N2O emissions to air	0,1	g/kgchar
Charring - NOx emissions to air	0,1	g/kgchar
Charring - PM2.5 emissions to air	24,2	g/kgchar
Yield	0,25	kg(char)/kg(raw materials)
Yield (dry)	0,29	kg(char)/kg(raw materials dry)
Transport of raw materials to processing		
distance	0	km

Figure 41 – LCA assumptions for charbriquettes on sourcing and production

Briquetting		
Mass of input char	0,93	kg/kg(final charbriquette)
Binder : corn starch from US	0,02	kg/kg(final charbriquette)
Water	0,07	kg/kg(final charbriquette)
Electricity	0,07	kWh/kg(charbriquette)
Deforestation		
N/A		
Packaging		
Mass of empty bag (plastic)	0,015	kg
Bag capacity	2	kg(charbriquette)/bag
Nb of use	3	
Transport		
Average distance (one way, minibus 4t)	200	km
Cooking device		
Composition		
Steel	100%	
Total weight	1,3	kg
Lifetime	0,75	years
Annual consumption of a family	24451	MJ(LHV)/year
Combustion		
Cooking efficiency	0,222	MJ(out)/MJ(LHV)

Figure 42 – LCA assumptions for charbriquettes, from sourcing to combustion

Non-carbonized briquettes

Element	*Value*	*Unit*
Sourcing and production		
LHV of non-carbonized briquettes	15	MJ/kg(briquette)
Raw materials		
Sugar cane straws	0%	
Sweet sorghum straws	0%	
Maize stovers	0%	
Cardboard	34%	
Waste paper	33%	
Sawdust	33%	
Allocation : annual sales revenue due to the co-product/annual sales revenue due to the whole plant (for a farmer)		
Sugar cane straws	10%	
Sweet sorghum straws	10%	
Maize stroves	10%	
Cardboard	0%	
Waste paper	0%	
Sawdust	-	
Transport to processing		
Distance	10	km
Briquetting		
Mass of input biomass	1,04	kg/kg(final briquette)
Water	0,035	kg/kg(final briquette)
Electricity	0	kWh/kg(briquette)
Other energy - precise : gasoline	0,01	kWh LHV/kg(briquette)

Figure 43 – LCA assumptions for non-carbonized briquettes on sourcing and production

Deforestation		
N/A		
Packaging		
Mass of empty bag (plastic)	0,015	kg
Bag capacity	2	kg(briquette)/bag
Nb of use	3	
Transport		
Average distance (one way, truck 10t)	5	km
Cooking device		
Composition		
steel	100%	
Total weight	4,6	kg
Lifetime	2	years
Annual consumption of a family	13570	MJ(LHV)/year
Combustion		
Cooking efficiency	0,4	MJ(out)/MJ(LHV)

Figure 44 – LCA assumptions for non-carbonized briquettes, from deforestation to combustion

Pellets

Element	*Value*	*Unit*
Sourcing and production		
LHV of non-carbonized bagasse pellets	14,7	MJ/kg(pellets)
Raw materials		
Sugar cane bagasse	1,04	kg/kg(final pellets)
Allocation : annual sales revenue due to the co-product/annual sales revenue due to the whole plant (for a farmer)		
Sugar cane bagasse	26%	
Transport to processing		
distance	0	km
Pelleting		
Electricity	0,09	kWh/kg(pellets)
Deforestation		
N/A		
Packaging		
Mass of empty bag (plastic)	0,015	kg
Bag capacity	2	kg(bagasse)/bag
Nb of use	3	

Figure 45 – LCA assumptions for pellets, from sourcing to packaging

Transport		
Average distance (one way, minibus 4t)	100	km
Cooking device		
Composition		
steel	100%	
Total weight	4,6	kg
Lifetime	2	years
Annual consumption of a family	13570	MJ(LHV)/year
Combustion		
Cooking efficiency	0,4	MJ(out)/MJ(LHV)

