Biomass Residues as Energy Source to Improve Energy Access and Local Economic Activity in Low HDI Regions of Brazil and Colombia (BREA)

(Revised Final Report – September 2015)

Partner Institutions:

Executive Summary

Access to cleaner and affordable energy options is essential for improving the livelihoods of the poor in developing countries. The link between energy and poverty is demonstrated by the fact that the poor in developing countries constitute the bulk of an estimated 2.7 billion people relying on traditional biomass for cooking and the overwhelming majority of the 1.3 billion without access to grid electricity (IEA, 2015a). The Brazilian Amazon region and the Colombian isolated areas – despite their national electrification rate of 99.5% and 97.1% respectively – account to about 2.4 million of people without electricity access. When it comes to cooking this number grows eightfold, almost 20 million people within these two countries rely on the traditional use of biomass for cooking. In fact, 6% of Brazilians and 15% of Colombians cook using firewood (IEA, 2015b).

The lack of modern and affordable forms of energy affects agricultural and economic productivity, opportunities for income generation, and more generally the ability to improve living conditions. Moreover, low agricultural and economic productivity as well as diminished livelihood opportunities in turn result in malnourishment, low earnings, and no or little surplus cash. This contributes to the poor remaining poor, and consequently they cannot afford to pay for cleaner or improved forms of energy such as fuels and equipment. In this sense the problem of poverty remains closely intertwined with a lack of cleaner and affordable energy services.

In this context, the main objective of the *"Biomass Residues as Energy Source to Improve Energy Access and Local Economic Activity in low HDI regions of Brazil and Colombia (BREA)"* is to develop a better knowledge of energy requirements for productive purposes among poor households in urban and rural areas of Brazil and Colombia (many of them in isolated regions), which could allow inputs for targeted policy interventions. Aiming to do that, BREA analyzed the perspectives to increase and improve energy access and energy for productive uses, as well as to enhance the Human Development Index (HDI) of the low-income population selected.

The goal was to combine the delivery of energy services with measures that generate cash incomes, following the Energy+ Initiative, as proposed by the United Nations Development Programme (UNDP). Through the use of small power and heat generation technologies fed with urban and rural biomass waste, BREA intends to replace traditional biomass and fossil fuels so as to enable the electrification and improvement of local economic activities.

This report identified that existing technologies available in the two countries include, as a first step, photovoltaic panels, but these are only possible for small power supply. Also, they are quite expensive systems since most are still imported. Therefore, the use of biomass residues allows the production of higher power, mainly in areas where such residues are available in a large amount, as shown in this report. The mains advantage of the use of biomass

residues is exactly the perspective of producing power also for productive activities, as well as contributing to reduce the negative impacts of inadequate use of such residues (i.e., municipal solid waste and animal residues, which currently are discharged inadequately, and agricultural and wood residues, which are burnt in open air or left *in situ*).

The main difficulty identified by the study is related to the use of biomass residues for power production:

a) Lack of funding (both private and from government).
b) Difficult economic feasibility since many of the municipalities are too small and households present a large dispersion in rural areas, mainly in the Amazon region of Brazil and Colombia.
c) Lack of local capacity building to operate and maintain some of the technologies.
d) Lack of political will.

Regarding the technologies proposed in this study for the recovery of biomass residues, each one has a different situation

a) Biodigestion – technology already commercialized in Brazil, but not too much used yet in rural areas. Despite some efforts in Colombia, the technology has not been widely implemented for power generation purposes in rural and isolated areas. Hence, it is needed to develop a large and widespread program in such regions.
b) Small-scale combustion (steam cycles) – technology already fully commercialized in Brazil by TGM Turbines[1] (from 200 kWe and up, and exported to other Latin America countries such as Colombia).
c) Small-scale biomass gasifiers (up to 200 kW) – technology already available but not yet fully commercialized. Some pilot plants were implemented in the Amazon region using agricultural and wood residues (i.e., Gaseifamaz project).

As a result, this study recommends policies and strategies to overcome the existing barriers, such as:

a) Adequate funding from the Federal Government and/or international agencies.
b) Adequate finance programs from existing local banks and/or international banks with low interest rates to be affordable for poor municipalities
c) Adequate policies enlarging the existing CCC to biomass power production, in Brazil, and the introduction of similar program in Colombia
d) To develop one local pilot demonstration plant in one of these municipalities selected

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[1] www.grupotgm.com.br/home/

e) To improve existing electric sector legislation and the existing programs to increase energy access, aiming to incentivize the utilities to provide this supply

In short, energy access – including energy for productive uses – may contribute to increase the (very) low HDI of the selected municipalities of the project in the following cases:

a) Productive uses may allow local people to commercialize more products with more value added (see example of Gaseifamaz project in Amazon region).
b) If MSW (disposed in an inadequate way in all municipalities) can be used for energy production, this could help to make feasible the adequate collection and disposal of waste.
c) In the case of agricultural/wood residues, mainly burnt in open-air, the energy conversion would eliminate the CO_2 emissions from this burning and the health impacts.

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1. Introduction

There are presently 1.3 billion people with no access to electricity worldwide and 2.7 billion people using traditional biomass for heating and cooking (AGECC, 2010). To address these problems, the UN Secretary General established in 2008 the Advisory Group on Energy and Climate Change (AGECC). One of the two main ambitious goals recommended by AGECC was to ensure universal access to modern forms of energy by 2030 in poor countries (AGECC, 2010).

The definition of energy access usually includes both electricity access and access to modern fuels for cooking and heating to replace traditional biomass[2]. However, only electricity access to allow basic needs is not enough for poverty alleviation and economic development. The concept of energy for productive use (or energy services) is being considered an important and fundamental factor (UN-Energy, 2007, AGECC, 2010, OECD/IEA, 2011, GEA, 2012), among others. In this context the Brazilian experience can be significant for other developing countries (DCs), since it addresses not only the electricity access for basic needs but also for the economic development of the region.

The lowest threshold is proposed by IEA (International Energy Agency), namely 100 kWh of electricity and 100 kgoe[3] of modern fuels (equivalent to roughly 1200 kWh) per person per year. This can be used as a starting target". This means that besides the implementation of energy access for basic needs, also a higher electricity supply is needed.

Also, UN-Energy (2007) discusses that energy services are an essential input to economic development and social progress, notably to achieving the Millennium Development Goals. "Energy services are necessary for successful implementation of almost all sectorial development programs, notably revenue generating activities, health, education, water, food security, agricultural development, etc.". Increased access to energy allows economic growth and poverty alleviation. This definition envisages clearly two steps: a first connection that solves the basic problems of lighting and the use of radio and TV; and a more ambitious step of using electricity for productive uses (OECD/IEA, 2011[4]).

Recently, Birol and Brew-Hammond (2012) have presented the results of the Task Force One – "Sustainable Energy for All" - aiming to achieve the objectives of AGECC (2010) – universal access to modern energy services by

[2] Further discussion on "traditional biomass" is presented in Karekesi, Lata, Coelho, 2006.

[3] kilograms of oil equivalent

[4] Considering this context, IEA has proposed the Energy Development Index (OECD/IEA, 2011) `in order to better understand the role that energy plays in human development`. According to the agency, EDI is an `indicator that tracks progress in a country's or region's transition to the use of modern fuels`, what confirms the importance of energy for productive use, since it includes key variables related to energy for productive use and energy for public services.

2030 - in the context of the Secretary General's High-level Group on Sustainable Energy for All. Also in this document, the concept of energy for productive use is pointed as an important and fundamental support for economic development.

I. Brazil

In Brazil, existing programs on energy access in the country allowed the country to reach more than 99% of the urban population with electricity access. More recently, the LPT – Luz Para Todos, or (*"Light for all"* program in English), launched by the Federal Government in November 2003, aiming to eliminate the electric exclusion in the country mainly in rural areas, has reached over 10 million people by 2008 (2 million households).

In Brazil, existing programs - i.e. LPT - on energy access in the country allowed the country to reach more than 99% of the urban population with electricity access. Also, what experience showed in Brazil in the case of electrification of urban slums is that initially 50 kWh per month was sufficient to solve immediate problems of the families, such as lighting in the evening, radio and TV. However, soon the consumers started installing refrigerators and other electrical equipment, including cooking with electricity, which of course required more than 50kWh/month. Installing meters and charging for the electricity consumed became essential (Boa Nova and Goldemberg, 1999). More recently, the LPT program, launched by the Federal Government in November 2003, aiming to eliminate the electric exclusion in the country mainly in rural areas, has reached over 10 million people by 2008 (2 million households).

This is actually the fundamental problem the LPT program is facing with electrification in isolated areas, in which PV systems correspond to the preferred option. A PV array for the production of 5 to 10 kWh per month is easy to install but as soon as consumption increases, either for residential consumption or productive process, PV installation only will not be enough. This is why electricity supply using biomass residues is seen as a good option to improve and or to complement energy access in rural areas of developing countries if PV systems already installed.

In the Brazilian interlinked system, all electric power plants are connected through long transmission lines from Southern to Northern Brazil, mainly along the coast; the isolated system, in Northern region (Brazilian Amazonia), is composed mostly by small thermoelectric power plants (diesel engines with difficulties on logistic for diesel supply through rivers in the rain forest). This region covers an area corresponding to 45% of Brazilian territory and 3% of the population (around 1.2 million consumers). These diesel fueled power plants are heavily subsidized through a special policy - *Conta Consumo de Combustiveis* - CCC (Fuel Account Consumption in English, created in 1973), since diesel costs are high for remote villages not covered by CCC, due to the high transportation costs by boat through the rainforest.

In 2007 there were nine biomass power plants in Amazonas and Para States with 22.05 MW installed. This shows there is a large room for the replacement of diesel engines, as well as to supply energy needs in the remaining about 4 thousand villages not having electricity access. Considering an average of 100 kW-demand per village (Rendeiro and Nogueira 2008), there is at least a demand of 373 MW not supplied.

The challenge still existing in these remote villages is very similar to the one in rural areas in other DCs and the lessons learned – and still being learned – could be used in those countries.

In fact, aiming to increase electricity access in a sustainable way in these villages, it is necessary to develop electricity access systems based in local energy sources like small hydro and biomass (such as rural residues), as being started in pilot projects in the region. Such systems allow higher installed power, contributing to the development of economic activities.

When using agro-industrial residues from sawmills[5] or animal waste to produce electricity to households around the mill, results are more positive than the implementation of local small power plants to be operated by the community (or the local utility) itself, since the mill itself takes care of O&M, without the need of the participation of the local utility, which in general is not so interested on these projects.

The experiences in Brazil with PV systems in remote villages in Amazonia show that the energy access provided by such systems is enough to provide basic needs such as lighting and pumping water. However to develop productive activities - to allow the payment for the electricity - it is necessary higher installed power. This is why Brazilian Government has funded pilot plants in Amazonia using existing local energy sources such as biomass residues and SVO and should keep funding it (Coelho et al, 2004, Coelho et al, 2005, Velazquez et al, 2010). Also India has developed small-scale biomass gasifier systems (Dasapa et al, 2011) like the ones installed in Amazonian remote villages.

It is also important to notice that recently the IEA have included, in the statistics provided, a new index (Energy Development Index), aiming to include figures for productive use of energy in DCs (OECD/IEA 2011).

Developing countries have a high potential to produce biomass due to more favorable climate conditions and lower labor costs and this can be possible to be done in a sustainable way (Coelho et al, 2012). The production and use of biomass for electricity production can also help to develop economic activities in such villages, making energy supply economically sustainable and affordable for the local population.

The use of agro-industrial residues to produce electricity for rural households in remote villages in Amazonia is similar to those in sugar mills and tea factories in Sub Saharan African countries, where the electricity surplus being generated will supply households around the industries, in the "Cogen

[5] ENERMAD project. GBio. http://143.107.4.241/projetos/enermad/enermad.htm

for Africa" GEF/Project[6][7][8]. This projects aims to introduce more efficient technologies for the energy conversion from biomass residues (mainly sugarcane bagasse from sugar production and wood chips from eucalyptus plantations) in the region, contributing to increase the electricity generation, reducing de fuel expenses and creating jobs in rural areas of such countries.

There are more than 5 thousand municipalities in Brazil, about half of them with less than 10 thousand inhabitants. On the other hand, the municipalities with the lowest Human Development Index (HDI) are in North and Northeast regions, where there are abundant and available biomass residues that could be used for energy generation, using efficient and sustainable technologies. These facts suggest that there is a significant opportunity for small-scale power generation, generating jobs and income in these municipalities.

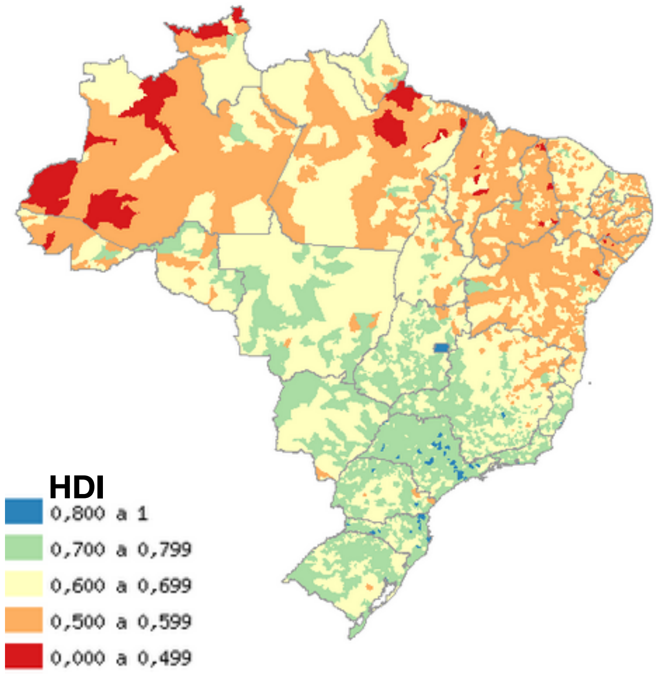

Figure 1: Municipalities HDI in Brazil (Source: UNDP, 2013).

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[6] http://www.afrepren.org/cogen/index.htm

[7] GEF - Global Environmental Facility. UNEP - United Nations Environment Program. AfDB - African Development Bank.

[8] According to UNEP, 'Cogeneration for Africa' is an innovative and first-of-its-kind clean energy regional initiative funded by GEF (Global Environment Facility). The initiative is co-implemented by UNEP (United Nations Environment Programme) and AfDB (African Development Bank) and executed by AFREPREN/FWD (Energy, Environment and Development Network for Africa). (...) It seeks to significantly scale up the use of efficient cogeneration systems initially in seven Eastern and Southern African countries (Kenya, Ethiopia, Malawi, Sudan, Uganda, Tanzania and Swaziland). (Cogen for Africa Project, 2012).

II. Colombia

Colombia is a country with 1,138,913 square kilometers and a population of 45 million inhabitants.

In 2005, this interconnected electricity system served 87% of the population, a percentage that is below the 95% average for Latin America and the Caribbean. In Colombia, electricity coverage is 93 percent in urban areas and 55 percent in rural areas. About 2.3 million people do not have access to electricity yet (ESMAP, 2007)

Electricity supply in Colombia relies on the National Interconnected System (SIN) and several isolated local systems in the Non-Interconnected Zones (ZNI). SIN encompasses one third of the territory, giving coverage to 96 percent of the population. The ZNI, which covers the remaining two thirds of the national territory, only serves 4 percent of the population.

Colombia has 28.1 megawatt installed capacity of renewable energy (excluding large hydropower), consisting mainly of wind power. The country has significant wind and solar resources that remain largely unexploited. There are also significant biomass residues, which are not well exploited as discussed ahead.

There are several options of biomass residues to be used for electricity generation. Like Brazil, they use the sugarcane bagasse to generate all the energy needed for processing. They also sell surplus bagasse-based power to the national electric grid. According to ASOCAÑA (2008), even though the cost of production of bagasse-based electricity is higher than the coal-based or hydroelectric-based electricity, the final price (after tax, commercialization, and transportation costs) that the mills would have to pay for conventional electricity would be higher than that of bagasse-based electricity. This electricity could also be used for the local communities.

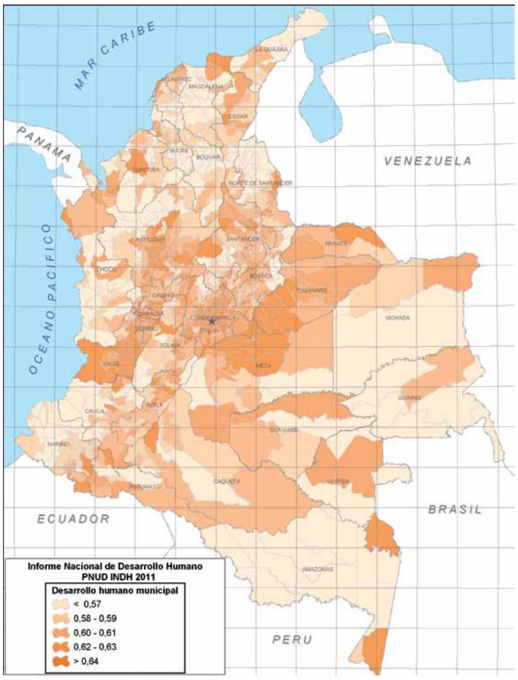

Figure 2: Municipalities HDI in Colombia (Source: UNDP 2011)

As in other countries, the zones outside the interconnected system pose especially challenging conditions for electrification, as well major inadequacies in service provision. This system, whose installed capacity is almost exclusively diesel-based, suffers from major diseconomies of scale as 80 percent of capacity is in plants below the 100 kW thresholds.

Colombia has a great biomass power (ESMAP, 2007) potential from agricultural residues (banana, coffee pulp, and animal waste). Its annual biomass power potential is estimated to be over 16 GWh, which is still less than 0.1% of current electricity production. The potential is distributed as follows:

- 11,828 MWh/yr. from agriculture residues
- 2,640 MWh/yr. from bioethanol production
- 698 MWh/yr. from natural forest residues
- 658 MWh/yr. from biodiesel production
- 442 MWh/yr. from planted forest residues

The potential for electricity production from bioethanol residues (sugarcane bagasse) showed above is quite conservative. If we consider the ethanol production of 327 million liters of ethanol, using efficient technologies already in use in Brazil (producing 60 kWh of electricity surplus per ton of cane) we can get 75 MW of installed power or 280,000 MWh/yr. of energy production. On the other hand ASOCAÑA 2008 estimates a total potential from cogeneration in Colombia of 631 MW, being 200 MW from sugarcane.

The region of Urabá in the north of the Department of Antioquia has approximately 19,000 hectares of banana plantations, producing more than 1 million tons annually. It has also been estimated that approximately 85,000

TOE/yr. could be produced from the 190 million m3/yr. of biogas generated from coffee plantations, equivalent to 995,000 MWh.

In addition, the landfills in the four main cities in Colombia (Bogotá, Medellin, Cali, and Barranquilla) are estimated to have the potential to provide for an installed capacity of 47 MW (0.3% of current installed capacity) - ESMAP, 2007, *Review of Policy Framework for Increased Reliance on Renewable Energy in Colombia.*

In this context the introduction of more efficient technologies could allow the production of higher energy surplus to be used for local energy supply in the region around the mill.

1.1. Objective

The main objective of the *"Biomass Residues as Energy Source to Improve Energy Access and Local Economic Activity in low HDI regions of Brazil and Colombia (BREA)"* is to develop a better knowledge of energy requirements for productive purposes among poor households in urban and rural areas of Brazil and Colombia (many of them in isolated regions), which could allow inputs for targeted policy interventions. Aiming to do that, BREA analyzed the perspectives to increase and improve energy access and energy for productive uses, as well as to enhance the Human Development Index (HDI) of the low-income population selected.

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This report covers seven tasks defined by the Term of Reference provided by Global Network on Energy for Sustainable Development (GNESD), facilitated by UNEP. The tasks are:

- **Task 1:** Data Assessment, which is covered in Sections 2, 3, 4 and 5.
- **Task 2:** Assessment of available energy sources, which is covered in Section 3.
- **Task 3:** Selection of municipalities with lower HDI, which is covered in Section 2.
- **Task 4:** Survey of available biomass residues that can be destined to energy generation based on selected technologies, which is covered in Sections 3, 4 and 5.
- **Task 5:** Assessment and discussion of existing policy through interviews with stakeholders, which is covered in Section 6.

- **Task 6:** Assessment and discussion of existing barriers and policy recommendations, which is covered in Section 7.

- **Task 7:** Outreach activities, which is covered in Section 9.

It is important to mention that Task 7 is a transversal activity. Therefore, it covered all tasks since the outreach activities comprise of project's results dissemination. Also, Section 8 presents the concluding remarks based on the answers of the project's research questions.

1.2. Methodological approach

The initial activity aimed to select the lowest HDI municipalities in Brazil and in Colombia. In Brazil those municipalities are located in North and Northeast regions, corresponding indeed to the less developed regions in the country. The same was performed to Colombia, with the selection of the regions with lowest unsatisfied basic needs.

After this selection, a detailed data assessment on figures regarding each municipality was developed, including geographic, economic and social characteristics, including local energy demand (LED).

In a next step it was assessed the economic activities being developed by each municipality and, in parallel, the estimates of biomass resources available for energy conversion.

Following these steps, it was evaluated the theoretical potential to produce energy from biomass residues (bioenergy) in each municipality (TBP).

In parallel, it was also performed the assessment of the best available technologies (BAT), which were considered for each type of biomass residue available.

The comparison between the local energy demand (LED) and the theoretical bioenergy potential (TBP) was then performed and, based on the identification of the existing barriers, policy proposals were presented.

The Figure 3 illustrates the methodological steps developed in the Project, aiming to not only answer the research questions proposed initially during the Term of Reference (ToR) of the study but also to establish the activities to fulfill the tasks of the ToR.

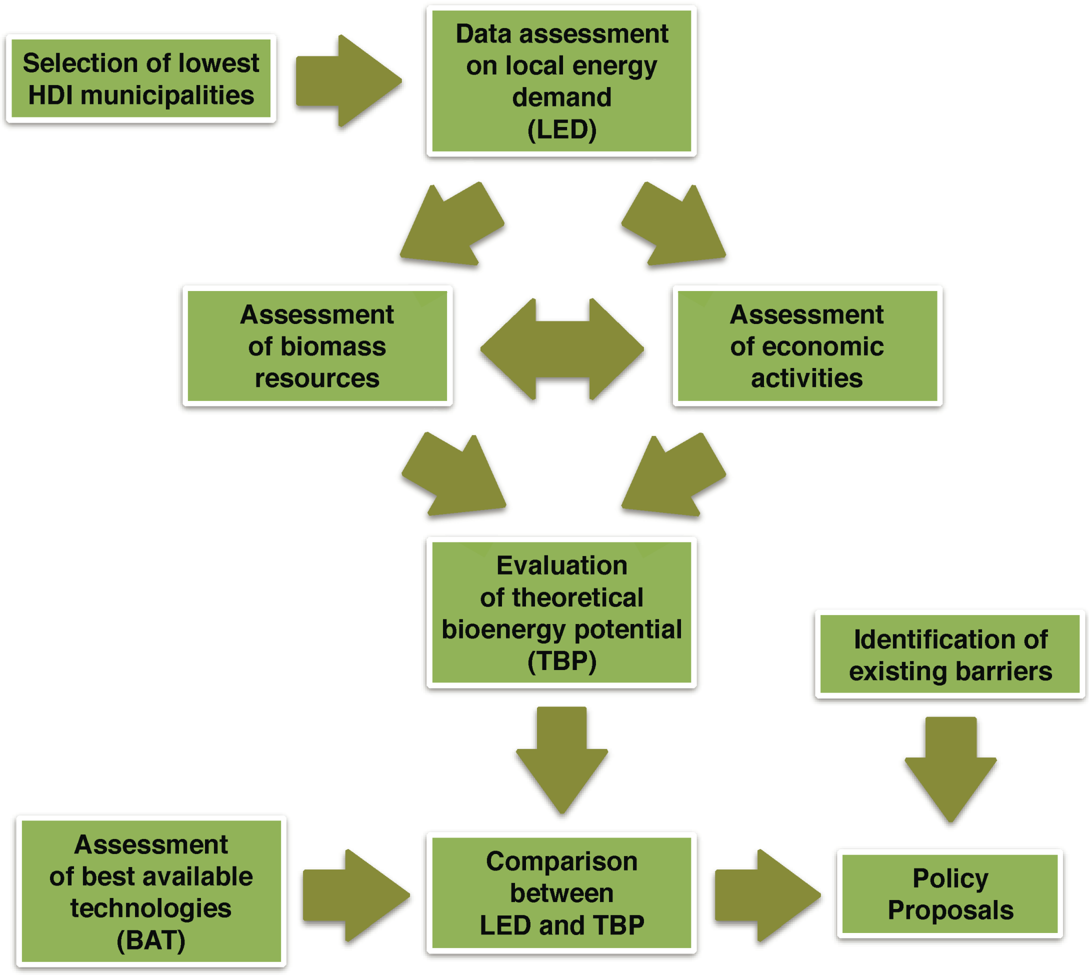

Figure 3: Methodological approach

The methodological approach guided the study to answer the following questions:

- What are the current and potential economic and production activities in small, poor and/or isolated municipalities? What are their power and heat consumption and demand including energy production uses? Which type of residues do they produce that can be used as an energy resource for productive uses?
- What are the renewable energy technologies available for increasing energy access and local production activities? What are the advantages and barriers for each one? Are biomass residues a good energy supply option for local productive uses?
- What is the availability of biomass residues in the selected municipalities (i.e., urban/solid waste and liquid effluents, and rural/agro-industrial wastes) that could be used to supply energy for productive activities? What are the estimates of the availability of each type of biomass residues and what is its current destination?

- How much energy could be supplied using biomass residues so as to supply low-income population and productive activities in rural and urban areas? What would be the local population income revenues from energy sale or fuel savings in their production processes? What would be the production possibilities using this energy?
- Are there locally available and appropriate technologies for recovery of energy from residues aiming at productive uses?
- What is the regional know-how to implement this potential?
- What are the barriers for implementing technologies for energy recovery from biomass residues for productive uses?
- Would it be possible to create a business model based on distributed energy micro-generation?
- How energy access and energy productive uses may contribute to increase the HDI of these municipalities?
- What are the measures currently being used to enable the utilization of biomass residues by low-income populations for energy access and productive uses?
- What policies and strategies must be taken to overcome the existing barriers?
- Whether the current rural electrification model(s) provide appropriate solutions to ensure enhanced electricity productive uses and their sustainability?

1.3. Working Group

BREA project is a product of a multilateral cooperation between Brazilian and Colombian institutions.

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2. Data assessment and selection of municipalities with the lowest HDI in Brazil and NBI in Colombia

In Brazil and Colombia, 32 municipalities and 15 municipalities respectively were selected. They represent localities in which people who lack access to cleaner and affordable energy are often trapped in a re-enforcing cycle of deprivation, lower incomes and the means to improve their living conditions.

The Brazilian municipalities represent the 32 municipalities with Low Development Index (HDI) and their HDI values range between 0.418 and 0.499, which is far below the national value of 0.744 (PNUD, 2013), from which 14 municipalities are located in the Northeast region of the country and the remaining 18 located in the North region.

Figure 4 shows the location of the selected municipalities. There are some distinguishing characteristics about those two regions: the total area of 18 municipalities within the North region is 21 times larger than the combined area of the 14 municipalities of Northeast region. However, when it comes to population density, the Northeast region is 9.4 times higher than the North region.

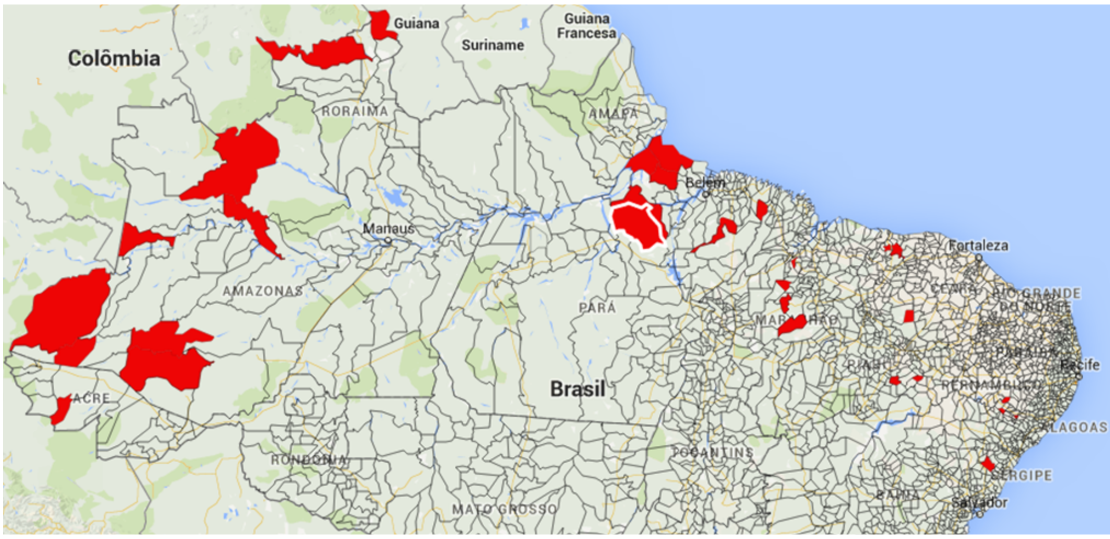


Figure 4: Map showing the location of the selected municipalities in Brazil

The Annex I: Profiles of selected municipalities in Brazil, which presents the profiles of the selected municipalities in Brazil.

In Colombia, there were no data available about HDI values at municipality level. Hence, the 15 municipalities were selected using an index of unsatisfied basic needs – "*Necessidades Basicas Insatisfechas*" (NBI) – to measure poverty. NBI indicates percentage of inhabitants of a given area that are under the minimum level of housing, nutrition, education, health, water and sanitation, and others (Hicks, 1998). According to census 2005, this index shows that about 28% of the population in Colombia lives without satisfying their basic needs (DANE, 2015).

The project selected 15 municipalities: Leticia, Puerto Nariño, Solano, Guapi, Timbiquí, Jurado, Unguía, Inírida, La Tola, Mosquera, Mitú, Taraira, Cumaribo, La Primavera, and Puerto Carreño. Up to now, only the municipality of La Primavera has its profile complete but the research group in Colombia is still profiling remaining ones and gathering missing data.

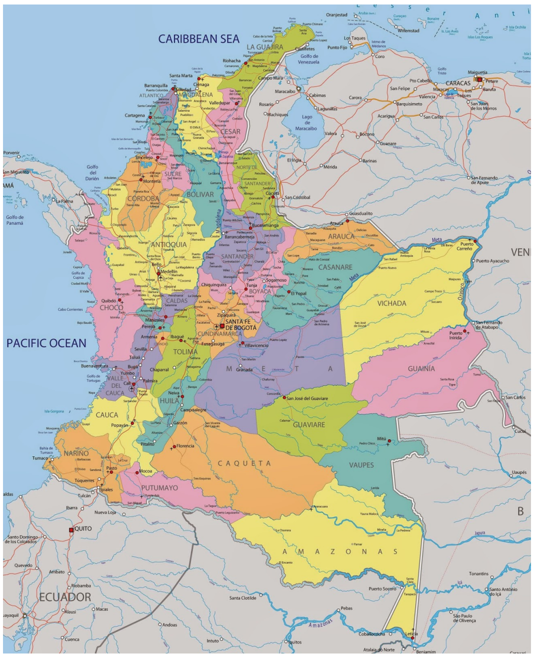


Figure 5: Map of Colombia

The Annex II: Profiles of selected municipalities in Colombia, which presents the profiles of the selected municipalities in Colombia.