Figure 46 – LCA assumptions for pellets, from transport to combustion

Ethanol

Element	*Value*	*Unit*
Sourcing and production		
LHV of ethanol	26,7	MJ/kg
density	0,79	kg/L
Composition		
Ethanol form sugar cane	100%	
Ethanol from sweet sorghum	0%	
Deforestation		
N/A	-	
Packaging		
Bottle capacity (PET Bottle)	1	L
Weight (empty)	0,05	kg
Transport		
Average distance (one way, minibus 4t)	100	km
Cooking device		
Composition		
Steel	90%	
Aluminium	10%	
Total weight	3,1	kg
Lifetime	2	years
Annual consumption of a family	5170	MJ(LHV)/year
Combustion		
Cooking efficiency	0,525	MJ(out)/MJ(LHV)

Figure 47 – LCA assumptions for ethanol

LPG

Element	*Value*	*Unit*
Sourcing and production		
LHV	46	MJ/kg
Deforestation		
N/A		
Packaging		
Bottle capacity	6	kg
Weight (empty)	9	kg
Number of refills	100	
Transport		
Average distance (one way, truck 5t)	30	km
Cooking device		
Composition		
steel	100%	
Total weight	4	kg
Lifetime	2	years
Annual consumption of a family	5121	MJ(LHV)/year
Combustion		
Cooking efficiency	0,53	MJ(out)/MJ(LHV)

Figure 48 – LCA assumptions for LPG

Electricity from solar microgrid

Element	*Value*	*Unit*
Sourcing and production		
Solar panels		
Peak power	93	kWp
Lifetime	20	years
Yield of a panel	15%	
Battery		
Capacity	400	kWh
Lifetime	2	years
Cables		
Section	0,000035	m2
Lenght	5	km
Density	6267	kg/m3
Lifetime	20	years
Electricity produced	61845	kWh/year
Global horizontal irradiation	1900	kWh/m2/year
Performance ratio	0,7	
Load factor on maximum power production capacity	0,5	

Figure 49 – LCA assumptions for electricity from solar microgrid on sourcing and production

Deforestation		
N/A		
Packaging		
N/A		
Transport		
N/A		
Cooking device		
Composition of the rice cooker		
Steel	67%	
PP	33%	
Total weight	4	kg
Lifetime	5	years
Annual consumption of a family	1345	MJ(produced)/year
Cooking		
Cooking efficiency	1	MJ(out)/MJ(produced)

Figure 50 – – LCA assumptions for electricity from solar microgrid, from deforestation to cooking

8.6 Definition of the Levelized Cost of Energy

For a given path, the levelized cost of energy (LCOE) represents the breakeven selling price of the fuel. For a processing step involving capital costs for equipments of lifetime n, the LCOE, expressed in USD/MJ is defined by:

$$LCOE = \frac{\sum_{i=0}^{n} \frac{Costs\ in\ year\ i}{(1+WACC)^i}}{\sum_{i=0}^{n} \frac{Energy\ produced\ in\ year\ i}{(1+WACC)^i}}$$

In this study, a weighted average cost of capital (WACC) of 8% was assumed. Costs were separated into CAPEX and operational costs, and both operational costs and yearly production were assumed constant over time.

8.7 Input data of fuel economics

Costs ($/MJ delivered)	Trad. Charcoal		Impr. Charcoal		Alternative solid fuels			Ethanol		LPG	Electricity
	Outside	In PaP	Outside PaP	In PaP	CRI c-briquettes	FDS nc-briquettes	Bagasse pellets	Min	Max	In Pap	
Raw material	Cost of acquisition operation of a woody land/(Wood available in a woody land*Charcoal carbonisation massic yield - traditional * kgtoMJ)		Cost of acquisition operation of a woody land/(Wood available in a woody land*Charcoal carbonisation massic yield - improved * kgtoMJ)		C-briquettes raw material cost / kgtoMJ	-	Mass of input biomass for pellets processing * Price of 1 kg bagasse / kgtoMJ	Price of 1 kg bagasse * (1 + Revenue increase from bagasse sales) / (Ethanol yield per ton of sugarcane * Ethanol density * kgtoMJ)			
Binder	-	-	-	-	C-briquettes binder cost	-	-	-	-		

Costs	Processing	OPEX fixed ($/an)	-	-	10% * CAPEX of improved carbonisation kiln	10% * CAPEX of improved carbonisation kiln	Number of full time equivalent employees in c-briquette factory *Qualified employee salary in PaP * Working days per year	Number of full time equivalent employees in c-briquette factory *Qualified employee salary in PaP * Working days per year	Number of full time equivalent employees in pellets factory * Qualified employee salary in PaP * Working days per year	Taken into account in variable OPEX		
		OPEX variable ($/MJ delivered)	Manwork required to produce charcoal - traditional * Minimum salary in PaP		Manwork required to produce charcoal - improved * Minimum salary in PaP / kgtoMJ		Electricity consumption for c briquettes processing*Grid electricty purchasing cost for industries / kgtoMJ	Number of gasoline gallons for nc briquette processing * Gasoline price / (Average weight of briquettes * kgtoMJ)	Electricity consumption for pellets processing * Grid electricty purchasing cost for industries / kgtoMJ	EtOH Fuel OPEX of a distillery plant / (Density ethanol * kgtoMJ)		
		Quantity of MJ delivered (MJ/yr)	-		Volume of the kiln * Bulk density of a tree log * Charcoal carbonisation massic yield improved * 365 * kgtoMJ		12 * Monthly production of c-briquettes factory * kgtoMJ	Annual production of the nc-briquettes factory * kgtoMJ	Annual production of the pellet factory * kgtoMJ	Working days per year * Daily production of the distillery plant *Density ethanol * kgtoMJ	Working days per year - 4 months * Daily production of the distillery plant *Density ethanol * kgtoMJ	

	LCOE ($/MJ delivered)	LCOE(CAPEX ; fixed OPEX; variable OPEX; MJ delivered ; Installation lifetime ; WACC)	
Packaging		Negligible	
Transport		Cost of transport of CRI bags/ (Weight of CRI bags * kgtoMJ)	
Retailer margin		(Charcoal bulk cost + Charcoal retailer margin (HTG)) / kgtoMJ	Fuel bulk cost * (1 + CRI retailer margin (%)) / kgtoMJ
Stove		LCOE (Purchasing cost of the stove adapted to fuel ; No fixed OPEX ; No variable OPEX ;Annual cooking energy demand per household ; Stove lifetime ; WACC)	
Total cost		Total retail cost + stove price	

Prices	**Minimum total price**	**Minimum fuel retail price + Stove price**
	Maximum total price	**Maximum fuel retail price + Stove price**

kgtoMJ is the coefficient specific to each fuel used to convert (kg fuel) to (MJ delivered to end-user)
kgtoMJ = LHV fuel x Combustion efficiency fuel

Figure 51 – Fuel economics calculations

Fuel	Fuel costs	Values used in the analysis	Unit	Source
N/A	WACC	10%		Enea
	Working days/yr	240	days/yr	Enea
	Minimum salary in PaP	270	HTG/man.day	HaïtiLibre
	Qualified employee salary in PaP - worker	10	$/man.day	CRI
	Qualified employee salary in PaP - management	2 * 10	$/man.day	Enea
Charcoal	Cost of acquisition/operation of a woody land for charcoal production	7200	HTG for 1,14 carreau	AFDI2012
	Wood available in a woody land	30	ton/ha	AFDI2012
	Manwork required to produce charcoal - traditional	6	man.day/ton-charcoal	Tarter, AFDI2012
	Manwork required to produce charcoal - improved	1	man.day/ton-charcoal	Enea
	Charcoal carbonisation massic yield - traditional	0,23	kg char/kg wood	Enea
	Charcoal carbonisation massic yield - improved	0,35	kg char/kg wood	Enea
	Bulk density of a tree log	300	kg/m3	HBWood
	CAPEX of improved carbonisation yield	3200	$ for a 3 m3 kiln	GERES
	Construction cost of a conventional carbonization kiln	0	HTG/kiln	Tarter, AFDI2012
	Average production of charcoal for a kiln	0,18	ton-charcoal/ton wood	AFDI 2012
	Retail selling price of charcoal outside PaP maximum	27	HTG/kg	Nexant2010
	Retail selling price of charcoal outside PaP minimum	18	HTG/kg	Vetiver
	Retail selling price of charcoal in PaP maximum	45	HTG/kg	Palmis Enèji
	Retail selling price of charcoal in PaP minimum	27	HTG/kg	Palmis Enèji
C-briquettes	C-briquettes raw material cost	0,63	$ for 30 kg bag	CRI
	C-briquettes binder cost	3,17	$ for 30 kg bag	CRI
	CAPEX of c-briquette factory	1373000	HTG for 750 tons/mois	CRI
	Number of full time equivalent employees in c-briquette factory	40 workers, 10 management	employees	CRI
	Electricity for c.briquette production	200	kWh / for 2 to 4 tons of briquettes	CRI
	Grid electricity purchasing cost for industries	14	HTG/kWh	EDHElec
	Mass yield of bagasse carbonization	0,33	ton-char/ton-bagasse	CRI
	Mass of input char for c-briquettes processing	0,93	kg-char/kg-briquette	CRI
	Electricity consumption for c-briquettes processing	0,07	kWhelec/kg-briquette	CRI
	Monthly production of the factory	750	ton/months	CRI
	Retailer margin of charbriquettes	24%	HTG/kg	CRI
	Retail selling price of charbriquettes	850	HTG/kg	CRI