Table 1 shows the selected municipalities in Brazil and Colombia. The reddish colors indicate the lowest living conditions or the poorest among the poor municipalities of each country. NBI in all selected municipalities in Colombia are significantly higher than the national average index. This indicates that these municipalities not only have inadequate housing, that is, housing with critical overcrowding and inadequate services, but also high levels of poverty, and a significant number of school-age children who are not enrolled in school.

Table 1: Selected municipalities in Brazil and Colombia

	FEDERAL UNIT	MUNICIPALITY	HDI
BRAZIL	ACRE	JORDÃO	0,469
	AMAZONAS	ATALAIA DO NORTE	0,450
		ITAMARATI	0,477
		SANTA ISABEL DO RIO NEGRO	0,479
		IPIXUNA	0,481
		SANTO ANTÔNIO DO IÇÁ	0,490
		PAUINI	0,496
		MARAÃ	0,498
	RORAIMA	UIRAMUTÃ	0,453
		AMAJARI	0,484
	PARÁ	MELGAÇO	0,418
		CHAVES	0,453
		BAGRE	0,471
		CACHOEIRA DO PIRIÁ	0,473
		PORTEL	0,483
		ANAJÁS	0,484
		AFUÁ	0,489
		IPIXUNA DO PARÁ	0,489
	MARANHÃO	FERNANDO FALCÃO	0,443
		MARAJÁ DO SENA	0,452
		JENIPAPO DOS VIEIRAS	0,490
		SATUBINHA	0,493
	PIAUÍ	SÃO FRANCISCO DE ASSIS DO PIAUÍ	0,485
		CAXINGÓ	0,488
		BETÂNIA DO PIAUÍ	0,489
		COCAL	0,497
		COCAL DOS ALVES	0,498
		ASSUNÇÃO DO PIAUÍ	0,499
	PERNAMBUCO	MANARI	0,487
	ALAGOAS	INHAPI	0,484
		OLIVENÇA	0,493
	BAHIA	ITAPICURU	0,486

	DEPARTMENT	MUNICIPALITY	NBI
COLOMBIA	AMAZONAS	LETICIA	38%
		PUERTO NARIÑO	58%
	CAQUETÁ	SOLANO	100%
	CAUCA	GUAPI	87%
		TIMBIQUÍ	73%
	CHOCÓ	JURADO	86%
		UNGUÍA	61%
	GUANÍA	INÍRIDA	58%
	NARIÑO	LA TOLA	91%
		MOSQUERA	84%
	VAUPÉS	MITÚ	52%
		TARAIRA	82%
	VICHADA	CUMARIBO	82%
		LA PRIMAVERA	100%
		PUERTO CARREÑO	46%

Rural poverty and urban poverty differ on many levels, with distinctive issues that characterize quality of life. Yet, there are similarities since poverty usually entails deprivation, vulnerability and powerlessness. However, these issues are sometimes inflicted on certain individuals or groups more than others. For example, women and children are more likely to experience poverty more intensely than men and minorities tend to suffer more greatly than other groups (The World Bank, 2015).

The International Monetary Fund (IMF) reports that 63% of the world's impoverished live in rural areas. Education, health care and sanitation are all lacking in rural environments. This causes many of the rural poor to move to cities, which often leads to a rise in urban poverty (IMF, 2015).

Currently, the rural population corresponds to 11.6 million people or 24% of the total population in Colombia and about 30 million people in Brazil, which is about 15% of the overall inhabitants of the country. Our selected municipalities in Colombia amount to 1.4% of the rural population. The Brazilian counterpart amounts to 1.3% (The World Bank, 2015). Figure 6 illustrates the population distribution in the selected municipalities. Figure 6 also shows that the number of people living in urban areas is smaller than the rural population. In average the selected municipalities in Colombia presents a population distribution with 45% urban and 55% rural. In Brazil, these figures are 33% urban and 67% rural.

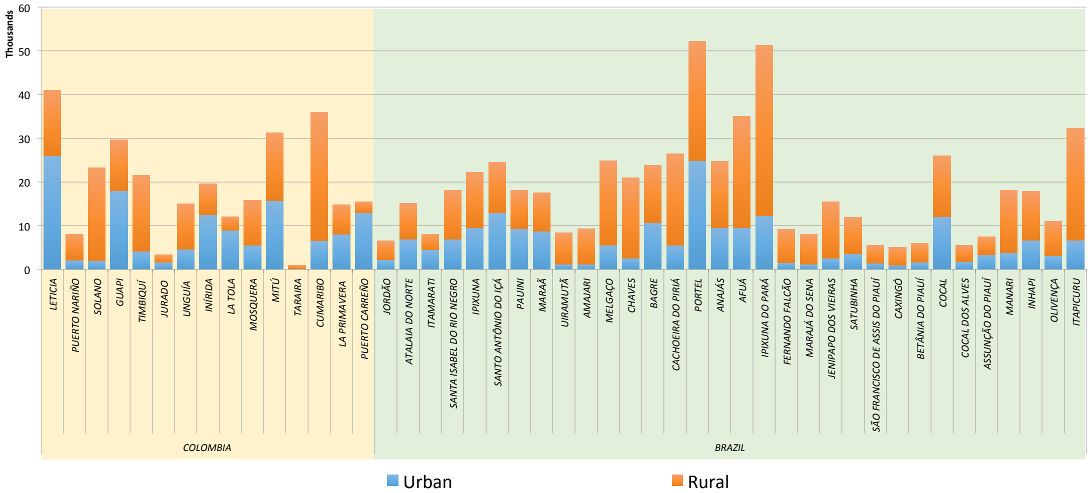


Figure 6: Population distribution in the selected municipalities of Colombia and Brazil

In average of monthly income per capita, 43% of the population within the selected Colombian municipalities is living under the threshold of extreme poverty, which means that 124 thousand people is living with US$ 2 per day or less. In Brazil, these figures are lower; more than 8 thousand people or about 1% of the population within selected municipalities are living under these conditions. However, only four Brazilian municipalities crossed the threshold of US$ 4 per day. They correspond to about 12% of the population within the selected municipalities in Brazil. Although these populations are high above the extreme poverty line when compared with other selected municipalities, they cannot satisfy basic needs beyond food and has a limited capacity to pay. Clearly, these figures are a generalized illustration of local inequalities and do not translate fully the complexity of poverty but they confirm that selected municipalities are areas with the lowest living conditions or the poorest among the poor municipalities in each country.

Figure 7 presents the monthly income per capita distribution in US$ and the threshold of extreme poverty (PNUD, 2013; Rico de Alonso, 2005; DANE, 2015).

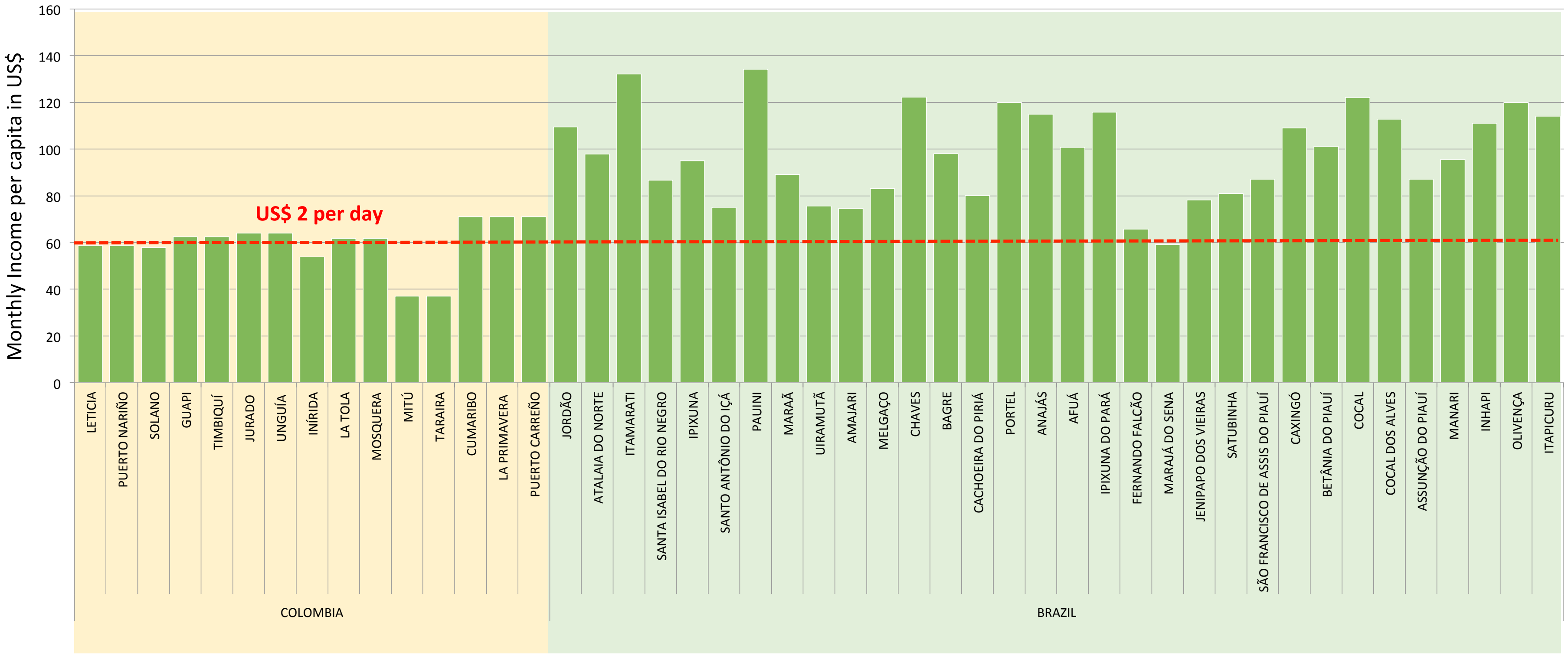


Figure 7: Monthly income per capita in US$ of the selected municipalities of Colombia and Brazil

Access to safe water and sanitation services is a constant and urgent problem for poor communities in developing countries. More importantly, sanitation services, both directly and indirectly, impact the economic climate in communities, and are essential to breaking the cycle of poverty (PNUD, 2013; Ministerio de Ambiente, Vivienda y Desarrollo Territorial, 2012a; 2012b). About 28% of rural population in Colombia has no access to clean water and sewage services. According to the National Health Institute – INS, differences in water quality along the national territory are significant (INS, 2014). This implies high health risks particularly in rural areas where water services, if available, are often of very low quality. Figure 8 shows the rate of access to clean water and sewage in the selected municipalities of Colombia and Brazil. Just four of the analyzed municipalities in Colombia have a rate of access to clean water and sewage higher than 50%. There are severe cases as in Solano, Timbiquí, and Guapi, where lack of access reaches levels higher than 70%. As a result, the need for investment to build and improve existing infrastructure is noticeable. For example, about 6.7 million USD are required just to improve access to safe water and sewage services in Guapi (Ministerio de Ambiente, Vivienda y Desarrollo Territorial, 2005; 2010a; 2010b; INS, 2014).

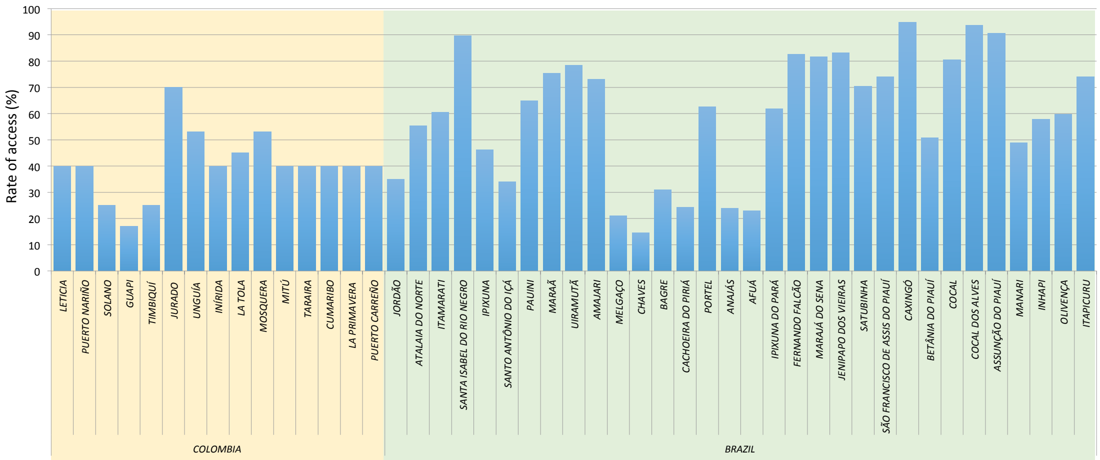


Figure 8: Rate of access to clean water and sewage in selected municipalities of Colombia and Brazil

Access to energy (including electricity) is considered an essential precondition for human development. This nexus is very clear on the macro scale such as the correlation between the HDI or NBI and primary energy consumption per capita. A positive impact of electricity supply on development options might also be derived at the household level, as the access to electricity is in practice indispensable for certain basic activities and cannot easily be replaced by other forms of energy. Therefore, electricity is an additional asset which offers end-users the option of new activities – such as productive activities – that were previously not possible or eases those already existent. Figure 9 shows the rate of access to electricity in the selected municipalities. In Colombia, diesel-based power generators supply selected municipalities. These municipalities are located in remote and isolated areas and are part of the non-interconnected system. They are provided with electricity through inefficient and contaminating diesel-based systems. These systems are permanently followed up through telemetry equipment, which allows monitoring of fuel consumption and power generation on real time basis. Since the electricity system relies on local grids, the service is mostly provided in areas that are close to the power generation plant. As a result, rural and isolated areas are often left without access to electricity due to investments required to extend the local grid. Twelve of the selected Colombian municipalities have rates of access to electricity higher than 70%. Yet, the service is frequently provided during few hours per day. In addition, given the source of power, electricity systems in these municipalities are significantly increasing greenhouse gases emissions and seriously affecting local ecosystems.

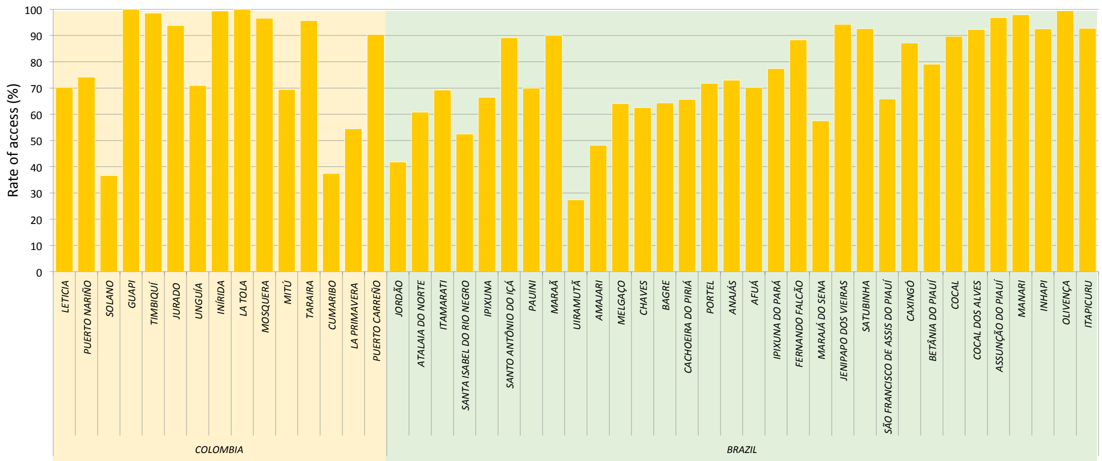


Figure 9: Rate of access to electricity in the selected municipalities of Colombia and Brazil

Assuming the energy ladder from Coelho & Goldemberg (2013)[9] and the rate of access to electricity in selected municipalities of Colombia and Brazil, it is possible to estimate the potential future demand to attend two distinctive phases:

- *First Phase:* basic energy needs (i.e., lighting, cooking, and heating), which would demand about 50 up to 100 kWh per person per year. This demand can be supplied with PV systems and firewood.
- *Second Phase:* productive uses (i.e., water pumping, irrigation, agricultural processes, heating, and cooking), which would demand about 500 up to 1 000 kWh per person per year. In this case, Solar Home Systems (SHS), engines fed with Straight Vegetable Oil (SVO), small-scale biomass-gasifier, and Liquefied Petroleum Gas (LPG) for cooking can supply the demand.

Figure 10 and Figure 11 show the potential increment on the current local energy demand for covering the basic needs of inhabitants without access to electricity while Figure 12 and Figure 13 present the increment on local

[9] A deeper discussion will be included in the Final Report.

demand for supplying new productive activities in the selected municipalities. The potential increment on local electricity demand for covering basic needs is based on the mean values of equations 1 and 2 for each selected municipality.

Equation 1: Low electricity demand estimate equation for covering basic needs of 50 kWh per capita

$$Electricity\ Demand\ (Low) = Number\ of\ inhabitants * Access\ Rate\ (\%) * 50\ kWh$$

Equation 2: High electricity demand estimate equation for covering basic needs of 100 kWh per capita

$$Electricity\ Demand\ (High) = Number\ of\ inhabitants * Access\ Rate\ (\%) * 100\ kWh$$

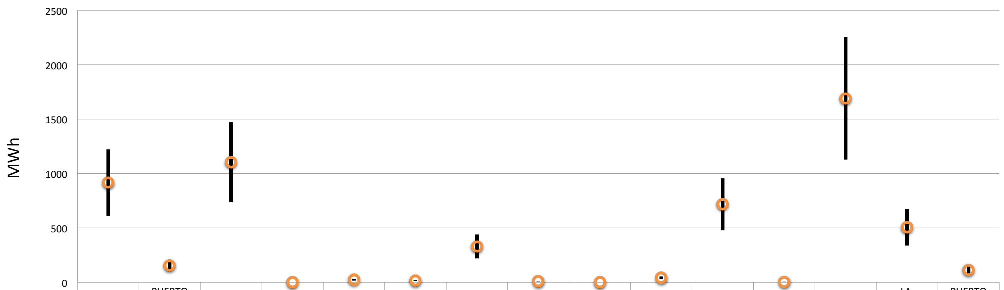
The same rationale is used to estimate the potential increment on local electricity demand for new productive activities, which is based on the mean values of equations 3 and 4 for each selected municipality.

Equation 3: Low electricity demand estimate equation for covering new productive activities of 500 kWh per capita

$$Electricity\ Demand\ (Low) = Number\ of\ inhabitants * 500\ kWh$$

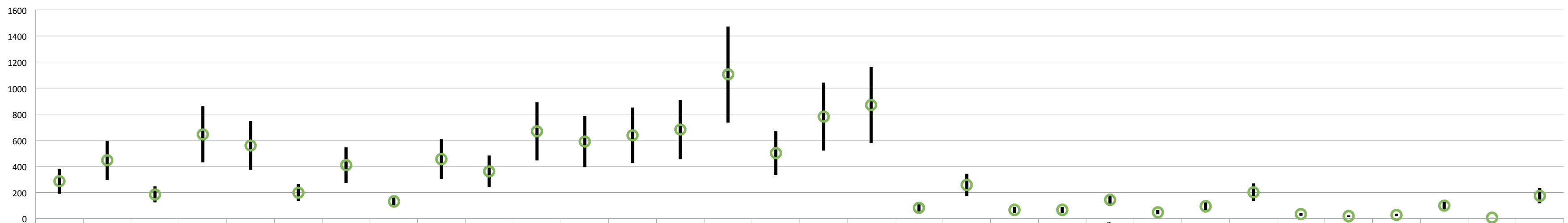
Equation 4: High electricity demand estimate equation for covering new productive activities of 1000 kWh per capita

$$Electricity\ Demand\ (High) = Number\ of\ inhabitants * 1000\ kWh$$



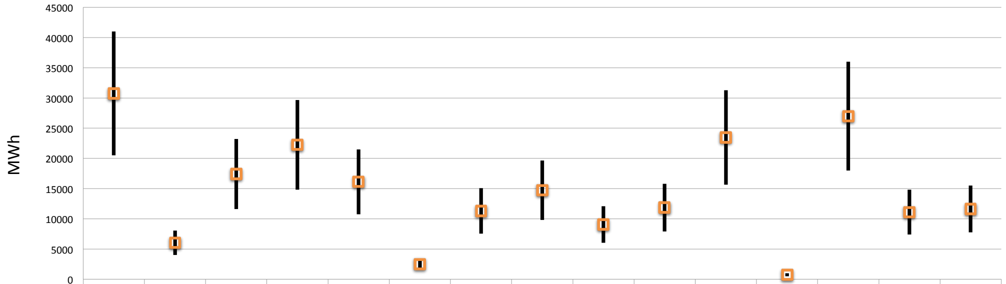
	LETICIA	PUERTO NARIÑO	SOLANO	GUAPI	TIMBIQUÍ	JURADO	UNGUÍA	INÍRIDA	LA TOLA	MOSQUERA	MITÚ	TARAIRA	CUMARIBO	LA PRIMAVERA	PUERTO CARREÑO
High Demand (100 kWh)	1221	208	1471	0	32	21	438	13	0	54	956	4	2254	674	149
Low Demand (50 kWh)	610	104	735	0	16	10	219	6	0	27	478	2	1127	337	75
Average Demand	916	156	1103	0	24	16	329	9	0	40	717	3	1691	506	112

Figure 10: Potential increment on local electricity demand (MWh) for covering basic needs in the selected municipalities in Colombia



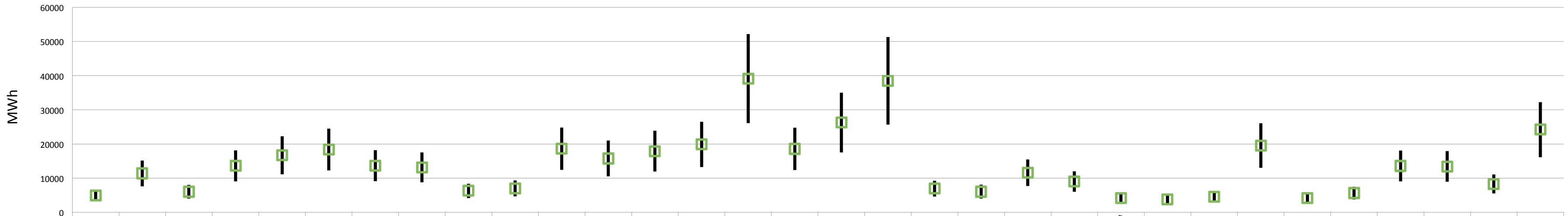
	JORDÃO	ATALAIA DO NORTE	ITAMARATI	SANTA ISABEL DO RIO NEGRO	IPIXUNA	SANTO ANTÔNIO DO IÇÁ	PAUINI	MARAÃ	UIRAMUTÃ	AMAJARI	MELGAÇO	CHAVES	BAGRE	CACHOEIRA DO PIRIÁ	PORTEL
High Demand (100 kWh)	383	593	247	862	747	265	546	174	608	483	892	787	851	909	1472
Low Demand (50 kWh)	191	297	124	431	373	132	273	87	304	242	446	393	425	454	736
Average Demand	287	445	185	646	560	199	409	131	456	362	669	590	638	682	1104

	ANAJÁS	AFUÁ	IPIXUNA DO PARÁ	FERNANDO FALCÃO	MARAJÁ DO SENA	JENIPAPO DOS VIEIRAS	SATUBINHA	SÃO FRANCISCO DE ASSIS DO PIAUÍ	CAXINGÓ	BETÂNIA DO PIAUÍ	COCAL	COCAL DOS ALVES	ASSUNÇÃO DO PIAUÍ	MANARI	INHAPI	OLIVENÇA	ITAPICURU
High Demand (100 kWh)	669	1043	1161	108	342	89	88	190	65	125	269	43	24	37	134	6	233
Low Demand (50 kWh)	335	522	581	54	171	44	44	95	32	63	135	21	12	19	67	3	117
Average Demand	502	782	871	81	257	67	66	143	49	94	202	32	18	28	100	5	175



	LETICIA	PUERTO NARIÑO	SOLANO	GUAPI	TIMBIQUÍ	JURADO	UNGUÍA	INÍRIDA	LA TOLA	MOSQUERA	MITÚ	TARAIRA	CUMARIBO	LA PRIMAVERA	PUERTO CARREÑO
High Demand (1000 kWh)	41000	8043	23210	29641	21490	3353	15077	19641	12073	15801	31265	984	35999	14810	15505
Low Demand (500 kWh)	20500	4022	11605	14821	10745	1677	7539	9821	6037	7901	15633	492	18000	7405	7753
Average Demand	30750	6032	17408	22231	16118	2515	11308	14731	9055	11851	23449	738	26999	11108	11629

Figure 12: Potential increment on local electricity demand (MWh) for supplying new productive activities in the selected municipalities in Colombia



	JORDÃO	ATALAIA DO NORTE	ITAMARATI	SANTA ISABEL DO RIO NEGRO	IPIXUNA	SANTO ANTÔNIO DO IÇÁ	PAUINI	MARAÃ	UIRAMUTÃ	AMAJARI	MELGAÇO	CHAVES	BAGRE	CACHOEIRA DO PIRIÁ	PORTEL	ANAJÁS
High Demand (1000 kWh)	6577	15153	8038	18146	22254	24481	18166	17528	8375	9327	24808	21005	23864	26484	52172	24759
Low Demand (500 kWh)	3288.5	7576.5	4019	9073	11127	12240.5	9083	8764	4187.5	4663.5	12404	10502.5	11932	13242	26086	12379.5
Average Demand	4933	11365	6029	13610	16691	18361	13625	13146	6281	6995	18606	15754	17898	19863	39129	18569

	AFUÁ	IPIXUNA DO PARÁ	FERNANDO FALCÃO	MARAJÁ DO SENA	JENIPAPO DOS VIEIRAS	SATUBINHA	SÃO FRANCISCO DE ASSIS DO PIAUÍ	CAXINGÓ	BETÂNIA DO PIAUÍ	COCAL	COCAL DOS ALVES	ASSUNÇÃO DO PIAUÍ	MANARI	INHAPI	OLIVENÇA	ITAPICURU
High Demand (1000 kWh)	35042	51309	9241	8051	15440	11990	5567	5039	6015	26036	5572	7503	18083	17898	11047	32261
Low Demand (500 kWh)	17521	25654.5	4620.5	4025.5	7720	5995	2783.5	2519.5	3007.5	13018	2786	3751.5	9041.5	8949	5523.5	16130.5
Average Demand	26282	38482	6931	6038	11580	8993	4175	3779	4511	19527	4179	5627	13562	13424	8285	24196

Figure 13: Potential increment on local electricity demand (MWh) for supplying new productive activities in the selected municipalities in Brazil

Comparing the results of applying the energy ladder suggested by C Goldemberg (2013) in Colombia, to the actual demand measu telemetry systems, selected municipalities seem to have covered the needs. The only municipality, in which the real energy demand wa than that shown in Figure 6, was Cumaribo. In this municipali consumption during 2014 was 1401 MWh, 17% below the average c illustrated in Figure 6. It is important to note that there is a time lag b the electricity provision and the improvement in local developme poverty reduction and this might be the case of these municipalities despite electricity services are available, poverty indexes such as NBI very high.

In contrast with local electricity demand for covering basic ne Colombia, demand for supplying productive activities in s municipalities is significantly lower than that suggested by Co Goldemberg (2013). Real demand in selected municipalities (exc Leticia, Puerto Carreño e Inírida) is below the average demand sh Figure 8. For example, municipalities such as Solano, Mosque Cumaribo reached less than 10% of the average demand propo Coelho & Goldemberg. It is widely accepted that electricity access promote the development of productive activities that enhance oppo for the creation of rural enterprises and improving productivity (2014). Yet, selected municipalities are well behind the ideal and, as a restricted productive activities act against local development.

In short, few municipalities do not require energy to cover basics during the first phase of the energy ladder (e.g., Guapi and La Colombia). However, they are still far from solving their inequality pr Therefore, fostering productive activities could enable the necessary economical change.

3. Assessment of available energy sources in Brazil and Colombia

The assessment's objective is to estimate the available biomass residues that could be used for energy production on selected municipalities with lowest HDI located in Brazil and Colombia.

To improve the access to electricity especially in isolated areas, renewable energy technologies have been gaining ground in the last decade. Biomass residues correspond to a renewable, low carbon fuel that is already widely available throughout the isolated areas of Brazil and Colombia. Its production and use also brings additional environmental and social benefits. For example, the development of bioenergy has the potential for engaging women in raising nurseries and collection of seeds, which could lead to their enhanced participation in the village economy.

Other benefits are job creation, provision of modern energy services to rural communities in developing countries, reducing levels of CO_2 emissions, waste management, and nutrient recycling, among others. In poorer regions, such as municipalities analyzed in this study, the production of sustainable biomass can contribute to the social development of the region to generate income for the local population, as well as encourage increased quality of life provided by access to energy.

Correctly managed, biomass (and biomass residues) is a sustainable fuel that can deliver a significant reduction in net carbon emissions when compared with fossil fuels. The most common source in the selected municipalities is agricultural residues, which can be divided into crop residues (e.g., husks, straw, peel, etc.) and animal residues (e.g., manure). Figure 14 presents the share of crop residues volumes in tonnes for selected municipalities in Colombia and Brazil. Figure 15 presents the share of animal residues.