NC-briquettes	CAPEX of NC-briquette factory	299000	$	FDS
	Number of full time equivalent employees in NC-briquette factory	15	employees	FDS
	Purchasing price of NC briquettes raw materials	0	HTG/kg	FDS
	Gasoline consumption for nc briquette processing	1	gal for 150 000 briquettes	FDS
	Gasoline price	189	HTG/L	TotalHaïti
	Average weight of nc briquettes	160	g	FDS
	Electricity for nc briquette production	0	kWh/kg-briquette	FDS
	Annual production of the nc briquettes factory	296,4	ton/year	FDS
	Retail selling price of briquettes	9	$ for a bag of 100 briquettes	FDS
Pellets	Mass of input biomass for pellets processing	1,04	kg-biomass/kg-briquette	FDS
	Price of 1 kg bagasse = C-briquettes raw material cost for 1kg c-briquettes * (Mass yield of bagasse carbonization / Mass of input char for c-	0,007	$/kg bagasse	Calculation
	CAPEX of bagasse pellets factory	5000000	$	Enea project
	Electricity consumption for pellets processing	0,10	kWhelec/kg-briquette	Enea project
	Number of full time equivalent employees in pellet factory	8 workers, 2 management	HTG	Enea project
	Annual production of the pellet factory	1420	ton/year	Enea project
LPG	Selling price of LPG in PaP	52	HTG/kg	PalmisEneji
Ethanol	Ethanol yield per ton of sugarcane	66	L/ton sugarcane	Novogaz, Green Social Bioethanol
	CAPEX of a distillery plant	690000	USD	Green Social Bioethanol
	Manwork to operate the distillery plant	12	man for 3500 L ethanol	Green Social Bioethanol
	Consumables costs of the distillery plant	106,05	$ for 3500 L ethanol	Green Social Bioethanol
	Electricity consumption for ethanol processing	1074	kWh for 3500 L ethanol	Green Social Bioethanol
Ethanol	OPEX of a distillery plant = (Consumables costs of the distillery plant + Electricity consumption for ethanol processing * Grid electricity purchasing cost for industries + Manwork to operate the distillery plant	0,13	$/L ethanol	Calculation
	Daily production of the distillery plant	3500	L ethanol/day	Green Social Bioethanol
Ethanol	Working days per year - 4 months - Ethanol max scenario	120	days/yr	Enea
Ethanol	Retail price imported ethanol max	140	HTG for 1,5 L	Novogaz
Ethanol	Retail price imported ethanol min	450	HTG for 5 L	Novogaz
Electricity	Minigrid solar system size	3,6	kWh/day	Enea
Electricity	Electricity price from solar minigrid	3	$/kWh	Enea