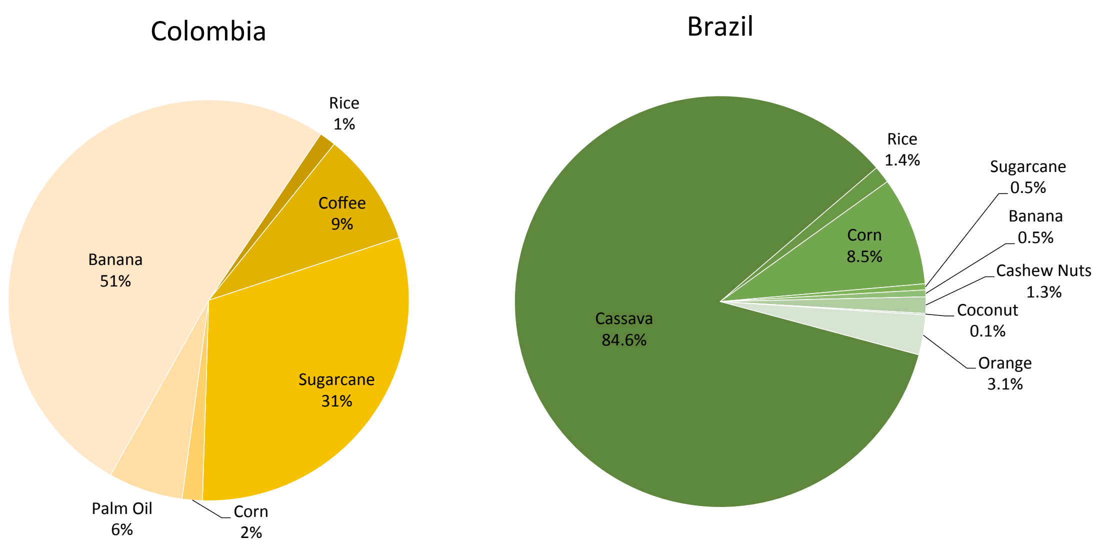


Figure 14: Share of crop residues amount for the selected municipalities of Colombia and Brazil

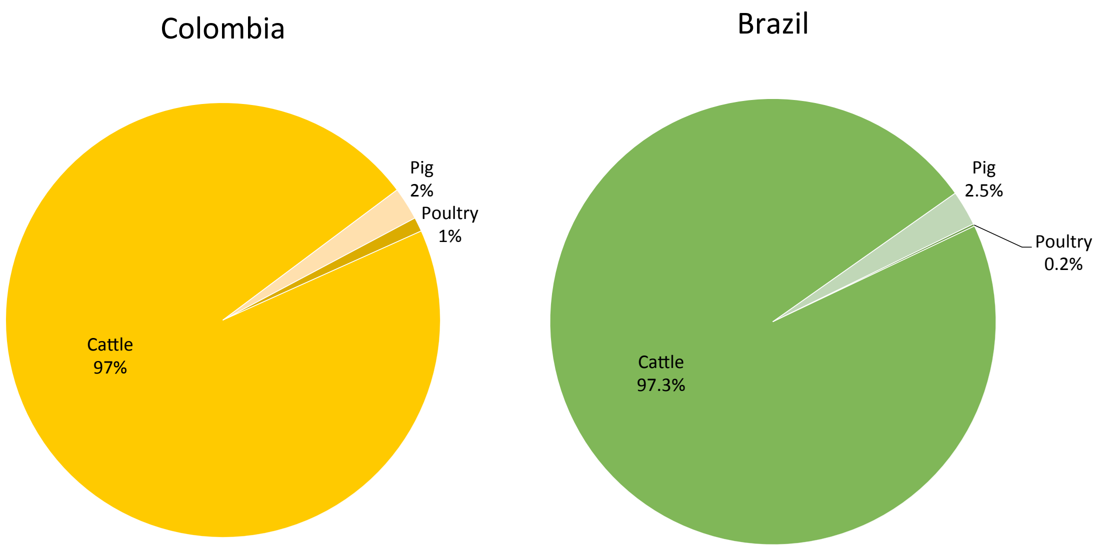


Figure 15: Share of animal residues amount for the selected municipalities of Colombia and Brazil

Urban Solid and Liquid (sewage) Waste is also an important bioenergy source alongside wood residues, which are discussed in the following sections the methodological approach for defining the theoretical energy potential.

3.1. Methodological approach for energy potential estimative in the Brazilian context

I. Animal Residues

The treatment of animal residues becomes a necessity due to the high content of organic matter present there and the large amount generated by the activity. If these residues do not have the proper treatment, the risks to the environment are significant, causing pollution and eutrophication of water bodies, among others.

One of the solutions to solve the problem of animal waste is the anaerobic digestion process in which, from the anaerobic degradation, occurs with the formation of biogas mainly composed of methane (CH_4) and carbon dioxide (CO_2).

The use of biogas thus produced for both electric and thermal energy generation in the villages enables the economic feasibility of the process. In addition to strengthening the distributed generation due to local or regional use and ensuring reduction in the costs of electricity and / or heat production, this use also provides the reduction and / or substitution of traditional biomass and (imported) LPG, in this case contributing to reduce import expenditures and contributing to a cleaner and renewable energy matrix, in addition to providing access to energy[10].

For the animal residue estimates, data on animal creations in the cities studied in the project were obtained in IBGE - Municipal Livestock Survey based on years 2011, 2012 and 2013 to establish the average value of these data. However, for aquaculture, only the year 2013 was used, since statistics have started only from this year.

Table 2 shows the estimation parameters that guided the dimensional analysis in order to design equations for each animal residue estimates.

Table 2: Estimation parameters for animal residues

Origin	Waste generated quantity in kg/day*unit
Cattle	20
Cattle Dairy	45
Swine	2,25
Poultry	0,18 +1,27 MS/head
Posture Poultry	0,12
Aquiculture	0,67

Source: Adapted from Motta, 1986, Manso, 2007 [a], Pohlmann, 2000 [b], SANTOS, 2001 [c], El Boushy, 1994 [d], Rodrigues, 2013 [e].

Cattle

Residues from cattle are manure; being used in this study 20 kg of manure per day. Calculation of residues generation is provided by the following equation (Motta, 1986; Manso, 2007):

Equation 5: Cattle residue estimate equation

$$\left(\frac{t}{year}\right) = \frac{n^{\underline{o}}\ UA * 365\ {}^{day}/_{year} * 20\ {}^{kg\ in\ manure}/_{day * UA} \ * 1\ t}{1000\ kg}$$

Dairy Cattle

According to the various authors studied, the amount of residues produced by a milk cow is between 35 and 55 kg per day. For this study will be used an average of 45 kg per day. Calculation of waste generation is given by the following equation (Pohlmann, 2000):

[10] These other uses from biogas are well known and include use in vehicles and injected in pipelines but this option is not feasible in the villages and it was not considered. Also the use of biogas for cooking, as used in many other countries, was not analyzed since in Brazil there is the LPG network and special programs to distribute. In fact this option is now not so accomplished due to changes in the existing programs, as discussed in Coelho et al, 2014, but this can be solved soon. Then this option was not considered in this study, since it is not a need.

Equation 6: Dairy cattle residue estimate equation

$$\left(\frac{t}{year}\right) = \frac{nº\ UA * 365\ {}^{day}/_{year} * 45\ {}^{kg\ in\ waste}/_{day * UA} * 1\ t}{1000\ kg}$$

Swine

Residues from the swine production are the average of the different stages of creation, being used in this study 2.25 kg of manure per day. Calculation of waste generation is given by the following equation (Motta, 1986; Manso, 2007):

Equation 7: Swine residue estimate equation

$$\left(\frac{t}{year}\right) = \frac{nº\ UA * 365\ {}^{day}/_{year} * 2.25\ {}^{kg\ in\ manure}/_{day * UA} * 1\ t}{1000\ kg}$$

Poultry

In the case of residues from the creation of broilers hens are made the excreta of birds, feathers, food scraps and aviary floor material contains the absorbent material used as bed, coming hence the term "poultry litter", usually used for waste broilers. Calculation of residues generation is given by the following equation (Santos, 2000):

Equation 8: Poultry residue estimate equation

$$\left(\frac{t}{year}\right) = \frac{nº\ UA * ((0.18\ {}^{kg\ in\ manure}/_{day * UA} * 365\ {}^{days}/_{year} + 1.37\ {}^{MS}/_{UA}) * 1\ t}{1000\ kg}$$

Posture Poultry

The residues generated by the creation of laying hens are made the excreta of birds, feathers, food scraps and aviary floor material. Calculation of waste generation is given by the following equation (El Boushy, *1994)*:

Equation 9: Posture poultry residue estimate equation

$$\left(\frac{t}{year}\right) = \frac{nº\ UA * 365\ {}^{day}/_{year} * 0.12\ {}^{kg\ in\ manure}/_{day * UA} * 1\ t}{1000\ kg}$$

Aquiculture

The data relating to the generation of wastes varies mainly according to the species, since this directly influences the performance characteristics of the fish. According to the data obtained from the questionnaire research, the yield of Brazilian Croaker (*Pachyurus adspersus*), Taínha (*Mugil brasiliensis*) and Jundiá (*Rhamdia quelen* and *R. sapo*) is 3/1, that is, for every 3 kg of raw fish is obtained 1 kg of product, the remainder is considered residue. Brazilian Flounder (*Paralichthys brasiliensis*), Traíra (*Hoplias sp.*) and the shrimp have a yield of 2/1 and 4/1 Catfish (fishes from the order *Siluriformes*), generating an even greater amount of fish waste (Rodrigues, 2013). Therefore, for purposes of this study will be used the ratio 3: 1, which is produced every tonne, 0.67 tonnes becomes waste. Calculation of waste generation (Rodrigues, 2013) is as follow:

Equation 10: Aquiculture residue estimate equation

$$\left(\frac{t}{year}\right) = nº\ UA * 0.61$$

II. Agricultural Residues

Many permanent and temporary crops are cultivated in the selected municipalities. The Table 3 shows the crops with registered production:

Table 3: Crops cultivated in the selected municipalities

Crop	
Permanent	**Temporary**
Annatto	Bean
Avocado	Cassava
Banana	Castor Beans
Black Pepper	Corn (maize)
Cashew Nut	Peanut
Cocoa	Pineapple
Coconut	Rice
Guava	Sugar Cane
Lemon	Sweet Potatoes
Mango	Tomato
Orange	Upland Cotton
Palm	Watermelon
Papaya	
Passion Fruit	
Rubber	
Tangerine	

Source: IBGE 2011, 2012, 2013

For most crops, the municipal production is lower than 1,000 tonnes per year. The Table 4 shows the main harvests in the target areas.

Table 4: Main crops in the selected municipalities

Crop	
Permanent	**Temporary**
Banana	Corn (maize)
Coconut	Rice
Cashew Nut	Sugar Cane
Orange	Cassava

Source: IBGE 2011, 2012, 2013

The objective of this section is to estimate the available agricultural and agro-industrial residues for energy production, on the municipalities with lowest HDI located in the North and Northeast regions of Brazil.

In order to know the agricultural production in the selected municipalities, figures were obtained from the Brazilian Institute of Geography and Statistics (IBGE) database of Municipal Agricultural Production for 2011, 2012 and 2013[11] (IBGE, 2015). IBGE obtained such information applying questionnaires in each municipality of the country.

The amount of agricultural and process residues is estimated applying specific mass ratios for each crop. These ratios was be found in bibliography and are presented below

Temporary Crops

Corn or maize (Zea mays subsp. mays)

Agriculture residue: Corn stover

The mass ratio between corn stover and corn production is approximately 1:1 (Kim & Dale, 2004). This study assumed that 60% of the corn stover could be collected without affect soil fertility (Sheehan, Aden , Riley, Paustian, & Brenner, 2002).

Process residue: Cob and Straw

Approximately, 1,000 kg of maize grains correspond to 1,429 kg of corn on the cob (FGV, 1991), which would give the cob and straw a 42.9% relative to the weight of the grains. This figure will be adopted as a coefficient regarding the weight of the grains.

Rice (Oryza sp)

Process residue: Rice husks

During the milling processes, husks are removed from the raw grain to reveal whole brown rice, which may then sometimes be milled further to remove the bran layer, resulting in white rice. Rice husks are between 18% (Bose &

[11] In this study was used arithmetic average production for 2011, 2012 and 2013.

Martins Filho, 1984) and 22% of the raw grain weight (Fonseca, Soave, Azzini, Banzatt, & Camargo, 1983.). Preliminarily, 20% of raw grain as available residue is adopted in this study. This may not happen in the villages considering the low level of development and it was not considered as an option.

Sugarcane (Saccharum officinarum)

Agriculture residue: Straw

In potential assessments, it is normally accepted a range of 14%–18% of the straw to stalk ratio (Leal & Galdos, 2013). In the target municipalities, sugar cane harvest is manual, so burning the straw is necessary for stalk collection. If harvest were mechanized, straw could be used as biomass source. In order to know this biomass potential, 16% is assumed as straw to stalk production ratio, and 50% of straw mass collection for soil protection. Therefore, these residues were not considered since they are burned.

Process residue: Bagasse

In Brazil were produced on average 277 kg of bagasse per tonnes of cane (CONAB, 2011), with a humidity of 50% (Lenço, 2010), on a wet basis and part of it is already in use in bagasse boilers to produce energy for process needs.

Cassava (Manihot esculenta)

Agriculture residue: Aerial parts

The aerial part of yield is estimated at 144% to 257.1% on the weight of the root% (Bose & Martins Filho, 1984). After root harvest, the plant can be used as animal feed. Forage is obtained from the leaves and shredded branches, chopped and mixed with wet pulp and starch lumps from the flour production, being homogenized, dried and pressed.

Process residue: Wastewater

Cassava flour is an important economic product of traditional and rural low technology agro-industry in the North and Northeast regions of Brazil. Wastes generated in the flour production are, proportionally to the weight of fresh roots processed, 18% of hulls, 30% of “manipueira” (cassava wastewater) and 24% of “crueira” (clusters) and losses through evaporation (Bose & Martins Filho, 1984). The solid residue is normally used as animal feed and cassava wastewater is discharged uncontrolled on soil and water bodies. This residue is carbohydrate-rich, with high chemical oxygen demand (COD), biochemical oxygen demand (BOD), and total solids.

Permanent Crops

Banana (Musa sp)

Agriculture residue: Aerial parts

After harvesting the fruit and bunches are transported to storage locations and other plant parts remain in the field. After harvest, the plant dies closing the vegetative cycle. This agricultural waste is used as ground cover to keep moisture, avoid erosion, control weeds and return nutrients to the soil reducing fertilization cost.

Process residue: Stem

The stem is usually discarded during bunches separation process at packinghouses, where is made the selection, cleaning and fruit classification. This residue is rapidly decomposed due to its high moisture, about 93% (Blanco Rojas, 1996). In this study, it is used as average for the weight of the stem 8% of bunch weight (Kluge & Scapare Filho, 1999).

Process residue: Peel

The amount of peel produced in a banana-based manufacturing facility is high due to this residue represent 33% of the total mass of bunches (Ministério do Interior, 1980). The peel has only 10% of dry matter and low heating value. These residues were not considered since there is no industrial processing industry in the villages considered.

Coconut (Cocos nucifera)

Process residue: husk and shell

In order to estimate the residues production potential from coconut is used the column "% Weight" of Table 5.

Table 5: Components of an Average Coconut

Components of an Average Coconut			
Component	**kg**	**% Weight**	**PCI (Kcal/kg)**
Meat	0.36	30	
Shell	0.18	15	5500
Husk	0.40	33.3	4000
Coco water	0.26	21.7	
TOTAL	1.2	100	

Source: (Banzon, 1980).

Cashew Nut (Anacardium Occidentale)

Process residue: Cashew Apple bagasse

Cashew apple fruit includes two parts: true and false fruit. The true fruit is surrounded by shell and nut; false fruit is developed from pedicel. False fruit contains 90% whole fruit weight (Nam, 2014). The industrial peduncle processes for juice production results in 40% (w/w) of bagasse, which represents no commercial value and is usually discarded (Rodrigues, Rocha , & Macedo, 2011).

Process residue: Shell

The cashew shell waste generated in small-scale cashew processing industries is 67.5% of total weight of cashew seed. The average higher heating value of the cashew nut shell was found to be 4890kcal/kg (Mohod, Jain, & Powar, 2011).

Orange (Citrus sinensis)

Process residue: Juice residue

Bark, seeds and fibers are 50% of orange weight (Amaro, 1974). It is important to mention that there are not yet processing industries in the region but this residue was considered since there are perspectives of industries to be installed in the referred municipality.

It is important to mention that, in this study, the amounts of agricultural waste available for energy production correspond to a theoretic potential (see Section 5). This potential is calculated assuming that all agricultural production is processed inside the municipal boundaries.

For example, when conducting the estimative for cassava, the analyses assumed that 100% of root yield is used for flour production, entailing wastewater as output. This assumption should not be far from reality because cassava root “*in natura*” is toxic and should be processed for human and animal consumption.

In the case of rice, it was assumed that 100% of brown grain is benefited in the municipality and its residue has accumulation points enabling its use.

For corn (maize) residue, the potential calculation is considered that grain separation from cob and straw is made centralized, but actually, much of this waste appears in the MSW because the locals bring whole cobs at home. There is no data about corn processing in the target municipalities.

In the case of banana, as happens with corn, much production will be taken at home without processing and, consequently, residues (peel and bunch) became part of MSW. Hence, the theoretic potential considers that whole production is processed centrally because there is no data of banana processing. For cashew nut and coconut were made the same considerations.

Only Itapicuru Municipality has significant potential for orange juice production because its agricultural potential has attracted private investors in 2014, so probably the residues will be available soon.

V. Wood residues

Estimates of wood residues generated annually in Brazil is 30 million tonnes; the main source of residues is the timber industry, which contributes to 91% of wood waste generated, following the waste wood from construction (3 %) and urban areas (8%) (SAE, 2011; MMA, 2009). In general, they come from industrial processing and urban areas. Table 6 shows the total amount of wood residue generated annually in Brazil.

Table 6: Estimated of Wood Residues in Brazil

Segment	Wood Residues 10^3 tonne/year	%
Timber Industry	27.750	90,7
Civil Constructions	923	3,0
Urban Areas	1.930	6,3

Source: Elaborated by authors

The major sources of these resources are the following:

- Forest-based industries: the source of residues wood processing. In this class are framed sawmills, veneer mills, panels, etc.;
- Industry reforestation: source of waste generated in the forest harvesting.
- Exploration of Native Forests: Source of residues generated by logging from forestry management.

Only a portion of the volume of waste generated has some economic exploitation, social or environmental. The majority of wood waste generated in the Amazon region, for example, is abandoned or burned without energy purposes (STCP, 2011).

However there is a large wooden residual potential from the sustainable management of forests in Brazilian Amazon, according to (Silva, 2007); (Numazwa, 2009), 1 m3 of wood removed for processing in the Amazon generates up to 8 m3 of waste (including extraction process and sawmill) Big companies of the timber industry in the Amazon, take advantage of this potential for extensive production of charcoal. This surplus can be used to increase access to energy in communities with low HDI. Table 7 shows the availability of wood residues from native or planted forests.

Table 7: Forest operations and waste generation (% of roundwood)

Operation (%)	Natural Forest		Planted Forest	
	Product	Residue	Product	Residue
Lumber	30-40	60-70	80-90	10-20
Primary and secondary processing	10-20	10-20	30-40	40-50
Total	**10-20**	**80-90**	**30-40**	**60-70**

Note: Part of these residues are used for different purposes (MMA, 2009)

Source: Adapted from (FAO, 2007)

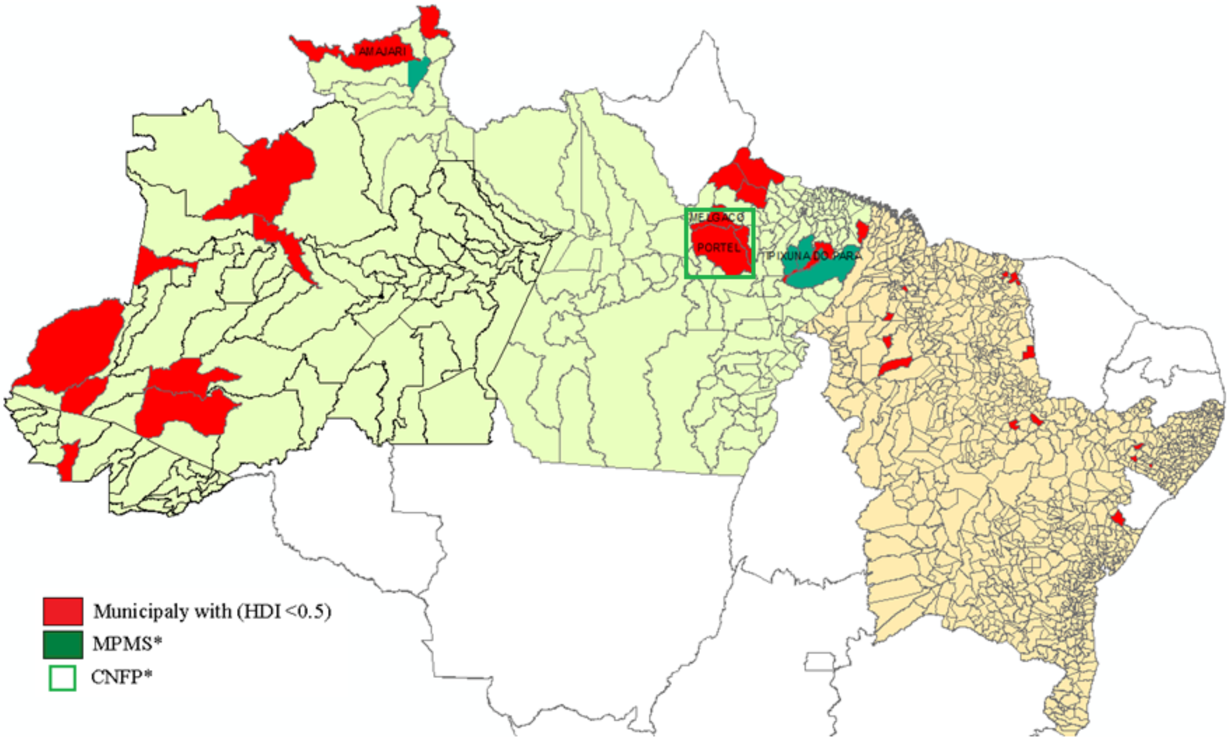
Table 7 demonstrates the residual potential of natural forest management (Amazon rainforest) reaching 70% available residues. Unlike planted forest having 10 to 20%, which is the field to reduce the cost of fertilization and soil nutrition.

To determine the volume of roundwood, it was consulted the Brazilian Institute of Geography and Statistics (IBGE) database of Municipal Agricultural Production for 2011, 2012 and 2013.

The amount of wood residues is estimated by processing index in sawmills and applying specific mass ratios as a function of the theoretical characteristics of medium density for the types of wood from the Amazon region, characteristic of the species found in the evaluated municipalities.

The ratio of the mass density used is 0.7 tonnes/m^3 (Lorenzi, 1992), and the yield of sawmills in the use is 30%, assuming that the remaining 70% are waste (Table 7).

To obtain greater accuracy in the results, we assessed and quantified the residual potential per year of areas (HFFS) National Forests Public Concessions granted to forest management in the Amazon and was also inserted the (MPMS) Central Area of Sawnwooden in Brazilian Amazon (Brazil, 2014). Figure 16 illustrates the main CNMP and MPMS near the municipalities.



MPMS* *Central Area of Sawnwooden in Brazilian Amazon*

CNFP* *National Concession of Public Forests*

Figure 16: Mains the CNMP and MPMS potential to generate wood residues in the municipalities of (HDI <0.5) in Brazil

Source: Elaborated by author (Brazil, 2014; IBGE, 2015)

In the previous figure we observe that the municipality of Portel and Melgaço in (Pará State) is located on the Caxiuanã National Forest (Brazil, 2014). This CNFP was laid to concession by the Federal Government in 2015, and has the potential to produce an average of 565,783 million tonnes of wood residues per year from sustainable forest management. We can also observe that the municipalities of Amajari in Roraima State and Paragominas and Tucuruí in Pará State, are near the MPMS, characteristic that increases the access to the wood residues.

VI. Municipal Solid Waste

The Northern region has an estimated production of about 15,169 tonnes/day of Municipal Solid Waste (MSW) but only 80.3% are collected. More than 60% of this generated waste has not an appropriate treatment yet and it has an inadequate destination in dumpsites. The invested amount per month to carry out cleaning services and collection services are around $ 2.68 per capita. The number of jobs in the urban sanitation sector in the municipalities of the northern region in 2013 was 23,399 jobs (ABRELPE, 2013).

In the Northeast region, it was generated in 2012 an amount of 53,465 tonnes/day of MSW from which 78.2% were collected and around 65% of this waste is still destined for dumps. The invested amount per month to carry out cleaning services and collection services are in order of $ 2.70 per capita (ABRELPE, 2013).

The Table 8 shows the MSW management data in the North and Northeast Regions.

Table 8: Characteristics of MSW management in the North and Northeast Regions

Region	USW collect per capita (Kg/inh./day)	Percentage separate collection	USW Disposal (%)	Financial to MSW collection (R $ million / year)
North	0.716	49.5	Landfill: 35,3% Dump (other form): 29,9% Dump: 34,8%	636
Northeast	0.750	40.4	Landfill: 35,2% Dump (other form): 33% Dump: 31,8%	1,864

Source: Research ABRELPE e IBGE.

According to the Ministry of Cities in Brazil, the municipalities of Melgaço, Satubinha, Assunção do Piauí and Inhapi dispose their waste in the following dumpsites (Melgaço Dumpsite, Satubinha Dumpsite and Municipal Dumpsite of Assunção do Piauí). Other municipalities did not inform about their waste destination. The lack of information on the waste management of these municipalities also shows the precariousness of the system, as well as the disposal of waste. However, this represents an interesting possibility to generate income and energy from waste.

It is important to mention that the research team has conducted telephone contact with all local governments in the selected municipalities so as to better understand the local reality of waste disposal. In 100% of the respondents have informed that waste is disposed in dumpsites. Only the municipality of Chaves mentioned that there is an initiative of recycling but it still not significant. Few municipalities did not answer the question. However, it possible to assume that waste disposal follows the same patterns.

VII. Brazilian estimate

The Brazilian estimate for most of the selected municipalities used conservative figures, which may make the values more robust. However, two municipalities – Portel and Melgaço – have presented the highest potential because they are located within the borders of national forests. Therefore, presenting the highest biomass resource availability. Note, that all figures presented are based on bibliographic review and not on field assessment. Hence, they should be validated through data collection *in situ*.

Based on the methodology presented above, the amount of waste was estimated and is presented in the tables ahead.

Animal residue estimate

Table 9: Animal residue estimative per selected municipality

Municipality	Federal Unit	Waste generated quantity (t/year)					
		Cattle Beef	Cattle milk	Swine	Poultry	Posture Poultry	Aquiculture
JORDÃO	AC	45,493.60	6,783.53	1,589.12	861.25	219	12
ATALAIA DO NORTE	AM	1073.10	180.68	688.48	1,274.33	569	47
ITAMARATI	AM	15,115.87	2,934.60	944.71	80.48	21	12
SANTA ISABEL DO RIO NEGRO	AM	2,469.83	492.75	290.45	212.16	116	13
IPIXUNA	AM	104,222.10	20,805.00	5,584.50	695.96	44	24
SANTO ANTÔNIO DO IÇÁ	AM	10,643.40	4,270.50	350.40	312.99	270	5
PAUINI	AM	80,786.67	16,096.50	568.03	831.67	336	10
MARAÃ	AM	5,742.67	0.00	103.48	1,436.42	610	0
UIRAMUTÃ	RR	128,061.47	6,088.20	519.03	452.25	98	2
AMAJARI	RR	568,655.40	39,315.98	2,067.09	461.08	162	2,596
MELGAÇO	PA	12,239.67	1,620.60	3,482.10	83.39	20	0
CHAVES	PA	666,300.20	86,778.75	20,202.75	204.16	66	0
BAGRE	PA	12,767.70	1,604.18	5,220.14	45.12	21	0
CACHOEIRA DO PIRIÁ	PA	312,659.00	4,232.18	1,531.91	1,340.53	219	0
PORTEL	PA	77,805.83	12,192.83	5,484.31	232.11	69	0
ANAJÁS	PA	6,716.00	3,701.10	6747.39	231.59	110	0
AFUÁ	PA	25,949.07	4,954.88	34,930.50	822.73	187	0
IPIXUNA DO PARÁ	PA	731,980.73	133,343.63	2,349.87	1,285.64	536	0
FERNANDO FALCÃO	MA	99,073.17	22,984.05	4,214.93	2,053.62	275	0
MARAJÁ DO SENA	MA	20,0857.07	15,330.00	7,344.71	2,172.84	500	32
JENIPAPO DOS VIEIRAS	MA	42,1429.00	97,679.48	5,367.69	1,508.58	399	0
SATUBINHA	MA	141950.93	15740.63	1092.26	993.57	362	0
SÃO FRANCISCO DE ASSIS DO PIAUÍ	PI	57139.53	8683.35	2647.71	642.15	215	0
CAXINGÓ	PI	40,563.67	8,048.25	1,866.15	826.93	236	0
BETÂNIA DO PIAUÍ	PI	58,348.90	1,3161.90	1,948.83	678.14	297	0
COCAL	PI	58,511.93	18,532.88	5,139.38	4,025.56	1,571	0
COCAL DOS ALVES	PI	11,774.90	3,055.05	4,881.51	1,455.42	402	9
ASSUNÇÃO DO PIAUÍ	PI	47,948.83	10,353.23	2,805.12	920.29	324	0
MANARI	PE	96,603.33	4,4347.50	1,710.94	1,873.49	642	0
INHAPI	AL	152,292.60	52,505.25	1,843.43	1,881.54	428	12
OLIVENÇA	AL	84,256.60	41,730.45	760.20	571.68	96	0
ITAPICURU	BA	159,042.67	36,802.95	1,130.59	2,367.46	1,149	0

Agricultural residue estimate

Table 10: Agricultural residue estimative based on temporary crops per selected municipality

TEMPORARY CROP		Cassava			Rice		Corn			Sugarcane		
Municipality		Root (t)	Aerial parts (t)	Wastewater *Manipueira* (m^3)	Raw grain (t)	Hulls (t)	Grain (t)	Corn stover (t)	Cob +straw (t)	Stalk (t)	Straw (t)	Bagasse (t)
1	Afuá - PA	878	1,757	264								
2	Amajari - RR	2,154	4,307	646	13,651	2,73						
3	Anajás - PA	1,667	3,333	500								
4	Assunção do Piauí - PI	392	783	118								
5	Atalaia do Norte - AM	3,237	6,475	971						1,233	98	370
6	Bagre - PA	1,167	2,333	350								
7	Betânia do Piauí - PI	191	2,383	357								
8	Cachoeira do Piriá - PA	2,8167	56,333	8,45								
9	Caxingó - PI	1,825	3,651	548	2,336	467						
10	Chaves - PA	683	1,366	205								
11	Cocal - PI	23,399	46,797	7,02			1,794	1,076	879			
12	Cocal dos Alves - PI	5,451	10,903	1,635								
13	Fernando Falcão MA	7,733	15,467	2,32	1,863	373	1,199	719	587	1,708	136	513
14	Inhapi - AL	917	1,833	275					0			
15	Ipixuna - AM	1,075	2,149	322					0			
16	Ipixuna do Pará - PA	217,3	434,6	65,19	4,5	900	19,487	11,692	9,548	1164	93	349
17	Itamarati - AM	2,764	5,528	829								
18	Itapicuru - BA	19,367	38,733	5810								
19	Jenipapo dos Vieiras - MA	2,032	4,064	610	4,244	849	1,183	709	579			
20	Jordão - AC	11,1	22,2	3,33								
21	Manari - PE	2	4	600			1,567	940	767			
22	Maraã - AM	2,848	5,696	854								
23	Marajá do Sena - MA	3,427	6,853	1,028	6,572	1,314	3,19	191	156			
24	Melgaço - PA	1,833	3,667	550								
25	Olivença - AL	123	247	37								
26	Pauini - AM	7,44	14,88	2,232								
27	Portel - PA	34	68	10,2								
28	Santa Isabel do Rio Negro - AM	4,642	9,284	1,393								
29	Santo Antônio do Içá - AM	5,58	11,16	1,674								
30	São Francisco de Assis do Piauí - PI	408	816	122								
31	Satubinha - MA	2,336	4,672	701	1,311	262						
32	Uiramutã - RR	1,477	2,955	443								

Table 11: Agricultural residue estimative based on permanent crops per selected municipality

PERMANENT CROP		Banana			Cashew nut			Coconut			Orange	
Municipality		Fruit (t)	Process Stem (t)	Process Peel (t)	Nut (t)	Process Bagasse (t)	Process Shell (t)	Nut (t)	Process Husk (t)	Process Shell (t)	Fruit (t)	Process Juice residue (t)
1	Afuá - PA	482	39	159								
2	Amajari - RR	1,083	87	357							129	65
3	Anajás - PA	467	37	154								
4	Assunção do Piauí - PI				17	103	11					
5	Atalaia do Norte - AM	231	18	76				5	2	1	75	38
6	Bagre - PA											
7	Betânia do Piauí – PI											
8	Cachoeira do Piriá - PA	10,24	819	3,379	8	48	5	94	31	14	35	18
9	Caxingó - PI		0	0	12	72	8					
10	Chaves - PA	720	58	238								
11	Cocal - PI	80	6	26	869	5,24	587	36	12	5	50	25
12	Cocal dos Alves - PI				739	4,456	499					
13	Fernando Falcão MA	101	8	33	8	48	5	11	4	2	95	47
14	Inhapi - AL											
15	Ipixuna - AM	168	13	55				2	1		10	5
16	Ipixuna do Pará - PA		0	0	1195	7	1	57	19	9	220	110
17	Itamarati - AM	187	15	62		0	0	5	2	1	48	24
18	Itapicuru - BA	113	9	37	113	681	76	433	143	65	193,5	97
19	Jenipapo dos Vieiras - MA	429	34	142	113	681	76	8	3	1	26	13
20	Jordão - AC	760	61	251							56	28
21	Manari - PE											
22	Maraã - AM	186	15	61				4	1	1		
23	Marajá do Sena - MA		0	0								
24	Melgaço - PA	67	5	22								
25	Olivença - AL		0	0	44	265	30					
26	Pauini - AM	1,448	116	478				6	2	1	71	36
27	Portel - PA	567	45	187								
28	Santa Isabel do Rio Negro - AM	203	16	67				8	3	1	133	67
29	Santo Antônio do Içá - AM										39	19
30	São Francisco de Assis do Piauí - PI	836	67	276								
31	Satubinha - MA		0	0								
32	Uiramutã - RR	127	10	42							56	28

Wood residue estimate

Table 12: Potential wood residue per year in municipalities with HDI <0.5

Municipaly	Natural Forest sawmill residues (t)	Planted Forest forest harvesting residues (t)	CNFP* logging residues (t)	MPMS* wood center sawmill residues (t)	Residual wooden potential (t)
1 Afuá - PA	19.553				19.553
2 Amajari - RR	784			30.708	31.492
3 Anajás - PA	39.200				39.200
4 Assunção do Piauí - PI					
5 Atalaia do Norte - AM	5.390				5.390
6 Bagre - PA	8.820				8.820
7 Betânia do Piauí - PI	433				433
8 Cachoeira do Piriá - PA	2.553				2.553
9 Caxingó - PI					
10 Chaves - PA	761				761
11 Cocal - PI	1.025				1.025
12 Cocal dos Alves - PI					
13 Fernando Falcão - MA	47				47
14 Inhapi - AL	126				126
15 Ipixuna - AM	441			106.132	106.573
16 Ipixuna do Pará - PA	66.325				66.325
17 Itamarati - AM	784				784
18 Itapicuru - BA					
19 Jenipapo dos Vieiras - MA	29				29
20 Jordão - AC	622				622
21 Manari - PE					
22 Maraã - AM	934				934
23 Marajá do Sena - MA	676				676
24 Melgaço - PA	9.800		565.783		575.583
25 Olivença - AL	8				8
26 Pauini - AM	479				479
27 Portel - PA	490.000		565.783		1.055.783
28 Santa Isabel do Rio Negro - AM					
29 Santo Antônio do Içá - AM	1.933				1.933
30 São Francisco de Assis do Piauí - PI	5				5
31 Satubinha - MA					
32 Uiramutã - RR					

MPMS* *Central Area of Sawnwooden in Brazilian Amazon*

CNFP* *National Concession of Public Forests*

Municipal Solid Waste and sewage estimate

Table 13: Biomass estimative based on Municipal Solid Waste and sewage per selected municipality

F.U.	Municipality	Total Pop 2011	Total Pop 2012	Total Pop 2013	MSW Production Factor	Avarage MSW produced	Avarage MSW Collected	Average MSW collected from 2010 to 2013	Organic fraction present in the MSW	Organic matter collected	Avarage sewage produced	Sewage not collected	Sewage Collected	Average sewage collected from 2010 to 2013
					kg/inha./day	t/year	%	t/year	60%	t/ano	t/year	%	%	t/year
AC	JORDÃO	6 740	6 898	7 147	0,75	1897	99,29	1883	0,6	1130	379326	65	35	132916
AM	ATALAIA DO NORTE	15 545	15 924	17 174	1,07	6333	50,61	3205	0,6	1923	887735	45	55	491983
AM	ITAMARATI	8 010	7 983	8 232	1,07	3154	52,80	1665	0,6	999	442106	39	61	267563
AM	SANTA ISABEL DO RIO NEGRO	18 729	19 292	20 986	1,07	7682	94,26	7241	0,6	4344	1076878	10	90	965098
AM	IPIXUNA	22 867	23 460	25 362	1,07	9333	74,46	6949	0,6	4169	1308324	54	46	605754
AM	SANTO ANTÔNIO DO IÇÁ	24 689	24 890	24 327	1,07	9621	65,57	6309	0,6	3785	1348785	66	34	460070
AM	PAUINI	18 249	18 329	19 149	1,07	7255	49,27	3574	0,6	2145	1017018	35	65	660248
AM	MARAÃ	17 563	17 596	18 310	1,07	6961	83,79	5832	0,6	3499	975809	25	75	734784
RR	UIRAMUTÃ	8 573	8 764	9 127	0,78	2511	53,15	1335	0,6	801	482968	22	78	378550
RR	AMAJARI	9 637	9 936	10 432	0,78	2847	100,00	2847	0,6	1708	547591	27	73	399961
PA	MELGAÇO	25 096	25 374	25 860	0,82	7615	83,13	6331	0,6	3798	1393023	79	21	293510
PA	CHAVES	21 286	21 557	22 029	0,82	6472	77,52	5017	0,6	3010	1183914	85	15	173325
PA	BAGRE	24 644	25 398	26 666	0,82	7653	82,39	6305	0,6	3783	1399921	69	31	433416
PA	CACHOEIRA DO PIRIÁ	27 332	28 153	29 533	0,82	8482	77,52	6575	0,6	3945	1551579	76	24	375792
PA	PORTEL	53 257	54 306	56 094	0,82	16328	88,79	14497	0,6	8698	2986740	37	63	1868206
PA	ANAJÁS	25 254	25 731	26 547	0,82	7735	89,43	6918	0,6	4151	1414959	76	24	339166
PA	AFUÁ	35 467	35 879	36 598	0,82	10769	96,90	10435	0,6	6261	1969978	77	23	453489
PA	IPIXUNA DO PARÁ	53 318	51 569	54 609	0,82	15912	83,44	13277	0,6	7966	2910802	38	62	1798293
MA	FERNANDO FALCÃO	9 415	9 584	9 783	1,02	3572	32,97	1178	0,6	707	525272	17	83	433612
MA	MARAJÁ DO SENA	7 772	7 751	7 721	1,02	2885	84,78	2446	0,6	1467	424203	18	82	346362
MA	JENIPAPO DOS VIEIRAS	15 589	15 733	15 899	1,02	5860	78,20	4583	0,6	2750	861783	17	83	716400
MA	SATUBINHA	12 301	12 600	12 959	1,02	4698	40,35	1896	0,6	1137	690945	30	70	486494
PI	SÃO FRANCISCO DE ASSIS DO PIAUÍ	5 628	5 686	5 728	0,98	2032	98,40	1999	0,6	1200	311017	26	74	230121
PI	CAXINGÓ	5 108	5 174	5 213	0,98	1848	96,68	1786	0,6	1072	282784	5	95	268079
PI	BETÂNIA DO PIAUÍ	6 029	6 042	6 086	0,98	2165	92,42	2001	0,6	1200	331365	49	51	168002
PI	COCAL	26 923	27 067	27 274	0,98	9689	78,19	7576	0,6	4546	1483068	20	80	1193721
PI	COCAL DOS ALVES	5 605	5 635	5 677	0,98	2017	28,91	583	0,6	350	308735	6	94	289161
PI	ASSUNÇÃO DO PIAUÍ	7 547	7 590	7 645	0,98	2716	63,65	1729	0,6	1037	415772	9	91	376772
PE	MANARI	18 472	18 847	19 788	0,94	6531	84,14	5495	0,6	3297	1042203	51	49	509324
AL	INHAPI	17 908	17 839	18 516	0,91	6008	97,28	5844	0,6	3507	990300	42	58	572393
AL	OLIVENÇA	11 100	11 150	11 594	0,91	3747	98,45	3689	0,6	2213	617653	40	60	369418
BA	ITAPICURU	32 641	33 008	35 255	0,96	11786	87,16	10272	0,6	6163	1841498	26	74	1361972

Average sewage production per person/day **150 l/day**

3.2. Methodological approach for energy potential estimative in the Colombian context

In Colombia, the estimative of biomass residues in the selected municipalities are still being assessed. The only available data found in the country for agriculture residues was figures at departmental level. The research team at the National Mining and Energy Planning Unit – UPME is currently working on the disaggregation of those figures[12].

For the purpose of this study, biomass sources including local crops, wood, livestock, and solid waste were analyzed for selected municipalities in order to estimate biomass energy potential. Electricity demand was also analyzed for each of these municipalities for 2014.

Selected municipalities are located in remote and isolated areas and are part of the non-interconnected system. They are provided with electricity through inefficient and contaminating diesel-based systems. These systems are permanently followed up through telemetry equipment, which allows monitoring of fuel consumption and power generation on real time basis. Measurements are transmitted to a central office located in Bogotá, the capital city. Therefore, telemetry reports provide very accurate information on electricity demand. In addition, studies estimating the current biomass energy potential in Colombia have already been developed at national level. All of them are valuable sources particularly regarding the energy content of the residues and the methodology we used to determine the theoretical and technical biomass energy potential. While the theoretical potential provides information on the energy content of the residues, that is, the maximum energy content that could be provided by residues, the technical potential is defined as the fraction of theoretical energy potential that could be extracted from the residues considering available technologies.

Mathematical models used to determine the energy potential of the biomass residues are based on the approach used by the Colombian Mining Energy Planning Unit – UPME, UPME, the Institute of Hydrology, Meteorology and Environmental Studies – IDEAM, the Administrative Department of Science, Technology and Innovation – Colciencias, and Industrial university of Santander – UIS, to build the Colombian Residual Biomass Energy Potential Atlas (Escalante, Orduz, Zapata, Cardona, & Duarte, 2010). This Atlas includes information on i) different residues of the agriculture sector, which was updated for the purpose of this study, ii) energy content of the residues based on field studies and laboratory analysis, and (iii) previous research at UPME. Also, a recent study (Gonzalez-Salazar, et al., 2014) summarized methodologies and data that are particularly important for the development of our analysis.

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[12] Information provided by Sandra Medina and Carlos Valles at the National Mining and energy-planning Unit – UPME.

Annual production of residues and their energy content expressed as Low Heating Value (LHV) were estimated based on the information provided by the Information System of the Colombian Ministry of Agriculture (Colombian Ministry of Agriculture and Rural Development, 2013) and other sources, as indicated in Table 14.

The theoretical biomass energy potential analysis is based on the fact that energy stored in biomass residues is proportional to dry matter and can be expressed as:

Equation 11: Biomass energy potential equation

$$EP = B_{dr} * LHV$$

Where: *EP = Energy potential (TJ/yr.)*

B_{dr} = Biomass dry residue (tonnes/yr.)

LHV = Low Heating Value *of the residue (TJ/tonnes)*

The energy content of the residue is equivalent to the Low Heating Value (MJ/kg). Having into account the previous equation and the particular characteristics of dry residues (livestock, agriculture and urban solid waste) for the selected municipalities, the applied models are described in sections below.

I. Animal residues

The energy potential of livestock residues is calculated from the amount of biogas produced from cattle manure through a bio-digestion process. Manure production is thus a function of the number of heads and its energy potential is calculated as indicated by the expression:

Equation 12: Animal residue energy potential equation

$$EP_{ldr} = \sum_{i=1}^{n} NA_i * M_i * B_{0i} * LHV_{CH4}$$

Where: EP_{ldr}= Theoretical energy potential from livestock (TJ/yr.)

NA_i = number of animals (heads)

M_i = Manure produced by one animal in one year (tonne/head-yr.) = 3.285 tonne/yr. taken as the average value reported by (Gonzalez-Salazar, et al., 2014)

B_{oi} = Biogas produced per tonne of manure (m^3/tonne) = 21.23 m^3/tonne taken as the average value reported by (Gonzalez-Salazar, et al., 2014)

LHV_{CH4} = Lower heating value of methane (MJ/tonne) = 0.021 TJ/m^3 taken as the average value reported by (Gonzalez-Salazar, et al., 2014)

A normally distributed coefficient of variability associated to each of the animal types is taken as 0.023, as suggested by (Gonzalez-Salazar, et al., 2014).

II. Agriculture residues

Agriculture residue's dry mass per year is expressed as:

Equation 13: Agriculture residue factor equation

$$B_{adr} = A * Y_c * B_{gr} * Y_{dr} \text{ (Eq. 1)}$$

Where: A = Cultivated area ha/yr.

Y_c = Crop Yield tonne product/ ha

B_{gr} = Residue factor (tonne residue/tonne product)

Y_{dr} = Dry residue fraction = 1 – moisture fraction

Table 14: Residues and basic information to estimate theoretical and technical biomass potential in selected municipalities

Type of residue				Residue factor (tonne residue/tonne product)	LHV (MJ/kg)2	Moisture	Source (LHV)
Agriculture residues	Temporary crops	Rice	Stem	2.35	14.60	0.82	(Gonzalez-Salazar, et al., 2014)
			Husk	0.2	15.55	0.10	
		Maize	Stem and leaves	0.93	16.11	0.15	(Gonzalez-Salazar, et al., 2014)
			Cob	0.27	16.34	0.29	
			Skin	0.21	15.59	0.08	
	Permanent crops	Palm oil	Stone	0.22	17.95	0.09	(Gonzalez-Salazar, et al., 2014; Salomon, Gómez, & Martin, 2013)
			Fiber	0.63	18.22	0.35	
			Rachis	1.06	17.99	0.54	
		Cassava	Stalk	0.60	18.35	0.72	(Pattiya, Sukkasi, & Goodwin, 2012 ; FAO, 2007)
		Plantain	Rachis	1.00	7.57	0.94	(Gonzalez-Salazar, et al., 2014)
			Stem	0.15	8.51	0.93	
			Rejected fruit	5.00	10.42	0.83	
		Sugar cane	Leaves and tops	2.53	17.34	0.43	(Gonzalez-Salazar, et al., 2014)
			Bagasse	3.75	17.39	0.28	(Gonzalez-Salazar, et al., 2014)
Wood				0.31	18.55		(Gonzalez-Salazar, et al., 2014)

Once the annual biomass dry residue is estimated for each agriculture residue available in the municipality, the corresponding energy potential is estimated through the expression:

Equation 14: Agriculture residue energy potential equation

$$EP_{adr} = \sum_{i=1}^{n} Bdr * LHV_i \quad \text{(Eq. 2)}$$

Where the counter n refers to available residues in a particular municipality, and EP_{adr} represents the theoretical energy potential of agriculture residues (MJ).

III. Wood residues

Residues from forestry operations include loose material, stumps and the roundwood balance, consisting of the stem wood balance, its crown mass and stump wood. Forestry operations are not fully mechanized in Colombia. Only 20% of extracted wood, mostly from primary forest, is effectively traded. The remaining 80% is left on the field in the form of leaves, branches, and stumps, or produced as residues in the form of bark, sawdust and wood chips at the sawmills. Energy potential from wood residues is calculated using:

Equation 15: Wood residue energy potential equation

$$EP_{wdr} = \sum_{i=1}^{n} Bwdr * LHV_i$$

Where: *$EP\ wdr$ = Theoretical residual wood energy potential (TJ/yr.)*

Bw_{dr} = Biomass *dry wood residue (tonne/yr.)*

LHV_i = Low Heating *Value of the residue i (TJ/tonne)*

Wood residue's dry mass per year is expressed as:

Equation 16: Wood residue factor equation

$$B_{wdr} = P_r * B_{gr} * \rho_{dr}$$

Where: P_r = Forestry product (m^3/yr.)

Bgr = Residue factor (tonne residue/tonne product)

ρ_{dr} = Residue density – dry basis (tonne/m^3) = 0,6 dry tonne/m^3 (Gonzalez-Salazar, et al., 2014)

IV. Municipal Solid Waste

Value of solid waste produced by each municipality is calculated using an average per capita production of 0.1707 tonne per year and data on population (Gonzalez-Salazar, et al., 2014; DANE, 2014). In spite of higher values reported by Colombian government (Colombian Ministry of Environment and Rural Development, 2006), it was preferred to use the more conservative values for the purpose of this study. The expression below was used to estimate the energy potential of Municipal Solid Waste

Equation 17: Municipal Solid Waste factor equation

$$EP_{lbr} = \sum_{i=1}^{n} MSW_i * OM * Y_{dr} * LHV_{dr} \quad \text{(Eq. 3)}$$

Where: MSW_i = Municipal Solid Waste (tonnes/yr.)

OM = Organic matter fraction = 0.6 (Metasus. European Sustainable Solutions, 2011)

Ydr = Dry residue fraction = 1 – moisture fraction.

Moisture fraction = 0.5 (Fobil, Carboo, & Armah, 2005)

LHV_{dr} = Lower heating value of dry residue = 15.75 MJ/kg, taken as the average value reported by (Escalante, Orduz, Zapata, Cardona, & Duarte, 2010)

V. Colombian estimate

Biomass is widely available in Colombia. It is used in the form of wood and charcoal mainly for the purpose of cooking and water heating. At industrial level, it is also used in the form of agro industrial residues for power generation and co-generation in sugar cane and palm oil industries. In the transport sector, it is used as bioethanol and biodiesel. Yet, there is still a significant potential to be explored, particularly in relation with residual biomass. The National Mining and Energy Planning Unit (UPME) identified a potential of residual biomass in the country of about 448,410 TJ per year including agricultural residues (331,000 TJ), livestock residues (117,000 TJ), and urban waste (410 TJ) (Escalante, Orduz, Zapata, Cardona, & Duarte, 2010). Estimates in this study indicate that biomass potential in selected municipalities could lead to an installed capacity ranging from 26 to 60 MW, enough to displace actual installed capacity in selected municipalities, which is about 40 MW. Tables 15 to 18 summarize residual biomass available per category at each municipality.

Animal residue estimate

Table 15: Animal residue estimate per selected municipality

Municipality	Cattle Residues (tonnes/year)
La Primavera - Vichada	413 089
Cumaribo - Vichada	77 526
Puerto Carreño - Vichada	821
Mosquera - Nariño	1 445
La Tola - Nariño	42 022
Solano - Caquetá	3 426
Mitú - Vaupés	-
Taraira - Vaupés	1 478
Guapi - Cauca	122
Timbiquí - Cauca	917
Juradó - Chocó	175 935
Unguía - Chocó	13 774
Inírida - Guainía	312
Puerto Nariño - Amazonas	2 171
Leticia - Amazonas	-

Agriculture residue estimate

Table 16: Agricultural residue estimative per selected municipality

Agriculture residues (tonnes/year)															
Municipality	Permanent crops										Temporary crops				
	Palm oil			Cassava	Plantain			Sugar cane		Rice		Maize			
	Stonnese	Fiber	Rachis	Stalk	Rachis	Stem	Rejected fruit	Leaves and tops	Bagasse	Stem	Husk	Stem and leaves	Cob	Skin
La Primavera - Vichada	136	391	657	432	383	57	1 915	-	-	2 319	197	470	136	106
Cumaribo - Vichada	415	1 188	1 999	432	1 164	175	5 820	-	-	7 057	601	1 428	414	322
Puerto Carreño - Vichada	79	226	381	250	222	33	1 110	-	-	1 344	114	272	79	61
Mosquera - Nariño	-	-	-	-	8 644	1 297	43 220	14 019	20 779	-	-	-	-	-
La Tola - Nariño	-	-	-	-	2 241	336	11 205	3 636	5 389	-	-	-	-	-
Solano - Caquetá	-	-	-	13 280	32 272	4 841	161 360	22 054	32 689	-	-	-	-	-
Mitú - Vaupés	-	-	-	1 558	96	14	480	-	-	-	-	-	-	-
Taraira - Vaupés	-	-	-	628	237	36	1 185	-	-	-	-	-	-	-
Guapi - Cauca	-	-	-	-	9 013	1 352	45 065	-	-	127	11	-	-	-
Timbiquí - Cauca	-	-	-	-	6 095	914	30 475	-	-	87	7	-	-	-
Juradó - Chocó	-	-	-	830	6 095	914	30 475	-	-	2 409	205	-	-	-
Unguía - Chocó	-	-	-	833	3 990	599	19 950	-	-	2 329	198	-	-	-
Inírida - Guainía	-	-	-	765	512	77	2 560	-	-	-	-	-	-	-
Puerto Nariño - Amazonas	-	-	-	10	8	1	40	-	-	-	-	-	-	-
Leticia - Amazonas	-	-	-	33	25	4	125	-	-	-	-	-	-	-

Wood residue estimate

Table 17: Wood residue estimate per selected municipality

Municipality	Wood residues (tonnes/year)
La Primavera - Vichada	5
Cumaribo - Vichada	17
Puerto Carreño - Vichada	3
Mosquera - Nariño	13 973
La Tola - Nariño	3 623
Solano - Caquetá	5 580
Mitú - Vaupés	76
Taraira - Vaupés	31
Guapi - Cauca	2 954
Timbiquí - Cauca	1 998
Juradó - Chocó	8 267
Unguía - Chocó	7 991
Inírida - Guainía	115
Puerto Nariño - Amazonas	49
Leticia - Amazonas	157

Municipal Solid Waste residue estimate

Table 18: Municipal Solid Waste residue estimate per selected municipality

Municipality	Solid waste-Organic fraction (tonnes/year)
La Primavera - Vichada	1 517
Cumaribo - Vichada	3 687
Puerto Carreño - Vichada	1 588
Mosquera - Nariño	1 618
La Tola - Nariño	1 237
Solano - Caquetá	2 377
Mitú - Vaupés	3 202
Taraira - Vaupés	101
Guapi - Cauca	3 036
Timbiquí - Cauca	2 201
Juradó - Chocó	343
Unguía - Chocó	1 544
Inírida - Guainía	2 012
Puerto Nariño - Amazonas	824
Leticia - Amazonas	4 199

4. Assessment of the best available technologies for converting biomass into energy for the selected municipalities

Several processes can convert biomass from residues into useful energy for production purposes. In a broad approach, the main available technologies for converting biomass into energy are summarized in the Figure 17 and Table 19.

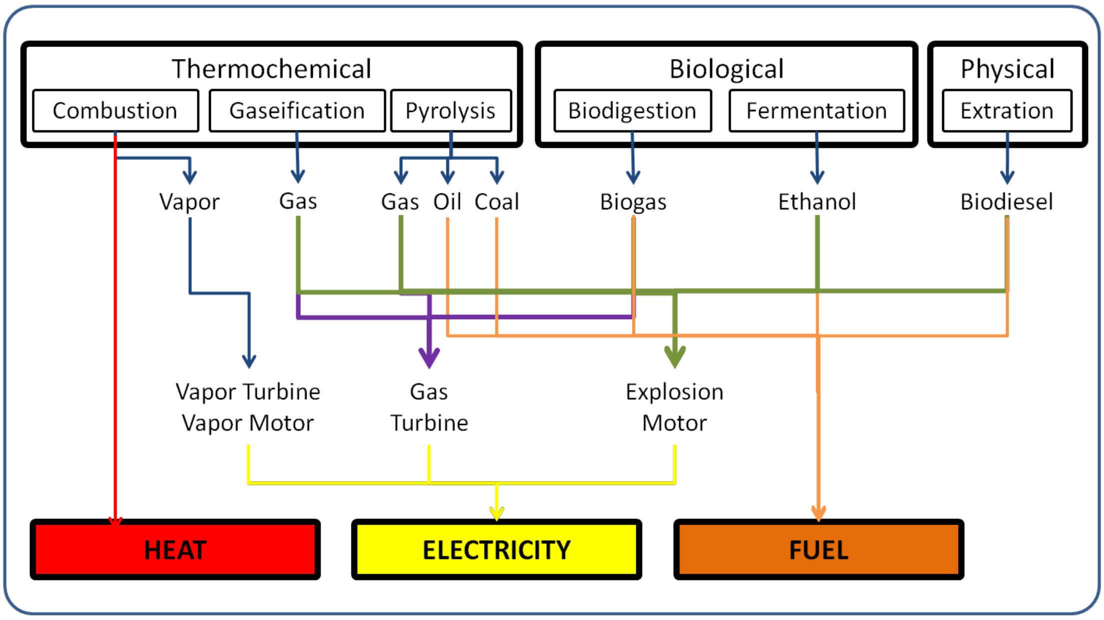

Figure 17: Main technology routes for biomass to energy transformation. Source: Authors.

Table 19:Technologies for biomass to energy transformation.

Technology Category	Biomass Conversion	Primary Energy Produced	Conversion and Recovery	Final Energy Products
Direct combustion	Stove/Furnace	Heat	Heat exchanger	Hot air, hot water
	Pile burners	Heat, steam	Steam turbine Steam engine	Heat and Electricity
	Stoker grate boilers	Heat, steam	Steam turbine	Heat and Electricity
	Suspension boilers:	Heat, steam	Steam turbine	Heat and Electricity
	Fluidized-bed	Heat, steam	Steam turbine	Heat and Electricity
Gasification (atmospheric)	Updraft, fixed bed	Syngas (Low Btu gas)	Spark engine	Heat and/or Electricity
	Downdraft, moving bed	Syngas (Low Btu gas)	Spark engine	Heat and Electricity
Pyrolysis	Kilns or retorts	Charcoal	Stoves and furnaces	Heat
	Reactors	Pyrolysis oil (biooil), charcoal	Combustion turbines, boilers, furnaces, reactors	Heat, electricity, synthetic liquid fuels, (BTL)
Anaerobic digestion	Digesters Landfills	Biogas (Medium Btu gas)	Spark ignition Combustion turbines	Heat and Electricity

Source: adapted from Missagia, 2011.

The small-scale availability of these technologies is the main restriction parameter that must to be applied. Only technologies adapted to produce below 1 MWe are considered in this study due to the scarce of energy demand and low biomass residues concentration[13] in the target areas. Furthermore, this study exclusively considers technologies with heat and electricity as final energy products, as already discussed. With these basic restrictions, the remained possibilities are showed in Table 20.

[13] Only in a few municipalities there are perspectives of plants above 1 MW, as discussed ahead in this report.

Table 20: Best Available Technologies for the selected municipalities

Technology Category	Biomass Conversion	Primary Energy Produced	Conversion and Recovery	Final Energy Products
Direct combustion	Pile burners	Heat, steam	Steam turbine Steam engine	Heat and Electricity
Gasification (atmospheric)	Updraft, Fixed bed	Syngas (Low Btu gas)	Spark engine	Heat and/or Electricity
	Fluidized bed	Syngas (Low Btu gas)	Spark engine	Heat and Electricity
Anaerobic digestion	Digesters Landfills	Biogas (Medium Btu gas)	Spark ignition Combustion turbines	Heat and Electricity

4.1. Direct combustion

I. Description

A steam cycle can be fed with dry or semi-dry residues, for example, residues from a sawmill industry or solid agricultural residues in a community. These thermoelectric units operate according to a simple Rankine cycle that is basically composed by a boiler, a steam machine (turbine or engine), an electric generator, a steam condenser and a water pump (see Figure 18). Usually, other equipment is installed in this kind of facilities, like a multi-cyclone filter to clean up combustion gases and a condensate tank, if necessary.

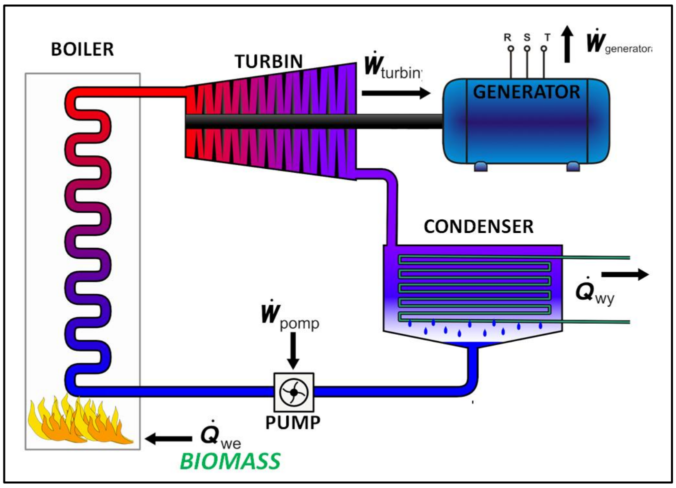

Figure 18: Simple Rankine cycle. Adapted from (Ainsworth, 2007)

Nowadays, the equipment that composes the steam cycle is available in the national market, supplied for Brazilian manufacturers [14]. Some national manufacturers offer micro and mini scale equipment, from 1 kWe to 1MWe, allowing suit community power demand.

From previous experience with the Enermad project, developed in Amazonia, the installation cost for a 200 kW was BRL 1,000,000 (342,465 USD, 2.92 BRL/USD in 2004) [15]. There is (as expected) the problem of the low conversion efficiency (as in every small power plant)[16] in these small facilities (Table 21), which involves an important consumption of biomass per kWe generated. For low power the steam engine is an alternative for turbine. The steam engine is produced in Brazil for powers in the 40-250 kW range. The efficiency of these machines varies between 20 and 30% depending on the installed power, working with steam pressures from 10 to 16 bar (Rendeiro & Nogueira, 2008). Also, there is a possibility to generate electricity and heat simultaneously burning a single fuel (so-called cogeneration, what increases the energy conversion efficiency).

Table 21: Small Plant Thermoelectric Efficiency

Electric Installed Power	Boiler Efficiency	Steam Machine Efficiency (Isentropic)	Generator AC Efficiency	Vapor Lines Efficiency	Mechanical Efficiency	Internal Loads (% Electricity Output)	Plant Thermoelectric Efficiency (%)
1-100 kWe	65-85%	20-30%	80-95%	95%	95%	20%	**2 – 4 %**
100-300 kWe	85-95%	40 -50%	90-97%	95%	95%	20%	**6 – 15%**

Source: Authors calculation based in manufacturers data.

According to the power plant size and site conditions, two installation ways can be considered in case of an Amazon isolated community:

Fixed Unit: Facilities are installed on mainland near the community. In this case, civil works are required to shelter the power plant equipment. This implies to transport all equipment, construction materials, electric generation support and specialized labor to installation place.

Mobile Unit: The power plant is constructed on a floating platform (Figure 19) in a place with good infrastructure and logistic conditions. After commissioning, the facility is carried to the operation place.

The first option is recommended when the power demand is higher than 200 kW-1 MW, due to the size of the installation and safety requirements. In this case, easy access by land to installation place is desirable. The second alternative is recommended for small power plants (<200 kW or 1MW) and access to installation place is impossible by land. This second alternative is

[14] Brazilian manufacturer TGM Industries produces a wide range of steam turbine since 200 kWe. Several boilers manufacturers are available in Brazil. All of them export to other countries in Latin America

[15] Further discussions are presented on Conclusions section.

[16] Plant Thermoelectric Efficiency = Electricity energy output / Biomass energy input (using the Low Heating value of biomass)

possible because the Amazon region has a very large river network density and waterway is the main transport form. With this option, almost any civil works are necessary with a significant cost savings. The foundation in isolated Amazon regions is often difficult and expensive because the ground is seasonally flooded producing low bearing capacity. When the village has a good access by road and does not need mobile units, there is also the possibility of using small biomass gasifiers (up to 200 kW).