Figure 52 – Input data on fuel costs and retail prices for fuel economics

Fuel	Stove costs	Values used in the analysis	Unit	Source
N/A	Average daily charcoal consumption of a household	2,31	kg/day/hh	EdMGS2014
N/A	Annual cooking energy demand per household = Average daily charcoal consumption of a household * 365 * LHV charcoal * Combustion	5428	MJ-delivered/HH/year	Calculation
Charcoal & C-Briquettes	Stove cost	150	HTG	Berkeley
	Stove lifetime	0,75	years	Berkeley
	Combustion efficiency	22%	-	Berkeley
NC-briquettes & Pellets	Stove cost	50	HTG	FDS
	Stove lifetime	2	years	CleanStoves
	Combustion efficiency	0,4	-	CleanStoves
Ethanol	Stove cost	1400	HTG	Novogaz
	Stove lifetime	2	years	EdM
	Combustion efficiency	0,525	-	EthaApro10
LPG	Stove cost	3295	HTG	Palmis Enèji
	Stove lifetime	2	years	EdM
	Combustion efficiency	0,53	-	EdMGS2014

Fuel	LHVs	Values used in the analysis	Unit	Source
Charcoal	LHV charcoal	29	MJ/kg	EdMBriq2009
C-briquettes	LHV C-briquettes	28	MJ/kg	Enea project
NC-briquettes	LHV saw dust	19	MJ/kg	Enea
	LHV waste paper & cardboard	12	MJ/kg	Enea
	Average LHV of NC-briquettes = 33% * LHV_saw_dust+(1-33%)* LHV waste paper	14,3	MJ/kg	Calculation
Pellets	LHV bagasse	14,7	MJ/kg	Enea
Ethanol	LHV ethanol	26,7	MJ/L	EBTP
	Density ethanol	0,79	kg/L	EBTP
LPG	LHV LPG	46	MJ/kg	CFBP

Figure 53 – Input data on stove costs and technical data for fuel economics

Sources used in the economic analysis are listed in Table 3.

Code name	Source	Code name	Source
Enea	[27]	FDS	[11]
Enea project	[17]	TotalHaïti	[28]
HaïtiLibre	[29]	Novogaz	[15]
CRI	[16]	Green Social Bioethanol	[6]
AFDI2012	[12]	EdMGS2014	[30]
Tarter	[31]	Berkeley	[32]
HBWood	[33]	CleanStoves	[34]
GERES	[18]	EthaApro10	[35]
Nexant2010	[36]	EdM	[37]
Vetiver	[13]	EdMBriq2009	[3]
Palmis Enèji	[14]	EBTP	[38]
EDHElec	[39]	CFBP	[40]

Table 3 – Code names of the sources used in the economic analysis

8.8 Categories of social impact in the Monitoring & Evaluation frame of the Alliance

The categories of social impacts comprised in the two domains of the Monitoring & Evaluation (M&E) of the Alliance and applicable to the scope of the present study are listed below.

Livelihoods

- Jobs
  - Number of paid employees at the organization/enterprise
- Quality of jobs created
  - Full-time/part-time
    - Number of paid full-time employees at the organization/enterprise
    - Number of paid part-time employees at the organization/ enterprise
  - Temporary/ seasonal
    - Number of temporary/seasonal employees at the organization/enterprise
  - Management level
    - Number of paid full-time management employees at the organization /enterprise
  - Area within the value chain
    - Number & percentage (m/f) of employees in product design
    - Number & percentage (m/f) of employees in production/manufacturing
    - Number & percentage (m/f) of employees in wholesale distribution
    - Number & percentage (m/f) of employees in retail distribution/sales
    - Number & percentage (m/f) of employees in after-sales service
  - Geographic location (urban/rural)
    - Number & percentage (m/f) of employees located in urban settings
    - Number & percentage (m/f) of employees located in rural settings
- Income full-time/part-time
  - Wages of all employees
  - Wages of full-time employees
  - Wages of part-time employees
- Income management
  - Wages of management staff
- Women-owned
  - Female ownership

Household Social & Economic Well-being

- Adoption
  - Use
    - Frequency of use of various cooking methods
    - Minutes spent cooking with each cooking method
- Households finances
  - Economic
    - Children in school
  - Money spent on fuel
    - Expenditure on specific fuel
    - Overall fuel expenditure
  - Income through productive use of cookstove
    - Business in which the customer uses the clean cooking product/device
    - Change in earnings from using the clean cooking product/device
    - Changes in business from using the clean cooking product/device
- Time use

- Time spent on fuel collection
    - Time spent on fuel collection
    - Household members involved in fuel collection
    - Perception of reduction in time spent on fuel collection
    - Use of time saved on fuel collection
- Time spent on cooking
    - Time spent on cooking
    - Household members involved in cooking
    - Multi-tasking while cooking
    - Perception of reduction in time spent on cooking
    - Use of time saved on cooking

- Status
    - Status within the family/community
        - Perception of change in status
- Safety/protection
    - Fuel collection safety/ protection
        - Perception of changes in cooking safety
    - Cooking safety/ protection
        - Experience of risks to respondent safety
        - Experience of risks to safety of other household members
- Drudgery
    - Fuel purchase drudgery
        - Drudgery associated with fuel purchase (# of trips/month, time spent, distance traveled, weight carried)
    - Fuel collection drudgery
        - Drudgery associated with fuel collection (# of trips/month, time spent, distance traveled, weight carried)
    - Cooking drudgery

Perception of change in cooking drudgery

8.9 Feedback from the interviews and literature review on social aspects of the fuels value chains

Firewood

Most of firewood is collected by women and children for direct use without formal or informal job creation.

Traditional charcoal

Charcoal production, transport and distribution is a significant source of employment and creation of local economic value in Haiti. Charcoal production is predominantly achieved by farmers as a complementary source of incomes. Farmers can produce charcoal alone or in groups with up to 5 persons [31]. In the South Department, a farmer produces 11 bags[49] of charcoal per week in average as a complementary activity to farming [41].

Men are in charge of wood cutting and carbonization while women take care of the charcoal packaging before transport. Charcoal transport to urban areas by truck is done by men while sales (wholesale and retail) are predominantly managed by women (Madame Sara).

Improved charcoal

The use of improved kilns to produced charcoal would require to transport the wood with additional work and burden on this step compared to traditional charcoal. The production of improved charcoal implies fixed kilns typically made of bricks and cement. The high capital cost of this type of kiln (in the order of magnitude of USD 1,000 per kiln [18]) may exclude smallholder farmers of the activity of charcoal production with the wealthiest farmers being owners of the kilns. The downstream steps of the value chain (i.e. those involving women) should not be impacted by the “improved” vs “traditional” feature of the charcoal.

Carbonized briquettes

Carbonized briquettes can be made from agricultural residues usually left on the field (stems, leaves, straws) or from by-products available at food processing units (bagasse). Women are active in almost all agricultural value chains [42]. The distribution of waged work for farming is balanced between women and men [42]. Men still tend to manage farms (in the South department only a quarter of farms are managed by women) [42]. The collection of agricultural wastes traditionally falls to women. Developing of a fuel value chain of charbriquettes based on agricultural residues may thus increase the burden of tasks achieved by women in rural areas. Charbriquettes made of bagasse are however not expected to impact women particularly because roles between women and men in the sugar cane value chain are balanced [43].

The only current example of charbriquette production in Haiti lies in the activity of Carbon Roots International (CRI). The company employs about 50 people with 40 for operational jobs and 10 for management jobs. Men weight for 60% of the employees, mostly in raw material sourcing (collection of bagasse) and fuel production, including operational and management jobs [16]. Women weight for the remaining 40% of jobs, mostly in sales, including operational and management jobs [16]. Kilns operators are equipped with safety boots, masks and gloves [16]. Operational jobs for supply and production are waged about 10-11 USD/day which is twice the minimum daily wage in PaP (approximately 5 USD/day) [16]. If CRI invests in a new generation technology for carbonization, a lower number of employees will be required [16].

[49] The weight or volume of this unit is not specified in the source but the bag mentioned should likely be a 30 kg bag.

Non-carbonized briquettes

The only current example of non-carbonized briquette value chain in Haiti lies in the activity of Fuego del Sol (FDS). The company accounts for 8 full time employees and 14 part time employees. Among this staff, 5 women are trainers and 1 is part of the management and own 5% of the company. The operational staff earns 8.5-10 USD/day and food for working days. The management/owner staff earns 450-500 USD/month.

Pellets

There is no production of pellets currently in Haiti. However, we can expect roles to be distributed similarly to carbonized briquettes produced from bagasse. In this case, the roles between men and women would be balanced for sugar cane production and transformation, mostly assigned to men for collection of bagasse and production of the fuel, and exclusively assigned to women for sales.