In the case of the selected municipalities, we could have 13 municipalities with such biomass power plants above 200 kW (from those, 8 units are above 1 MW) (see discussion on Section 5). Considering power plants below 200 kW, which would be adequate for gasification or micro steam plants (mobile units), we would have 14 small unities.

Figure 19: Mobile biomass power unit based on Rankine cycle (50 kWe) in the Amazon region. Source: (Nogueira, 2012)

Furthermore, manufacture, assembly, operator training and commissioning are performed in a place with good communication, service and infrastructure, like States' Capitals (e.g. Manaus/AM, Belem/PA, etc.). Assembling the entire facility into a place of good communication and infrastructure facilitates the work, reduces spending time and costs. The transport of skilled labor, equipment and material to the implantation site is not necessary. Besides, the work environment is more organized, safe and stable, favoring good working conditions and increasing efficiency. The power plant equipment not suffers the unloading and displacement in a ground with low bearing capacity, increasing safety and reducing installation time.

Another advantage of a mobile unit is that operation place may vary over time adapting to the circumstances, attending a technical, a social or an economic reason. Once abandoned the operation place, initial environmental condition and landscape restoration can be easy, instant and total, removing environmental impacts in a high ecological value area.

In order to prevent environmental impacts during the operation, the combustion facilities must include a combustion gases treatment, necessary to prevent particulate emissions. Also, correct ash disposition is required.

The Norm NR 10 of Brazilian Ministry of Labor and Employment disposed on the basic guidelines for the implementation of control measures and preventive systems designed to ensure the safety and health of workers directly or indirectly involved in electrical installations and electricity service in phases of generation, transmission, distribution and consumption, including the stages of design, construction, installation, operation, maintenance of electrical installations. This Norm sets a minimum number of operators generating unit electricity. Based on this standard, the number of skilled operators for a biomass combustion power plan in the range of 50-300 kW can then be defined as (Rendeiro, 2011):

- Two boiler operators per shift
- One stoker per shift
- One Industrial Mechanic
- One Electrician (eventually)

II. Previous experiences on installations

An example of micro power generation using a steam turbine is the pilot power plant located in the Mechanical Engineering Laboratory of Para States Federal University (UFPA). The system operation parameters were monitored (Oliveira, 2006) such as fuel heating value, biomass consumption rate, equipment efficiency and power output. The Table 22 shows the technical specifications of this facility. The total thermoelectric efficiency of this plant is only 2%. This means that to achieve the maximum electric power output of 6 kWe, are necessary 80 kg of biomass per hour with a low heating value of 3200 kcal/kg.

Another example is the ENERMAD Project[17]. Its goal was to install a 200 kW micro steam turbine system in an Amazon isolated community. The project purpose was to supply the energy demand of a local sawmill, a brooms factory and 80 households. Besides, this project also increased the added value of the wood sold by the community, considering that the generated steam supplied a greenhouse to dry this wood. The plant was inaugurated in November 2009, but there is no information if it still operating. The chosen community for the power plant to be installed was Porto Alegre do Curumu village, Pará State (Brazilian Amazon). The main economic activities of this community were wood first and second processing. Beyond those activities, the community has great potential for fishing and preparation of local fruits pulp (açaí) and vegetable oil. This community was selected, and it was verified that all the processed wood in the saw-mill is derived from a extractive reserve that possess a handling plan approved for the IBAMA -

[17] Enermad project, in Amazonia, www.iee.usp.br/gbio or http://143.107.4.241/projetos/enermad/enermad.htm

Brazilian Institute for the Environment and Natural Renewable Resources. The equipment that composes the steam cycle was acquired from national manufacturers, for prices with significant discounts. The installation of the system was ended and the manufacturer companies performed the commissioning of the equipment. The main problem was the remote location, what implied to transport all equipment, construction materials and specialized labor to installation place. The main learning in this project was that a mobile unit is more suitable for small power plants in Amazon region.

Another experience is that from Federal University of Pará, which developed a mobile steam system. The system couples a steam engine power plant to local small factories of vegetable oils and ice, using the oil production residues. The equipment was assembled on three boats in a metropolitan area, and then transported to the community by river. To supplement the power generation, the system is hybridized with PV panels on the top of the boats (Figure 20).

Figure 20: Mobile power unit project hybridized with PV panels. Source: (Nogueira, 2012)

The characteristics of the system are resumed in Table 22.

Table 22: Main characteristics of the pilot project in Marajo Island, State of Pará.

Steam engine installed power	50 kW
Parameters of the steam boiler	1000 kg/h, pressure 21 bar
Vegetable oil production	100 kg/h pulp oilseed production
Ice production	10 tonnes/day
Power demand for ice production	35 kW
Power demand for vegetable oil production	8 kW
Parasitic charges of the system	5 kW

Energy used for the community	2 kW from the steam engine and 10 kW from the PV system

Source: Interview with Prof. Rendeiro of UFPA (Nerini, 2012)

This example shows how energy production allows local economic activities, increasing the value added to the products from amazon ecosystem. A key challenge for this system is how to keep the system working properly thought the years. In 2012, a local NGO was taking care of the correct operation. However, the challenge was to keep the activity without any external help, through trained local people for operation (Nerini, 2012)[18].

Main lessons learned in the projects mentioned include?

- Lack of local technical capacity and in some cases capacity building is not enough without the support of local utilities.
- The technology to be used must be the simplest one, to be possible the operation and maintenance by local people, as proposed in this study.
- Lack of interest from local utilities on contributing to operation and maintenance of the systems, since they receive the payment of diesel oil from the CCC, as discussed in this report (see Conclusions Section).
- Lack of adequate policies making mandatory the participation of local utilities.

III. Installation and operation costs

Thermal diesel power generators can be installed quickly and have a small installation cost when compared to biomass plants, BRL 650/kW for diesel compared to BRL 1,600/kW for biomass (Rendeiro & Nogueira, 2008). The time between acquisition and operation varies between 4 to 8 months depending on the power and can be acquired from the power 7.5 KW to 1 MW. The Table 23 presents the installation cost for a mobile unit of 300 kW, which had a specific cost of BRL 4,000/kWh.

Table 23: Installation cost for a mobile unit of 300 kW.

Item	Costs (BRL)[19]
Serial Manufacture Equipment	496,000
Specific Manufacture Equipment	23,224

[18] The Marajó Project, in Santo Antônio community, failed due to business and management problems. This project was inaugurated in 2007 and the variables were similar to the ENERMAD project. Since 2009 the project is not in operation due to difficulties in business and administration practice of the semi-illiterate population and also due to corruption problems (Missagia, 2011).

[19] USD 1.00 equals to BRL 3.10 in June 2015.

Shelter And Boat Structures	209,500
Infrastructure And Logistics For Implementation	56,600
Assembly.	155,767
Operator Training	4,120
Execution Budget (E.B.)	**955,211**
General Expenses Infrastructure (10% E.B.)	95,521
Profit Industrial (6% E.B.)	57,313
Execution Budget Contract Before Taxes (E.B.C.B.T)	**1,108,045 BRL**
Taxes (10% (E.B.C.B.T)	110,804
Execution Budget Contract After Taxes	**1,218,849 BRL**

Source: (Poveda M. M., 2008)

The main disadvantage of the generation with fossil fuel lies in the cost of generation. The cheapest diesel power generation in the Amazon region is BRL 700/MWh (BRL 600.00/MWh just for fuel), but it is very common to find generation cost between 900 and 1100 BRL /MWh and eventually cost BRL 1300/MWh. For a biomass plant, the O& M cost depend on the potency installed. Figure 21 and Figure 22 show graphs for the costs of O& M for plants for electricity generation with the power between 50 and 300 kW installed.

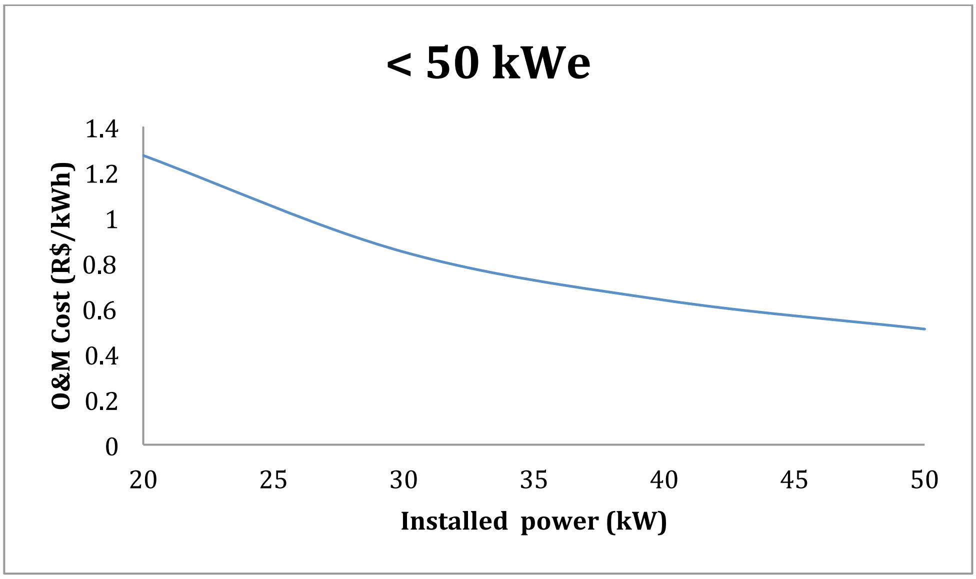

Figure 21: Operation & Maintenance costs for plants for electric power generation below 50 kW. Source: (Santos, 2007)

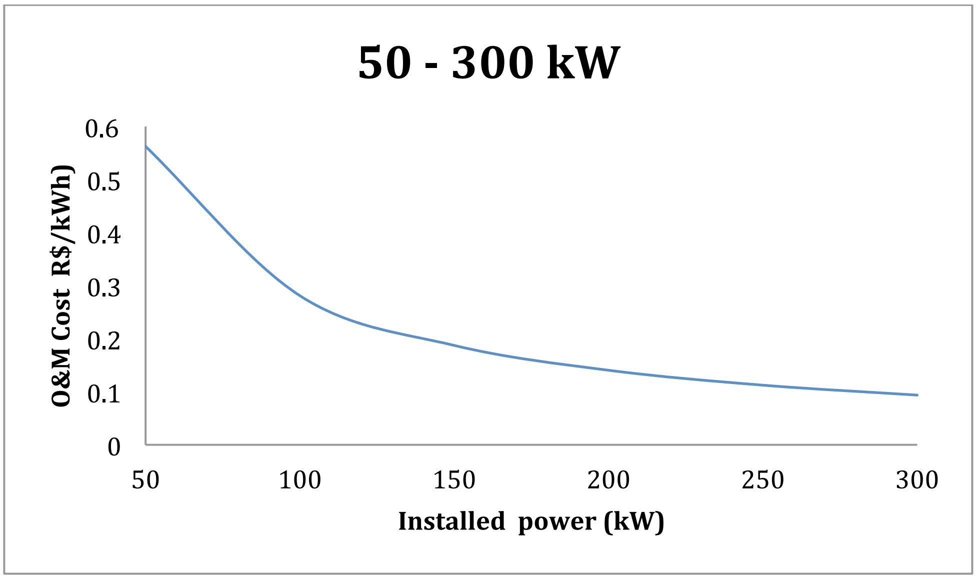

Figure 22: Operation & Maintenance costs for plants for electric power generation between 50-300 kW. Source: (Santos, 2007)

4.2. Gasification

Gasification is a thermochemical process that converts the carbon in the chemical structures of the elements by the decomposition of organic matter in a gas (syngas).

The gasifier can be a continuous flow or batch, the most common technique for partial oxidation using a gassing agent (oxygen, air or hot steam) in quantities less than stoichiometric (theoretical minimum for combustion).

The production of the gas (producer or synthesis gas) called gasification is from the partial combustion of a solid fuel (in this case, biomass) and takes place at temperatures of about 1000° C. The reactor is called a gasifier. The combustion products from the complete combustion of biomass generally contain nitrogen, water vapor, carbon dioxide and surplus of oxygen. On another hand, gasification means incomplete combustion of biomass resulting in production of combustible gases consisting of Carbon monoxide (CO), Hydrogen (H2) and traces of Methane (CH4). This mixture is called producer gas or synthesis gas. Producer gas can be used to run internal combustion engines (both compression and spark ignition), can be used as substitute for furnace oil in direct heat applications and can be used to produce, in an economically viable way, liquid fuels for chemicals and to be used as fuel for engines (Reed, 1982).

Four distinct processes take place in a gasifier as the fuel makes its way to gasification (drying, pyrolysis, combustion and reduction)[20][21].

[20] Though there is a considerable overlap of the processes, each can be assumed to occupy a separate zone where fundamentally different chemical and thermal reactions take place.
[21] The composition of the gas and concomitant production of solid fuels (coal), and condensable liquids (pyroligneous) depend on the following factors: type of gasification furnace, as power supply to the

Indian companies, with fixed bed technology “down-draft”, primarily produce small systems. The units with power up to 100-200 kW operate in most cases on diesel fueling dual systems (synthesis gas-diesel[22]), but there are some experiments with adapted Otto engines. These systems are easy to operate and can be used for power generation in rural and isolated systems in developing countries. There are several examples of systems installed in India - Bangalore (IISc, 2010), Brazil/ Amazon (CENBIO, 2006) and recently in Cuba (GEF/UNIDO, 2014)[23].

A 1 MW (fluidized bed) gasification plant is in operation in Güssing, Austria (GRE, 2014), where the gasifier is fed with wood chips and the gas synthesis gas is fed into an engine. Gasification technology for MSW in Brazil starts to be tested, in particular in a pilot plant as the Carbogas (Carbogas, 2014), in Mauá, Sao Paulo. This pilot plant has a 1 MW gasifier coupled to a 200 kW Otto engine (Miranda, 2014, Carbogas[24]).

The other larger scale units are for thermal power generation. This is because the great technological challenge is the proper cleaning of the synthesis gas to power the motor to generate electricity. Table 24 shows some general figures for gasifiers.

process, the introduction or not of water vapor with the oxidant (air or O2), the charge retention time, gas withdrawal system and other products used in organic matter (FEAM, 2010).

[22] 80% syngas, 20% diesel.

[23] Project GEF/UNIDO. Unit with 50 kW in Cocodrilo, Isla de la Juventud, Cuba (in operation), which was visited by S. Coelho in 2014.

[24] www.carbogas.com.br

Table 24: Characteristics of gasifiers

Characteristics	Variations
Calorific power of the produced gas	Low: Up to 5 MJ / Nm³ (997 kcal / kg) Medium: 5 to 10 MJ / Nm³ (997-1993 kcal / kg) High: 10 to 40 MJ / Nm³ (1993-7972 kcal / kg)
Type of precursor gasifier	Air, water vapor, oxygen, hydrogen Fixed: parallel current or countercurrent
Type of bed	Fixed bed: parallel current or countercurrent Fluidized bed: Bubbling or circulating bed
Pressure of work	Under or atmospheric pressure Pressurized (up to 6 MPa)
Type of biomass	Agricultural waste, industrial or municipal Biomass in natura, pelletized or pulverized (depending on the type of bed)

Source: Elaborated by authors, adapted from Miranda (2014).

In most currently installed systems the gasifier agent is air, which causes the gas to be produced from low / medium heating value. Additionally, most operate at atmospheric pressure, but there were systems (now shut down) operating with pressurized gasifiers. The type of biomass fueled basically depends on the type of gasifier. Figure 23 shows the types of gasifier in the power range of power generation.

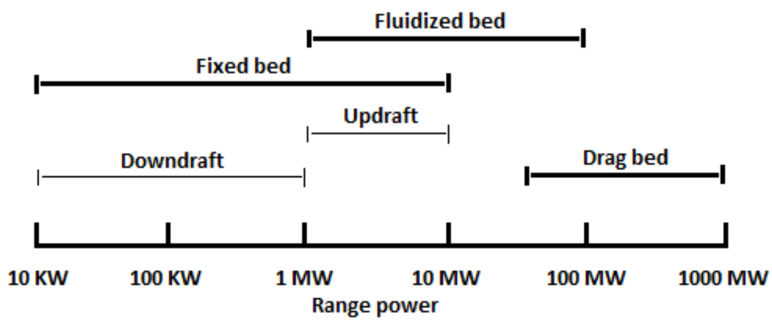

Figure 23: Gasifier in the power range. Source: elaborated by the authors based on Kinto (2012)

In this study to the case of small municipalities will be analyzed only the fixed bed gasifier residues for solid biomass (wood and agricultural residues). Fluidized bed gasifiers are usually large-scale, over 1 MW, but there is now the Carbogas system in Brazil, with fluidized bed, and working with MSW. This system could be evaluated for small municipalities in a near future[25].

[25] In this study, considering the low development of the municipalities, it was adapted a more conservative approach and it was considered only fixed bed systems for wood residues.

In this study the utilization of the fluidized bed could be possible only if the MSW is mixed with the existing wood in the municipalities.

Overall, the gasifiers have great advantage over small plants for power generation, especially in isolated regions and for the disposal of municipal solid waste in small towns. In addition, we can mention other benefits:

- Gasification has a higher energy efficiency (65 to 80%) compared to direct combustion (60 to 75%);
- The ash and residual carbon remain in the gasifier, thus reducing particulate emissions;
- It is easily distributed;
- Your burns more easily controlled.

In general, the average composition of the syngas is presented in Table 25.

Table 25: Average composition of syngas

Components	Concentration (%)
CO	8 a 25
H_2	13 a 15
CH_4	3 a 9
CO_2	5 a 10
N_2	45 a 54
H_2O	10 a 15

Source: Elaborated by authors, adapted from (Reed, 1982)

The gas produced from gasification of biomass can be used in several applications, like generation of electricity, heat generation for direct heating and as a raw material for obtaining liquid fuels by the Fischer-Tropsch synthesis (producing methanol ethanol, ammonia, gasoline, diesel, etc.).

I. Fixed bed gasifiers

The fixed bed gasifiers require a suitable particle size and humidity up to 20%. For less dense biomass, these gasifiers require that biomass must be pelletized. The material to be gasified moves by gravity. Such gasifiers are constructed with a fixed bed where the fuel is supported by a grid, which can be up flow (up-draft) or down (down-draft) with respect to the produced gas. Down draft gasifier is the most widespread technology, known and dominated operationally, which is being implemented mainly at small scales.

The generation of electricity from fixed bed gasifiers has been (and can be) used in power internal combustion engines, in capacities from 1 kW system and 200 kW (see Figure 24) (Rendeiro, 2008).

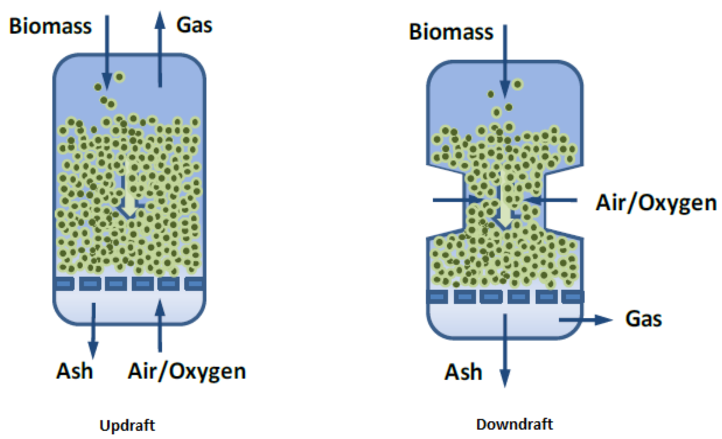

Figure 24: Types of Fixed bed gasifiers. Source: Adapted from E4 Tech (2009)

Gasifiers down flow or co-currents (down-draft)

The biomass is fed in at the top of the gasifier and the air[26], and oxygen or steam intake is also at the top or from the sides, hence the biomass and gases move in the same direction. Some of the biomass is burnt, falling through the gasifier throat to form a bed of hot charcoal that the gases have to pass through (a reaction zone). This ensures a fairly high quality syngas, which leaves at the base of the gasifier, with ash collected under the grate.

The downdraft gasifiers have the oxidant (air) and the gas produced flowing downwards (see Figure 25), generating gases with low tar and particulates. The low yield (around 15-20% from CENBIO, 2006), the difficulty of handling (manual feed) and the generated ashes are common problems in these small down draft gasifiers.

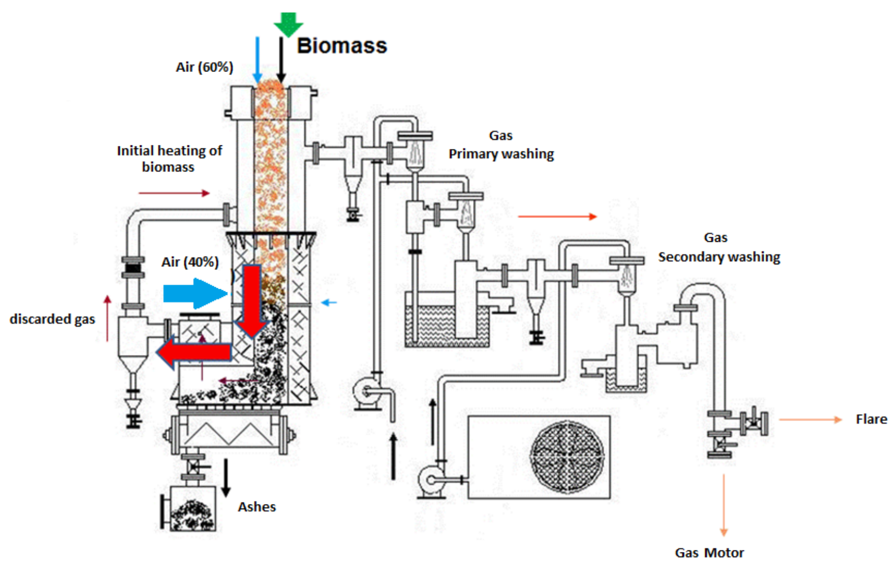

Figure 25: Biomass (downdraft gasifier). Source: Adapted from Gaseifamaz (CENBIO, 2006).

[26] Air is the most used as oxidation agent since oxygen is very expensive and steam needs to be locally produced.

Gasifiers Updraft

The biomass is fed in at the top of the gasifier, and the air, oxygen or steam intake is at the bottom, hence the biomass and gases move in opposite directions.

Some of the resulting char falls and burns to provide heat, The methane and tar-rich gas leaves at the top of the gasifier, and the ash falls from the grate for collection at the bottom of the gasifier produce gases with little particle but with higher tar (10 to 20%). For applications in internal combustion engines, tar must be removed. This type of gasifiers is not so much applied.

Air and steam are injected to keep the ash below the melting temperature and facilitate coal conversion.

Fluidized bed gasifiers

In this type of equipment there is a bed of inert particles (sand, ash or alumina) fluidized by the air stream, which drags the biomass. It can be of the bubbling or circulating type as the speed at which the material passes through the bed (see Figure 26).

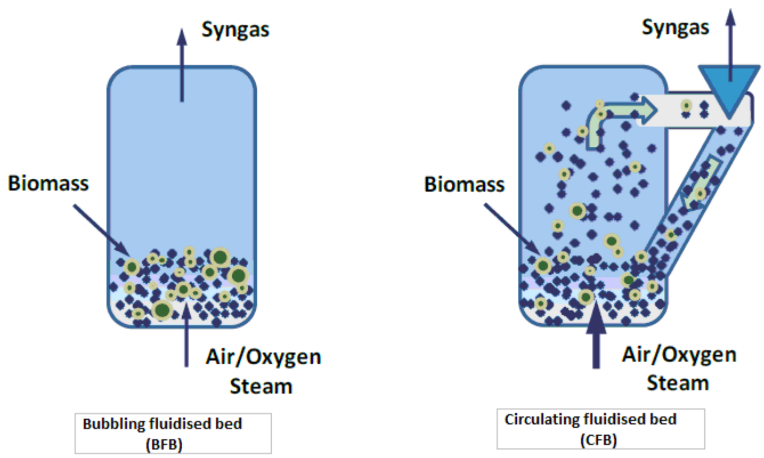

Figure 26: Types of fixed bed gasifiers. Source: Adapted from E4 Tech (2009).

A gasifier with bubbling fluidized bed consists of a container with a grid at the bottom through which air is introduced, so a gas stream upwards through the grid reaching a bed of fine-grained material, usually sand, where the biomass is found.

Circulating fluidized bed gasifiers differ from the bubbling bed because there is no clear-cut separation between the area of dense solid and the area of diluted solids.

These types of gasifiers are more suited to the conversion of a larger amount of biomass; systems with a capacity of 10 to 20 tonnes of biomass per hour are already operational. They are also more flexible as to the feedstock characteristics and can be used to convert biomass with minimal processing requirements. However, as mentioned above, there are now fluidized bed systems built for small scale in Brazil by Carbogas Ind.

Gasification bed of drag

In this type of gasifier dry biomass (or liquid) is injected with a relatively high amount of oxygen and / or pressurized steam. This technology is mainly characterized by the production of a clean gas and no tar. This is due to the use of oxygen, which allows the machine to work at temperatures around the melting point of the ash. And also allows the raw material used to supply the gasifier may be either dried as humid, which despite being a positive, can become negative due to the fact that the more moisture, oxygen injection increases (Kinto, 2012). It can only be used in places where oxygen is available and when it is economically feasible. This option was not considered in this study, for these difficulties.

II. Pretreatment of biomass

The biomass to be used as fuel in the direct combustion and gasification depends on its conditions. For conventional boilers and for fixed bed gasifiers, biomass must be maximum 50% wet. Moreover, for fixed bed gasifiers, biomass must have specific sizes.

For higher humidity, a fluidized boiler is required (but they are still very expensive and not available for small scale).

For fixed bed systems it is required a pretreatment, to have a water content below 20%, and to obtain a better energy conversion efficiency but also due to requirements of the fixed bed gasifier.

In this case a thermo-mechanical treatment must be used. Among the most common thermo-mechanical treatments available are drying, grinding, torrefaction, briquettes and pellets. These processes are employed to improve the heating value and the energy efficiency of biomass, which is directly related to humidity content, as shown in (see Figure 27).

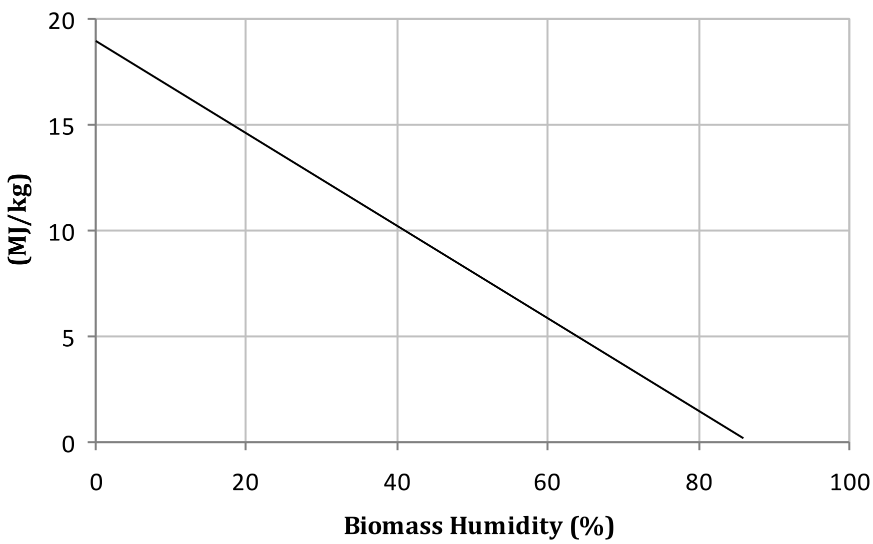

Figure 27: Heating value of wood due to its humidity. Source: Elaborated by the authors

The demand of wood for heat and power generation tends to keep growing in the various residential and industrial sectors, mainly in the direct burning of wood in nature. However, the challenge lies in applying more efficient technologies such as torrefaction or mechanical compression (briquettes and/or pellets) seeking to improve the energy use of wood.

Torrefaction

The torrefaction can be defined as pre-charring. This process results in an intermediate material between the biomass and charcoal. The fundamental purpose of torrefaction is to concentrate the energy of the biomass into a product formed in a short time, low heating rates and moderate temperatures, allowing retain volatile higher heating value in the product itself. Torrefaction results of various wood species show that the lower heating value of wood depends on the final Torrefaction with volatiles and ash content ranging from 22 MJ/kg. For acceptable results, simply process timber around two hours at 280 °C (Rajvanshi, 1986).

When comparing torrefaction with carbonization in terms of energy efficiency, torrefaction has advantages because the torrefaction biomass has around 80% of the initial energy, while the charcoal has only 50%.

Thermal-mechanical processing (briquettes and pellets)

The briquettes and pellets are solid biofuels result of industrial processing and thermo-mechanical compaction of biomass lignocellulosic biomass. Through this process, the waste biomass is converted into higher value energy products.

Due to its high-density characteristics, low humidity (7-10%), easy to handle, transport and store, by having a low moisture content, transportation is facilitated, as well as handling and storage.

This results in a biofuel with a high-energy value of about 18 MJ/kg. The briquettes have a size of 70 to 400 mm and, the pellets, from 6 to 16 mm. Figure 28 shows the variation of biomass (briquettes and pellets)

Figure 28: Variation of biomass, firewood/briquettes and pellets

The thermo-mechanical compaction is an effective way to focus on biomass energy available, taking into account the density and the heating value obtained after the process. The compaction of biomass residues obtained briquettes and/or pellets with superior any kind of firewood, with 2 to 5 times more energy density. Table 3 shows the price compared to other fuels.

Table 26: Energy value and price per fuel

Fuel	Calorific Power		Fuel Price
	(MJ)	(Kcal)	(R$)
wood chip (kg)	13	3100	0,35
briquetts or wood pellets (kg)	18	4800	0,50
natural gas (m^3)	35	8447	1,20
oil (l)	38	9160	2,50

Source: Elaborated by authors, adapted from (ANP, 2015; MME, 2007).

This fuel can be used directly in boilers and industrial burners, with a variety of domestic, commercial and industrial applications. In addition to the waste wood may be used other biomass residues. With this, you can minimize the volume of biomass and higher the heating value, making better use of these wastes.

The typical thermo-physical characteristics of briquettes and pellets are:

- Lower heating value 19.2 MJ / kg
- Humidity: 12%
- Fixed carbon: 14%
- Volatile: 84%
- Ash: 2%
- Density: 1200 kg / m3

In Brazil there are already several factories producing briquettes and pellets installed and the use of this fuel is already found in several segments. Figure 29 shows the types of briquetting and pelletizing technology in small-scale.

Figure 29: Briquetting and pelletizing technology in small-scale. Source: Lippe

The structure of the production costs is divided as follows: feedstock: 26%; electricity: 5%; staff: 15%; Administrative expenses: 5%; replacement parts: 5%; marketing: 24%; cost and funding: 20%. Similar projects show that the total cost of pelletizing process amortized over 15-30 years have values around 20-40 dollars per tonne (Escobar, 2013).

In short, the use of a native biomass is greatly favorable because of it is an abundant local resource and already part of the local culture, which could ensure the power supply especially with residual wood for several municipalities in Brazil and Colombia.

Through gasification can be generate power in rural and isolated systems, with power units below 200 KW. The use of gasification and combustion of biomass generally may reduce the use of fossil fuels in the selected municipalities, causing many social, environmental and economic benefits.