Ethanol

Ethanol is currently not produced locally in Haiti but we can expect the activities of production and transformation of sugar cane into ethanol to be balanced between men and women, as it is for the current production of alcoholic beverage from sugar cane [43]. Similarly to other fuels, sales would be under the responsibility of women.

Novogaz is the sole company active in Haiti in the ethanol sector. They package and sell imported ethanol and account for 5 employees including 1 manager, 2 operators on the packaging step and 2 vendors [44]. Among this staff, only 1 person is a male, working on the packaging step.

LPG

The LPG value chain relies on an imported fuel and should thus be expected to create a low number of jobs compared to value chains based of fuels locally produced and sourced. Because the LPG value chain is mostly oriented towards sales, its jobs should traditionally be assigned to women. However, LPG tend to be sold in large shops not necessarily owned and managed by women. Within Palmis Enèji shops selling LPG, one third of employees are women.

Electricity

Cooking on electricity from a solar microgrid in Haiti is expected to create a relatively low number of local jobs because it implies the local activity of a microgrid operator only while most of the value is located in imported equipments (i.e. solar panels, batteries). Gender issues for the operation of a microgrid in Haiti cannot be presumed at this stage given the low maturity and feedback available so far.

8.10 Summary of information collected on LPG

Information collected from interviews with P. DION, R. JEAN-JUMEAU, J.F. LAMBERT, N. DAVID.

Current Market Trend:

- The Haitian LPG market is significantly underdeveloped with an annual consumption of 15,000 tons or less than 2 kg per inhabitant when other developing countries in the sub-region have a consumption of 5 to 10 kg per inhabitant (up to 25 kg in El Salvador). It has been stagnating for many years.
- Most past attempts at developing LPG on a larger scale have failed due to two main factors:
  - The high cost of purchasing the cylinder and LPG stove for middle and low income households.
  - The lack of a robust regulatory framework for the LPG sector and the opening of hundreds of independent microfilling centers which fail to abide by the minimum safety standards of the sector. Crossfilling of cylinders by these actors in particular has led the two largest LPG marketers, Dinasa and Total, to postpone their investments in this activity.
- Nevertheless the existing storage capacity is sufficient to enable a significant growth of the sector: the combined storage capacity of Dinasa and Total could serve a market of 50,000 tons per year (USAID, 2010: 7).

Overview of the LPG value chain:

- There is no LPG production in Haiti and the fuel is imported from abroad.
- Total and Dinasa are the only two companies to own the port facilities needed to land LPG from the sea, and as such the only two importers of LPG. Some LPG also comes overland from the Dominican Republic, both legally and through black market channels. Dinasa markets its LPG under the Sodigaz brand.
- In 2010 Dinasa had 850 tons in storage capacity while Total had 1,000 with the foundations already built to expand to 1,400 tons. Dinasa accounted for 60% of LPG imports while Total accounted for 40%. Dinasa is thought to import 750 tons of LPG every 2-3 weeks while Total imports 900 tons a month (USAID, 2010: 8).
- Dinasa and Total supply the two other large size distributors of the country: Ecogaz and Canez Distribution who in turn supply the small size distributors (eg: owners of one or two microfilling centers). The latter cannot purchase LPG directly from Dinasa and Total because they lack the vehicles needed to transport bulk LPG.
- The price structure of LPG is unregulated and is heavily skewed toward the top of the value chain. The two LPG importers retain a disproportionate share of margins.
- In October 2016, the retail price of LPG purchased from a Total reseller was 310 HTG (4.75 USD) for a 12 Lbs refill and 640 HTG (9.85 USD) for a 25 Lbs refill.

Development path:

A concept note developed by the LPG working group convened by the line ministry (MTPTC) in 2010 advocated for the following actions in support of LPG development:

- Adoption of a law regulating the LPG sector, enabling an independent body to enforce safety standards and the protection of cylinder ownership.
- Creation of a system of controlled prices to protect consumers against international market volatility.
- Support of marketer investment in new LPG cylinders through the creation of a sector organization in charge of managing the cylinders and removing damaged cylinders from the market. The report recommended that the price of the cylinder be largely subsidized to boost the development of the market.
- Set up of partnerships with MFIs to offer credit facilities to new LPG users.

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