4.3. Anaerobic digestion

I. Digesters

Description

Biodigesters are equipment used for the digestion of organic materials in urban and rural waste. The major by-products of the anaerobic digestion process are sludge[27] and biogas.

Biogas is generated by the microorganisms present in the effluent, the process of digestion of organic material in the absence of oxygen and has high methane content (CH_4).

The methane produced in the process is a gas highly harmful to the environment, it has a global warming potential 21 times greater than carbon dioxide, heavily contributing to the deterioration of the greenhouse effect and accordingly a global warming, when released directly to the atmosphere. Although methane is less than the contribution of carbon dioxide to the greenhouse effect, a specific action is more intense, or is more active in heat retention in the stratosphere. An alternative to reducing the environmental impacts caused by the emission of this gas is its flaring or your energy use (as fuel in the generation of heat, electricity or mechanical energy) converting the CH_4 to CO_2.

Besides methane, biogas has significant quantities of carbon dioxide, which is the most oxidized form of the carbon can't be burned, so decreasing the heat of the gas.

Other components which are part of the biogas are: hydrogen sulfide (H_2S) which causes the corrosion effect of decreasing both yield, as the useful life of the equipment; moisture, which affects the proper functioning of the internal parts of equipment, in addition to causing the impoverishment of calorific biogas power; and traces of siloxanes, silica compound which is directly linked to the use of cosmetics and personal care products, especially toothpaste.

In the municipalities analyzed in this study, the biogas will be used as fuel in Otto cycle engine for energy generation, as discussed in section 4.4.3. In this case, it is necessary to remove only H_2S using iron filings filters, and humidity by means of dehumidifier[28].

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[27] In the case of sewage treatment, the residual sludge wastewater treatment process is considered a semi-solid waste that requires disposal adequate, according to the National Solid Waste Policy (Law Nº 12.305/2010) (Valente, 2015), presented in Task 5.

[28] The dehumidifier cools biogas, forcing a controlled condensation of water vapor present in the gas. Thus, the humidity present in the gas is removed, preventing any irregularity in the operation of generators.

For the use of biogas in gas micro-turbine, which is not the case studied, addition of H_2S and humidity, it is also necessary to remove siloxanes by means of activated carbon filters.

They correspond to a quite old technology; already known by the Chinese and Indians, who designed it for animal manure treatment. This technology was originally used for the purpose of fertilizer production and only later on it was found the possibility of energy generation and use of biogas as a fuel. Indian (left side) and Chinese (right side) biodigesters are illustrated in Figure 30.

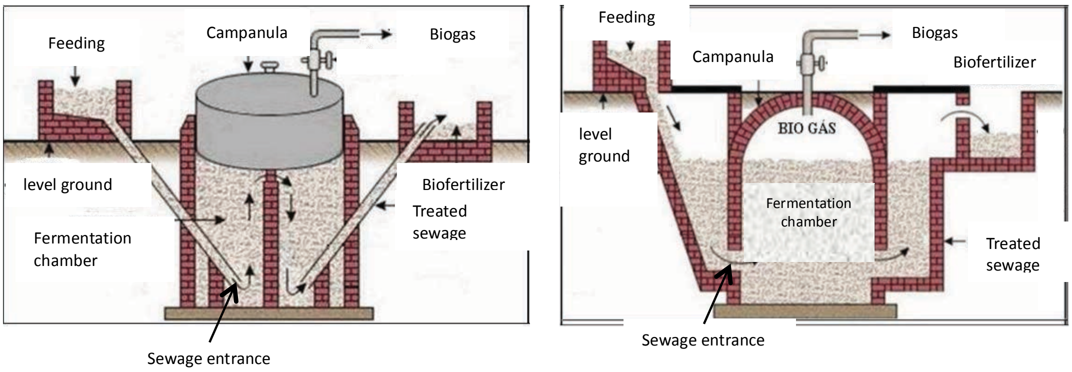

Figure 30: Indian and Chinese biodigesters. Source: (Junqueira, 2014)

The predominant technology related to anaerobic systems in Brazil is the UASB (*Up-flow Anaerobic Sludge Blanket*) (Figure 31). It is the most widespread for sewage and can also be used for the treatment of organic matter present in municipal and rural waste. This type of biodigester has a sludge layer that allows liquid to pass and removes the organic nutrients generating the gas phase.

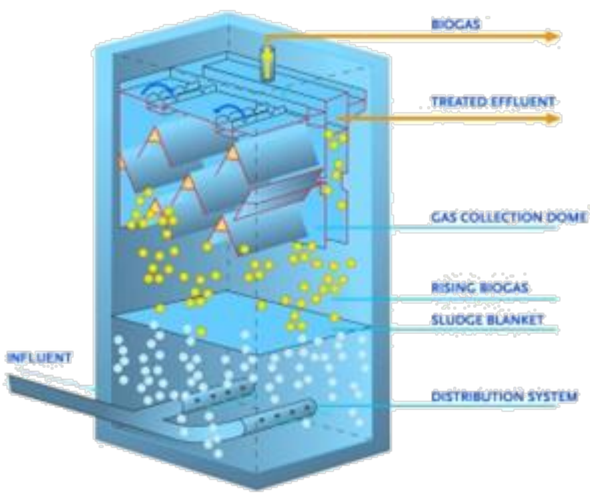

Figure 31: UASB Biodigester. Source: (PAQUES, 2013).

Sewage Treatment

This model of biodigester shown in Figure 31, in a way, revolutionized wastewater treatment area as it began to offer many advantages which until then had not as low operating cost, low power consumption and greater process stability (Hirata, Craveiro, & Soares, 1986), besides possessing high treatment efficiency. In UASB digesters, BOD reduction (Biochemical Oxygen Demand) can reach 95%, depending on the operating parameters.

This type of treatment provides an excellent removal of organic material, as well as reduction of pathogenic microorganisms. At this stage BOD reduction should reach 90% or more, depending on the type of treatment used.

Since the UASB biodigester is mostly used in Brazil, it was the model adopted for this study.

Previous experiences on implementation

The PUREFA[29] project on biogas (Rational Use of Energy Program and Alternative Sources) was developed by former National Biomass Reference Center - CENBIO[30], aiming to install a small scale system to analyze the use of biogas from university sewage for a 18 kW-electricity engine (capture, purification, storage and energy conversion) as shown in Figure 32.

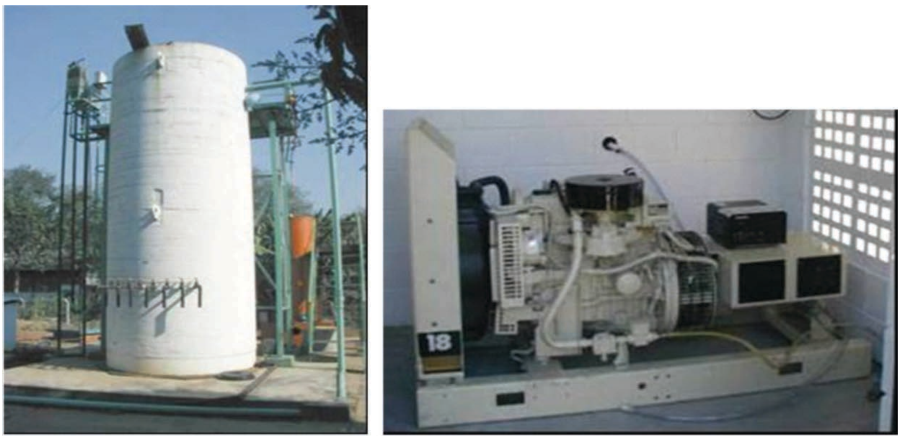

Figure 32: UASB Biodigester and Engine Cycle Otto of 18 kW. Source: (Pecora, 2006)

There are several other similar systems installed in sewage treatment stations in Brazil. The best example for this study if the Ouro Verde Sewage Treatment Station, in Foz do Iguassu municipality, Parana State, Brazil, where the biogas from an UASB reactor feeds an 18 kW engine, connected to the grid[31]

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[29] http://143.107.4.241/projetos/purefa/purefa.htm or www.iee.usp.br/gbio

[30] CENBIO has changed its name and now it is called GBio - Research Group on Bioenergy at the Institute for Energy and Environment (IEE) at the University of São Paulo (USP) www.iee.usp.br/gbio

[31] Sanepar Sewage Station http://www.temasactuales.com/temasblog/environmental-protection/generating-power-from-water-treatment-stations/

Installation and operation costs

The biodigesters are sized according to the needs of the treatment, such as wastewater characteristics to be treated (BOD, COD, etc.), local conditions, capital, and energy need of the location and availability of raw materials.

The cost of a biodigester varies according to their size and effluent to be treated. If the equipment is larger, the cost is lower in terms of BRL/m^3. For the wastewater treatment, UASB digesters cost between R $ 3,200.00 and BRL 3,600.00 by m^3 of reactor. For the treatment of wastewater with BOD = 2500 mg / l DQO = 4000 mg / l (slaughterhouses, for example), the cost can be estimated at BRL 3,600.00 to BRL 3,900.00. For more concentrated wastewater of course the relative cost will be higher[32].

Rural-animal residues

In rural areas, besides UASB biodigester, it is also possible to be used biodigester model known as covered lagoon, which uses the geometry of the anaerobic treatment lagoons to coverage order to capture the biogas generated, which can be seen in Figure 33 and Figure 34.

Covered lagoon digester is a large, in-ground, earthen or lined lagoon with a flexible or floating, gas-tight cover. Covered lagoons are used for digester feedstock of 0.5 to 2% solids. They are not heated digesters. Hydraulic retention time is usually 30 to 45 days or longer. They are best used in warning regions, where atmospheric heat can help maintain digester temperature (Chen & Neibling, 2014).

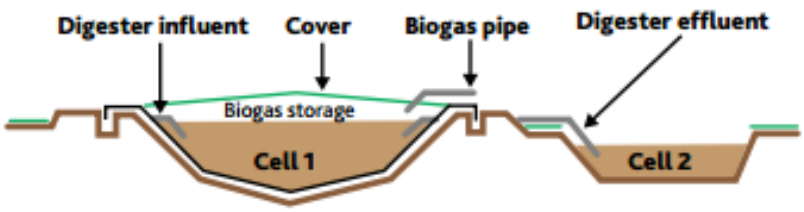

Figure 33: Covered lagoon schematic[33]

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[32] Personal information provided by Prof. Servio Tulio Cassini and Ricardo Franci of the Federal University of Espírito Santo (UFES).

[33] Source: http://www.epa.gov/agstar/anaerobic/ad101/anaerobic-digesters.html

Figure 34: Photo of Biodigester Covered Lagoon[34]

Previous experiences on implementation

A successful initiative of the use of biogas from agricultural waste is the condominium Agroenergy Ajuricaba project.

The Condominium Agroenergia for Family Agriculture - Ajuricaba is located in Rondon – Parana State. The Condominium consists of 33 small farms with swine and cattle activities.

According CIBiogas (2015), the residual biomass produced is treated in the very pro-ownership through digesters, covered or hard lagoon that produces digestate (used as bio-fertilizers) and biogas.

The biogas produced is channeled through a rural pipeline with low pressure, with 25.5 km in length, to a micro-station Thermal Power - MCT, allowing the use of 821.8 m³ / day of biogas that generates electricity by means of a motor-generator group 104 kVA or for Thermal drying grain. In addition, there is national use of biogas in 16 properties. Since August 11, 2014 the condominium operates in distributed generation (DG) to be connected to the public electricity distribution (Copel) (CIBiogás, 2015).

This experience could be replicated in the municipalities selected for this study, together with the one from Ouro Verde Sewage Treatment Station, showed above.

Installation and operation costs

In Macedo (2014), It was observed that the price of the digester decreases with increasing storage volume and tends to stabilize at a fixed price of R $ 180.00 m³. Analyzing the cost per potential production of CH4, investment to produce 1 m³ of CH_4 varies from R $ 1,500.00 to R $ 500.00, for cost biodigester is less the greater the volume and the cost of production of 1m³

[34] Source: http://www.epa.gov/agstar/anaerobic/ad101/anaerobic-digesters.html

of CH_4 is lower as greater volume and concentration of Volatile Solid (Macedo, Tavares, Belli Filho, Coldebella, & Oliveira, 2014).

Municipal Solid Waste

Description

The adequate disposal of MSW is a challenge for public management in Brazil, producing serious environmental impacts.

According to the National Basic Sanitation Survey (IBGE – Instituto Brasileiro de Geografia e Estatística, 2008), it can be realized that during the last 20 years, an optimistic outlook regarding the final and adequate disposal of waste in Brazil is far from the ideal situation (moreover in the municipalities selected for this study). Dumpsites are still the final destination of 50.8% of MSW from the municipalities of the country.

The Northeast and North regions, which correspond to this study, still report the highest shares of municipalities that present inadequate disposal, reaching values of 89.3% and 85.5%, respectively, while the South (15, 8%) and Southeast (18.7%) have the lowest shares. And finally, the allocation appropriately for landfills[35] that increased 60%, corresponds to only slightly more than a quarter of the total volume of waste generated.

Dumpsite is inadequate way to final disposal of MSW as it is characterized by simple discharge the waste on the floor without protection measures for the environment to public health[36].

As discussed in Section 3, all municipalities have inadequate disposal of MSW (dumpsites) and the possible technologies for energy recovery will be discussed. Considering the small amount of residues, this discussion will take into account the economic feasibility of each one and real perspectives to be implemented.

The energy recovery MSW by biological process occurs through anaerobic digestion process carried out in digesters, covered by one power generation plant, and even a dry recyclables removal system at the front desk of MSW[37], according to the configuration shown in Figure 35. This serves two complementary reasons. The first is that the digestion takes place in the degradable material (organic matter present in the MSW). Thus, the inclusion plastics, metals, glass, paper and cardboard in the digester, only reduce productive space inside, reducing the production of biogas for processed volume. The second and main reason is that the separation of dry

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35 Landfills are considered the most correct way of disposal of environmentally. The landfill must include waterproofing the land with geotextile to prevent slurry infiltration into the soil. There must be, too, biogas extraction system and slurry within the landfill.

36 In Dumpsites, there is no control as to the types of waste disposed of or the disposal site of the same. In such cases, household and commercial waste are low hazard deposited along with the industrial and hospital, high-polluting power. In addition there can't be other associated problems such as: the presence of animals, the presence of scavengers (which in most cases lie in the location) and polluting underground water supplies.

37 For small municipalities, as in the case of this work, removing recyclable of MSW dried (separation of non-digestible material) can be performed manually.

recyclables is one of the pillars of National Solid Waste Policy, the multiple benefits that entails for economic, social and environmental cycles (ClimatWorks, 2012)[38].

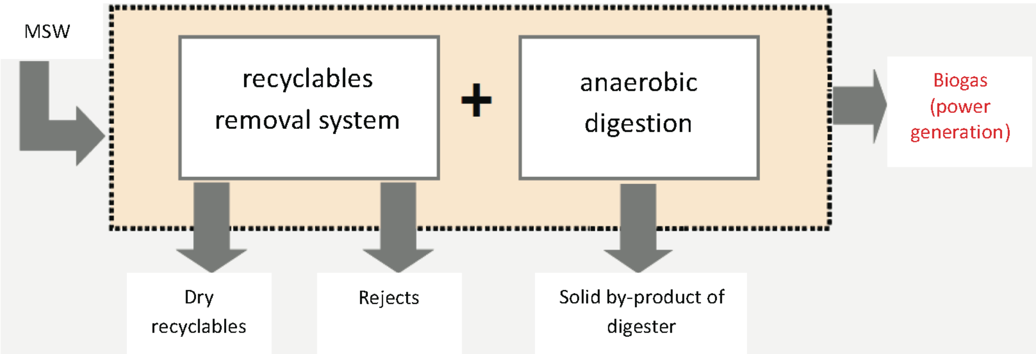

Figure 35: Anaerobic digestion of MSW through biodigester Source: Adapted from (ARCHER, 2005)

The separated organic matter in the process is sent to the biological treatment, which undergoes anaerobic decomposition in digesters to produce biogas, which can be used for energy generation, and a solid by-product and liquid. Within the digester the material is diluted to obtain the desired solids content. For dilution it may be used municipal sewage itself, as discussed in this study. The sludge formed in the digester and the treated effluent can be used as organic compost.

Previous experiences on implementation

In Brazil, until now there is no installed plant for anaerobic digestion of MSW using biodigester. In April 2004, the Municipality of Campo Grande / MS published the bidding rules for hiring a company to meet 100% of the sources of the municipality[39], with subsequent generation of electricity with an installed capacity of at least 12 MW of power to process 450 tonnes per day of waste (Caixeta, 2005). This was the first initiative for this technology in Brazil, but there is any installed plant with these characteristics.

Although there are not yet any units installed in Brazil, some equipment manufacturers already dominate the process[40].

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[38] The separated organic matter in the process is sent to the biological treatment, which undergoes anaerobic decomposition in digesters to produce biogas, which can be used for energy generation, and a solid by-product and liquid. Within the digester the material is diluted to obtain the desired solids content. For dilution may be used municipal sewage itself, as discussed in this study. The sludge formed in the digester and the treated effluent can be used as organic compost.

[39] Through concession, to provide waste collection, sorting, treatment of organic and separation of recyclable materials; electric power generation and disposal of MSW, commercial waste and health services.

[40] Process control requires intensive monitoring of operational procedures and the quality of the material that will feed the digester because the digestion process can be affected by various factors such as pH; air impermeability; water content; inoculation; organic fraction of MSW; ratio carbon / nitrogen; temperature.

Installation and operation costs

As there is not yet this type of technology implemented in Brazil, mainly in small towns, the figures shown here were taken from the document published by (ClimatWorks, 2012).

The budget for equipment with a capacity to process 510 tonnes / day[41] organic matter, it costs on average $ 60,000 per nominal tonnes of treated waste.

The biodigester operating costs were calculated from the necessary framework of human resources, consumables and supplies observed in similar facilities in the European Union. The equipment maintenance costs were largely dominated by the power generation equipment (Otto cycle engines), since the digesters are relatively simple constructions with cheap peripheral equipment and available in the Brazilian and international markets.

According to the financial analysis prepared by the study (ClimatWorks, 2012), it was considered an investment of BRL 120 million in the digestion system for processing 510 tonnes/day of organic MSW, from 1,000 tonnes daily.

The digestion system design adopted in the study includes a recyclable recovery area (capable of processing 320 tonnes per day of plastic, paper, cardboard, glass etc.), whose investment is part of the capital cost of the proposed system (BRL 32 million in BRL 120 million). This investment is dimensioned so that all recyclable dry material present in the MSW can be separated in the digestion plant, the amount of biodigesters.

Energy Use Technologies for Biogas

The biogas captured in most plants, mainly in landfills and sewage treatment plants (ETE) has not an adequate end use, as it is simply flared (sometimes to obtain carbon credits under the Kyoto Protocol)[42]. However, recently this alternative has become unaffordable for the low valuation of loans.

The benefits granted to biogas use are linked to the type of use to which it is intended.

The use of biogas for power generation[43] is done by burning in combustion systems, especially for Otto cycle engines, which still has residual heat from the exhaust gases that can be utilized as thermal energy. Otto cycle engines are easy to operate and are the equipment most commonly used to generate electricity from biogas, including because they have lower cost when compared to micro-turbines. The yield of this technology is between 28 and

[41] This value refers to 1,000 tons per day of municipal solid waste, with 51.4% organic portion MSW. Therefore, the study of (ClimatWorks, 2012) was considered 510 tonnes per day of organic matter processed in the digester.

[42] Some sewage treatment stations from SANEPAR, Parana State, feed biogas into engines instead of burning in flare (Ouro Verde, in Foz do Iguassu, in Curitiba)

[43] Biogas can be also used to generate electrical and / or thermal energy, and can be a substitute of natural gas in vehicular use. Each of these alternatives involves the use of turn in different types of biogas treatments to achieve the technical requirements for such allocation.

30%. In addition to a lower cost of implementation, the main features of these systems are (Poveda M. , 2012):

- They can be used for small and medium power demands. The powers available today in the domestic market ranging from 4 kW to 1 MW[44];
- The efficiency of internal combustion engines is not as sensitive to local environmental conditions (temperature, pressure and humidity) as the gas turbine is.
- The facilities are modular and flexible, with this time construction of a facility is short and the start-up ("start-up") is fast. In addition to being suitable for the conditions of matches and daily charts.

Currently, internal combustion engines are already prepared for burning the biogas with different levels of methane and carbon dioxide. However, as discussed previously, before feeding the engine it is mandatory to remove moisture and the H_2S present in biogas in order to prevent future corrosion[45]. It is important to note that whatever the final destination of biogas must be removed also siloxanes (when biogas is from sewage or from MSW) if they are present in biogas.[46]

In developing countries, in small towns, biogas can also be sent directly to households, to be used for cooking. This does not seem to be the case in Brazil since LPG programs contribute to make this fuel available for cooking all over the country. Anyhow this is not the main purpose of the study, which concentrates on the issue of electricity production.

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[44] Engines above 1 MW of power, which is not the case of this study, are imported. This makes the initial investment is high.

[45] For use as a fuel in vehicles it is necessary to also remove CO2

[46] To be fed into NG pipelines it is necessary to remove all material producing the so called biomethane. For the moment, ANP did not yet set standards for siloxanes from landfills and sewage treatment and so it is not yet allowed to feed biomethane from these sources into NG pipelines sought to establish the Biomethane specification contained in Regulation No 1/2015 Technical ANP, and later the development of the ANP Resolution No. 8 of 01/30/2015. ANP Resolution No. 23 of August 13, 2012). On another hand for the small municipalities analyzed here, this is not a feasible option.

Installation and operation costs

Although the Otto cycle engine is the most widely used equipment for generating electricity from biogas in Brazil, the powers available in the domestic market vary 4-264 kW. Engine power above that is imported, which ends up raising the cost of initial capital. Table 27 shows the power and costs related to the national biogas generator.

The costs presented were obtained from three national engine manufacturers Otto cycle biogas in 2010. The engines of 200 and 264 kW were rated at different manufacturers, hence the discrepancy in values.

Table 27: Power generated and costs related to the national biogas generator

Generator				
KW	**Equipment**	**Shipping and handling**	**Installation**	**Total**
4	BRL 4,500	BRL 360	BRL 900	BRL 5,760
8	BRL 11,500	BRL 920	BRL 2,300	BRL 14,720
24	BRL 107,435	BRL 8,594	BRL 21,487	BRL 137,516
40	BRL 112,725	BRL 9,018	BRL 22,545	BRL 144,288
50	BRL 120,300	BRL 9,624	BRL 24,060	BRL 153,984
56	BRL 124,875	BRL 9,990	BRL 24,975	BRL 159,840
80	BRL 152,310	BRL 12,184	BRL 30,462	BRL 194,956
100	BRL 252,100	BRL 20,168	BRL 50,420	BRL 322,688
200	BRL 540,250	BRL 43,220	BRL 108,050	BRL 691,520
264	BRL 353,545	BRL 28,283	BRL 70,709	BRL 452,537

Source: (CENBIO/IEE/USP, 2010)

5. Evaluation of the theoretical bioenergy potential to attend the local energy demand

The power demand was evaluated considering different scenarios the rates of 50-100 kWh/person.year to supply the basic needs, as discussed in Section 2. This scenario considers two sub-cases:

- The electricity supply during only 8 hours per day
- The electricity supply considering 12 hours per day

The rate of 500 kWh/person.year aims to guarantee energy for productive activities in the municipalities. In this case it was considered the electricity supply during 24 hours per day

The theoretical potentials for Brazil and Colombia were evaluated for each one of the residues and it was then summarized for each type of technology, taking into account that it would be important to use in the same plant all the residues available for each technology, aiming to benefit from the project scale.

Although the best available technologies (BAT) were presented in Section 4, this analysis considers only small-scale energy conversion technologies presented in Table 20.

5.1. Brazilian context

Table 28 summarizes the main results of the assessment of theoretical potential of biomass residues electricity production in the selected lowest HDI municipalities in the North and Northeast regions of Brazil. The check mark indicates that the theoretical potential meets the local demand.

Table 28: Theoretical potential of biomass residues for selected municipalities in Brazil

Municipality	Power demand (kW)			Treatement Technology/Instaled power (kWe)									
	8h/day	12h/day	24h/day	Biodigestion Instaled power 8h/day (kWe)	Biodigestion Instaled power 12h/day (kWe)	Biodigestion Instaled power 24h/day (kWe)	Combustion Instaled power 8h/day (kWe)	Combustion Instaled power 12h/day (kWe)	Combustion Instaled power 24h/day (kWe)	or	Gasification Instaled power 8h/day (kWe)	Gasification Instaled power 12h/day (kWe)	Gasification Instaled power 24h/day (kWe)
AFUÁ	627	1 253	2 089	✓ 747	✗ 498	✗ 249	✓ 2 986	✓ 1 990	✗ 995		✓ 4 976	✓ 3 317	✗ 1 659
AMAJARI	179	357	595	✓ 637	✓ 425	✗ 212	✓ 5 249	✓ 3 500	✓ 1 750		✓ 8 749	✓ 5 833	✓ 2 916
ANAJÁS	455	909	1 515	✗ 261	✗ 174	✗ 87	✓ 5 986	✓ 3 990	✓ 1 995		✓ 9 976	✓ 6 651	✓ 3 325
ASSUNÇÃO DO PIAUÍ	131	262	436	✓ 239	✗ 159	✗ 80	✗ -	✗ -	✗ -		✗ -	✗ -	✗ -
ATALAIA DO NORTE	294	588	980	✗ 149	✗ 99	✗ 50	✓ 853	✗ 569	✗ 284		✓ 1 421	✓ 948	✗ 474
BAGRE	457	913	1 522	✗ 153	✗ 102	✗ 51	✓ 1 347	✗ 898	✗ 449		✓ 2 245	✓ 1 496	✗ 748
BETÂNIA DO PIAUÍ	104	208	347	✓ 187	✗ 125	✗ 62	✗ 66	✗ 44	✗ 22		✓ 110	✗ 73	✗ 37
CACHOEIRA DO PIRIÁ	506	1 011	1 686	✓ 1 447	✗ 965	✗ 482	✗ 476	✗ 317	✗ 159		✓ 793	✗ 529	✗ 264
CAXINGÓ	89	179	298	✓ 175	✗ 117	✗ 58	✗ 77	✗ 52	✗ 26		✓ 129	✗ 86	✗ 43
CHAVES	377	754	1 257	✓ 1 287	✓ 858	✗ 429	✗ 116	✗ 77	✗ 39		✗ 194	✗ 129	✗ 65
COCAL	467	934	1 557	✓ 2 100	✓ 1 400	✗ 700	✗ 458	✗ 305	✗ 153		✓ 763	✗ 508	✗ 254
COCAL DOS ALVES	97	194	324	✓ 1 466	✓ 978	✓ 489	✓ 116	✗ 78	✗ 39		✓ 194	✗ 129	✗ 65
FERNANDO FALCÃO	168	335	558	✓ 414	✗ 276	✗ 138	✓ 217	✗ 145	✗ 72		✓ 362	✗ 242	✗ 121
INHAPI	317	634	1 057	✓ 598	✗ 399	✗ 199	✗ 19	✗ 13	✗ 6		✗ 32	✗ 21	✗ 11
IPIXUNA	317	634	1 057	✓ 410	✗ 273	✗ 137	✓ 16 206	✓ 10 804	✓ 5 402		✓ 27 010	✓ 18 007	✓ 9 003
IPIXUNA DO PARÁ	935	1 870	3 117	✓ 2 009	✗ 1 339	✗ 670	✓ 12 050	✓ 8 034	✓ 4 017	or	✓ 20 084	✓ 13 389	✓ 6 695
ITAMARATI	141	282	470	✓ 91	✗ 61	✗ 30	✓ 120	✗ 80	✗ 40		✓ 201	✗ 134	✗ 67
ITAPICURU	604	1 207	2 012	✓ 30 276	✓ 20 184	✓ 10 092	✗ 62	✗ 41	✗ 21		✗ 103	✗ 69	✗ 34
JENIPAPO DOS VIEIRAS	272	544	907	✓ 1 413	✓ 942	✗ 471	✗ 266	✗ 177	✗ 89		✓ 443	✗ 295	✗ 148
JORDÃO	122	245	408	✓ 155	✗ 103	✗ 52	✗ 95	✗ 63	✗ 32		✓ 158	✗ 106	✗ 53
MANARI	339	678	1 129	✓ 541	✗ 361	✗ 180	✗ 140	✗ 93	✗ 47		✗ 233	✗ 156	✗ 78
MARAÃ	314	627	1 045	✗ 155	✗ 103	✗ 52	✗ 143	✗ 95	✗ 48		✗ 238	✗ 159	✗ 79
MARAJÁ DO SENA	132	264	441	✓ 329	✗ 219	✗ 110	✓ 344	✗ 229	✗ 115		✓ 573	✓ 382	✗ 191
MELGAÇO	443	886	1 476	✗ 113	✗ 75	✗ 38	✓ 87 888	✓ 58 592	✓ 29 296		✓ 146 480	✓ 97 653	✓ 48 827
OLIVENÇA	199	397	662	✓ 542	✗ 361	✗ 181	✗ 8	✗ 5	✗ 3		✗ 2	✗ 1	✗ 1
PAUINI	328	656	1 093	✓ 469	✗ 313	✗ 156	✗ 74	✗ 49	✗ 25		✗ 123	✗ 82	✗ 41
PORTEL	961	1 921	3 202	✗ 619	✗ 413	✗ 206	✓ 161 212	✓ 107 475	✓ 53 737		✓ 268 686	✓ 179 124	✓ 89 562
SANTA ISABEL DO RIO NEGRO	359	719	1 198	✗ 205	✗ 137	✗ 68	✗ 1	✗ 1	✗ 0		✗ 1	✗ 1	✗ 0
SANTO ANTÔNIO DO IÇÁ	417	833	1 389	✗ 91	✗ 61	✗ 30	✗ 295	✗ 197	✗ 98		✓ 492	✗ 328	✗ 164
SÃO FRANCISCO DE ASSIS DO PIAUÍ	98	196	327	✓ 267	✗ 178	✗ 89	✗ 1	✗ 1	✗ 0		✗ 1	✗ 1	✗ 0
SATUBINHA	222	444	740	✓ 249	✗ 166	✗ 83	✗ 42	✗ 28	✗ 14		✗ 71	✗ 47	✗ 24

Based on the results presented in Table 28 for the Brazilian context, it is important to make the following considerations, as ahead: biodigestion, combustion, and gasification.

I. Theoretical energy potential for organic residues through biodigestion

For this technology the following residues were taken into account

- Organic matter from MSW – considering that there would be a (mechanical or manual) separation of the MSW collected[47] and the organic portion would be fed into the biodigester to produce biogas that would feed an engine to produce electricity
- Liquid effluents – considering that the liquid effluents would have adequate treatment[48] and the biogas produced would feed an engine to produce electricity
- Agricultural and animal residues – considering that all residues (available and potentially available) to feed the biodigestion

The residues show that in some municipalities there may be a significant energy production from biogas, such as Cachoeira do Piria (banana residues), Chaves and Jenipapo dos Vieiras (cattle), Cocal and Cocal dos Alves (cashew nuts), Itapicuru (orange[49]).

II. Combustion and gasification

Solid residues from agricultural and wood residues were evaluated taking into account two options: combustion or gasification system.

The definition of the best technology (combustion or gasification) for each municipality depends upon a next analytical step, in which a field assessment addressed the location of the residues since the desk review could not find relevant information on this topic. Considering the dispersion of biomass residues and the amount available in each location, the more adequate technology was selected, as follow:

- For residue availability able to produce up to 200 kWe, the technology recommended is a small-scale biomass gasification plant.
- For residue availability able to produce values higher than 200 KWe, the technology recommended is steam cycles.

[47] Initially two scenarios were considered: the current situation where only partial collection of MSW is treated; the optimistic scenario where all the MSW would be collected and treated. In a second phase it was considered the first scenario as a conservative approach.
[48] Similarly to MSW, two scenarios were considered to sewage. The current situation, in which occurs partial collection of sewage that is treated. The optimistic scenario considers that all sewage would be collected and treated. In a second phase it was considered the first scenario as a conservative approach.
[49] The municipality of Itapicuru is already one of the biggest producers of orange production in the Bahia State. Due to its high production, there is a plan of installing an industry for orange processing (http://paginarural.com.br/noticias_detalhes).

Therefore, the theoretical potential was evaluated for both technologies, taking into account the corresponding energy conversion factor based on existing systems already installed in Brazil and abroad.

Some municipalities have presented a high theoretical potential. For example, Ipixuna, Ipixuna do Pará, Melgaço, and Portel. These high values are due to the fact of residues from sawmills and existing forests.

In the cases of Melgaço and Portel these values are higher because of the wood residues potential based not only on residual potential of sawmills but also on the National Concession of Public Forests (CNFP) and the Central Area of Sawnwooden (MPM).

In fact, there is a large wooden residual potential from the sustainable management of forests in the Brazilian Amazon: 1 m^3 of wood removed for logging in Amazon generates up to 5 m^3 of wood (if considered only the *CNFP*). Big companies of the timber industry in the Amazon take advantage of this potential for sustainable charcoal production. Then, the surplus can be used to increase access to energy in communities with low HDI in the region.

The municipalities of Portel and Melaço, located in the Pará State, that have HDI lower than 0.5, are situated in the Caxiuanã National Forest, which is a National Concession of Public Forests (POAP). Since the Federal Government in 2015 offered the concession of 322,000 hectares for a management plan, in which 184,000 hectares was approved for sustainable forest management that represents a potential to produce an average of 566,000 tonnes of wood residues per year.

The wood residues generated in the Sustainable Forest Management Plan (PMFS) could generate energy in small steam cycles (with a 12% yield), producing approximately 253,000 MWh/year for the two municipalities. This would correspond to an installed power of 28 MW, without considering sawmill residues.

Table 29: Theoretical potential of Melgaço and Portel

Residue	Residue (ton/year)	Treatement Technology	Methane production (m3/year)	Conversion Efficiency (kWhe/ton)	Power generation (kWhe/year)	Instaled power 8h/day (kWe)	Instaled power 12h/day (kWe)	Instaled power 24h/day (kWe)
Portel e Melgaço	565783,0	Combustion	N.A.	445,9	252263780,3	86391,7	57594,5	28797,2

We can also observe that the municipality of Amajari in Roraima and Ipixuna do Pará in Pará, is near the *Central Area of Sawnwooden*, characteristic that enhances access to the sawmill residues.

5.2. Colombian context

Table 30 summarizes the main results of the assessment of theoretical potential of biomass residues electricity production in the selected lowest HDI municipalities located in non-interconnected areas in Colombia. The check mark indicates that the theoretical potential meets the local demand.

Table 30: Theoretical potential of biomass residues for selected municipalities in Colombia

Municipality	Power demand (kW)			Treatement Technology/Instaled power (kWe)										Actual diesel-based installed power generation (kW)	Possible diesel sustitution (%)[1]
	8h/day	12h/day	24h/day	Biodigestion			Combustion			or	Gasification				
				Installed power 8h/day	Installed power	Installed power	Installed power 8h/day	Installed power	Installed power		Installed power 8h/day	Installed power	Instaled power		
La Primavera	254	507	845	✓ 854	✓ 569	✓ 285	✓ 896	✓ 598	✓ 299		✗ 69	✗ 46	✗ 23	1.400	60
Cumaribo	616	1.233	2.055	✓ 1.157	✓ 771	✗ 386	✓ 2.726	✓ 1.817	✓ 909		✗ 209	✗ 139	✗ 70	1.000	205
Puerto Carreño	265	531	885	✓ 411	✓ 274	✗ 137	✓ 519	✓ 346	✗ 173		✗ 40	✗ 27	✗ 13	5.750	15
Mosquera	271	541	902	✓ 2.326	✓ 1.551	✓ 775	✓ 18.050	✓ 12.033	✓ 6.017		✓ 5.312	✓ 3.541	✓ 1.771	800	113
La Tola	207	413	689	✓ 811	✓ 540	✓ 270	✓ 4.681	✓ 3.121	✓ 1.560		✓ 1.377	✓ 918	✓ 459	730	94
Solano	397	795	1.325	✓ 9.709	✓ 6.473	✓ 3.236	✓ 21.207	✓ 14.138	✓ 7.069		✓ 2.121	✓ 1.414	✓ 707	400	331
Mitú	535	1.071	1.785	✓ 887	✓ 591	✗ 296	✗ 36	✗ 24	✗ 12		✗ 29	✗ 19	✗ 10	1.500	119
Taraira	17	34	56	✓ 161	✓ 107	✓ 54	✓ 18	✗ 12	✗ 6	or	✗ 12	✗ 8	✗ 4	1.500	4
Guapi	508	1.015	1.692	✓ 2.701	✓ 1.801	✓ 900	✓ 1.503	✓ 1.002	✗ 501		✓ 1.127	✓ 751	✗ 376	2.300	74
Timbiquí	368	736	1.227	✓ 1.858	✓ 1.238	✓ 619	✓ 1.017	✓ 678	✗ 339		✓ 762	✓ 508	✗ 254	825	149
Juradó	57	115	191	✓ 1.756	✓ 1.171	✓ 585	✓ 4.133	✓ 2.755	✓ 1.378		✓ 3.212	✓ 2.141	✓ 1.071	360	53
Unguía	258	516	861	✓ 1.361	✓ 908	✓ 454	✓ 3.966	✓ 2.644	✓ 1.322		✓ 3.105	✓ 2.070	✓ 1.035	760	113
Inírida	336	673	1.121	✓ 633	✓ 422	✗ 211	✗ 60	✗ 40	✗ 20		✗ 44	✗ 29	✗ 15	3.777	30
Puerto Nariño	138	275	459	✓ 174	✗ 116	✗ 58	✗ 23	✗ 15	✗ 8		✗ 19	✗ 13	✗ 6	482	95
Leticia	702	1.404	2.340	✓ 871	✗ 581	✗ 290	✗ 72	✗ 48	✗ 24		✗ 60	✗ 40	✗ 20	19.303	12

[1]*Estimated as percentage of actual diesel-based power generation installed capacity; assuming electricity is supplied 12 hours per day and 500 kWh/person-year to guarantee energy for productive activities in the municipalities.*

Based on results presented in Table 28, particular considerations for biodigestion, combustion, and gasification technologies are described below.

I. Theoretical energy potential for organic residues through biodigestion

The theoretical energy potential estimate for biodigestion technology includes biomass from agriculture and animal residues, and solid waste residues. While agriculture residues with potential to generate biogas consider cassava and plantain (rejected fruit), animal residues consider livestock (cattle manure). In many of the selected municipalities the development plan already considers the construction of landfill sites for final disposal of solid waste. For this reason, this study considers organic matter from municipal solid waste as a potential source for power generation.

Results in Table 30, show that in all the municipalities there is significant potential for power generation from biogas, which would be enough to cover their power needs on an 8h-day basis. On the one hand, it is important to mention that the potential for biogas production from agriculture residues could be overestimated due to lack of information at municipal level[50]. Estimates presented in this study correspond to approximations, based on agriculture residues produced at department level. On the other hand, estimates for biogas production from cattle manure are more accurate as the information is available at municipal level (FEDEGAN, 2015).

The theoretical potential was estimated considering efficiency factors available in literature (Mebarki et al., 2015;Payán, Leal, & Gil, 2014; Lantz, 2012; Eurelectric/VGB, 2003; González- Salazar et al., 2014).

II. Combustion and gasification

Agricultural and wood residues potential for power generation was estimated considering combustion and gasification technologies. For the purpose of this study the volume of wood residues was estimated based on legally traded wood volume. Logging industry is not as developed in Colombia as it is in Brazil and exploitation of wood resources is often uncontrolled. As a result, the estimated potential could vary, as some of the traded volume is not reported to official institutions. Yet, based on the national statistics, this source has the potential to at least partially cover energy needs in most of the municipalities. It is important to keep in mind that some restrictions are imposed to wood trade, particularly in the Amazon region where, despite a significant availability of the resource, it cannot be fully exploited. This situation is clearly reflected in potential estimated for Puerto Nariño and Leticia where neither combustion nor gasification technologies seem to be appropriated. In addition, the main economic activity in these municipalities

[50] This can explain the high values for biogas production in municipalities such as Solano, Mosquera, and Guapi, where agriculture residues are the main source for biogas production.

is subsistence agriculture that does not provide enough residues to generate the required power.

In other municipalities with a higher wood residues production such as those located in Chocó, the estimation provides important information about possible technologies to be implemented. However, neither this estimate nor the estimative for agriculture residues indicate the level of dispersion of these residues. This analysis assumes in a first approach, that these residues are suitable for power generation either through a dedicated steam cycle or through CHP systems, depending on the residue availability. Results are shown in the column “Combustion” of Table 30. The column “Gasification” considers small-scale biomass gasifiers for wood residues and rice husks. The theoretical potential was evaluated for both technologies, considering typical efficiency figures for power generation from biomass available in literature (IEA, 2007).

Estimates for residual biomass potential for power generation in municipalities such as Solano and Mosquera are particularly high. The main potential resides in wood and sugar cane. Once again, these values can be overestimated due to approximations made from department information. In contrast, potential estimated for Mitú is very low. Most of the territory in Mitú corresponds to virgin jungle and forest with a vast biodiversity that is protected by law. Less than 1% (about 4 km^2) of the municipality is dedicated to urban areas. Despite being surrounded by forest, which could be sustainably exploited, Mitú’s economy evolves around commerce and service activities. The municipality has also been deeply affected by actions from drug dealers and guerrillas who have also prevented further development.

Table 30 also shows the potential of residual biomass to substitute diesel-based power generation. In some municipalities, the resource is enough not only to displace diesel technologies but also to expand electricity services. Such is the case of Cumaribo, Mitú, Mosquera, and Solano. Our estimates in this study indicate a theoretical potential of about 2,700 TJ in selected municipalities. That is, about 0.6% of the national potential resides in these municipalities. This potential could lead to an installed capacity of about 50 MW, enough to displace actual installed capacity in selected municipalities. Yet, there are still important barriers to overcome when it comes to providing the service to inhabitants of non-interconnected and low HDI areas. In spite of new rules and models, and a clear interest for harmonizing technologies with the regional context, there is agreement among bioenergy experts on the fact that “a long-term vision, a strategic plan, and a sustainable scheme to deploy bioenergy in Colombia are missing” (González-Salazar, Venturini, Poganietz, Finkenrath, Kirsten, & Acevedo, 2014b).

III. Conversion technologies

Biodigestion

There are local technologies for digesters manufacturing, for different types of organic residues but biogas engines are imported.

Combustion

Small-scale steam turbines are produced in Brazil and exported to Colombia. Therefore, there is a local availability in Latin America, supplied by Brazilian manufacturers, as mentioned above

Gasification

Gasification systems are still new in Colombia and only a small scale Indian biomass gasifier was installed in a pilot plant in Colombia, later on deactivated. Therefore, for biomass gasification the nearest supply would be Carbogas Co. from São Paulo, Brazil.

6. Interview with stakeholders

All the selected municipalities have shown socioeconomic backwardness, which impacts various aspects of quality of life in these places. One aspect is that governmental body has low education level when compared to other developed regions of Brazil and Colombia.

In fact, most of municipalities do not have their own websites. Therefore, most of the information was gathered through State or Federal databases.

These municipalities differ in everyday reality and suffer from isolation, such as the ones located in the Amazon region, rudimentary infrastructure for transport and difficulty to access governmental services.

There are also municipalities, with better electricity distribution, such as the ones located in Northeast region of Brazil and few Colombian municipalities. However, inhabitants of these rural areas still lack access to energy. In addition, all municipalities present conditions of extreme poverty with infrastructure problems and low education levels.

In this context, this study managed to contact local stakeholders to valid the information gathered through desk review.

In Brazil, all municipalities were contacted but only two of them mentioned initiative strictly related to MSW and nothing else. The first was the Chaves Municipality, which mentioned a modest recycling initiative, and the second was the Amajari Municipality, which is preparing a public consortium to build a landfill. All interviewees had willingness to answer the question but they lack technical knowledge and, in some case, they sound suspicious and intimidate to answer questions.

There were also interviews with specialists and utility companies; Table 31 presents the list of stakeholders:

Table 31: Stakeholders interviewed in Brazil

Name	Title	Additional Information
Hugo Machado	Heaf of Special Operations Department of Companhia de Eletricidade do Estado da Bahia (COELBA)	In charge of rural electrification in COELBA
Silvano Ragno	Under-Secretary of Infrastructure of State of Bahia	In charge of Energy and Transportation
Daniel Sarmento	Head of Division of Energy Eficiency and solar energy of Companhia Energética de Pernambuco	Presented the electrification cost in Pernanbuco
Nilson Sarti	President of Enviroment Commission of Brazilian Chamber of Construction Industry	Presented information about sustainable cities and constructions
Juliano Matos	Director of Regulation and Institutional Relations of Global Participações	Global makes investments on thermal plants for power generation
Manuel Mendonça	Secretary of Science, Technology and Innovation of Bahia	He considers that top priorities for S&T in Bahia is Wind energy and information technology
Municipality Staff	Municipality of Ipixuna do Pará	
Municipality Staff	Municipality of Amajari	
Municipality Staff	Municipality of Olivença	
Municipality Staff	Municipality of Chaves	
Municipality Staff	Municipality of Caxingó	
Municipality Staff	Municipality of Portel	

The interviews in Brazil presented the following information presented in Table 32.

Table 32: Key findings during interviews in Brazil

Municipality	Additional Information
Municipality of Ipixuna do Pará	There is not Waste Management Plan, actually use dumpsite Actual Source Energy: Diesel engine generator Opportunities: Forest preservation maintenance; Use biodigester; Development of the productive chain agriculture Recycling
Municipality of Amajari	There is not Waste Management Plan, actually use dumpsite; Forecast landfill Actual Source Energy: Diesel engine generator Features: Extractive Reserve and National Forest Opportunities: Ecological Tourism; Forest preservation maintenance; Use biodigester; Development of the productive chain agriculture
Municipality of Olivença	There is not Waste Management Plan, actually use dump Actual Source Energy: No data available Features: Agriculture and livestock Opportunities: Use biodigester; Development of the productive chain agriculture
Municipality of Chaves	Use dump, but there is an Recycling Initiative Actual Source Energy: Diesel engine generator; Isolated areas without access energy (possibility) Features: Problem to access isolated areas; Access Problem (structural); Problem Access Energy in Rural Area Opportunities: Use biodigester; Development of the productive chain agriculture
Municipality of Caxingó	There is not Waste Management Plan, actually use dump Actual Source Energy: Hydropower energy Features: Agriculture Opportunities: Use biodigester; Development of the productive chain agriculture
Municipality of Portel	Use Dump Actual Source Energy: Hydropower energy Isolated areas without access energy (possibility) Features: Problem access isolated areas; Access Problem (structural) Opportunities: Use biodigester; Development of the productive chain agriculture

In Colombia, besides quantitative data sources, this study considered a variety of qualitative data including an extensive literature review, and the collection of evidence in the form of semi-structured interviews. Even though interviews with communities or their representatives where difficult to achieve, semi-structured interviews with representatives from the governmental institutions were a useful tool to obtain information on conditions surrounding rural and remote communities (See Table 32).

Table 33: Stakeholders interviewed in Colombia

<table>
<tr><th>Name</th><th>Title</th><th>Additional Information</th></tr>
<tr><td>Mauricio Molina</td><td>Especialized Professional. Planning. Sub-Direction National Planning Institute for non-Interconnected Areas – IPSE</td><td>Discussion on available technologies for electricity provision in non.interconnected areas.</td></tr>
<tr><td>Sandra Molina</td><td>Especialized Professional.. National Mining Energy Planning Unit – UPME</td><td rowspan="2">Discussion on residual biomass potential and status of residual biomass atlas</td></tr>
<tr><td>Carlos Valles</td><td>Especialized Professional. National Mining Energy Planning Unit – UPME</td></tr>
</table>

A first interview with Mauricio Molina, from the National Planning Institute for non-Interconnected Areas (IPSE), provided understanding on available biomass-based technologies in non-interconnected areas. According to Mr. Molina, there is only one gasification system in Antioquia. It was built and operated by IPSE with support from National University. The system used wood as fuel. The cost of the system was about USD 615.000 and today it is not operative. There is a PV-system in San Vicente del Caguán that provides electricity to about 100 families. In summary, biomass-based technologies do not exist today in non-interconnected areas and the main barrier for their implementation is related to costs. The idea is to provide electricity with a price lower than that offered by diesel-based electricity (about $1300/kWh).

A second interview with Sandra Molina and Carlos Valles, from the National Mining Energy Planning Unit – UPME, provided information on current research about residual biomass. According to UPME representatives, data is currently being disaggregated so that information at municipal level can be used for more accurate definitions of potential. Interviews at UPME also provided information on existing plans for improvement of actual supply models in non-interconnected areas. These plans consider new agents and a new model to promote productive activities in rural and isolated areas.

7. Policy context in Brazil and Colombia

7.1. Barriers against the increase of energy access in Brazil and for the use of biomass residues for energy production in North and Northeast municipalities

To discuss the Brazilian programs for electricity access, we must distinguish between the Interlinked (ILS) and the Isolated Systems (IS) in which the Brazilian electric system is divided. In the ILS, all electric power plants are connected through long transmission lines from Southern to Northern Brazil, mainly along the coast; the IS, in North region (Brazilian Amazonia), is composed mostly by small thermoelectric power plants (diesel engines with difficulties on logistic for diesel supply through rivers in the rain forest). This region covers an area corresponding to 45% of Brazilian territory and 3% of the population (around 1.2 million consumers)

We will discuss each situation separately in this section.

Considering that the two regions selected in this study (N and NE) belong to these two different systems (North region corresponds to the IS and the NE region belongs to the ILS), the discussion of the barriers will address each one separately.

I. Interlinked system – Challenges for the future of universalization

As discussed in Coelho and Goldemberg, 2013, in 2003, the LPT (*Luz para Todos* – Lighting for All) program was established by the Federal Government, with the aim of providing free electricity access for 10 million people in rural areas in Brazil by 2008. It has defined that "energy must be the way for social and economic development, contributing to poverty alleviation and increase the families revenues". In 2011, a new phase was established for the period 2011-2014 since the Census 2010 from IBGE (IBGE, 2010) has realized that there were still households without electricity access mainly in Northern and Northeastern regions.

According to the program, utilities were obliged to provide electricity access for free when required by the consumer (otherwise they have to inform deadlines to provide the access) (ANEEL, 2010).

This Program is coordinated by the Ministry of Mines and Energy, implemented by Eletrobras (the holding company of the Brazilian electric sector) and executed by the utilities and rural co-operatives. For meeting the initial goal, R$ 20 billion (around US$ 10 billion, Nov 2011) was invested, being almost 70% from Federal Government. The assessment of electric exclusion in the country showed that the families with no energy access are mostly low-income families, in locations with a low Human Development Index - HDI (MME, 2010, MME, 2011)

According to the Household Census of 2010 accomplished by the Federal Government (IBGE, 2010), Brazil has achieved the level of 98.73% of universalization of electric power access in urban and rural areas (in the interlinked system), compared to 74.90% in 1981 and 94.54% in year 2000.

The situation in rural areas also shows an important increase in electricity access when compared to year 2000 (92.6% in 2010 against 71.0% in 2000). However it must be considered that the figures shown by the statistics do not include remote villages in Amazonian region, discussed in the next section.

However, as discussed by Pereira (2015), the challenge of ensuring universal electric service is still far from complete. More than 280,000 households still did not have electric lighting, according to the National Household Survey 2013 (PNAD 2013), reflecting the position of the end of 2012. However, these numbers, as previously shown when the Luz no Campo was designed using the 2000 Census, are certainly underestimated. They do not coincide with the records of the concessionaires, other instrument authorized by ANEEL (The Brazilian Regulatory Agency for Electric Energy[51]) to enable the development of new universal plans of the concessionaires. It notes that the IBGE´s[52] concept of electric lighting does not necessarily coincide with the concept of electrified domicile, recognized for universalization effect by ANEEL.

Taking just for example purposes the case of Bahia State[53] (Northeast region), according to PNAD 2012, the state has with the second largest number of households without electric lighting, with 88,000 households. The agreement signed between COELBA and the LPT Program for implementation by the end of the Program, will install between 2011 and 2014 of 128 thousand new connections. However, the registration of the utility accounts for more than 200,000 households to be electrified. With the extinction of LPT, originally forecast for 2014, the new horizon of universal access would for at least another ten years. Extrapolating these figures to the country, one would assume that the electrical exclusion could overcome one million households. By the end of 2014, the LPT Program was extended up to 2018.

However, the reduction of the charges proposed under Provisional Measure 579/2012, which deals with the renewal of concessions for the Electric Sector, the possibilities of anticipating the universalization moved away. The levy on ratepayers to feed the fund (CDE), which used to supported rural electrification, has been alleviated. Among the dilemma of a higher rate and the universal access, the electricity sector opts for the first option, which, however, should not be mutually exclusive, as the national treasure as well as state treasures could provide the means to achieve this. However, currently fiscal situation of the country, with huge cuts in the national and state budgets do not allow this alternation. Again, as an example, the Bahia state

[51] www.aneel.gov.br
[52] Instituto Brasileiro de Geografia e Estatistica - Brazilian Geography and Statistics Institute
[53] Where are some of the low HDI municipalities selected in this study.

estimated resources in the range of four billion BRL (US$ 1.3 billion) in order to provide universal access to the state, a horizon of just over ten years.

Study by Campbell (2010) concluded that, with the end of LPT, electrical exclusion would return to rural areas, considering that:

- According to current legislation, utilities are only required to bring the network up to the limit of land ownership with the public road, and the additional costs are borne by the consumer. The Program ensures the supply to the home, and two lamps and three outlets. In this way, households within farms should be no access given the costs of carrying limit of the energy property to the interior of house.
- According to the Ministry of Mines and Energy, 60% of beneficiaries of the program were families with income less than minimum wage, consequently unable to afford the costs of network extension to his house.
- Most remote and isolated locations, as is the case in many areas of the Amazon region, require the creation of small power plants to meet their demands because they cannot be interconnected to the grid.

These two situations are exactly those of the two regions where the municipalities of lowest HDI were selected for this study

Despite the extension of the Program, it is not clear whether the funds will be assured to its implementation. Another 228 thousand families will access power services in the new horizon, according to the government.

Other difficulties overlap with this scenario. One is the accounting operation and maintenance costs of the new universalized areas, which tend to impose burdens on local fare or in the case of its non-recognition by the regulatory agency, a tendency to postpone the goal. An alternative that could certainly contribute to minimizing the impact on the level of resources needed is the use of individual generation systems (SIGFIs), already regulated since 2004, or isolated micro-generation and distribution systems (MIGFIs), regulated in 2012, which can use diesel, biomass residues or hybrid systems. However, due the lack of urgency to fulfill universal access requirement they have been little encouraged, their benefits have little recognition, so they have a use enough reduced in the country.

With the most recent fall of the costs of PV modules, they could be used on a larger scale, particularly with the possibility of being subsequently incorporated into the system as micro and mini-generation units. The option has been little encouraged by LPT, especially because utilities tend to install smaller systems, which do not attire new consumers. On the other side, they are discouraged to the extent that the accounting of the physical progress of universalization not found ways to take them into account. One possible solution would be to count the kilometers avoided networks and not only built and placed the poles.

A particularly big challenge is universal access in the North that despite accounting for over 40% of not electrified households, it received less than

20% of new connections, difficulty strengthened by the dispersion of areas and the situation of regional power concessionaires, which are owned by federal government, living dire financial straits.

Thus, the challenge to universalize endures, and is something that permeates the entire society, with a role for government, providing resources, and the regulatory agency finding ways to encourage the minimization of resources to be allocated and the impact on future rates and allow concluding the second decade of this century, all Brazilians already have access to electricity.

II. Isolated System

As discussed above, the Brazilian rural electrification initiative LPT Program has proved effective in pursuing electricity access during its first phase, mainly characterized by three attributes. First, the recognition of electricity access as a civil right defined the basis for electrification goals in Brazil. Second, the recognition of the role that electricity access plays in addressing and achieving human development goals has been important for the mobilization of political will and definition of policies to promote full coverage at national and regional level. Third, a grid-extension approach has been central to the achievement of electrification goals. Unfortunately, LPT has not been equally successful all over the national territory. New challenges have emerged as the grid reached its physical and economic limits, and grid-extension became more difficult and at some point, unfeasible in very remote areas.

The Brazilian government incorporated a new set of rules within the existing LPT framework addressing the design, implementation, and operation of off-grid power generation. In terms of institutional structures, the rules incorporated new agents into the process through a procurement model. In terms of technology, the scheme has added renewable and hybrid systems to the traditional diesel-based systems. In relation to funding structures, the new set of rules includes capital, operation, and consumption subsidies. As a result, the new scheme has the potential to increase clean electricity access, promote renewable energy technologies, and reduce CO_2 emissions in remote areas (Coelho et al, 2014).

However, questions remain in connection with the operationalization of the new scheme especially because it is not clear how new agents are going to interact with communities nor how the appropriate technologies will be delivered and operated to guarantee not only energy access but also a reliable electricity provision. In this sense, new rules are important but not enough to achieve universalization goals in the Amazon region.

Important remaining challenges come to providing the service to inhabitants of remote areas:

- Adapting the existing institutional structures;
- Harmonizing technologies with the regional context, and
- A more effective use of government funds.

A new model, in which local institutions and communities are better placed to share their knowledge, will be useful for the purpose of designing, implementing and operating effective off-grid solutions that can support not only the achievement of universal electricity access in the region but also help to identify synergies among electricity access and development initiatives. The role of the government at central and local levels will be decisive but needs to be complemented with contributions from other agents, especially the role of community based organizations in operationalizing the new rules.

7.2. Barriers and potential policies to scaling-up of energy use of biomass residues in small municipalities

The main advantages of biomass residues energy conversion are related to emissions avoided from diesel engines through the generation of energy from renewable sources, the adequate use of residues (previously disposed in an inadequate way or burned in open air), the increase in the energy access in areas without access and the reduction of energy demand from local utilities in regions where there is already energy access. However, as discussed here, there are still several barriers against the use of biomass residues in these municipalities to increase energy access. These barriers are discussed here and the discussion is followed by the proposal of policies to reduce them.

I. Urban residues (MSW)

The allocation of MSW is now a challenge for public management in Brazil, moreover in small municipalities.

According to a survey by ABELPE (2013), although 99.8% of the municipalities have waste collection services, only 62% is a selective collection and 28% waste is disposed in precarious and inadequate landfills (dumps). In the North and Northeast the selective collection percentage is 49.5% and 40% respectively. On the other side, 55% and 47% of waste is disposed in those precarious landfills. To reverse this situation is a priority, both for environmental impacts and for the costs of disposal and MSW storage.

Under the new guidelines introduced by Law 12,305 / 2010, which established the National Policy on Solid Waste (Política Nacional de Resíduos Sólidos - PNRS) is the energy recovery and the possibility of the municipalities to join in partnership to enable and optimize the landfill project costs according to the parameters set by the new legislation. Although its implementation has been delayed, this is indeed a priority for the country.

An important aspect of the Act mentioned above is the prohibition of MSW disposal *in natura* in any kind of precarious landfill from 2014. The postponement of the entry into force of the law constitutes a barrier to the urgency of solving the problem of MSW. The main difficulty arises from the demand for investments in the works for installation of waste treatment systems, under the direct responsibility of the municipality and resources for enforcement actions.

Hiring collection service, storage, transport, treatment and disposal of solid waste are the responsibility of municipal governments, as well as damage that may be caused by inadequate management of them. Thus, the municipality also started having to pay for any damage to the environment or to third parties by the waste disposal process generated on its territory, although the new regulations introduce the concept of shared responsibility, which makes all members of the production and consumption chain as supportive as the post-consumer stage.

Municipal governments usually do the collection, but the final disposal is still a problem for most of them that cannot afford the capital investment to implement the landfills, and there is usually not enough scale to motivate a possible concessionaire to explore the energy use of RSU. As mentioned above, the situation is more serious in the North and Northeast regions.

The energy conversion of MSW also includes the recycling of the material collected as paper and cardboard, glass, plastics, rubber and metals, which produced on a small scale also generates a difficulty of implementation. The requirement of a social function to the waste, as imposed by the Law, creates a situation of conflict in some cases, especially when the collector associations are not yet established, despite the efforts to establish and empower them. Alternatively, in many cases a conflict situation may appear when such associations are already established and, then, local authorities decide to give an energy allocation to the MSW (there is a fear of losing the jobs[54].

Another major limitation in the country is the lack of adequate commercialized technology for energy conversion mainly for small volumes, typical of cities with populations of less than 50,000 inhabitants, technically considered small[55].

The technology commonly used in the country is the disposal in landfills and to use the biogas for energy conversion, but this occurs typically in large cities. Incineration is not used in the country yet, and its potential use tends to establish situations of conflict with collectors' associations, which tends to further complicate the licensing process. Moreover, a great difficulty of incineration is the need for large plants (over 10 MW), which prevents their use in small municipalities. Gasification, which would be more appropriate for smaller urban conglomerates, still needs technological improvements. Thus, major technological barriers need to be overcome.

Energy use of municipal waste is an important source of power generation within a regional or local strategy that transcends the energy dimension. However, it does not present a scale to support a strategy of expanding

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[54] In fact there is not this danger of losing Jobs, as discussed in several situations (Coelho et al, 2014b) but there is a lack of information.

[55] Corresponding to the situation of the selected municipalities in this study

electricity supply in the country or biofuel in the long run. On top of this, energy thus produced cannot currently compete with other sources, unless the strategic dimension is taken into account.

II. Rural residues

Even with the increase in demand for projects using biogas as fuel in Brazil, we highlight the small projects, mostly in rural areas. In these places, where biogas generation may be implemented from the digestion of animal and urban waste, they are small scale-power systems (4 -100 kW) in adapted vehicle-engines. These adjustments result in a lower system cost, but also lower reliability and durability.

The related political barriers against biogas energy conversion are associated with lack of political incentives and the lack of prioritization for issues relating to sanitation in the country. Political incentives concern the lack of legislation to incentivize investments in renewable energy sources, mainly from biomass residues, as well as subsidies in differentiated financing and rates for this type of energy.

The lack of market incentive legislation in this regard is another negative factor for the use of this energy source, whether in adopting incentive policies (tariffs and subsidies) or with regulation instrument (more efficient technologies). Since there is no legal obligation to purchase electricity generated from renewable sources, the utilities can choose other options of energy supply.

In this context, for decentralized energy systems from biogas, it is important to define public policies that integrate the sanitary waste treatment and energy utilization of biogas.

III. Forest residues

In Brazil, the Forest Management Plan has received the approval and authorization from the environmental agency for both private companies and for the Concessions of Federal Public Forests (FPF), only determines the species with commercial value for exploitation.

In theory this license, prioritizes the removal of noble timber species with high commercial value and is prohibited by law the removal of other species outside the previously approved management plan. In practice, apart from raw material sourced from deforested areas, often part of it illegal, as well as the withdrawal of secondary forests of the region, generates large amounts of waste.

The wood residues generated annually in Brazil are estimated at 30 million tonnes. The main source of waste is the timber industry, which contributes to 91% of waste generated. The Sustainable Forest Management Plan activities (PMFS) generate an amount of waste from the trees removed during the execution of the necessary infrastructure, such as the openings of courtyards, roads and trails and other materials - for example, tabular roots, shavings of hollow logs, trees broken or fallen among others - that are in the forest and can be used for various purposes highlighting energy production.

It should be noted the significant potential of waste from managed forests in the Amazon, producing up to 5 m^3 per 1 m^3 of wood removed from the forest.

In this particular case, the companies acquiring the granting of private forest prove the availability of this residue through the Annual Operations Plan - POA (PMFS). After confirming the existence of wood waste generated in the forestry, as well as obtaining legally the full ownership of the residual potential generated, the government would better administer it.

Nowadays, companies mainly use this waste as a raw material for the steel industry (charcoal production), installed mostly by timber companies in the states of Pará and Maranhão States. This market is so lucrative that reaches the point of generating more profitability that lumber[56].

In this context, the Federal Public Forest Concessions (FPF) may be a possibility of changing the current situation, with the registration of approximately 313 million hectares, which concentrates (92.1%) in the Amazon region, where coincidentally is found the municipalities with the lowest Human Development Index (HDI) in the country that depend exclusively on fuel consumption (CCC) account for the generation of electricity in the National Remote System, where generation is predominantly thermal diesel oil-based subsidized by the government.

Considering that the Amazon rainforest is a resource of Brazilian society, such as oil and water resources, among others, is necessary for the government to create new conditions when offering forest concessions - (FPF), viewing waste as energy potential.

Moreover, this option can contribute to reduce the CCC account[57] paid by Brazilian National Treasure (which means all Brazilian society). The government to increase energy access in low HDI municipalities could allocate this potential. In the first step the government offers (FPF) concessions for logging, which generate environmental impacts. It is possible to value these residues as energy, supplying the demand of the poorest municipalities, thus reducing diesel consumption (and expenditures with CCC), and consequently reducing greenhouse gases.

Historically, isolated systems have been served by the distributors themselves or by independent power producers, through generating systems on diesel oil. For households supply, utilities use exclusively diesel oil as energy source, whose costs are covered by CCC, as mentioned above. Government allows also CCC to be used for power production using some

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[56] This is supposedly the primary purpose of forest concessions that prioritizes avoid less intervention in the surroundings, only removing the species with the highest economic value

[57] CCC account – Conta Consumo de Combustiveis (Fuel Consumption Account - http://www.eletrobras.com/elb/data/Pages/LUMISBDD9AB86PTBRIE.htm) is the full payment of diesel oil consumed by utilities in Isolated System for electricity generation. This payment is made by Eletrobras (the Brazilian electricity holding company) with funds from the Brazilian National Treasure

renewable energy sources such as small hydro and biodiesel. If CCC could be used for biomass residues, this could foster the use of such residues, to replace the thermoelectric generation from diesel oil, with significant environmental and social benefits in Amazonia.

To illustrate this potential, let us analyze the municipalities of Portel and in Melgaço (Pará) - with HDI lower than 0.5 - located in Caxiuanã National Forest. This FPF was offered for concession by the Federal Government in 2015 and has an area of 322 hectares, with an approved management plan of 184 hectares. This presents an average potential of 566,000 tonnes of waste of wood per year, only from the biomass produced from the management of this National Concession for Public Forest (FPF). Using a steam cycle power plant (with a 12% conversion efficiency), it could be produced approximately 253,000 MWh/year. If we consider a power demand of 100 kWh/person.year, the consumption would reach a maximum of 10,000 MWh / year for both cities, less than 5% of the potential available.

There are several FPF being approved by the government in Amazonia, making possible to replace a significant share of the Isolated System demand with residual biomass – that is inevitably generated in the management of these areas and by law belonging to the Brazilian society. This would correspond to a significant energy supply and a strategic potential for the country.

This is just one example of the lack of knowledge of the energy potential of forest biomass and other biomass residues in Brazil. Public policy could be created directed the best use of these residues, which in this case may be intended partially or in full for the population in the form of electricity, and not just be treated and abandoned as the name which defines it - residue.

8. Concluding remarks: answering research questions

This section presents the main concluding remarks from the study, aiming to answer the research questions that guided this project.

One of the first objectives of the project was related to the current and potential economic and production activities in small, poor and/or isolated municipalities, including their power consumption and demand including energy production uses. Also, it was assessed the residues produced that can be used as an energy resource for productive uses.

Section 2 of this report (as well as in the annexes I and II) presents a detailed description of the municipalities. Our findings show that there are agricultural residues, animal residues, some agro-industrial residues (such residues from manioc/cassava powder production in North region of Brazil) and also urban wastes since most villages have no adequate disposal for solid and liquid urban residues in both countries.

Another important finding was that there is a wide range of power demand mainly due to the different sizes of municipalities. For example, in Brazil, those municipalities located in the North region have a larger area than those in the Northeast region but these smaller municipalities present larger populations in comparison with the municipalities located in the North region.

The demand was estimated considering different scenarios of power supply for Brazil and Colombia, following the methodology already discussed in Coelho and Goldemberg (2013). The scenarios adopted for power supply considered local use (lighting, etc.) and productive activities, as discussed in Sections 3, 4 and 5.

Annexes I and II present the residue available potential for each municipality. Depending on the municipality and on the region in which it is located. It is important to mention that residues availability presents specificities. For example villages in the Amazon region of Brazil and Colombia present wood residues not only from sawmills but also from (sustainable) logging and management in local forests. Other regions rely mostly on residues from local cultures such as cassava and/or residues from animal origin.

Another important finding of the project was related to the availability of renewable energy technologies (i.e. biomass–based energy conversion technologies) for increasing energy access and local production activities, which was discussed in Section 4.

The existing technologies for energy access already available (in the two countries) include, as a first step, photovoltaic panels, but these are only possible for small power supply, as discussed in Coelho and Goldemberg (2013). Also, they are quite expensive systems since most are still imported.

As a result, the use of biomass residues allows the production of higher power, mainly in areas where such residues are available in a large amount, as shown in this report. However, there are advantages and barriers to introduce the identified technologies but, for sure, biomass residues represent a viable and efficient energy supply option for local productive uses.

Our finding in this topic show that the main advantage of the use of biomass residues is the perspective of producing power for productive activities as well as contributing to reduce the negative impacts of inadequate disposal of such biomass residues such as Municipal Solid Waste (MSW) and animal residues, which currently are discharged inadequately. Also, there are agricultural and wood residues, which are burnt in open air or left *in situ*.

In Colombia, open-air burning is penalized, similar to Brazil (the main additional difficulty in Brazil is the large extension of the country, making the enforcement quite difficult). This practice diminished a lot in the countries, due to the legislation launched recently, particularly when it comes to agriculture residues that are originated from large-scale crops. Considering this aspect, biomass residues became the best option for energy supply for productive use in the selected municipalities.

Based on this our report identified the main difficulties related to the use of biomass residues for power production and the findings are related to:

a) Lack of funding (both private and from government).
b) Difficult economic feasibility since many of the municipalities are too small and households present a large dispersion in rural areas, mainly in the Amazon region of Brazil and Colombia.
c) Lack of local capacity building to operate and maintain some of the technologies, as discussed in Section 6.
d) Lack of political will.

Another important issue is the (technical and economic) availability of biomass residues in the selected municipalities (i.e., urban/solid waste and liquid effluents, and rural/agro-industrial wastes) that could be used to supply energy for productive activities.

Section 3 showed the estimated amount of biomass residues available in each municipality and the theoretical potential to supply productive activities. Also, it showed the current destinations of residues, which – in most cases – are still being discharged in an inadequate way.

Section 5 presented the theoretical potential for power production available to be supplied in each low-income municipality from biomass residues (both urban and rural areas). However, considering the fact that we are dealing with low-income municipalities, our findings shows that the biggest challenge is how to make it economically feasible and if there will be any income revenue from this energy conversion.

In most cases, there is no possibility of selling surplus because there is no distribution grid linking one municipality to another (also they are not linked to the national grid). In addition, municipalities located in the Amazon region of Brazil and Colombia has no cost-effective solution able to build distribution lines through the forest (not even considering environmental issues). In other municipalities outside the Amazon region, they are very far from the grid and there is no possibility of selling any surplus. Therefore, in all cases, the power supply is considered in our analysis to be used for local activities only.

For the Amazonian villages, the greater advantage is the replacement of diesel oil used by the villages. As discussed in Coelho and Goldemberg (2013) and Coelho *et al.* (2005a, 2005b) and also analyzed in the projects Gaseifamaz[58] and Enermad[59]. In the Amazon region, many of the villages have already a diesel engine but they cannot afford to pay for the diesel oil because of the high oil prices due to transportation costs. Diesel oil is transported to the villages by boat (also using diesel oil). These previous studies showed that the final price of the oil is too high for local people.

There is also the possibility of replacing fuelwood used for cooking by biogas from organic residues through anaerobic digestion or synthesis gas from small-scale gasifiers.

The use of firewood in Brazil still exists in households as discussed in Coelho *et al.* (2014), but the LPG[60] program can play an important role to reduce it (Lucon et al., 2004; Coelho and Goldemberg, 2013) but it must be improved, as discussed in the mentioned references. However, this is not a huge problem such in other DC´s such as in Africa and Asia (GBEP/GIZ, 2015).

Regarding the technologies proposed to use biomass residues for energy conversion (as discussed in Section 4), which are available and considered appropriate, each one has a different situation:

a) Biodigestion – technology already commercialized in Brazil, but not too much used yet in rural areas. Despite some efforts in Colombia, the technology has not been widely implemented for energy generation purposes in rural and isolated areas. Hence, it is needed to develop a large and widespread program in such regions.
b) Small-scale combustion (steam cycles) – technology already fully commercialized in Brazil by TGM Turbines[61] (from 200 kWe and up, and exported to other Latin America countries such as Colombia). Main difficulty is economic feasibility.
c) Small-scale biomass gasifiers (up to 200 kW) – technology already available but not yet fully commercialized. Some pilot plants were implemented in the Amazon region using agricultural and wood residues (i.e., Gaseifamaz project). There is one local producer in São Paulo, manufacturing small-scale biomass gasifiers even for MSW (Carbogas[62] Ind), which are responsible for the project being installed in the Vale do Paranapanema, São Paulo State. In Colombia, a 40-kW

[58] www.iee.usp.br/gbio or http://143.107.4.241/projetos/gaseifamaz/gaseifamaz.htm
[59] www.iee.usp.br/gbio or http://143.107.4.241/projetos/enermad/enermad.htm
[60] Liquefied petroleum gas
[61] www.grupotgm.com.br/home/
[62] www.carbogas.com.br. Biomass fluidized bed gasifiers available for 200 kW and up.

gasification pilot plant using Indian technology to gasify residual wood was installed in Necoclí (Antioquia). It was installed in 2008 and operated by the National Planning Institute for non-Interconnected Areas – IPSE with support from Universidad Nacional de Colombia for a short period and today is inactive[63].

Therefore, it is important to discuss the regional know-how to implement this potential for energy conversion from biomass residues. Our findings shows that in Brazil, there is know-how to implement this potential, if economically feasible. Colombia uses mostly equipment imported from Brazilian manufacturers.

Local manufacturers include the following:

a) Biodigesters - there are several digesters manufacturers in Brazil. The company Nova Era Ambiental Co.[64], located in São Paulo, provides executive project services, implementation and operation of sewage treatment systems focusing on power generation, particularly in small municipalities in the country. Besides UASB digesters, the company also provides the covered lagoon digesters model. This company was also responsible for UASB digester implemented in PUREFA project, presented in Section 4.
b) Small-scale combustion (steam cycles) – steam turbines are manufactured by TGM Turbines[65], in São Paulo. Also, it is responsible for the first project supplying a 200 kW-system in the Brazilian Amazon (i.e., ENERMAD project). Steam boilers are largely produced in the country in any size and power
c) Biomass gasifiers – the only Brazilian manufacturer is CARBOGAS[66], producing biomass fluidized bed systems for wood, agricultural and MSW residues.

However, despite the existing manufacturers, there are still barriers for implementing technologies for energy recovery from biomass residues for productive uses.

As discussed in Section 7 the main barriers are the lack of funding not only for the implementation of the project but also for the adequate local capacity building to allow local people to work on it. Also, there is no adequate legislation to oblige the local utilities mainly in the Amazon region to change from diesel oil engines to other renewable systems. As discussed in the same section, the existing CCC[67] policy gives incentives for power production from diesel engines but not from other renewable options.

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63 http://historico.agenciadenoticias.unal.edu.co/articulos/ciencia_tecnologia/ciencia_tecnologia_20080826_ipse.html
64 www.novaeraambiental.com.br
65 www.grupotgm.com.br/home/
66 www.carbogas.com.br
67 CCC – Conta Consumo de Combustiveis – Fuel Consumption Account (please see above)

The project has also discussed the possibility of creating a business model based on distributed energy small/micro-generation. It was concluded that it is not be possible to create a concrete business model without a further detailed study based on local field assessment.

In this study the field assessment was not included in the objectives. Hence, there was no precise information regarding the distribution of the households in the municipalities. The households' dispersion plays a very important role regarding the feasibility of the proposed model – information confirmed by the interviews with the stakeholders, as mentioned in Section 6. However, this study has identified the barriers to use local biomass residues as energy sources to supply the local economic activities.

When discussing technological barriers, our findings show that they are mainly related to the lack of capacity in the villages for operation and maintenance, despite the fact that the technologies proposed are already commercially viable. A strong effort on capacity building would be necessary, similarly to the one developed in similar projects in the Amazon as mentioned in this report.

Economic barriers are mainly due to the lack of funding locally, since the local municipality administration has no funds available not even for the basic services such as waste collection and treatment. Also, despite the existing LPT[68] program from Federal Government, local utilities have no interest to invest on energy access in such small Brazilian municipalities due to difficulties of logistic and a small number of consumers. In the Amazon region, both in Brazil and Colombia, the local communities operate the existing diesel engines and in most cases there are no funds to by the diesel oil (not only to buy but also to transport it by boat to the village). In other municipalities out of the Amazon, which are located in regions that should be supplied by the national grid, the local utilities have no interest in supplying due to the long distance from the grid (allegedly due to high costs).

Our study presents two preliminary theoretical business models based on the Brazilian context and information gathered by the project:

- ***Isolated System theoretical business model:***

  As mentioned in this report, in the Brazilian Amazon the Federal Government reimburses all utilities' expenses of diesel oil[69]. Only in 2014 the total amount paid for the diesel oil consumed, according to Eletrobras, was about USD 1.8 billion (exchange rate 3.3 BRL/USD)[70]

  For decentralized generation, and considering a diesel oil generator (200 kW) operating 8 hours per day, 22 days per month and for a diesel price as U$ 1.00 per liter (the exchange rate of 3.3 BRL/USD in

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[68] Luz para Todos – Lightining for All – Program (please see above)
[69] http://www.eletrobras.com/elb/data/Pages/LUMISBDD9AB86PTBRIE.htm.
[70] Available at:
http://www.eletrobras.com/elb/main.asp?Team=%7BD4C1EFFF%2D9895%2D440B%2DBDD6%2D3E4D6F56FB2D%7D

July 2015), the implementation of a biomass based residue would allow the savings of USD 3,000 per month[71].

In the case of Amazon villages, considering that the CCC pays for the diesel oil used by the local utilities, the corresponding amount could be paid to the villages. Since there is no cost for the biomass residues, such payment could afford the community to install such a system. From previous projects (Enermad), the investment for a 200 kW was BRL 1 million (342,465 USD, 2.92 BRL/USD in 2004).

This means that, if the existing CCC legislation was adapted to include expenses for electricity generation using biomass-residues, the total amount paid would be USD 360,000 per year, which would be enough to pay for the 200 kW-power plant only with the amount saved in the first year, with the advantage of reducing carbon emissions from diesel oil since biomass residues correspond to a renewable energy.

- ***Interlinked System theoretical business model:***

  In the Interlinked System there are no CCC policies. In Brazil, one possibility could be the use of the existing Resolution 482/2012 from ANEEL (www.aneel.gov.br), introducing smart grid up to 1 MW of installed power. However, this policy cannot be applied since there is no grid from the Interlinked System in any of these communities (far from the grid).

  Therefore, we must analyze the implementation of a decentralized power plant by the local utility. Considering an investment of BRL 1 million (about 350,000 USD, 2004) for a 200 kW power plant, for a electricity production during 8 hours a day, 22 days a month, we would have 35,200 kWh per month. For a 10-year payback time, we would have 100,000 USD/year, or 8,333 USD per month, to be paid in a rate of 0.24 USD/kWh (240 USD/MWh), which is not affordable by the local people. Even for a 20-year payback time we would have a rate of 120 USD/MWh (0.12 USD/kWh), not possible for poor people. This means that a policy similar to CCC should be discussed for such villages, since they seem to really be isolated villages, despite the geographic location out of Amazonia.

Finally it is important to discuss how energy access and energy productive uses may contribute to increase the HDI of these municipalities. Our findings show that energy access – including energy for productive uses – may contribute to increase the (very) low HDI of the selected municipalities in the following cases:

a) Productive uses may allow local people to commercialize more products with more value added (see example of Gaseifamaz project in Amazon region).

[71] But in most cases there are no funds for this expense with diesel oil and the village stay without energy access or relying on candles or batteries.

b) If MSW (disposed in an inadequate way in all municipalities) can be used for energy production, this could help to make feasible the adequate collection and disposal of waste.
c) In the case of agricultural/wood residues, mainly burnt in open-air, the energy conversion would eliminate the CO_2 emissions from this burning and the health impacts (Varkulya, 2004)

However, despite the positive results from such scenario, this study has not identified any measure currently being used to enable the utilization of biomass residues by low-income populations for energy access and productive uses.

In fact, not even the current rural electrification model(s) is able to provide appropriate solutions to ensure enhanced electricity productive uses and their sustainability. As discussed in Section 7, the current rural electrification models do not provide any appropriate solutions to enhance electricity for productive uses. Therefore, our report concludes that it is important that policies and strategies must be taken to overcome the existing barriers.

Policies and strategies to overcome the existing barriers are suggested in Section 7. The list below presents the highlights:

a) Adequate funding from the Federal Government and/or international agencies.
b) Adequate finance programs from existing local banks and/or international banks with low interest rates to be affordable for poor municipalities
c) Adequate policies enlarging the existing CCC to biomass power production, in Brazil, and the introduction of similar program in Colombia
d) To develop one local pilot demonstration plant in one of these municipalities selected
e) To improve existing electric sector legislation and the existing programs to increase energy access, aiming to incentivize the utilities to provide this supply.

9. Outreach activities

The Task 7 was responsible for dissemination initiatives directed at the general public. The primary goal is to create awareness of the importance of GNESD activities and the BREA Project to society and to raise awareness about energy access and social development.

BREA uses a variety of formats to produce scientific information regarding its research results with the institutional support of our partners. The project results are presented at institutional homepages of our partners.

9.1. Institutional support

I. LIMA – Interdisciplinary Laboratory Environment

Homepage: http://www.lima.coppe.ufrj.br/

LIMA is linked to the Energy Planning Program (PPE), Center of Technology from the Federal University of Rio de Janeiro..

II. CentroClima – Integrated Center for Environmental and Climate Change Studies

Homepage: http//www.centroclima.coppe.ufrj.br/

CentroClima was established in 2000 in order to generate and disseminate specific knowledge about climate change..

III. CBEM – Brazilian Energy Centre and Climate Change

Homepage: www.cbem.com.br

CBEM is a consulting firm, supporting decision-making and investment management specializing in renewable energy sources and carbon market.

The descriptive project in question is already available at CBEM's homepage via the link:

http://cbem.com.br/residuos-de-biomassa-como-fonte-de-energia-para-melhorar-o-acesso-a-energia-e-atividade-economica-local-em-regioes-de-baixo-indice-de-desenvolvimento-humano-idh-no-brasil-e-na-colombia/

IV. Research Group on Bioenergy, GBIO/IEE/USP (former CENBIO)

Homepage: www.iee.usp.br/gbio

The Institute for Energy and Environment (IEE) is a specialized institute of the University of São Paulo and has its activities based on university extension, research and teaching, and it participates of international groups in scientific, technological and agro-industrial sectors.

V. Universidad de La Sabana

Homepage: www.unisabana.edu.co/unidades/investigacion/grupos-de-investigacion/facultad-de-ingenieria/

The Universidad de La Sabana was founded in 1979. It is located in Chía, 25 minutes from Bogotá, Colombia's capital. s.

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Annex I: Profiles of selected municipalities in Brazil

Selected Municipalities in the North Region

INEDES prepared these profiles.

VI. Municipality of Jordão

Physical Geography Aspects

Figure 36: Map of Jordão, State of Acre

Until few years ago, the economy of Jordão was based mainly in rubber extraction and forest species. Nowadays, in the other hand, it has changed to agribusiness and trade. In the region, there are many native palm trees and other natural resources. Most of population lives in rural areas, about 80%. Jordan has been national news because of the existence of uncontacted tribes in its area.

Country: Brazil

State: Acre

Region: North

Border: Municipalities of Marechal Thaumaturgo, Tarauacá, and the country of Peru

Area: 5,357 km^2

Population (IBGE, 2010): 6,577 (almost half are Kaxinawá or Huni Kui Indians)

Population Density: 1.23/km^2

Population Rank: 20th (Acre State has 22 municipalities)

Urban population (IBGE, 2010): 2,272

Rural population (IBGE, 2010): 4,305 (65.4% of population)

Elevation: 278 m

Created by: State Law Number 97 of 10/17/1995 (Jordão was part of Rio Branco Municipality)

Distance from State Capital (Rio Branco): 344 km

How to reach Jordão from Rio Branco: there is a small airport in the municipality, only to charter flights and small planes. The trip to Rio Branco is done by highway (BR-364) until Tarauacá and then by boat through Tarauacá River.

Main Rivers: Uraricoera, Parimé and Jordão

Average Temperature: 28.5°C

Climate: Tropical Rainforest

Human Development Indexes (PNUD, 2010)

HDI-M: 0.469

Rank Acre State: 22th (of 22)

Rank Brazil: 5,559th (of 5,565)

Longevity index: 0.731

Education index: 0.283

Income index: 0.469

Gross Domestic Product (US$ 1,000)

Table 34 presents the local Gross Domestic Product (GDP) between 2008 and 2012.

Table 34: Gross Domestic Product of Jordão Municipality from 2008 to 2012 (US$ 1,000)

GDP TOTAL	2008	2009	2010	2011	2012
	27,426	**22,735**	**24,235**	**30,135**	**37,460**
GDP Agribusiness	11,700	5,994	5,907	6,618	10,119
GDP Industry	1,124	1,334	1,490	2,060	2,082
GDP Servicing	14,259	15,063	16,489	20,941	24,570
GDP Taxes	343	345	349	516	689
GDP per capita (US$ 1.00)	**4,331**	**3,487**	**3,685**	**4,471**	**5,431**

SOURCE: IBGE (2013)

Agriculture (2013)

Table 35 presents the local agricultural production in 2013.

Table 35: Agricultural production of Jordão Municipality in 2013

Product	Area (ha)	Quantity produced (tonnes)
Banana	76	760
Açaí Berry	-	20
Rice	50	75
Sugarcane	12	480 tonnes
Bean	28	16
Cassava	610	11,840
Watermelon	10	160
Corn or maize (grain)	520	832
Tobacco	5	5
Pineapple	2	20 (thousand fruits)
Avocado	4	20
Orange	76	56
Lemon	4	34
Papaya	7	70
Tangerine	4	52

SOURCE: IBGE (2013)

Livestock and animal production (2013)

Table 36 presents the livestock composition.

Table 36: Livestock composition of Jordão Municipality

Description	Amount
Bovine	6,293 heads
Caprine	62 heads
Equine	72 heads
Swine	1,925 heads
Poultry	14,785 heads
Buffalo	21 heads
Ovine	1,215 heads
Milk (liters)	85,000
Eggs (dozens)	12,000
Fishing (tonnes)	18

SOURCE: IBGE (2013)

Wood

Jordão produced, in 2013, 1,260 m^3 of round wood, 10,504m^3 of firewood, and 13 tonnes of charcoal.

Environment and Preservation

One of the greatest assets of the Jordão is its forest coverage, almost completely preserved. Almost 40% of the total area of Jordão municipality belongs to Indian lands.

VII. Municipality of Atalaia do Norte

Physical Geography Aspects

Figure 37: Map of Atalaia do Norte, State of Amazonas

Country: Brazil

State: Amazonas

Region: North

Border: Municipalities of Benjamin Constant, Ipixuna, Guajaará, Acre State and the country of Peru

Area (SEPLAN, 2013): 76,355 km^2

Population (IBGE, 2010): 15,153

Population Density: 0.20/km^2

Population Rank: 45th (Amazonas State has 62 municipalities)

Urban population (IBGE, 2010): 6,893

Rural population (IBGE, 2010): 8,260

Villages in the Rural Area (IDAM): 18

Elevation: 65 m

Created by: State Law Number 96 of 12/19/1955 (Atalaia do Norte was part of Benjamin Constant Municipality)

Distance from State Capital (Manaus): 1,138 km in straight line or 1,638 km following the rivers

How to reach Atalaia do Norte from Manaus: there is one airport in the municipality, but only for charter flights. Normally, the trip lasts about 6 days + 12h by regional boat; by plane from Manaus to Tabatinga (3h) + 1h by fast boat from Tabatinga to Benjamin Constant and more 20 minutes through BR-307 until Atalaia do Norte. There is just the BR-307 highway linking Atalaia do Norte to Benjamin Constant. Hence, rivers are the main transportation pathways.

Dry season: From June to November, the dry season has great impact on mobility since it difficult the use of boats

Main Rivers: Javari, Quixito and Ituí

Temperature (SEPLAN, 2013): Max. 40°C, Min. 15°C and Mean 25°C

Climate: Tropical Rainforest

Human Development Indexes (PNUD, 2010)

HDI-M: 0.450

Rank Amazonas State: 62th (of 62)

Rank Brazil: 5,563th (of 5,565)

Longevity index: 0.733

Education index: 0.259

Income index: 0.531

Gross Domestic Product (US$ 1,000)

Table 37 presents the local Gross Domestic Product (GDP) between 2007 and 2011.

Table 37: Gross Domestic Product of Atalaia do Norte Municipality from 2007 to 2011 (US$)

GDP TOTAL	2007	2008	2009	2010	2011
	22,836	**27,902**	**27,346**	**37,187**	**44,425**
GDP Agribusiness	3,129	3,310	3,116	4,069	5,726
GDP Industry	2,216	2,706	2,659	4,018	4,563
GDP Servicing	17,045	21,328	21,040	28,323	33,316
GDP Taxes	446	558	531	777	821
GDP per capita (US$ 1.00)	**1,670**	**1,952**	**1,858**	**2,455**	**2,858**
Poverty line (US$ 1.00)	1.19	1.48	1.29	1.99	2.38

SOURCE: SEPLAN (2013)

Agriculture (2013)

Table 38 presents the local agricultural production in 2013.

Table 38: Agricultural production of Atalaia do Norte Municipality in 2013

Product	Area (ha)	Quantity produced (tonnes)
Pineapple	10	220 (thousand fruits)
Yams	12	160
Sugarcane	30	1.5
Bean	100	130
Cassava	260	3.1
Watermelon	18	350
Corn or maize (grain)	100	200
Banana	20	320
Cocoa	24	1 (thousand fruits)
Coconut-from-Bahia	1	1 (thousand fruits)
Palm	110	110
Orange	5	110
Lemon	5	50
Papaya	6	150
Passion fruit	6	200
Tangerine	2	8
Rubber	-	6
Babassu Palm	-	6
Açaí Berry	-	168

SOURCE: IBGE (2013)

Livestock and animal production (2013)

Table 39 presents the livestock composition in 2013.

Table 39: Livestock composition of Atalaia do Norte Municipality

Description	Amount
Bovine	170 heads
Swine	500 heads
Ovine	190 heads
Caprine	70 heads
Honey (kg)	120
Poultry	19 heads
Chicken egg (1,000 dozens)	28
Milk (1,000 liters)	4
Fishing (tonne)	0.07

SOURCE: IBGE (2013)

Wood (IBGE, 2013)

In 2013, Atalaia do Norte produced 3 m^3 of firewood and 11 m^3 of round wood.

Environment and Preservation

The municipality of Atalaia do Norte is known worldwide for include most of Vale do Javari indigenous territory, which is the largest reserve of isolated Indians of the world. According SEPLAN, in 2013 there were 56 burned areas in Atalaia do Norte. The forest covers 72,469 km^2 of the municipality but the deforestation reached 241.6 km^2 in 2013.

VIII. Municipality of Itamarati

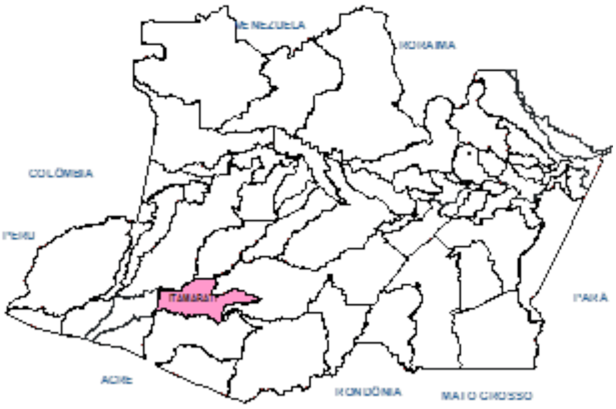

Figure 38: Map of Itamarati, State of Amazonas

Country: Brazil

State: Amazonas

Region: North

Border: Municipalities of Eirunepé, Tapauá, Pauini, Envira, Jutaí and Carauari

Area: 25,277 km^2

Population (IBGE, 2010): 8,038

Population Density: 0.32/km^2

Population Rank: 61th (Amazonas State has 62 municipalities)

Urban population (IBGE, 2010): 4,472

Rural population (IBGE, 2010): 3,566

Villages in the Rural Area (IDAM): 40

Elevation: 60 m

Created by: State Law Number 12 of 12/10/1981 (Itamarati was part of Carauari Municipality)

Distance from State Capital (Manaus): 985 km in straight line or 1,930 km following the rivers

How to reach Itamarati from Manaus: there is no airport in the municipality. Normally, the usual trip is by plane 3h00m until Eirunepé and more 10 hours using a regional boat. There are no highways linking the municipality to its neighbors. Hence, rivers are the main transportation pathway.

Dry season: September. The dry season has great impact on mobility since it difficult the use of boats

Main Rivers: Juruá, Xeruã, Quirirú and Canamã

Temperature (SEPLAN, 2013): Max. 35°C, Min. 20°C and Mean 27°C

Climate: Tropical Rainforest

Human Development Indexes (PNUD, 2010)

HDI-M: 0.477

Rank Amazonas State: 61^{th} (of 62)

Rank Brazil: $5{,}556^{th}$ (of 5,565)

Longevity index: 0.772

Education index: 0.266

Income index: 0.529

Gross Domestic Product (US$ 1,000)

Table 40 presents the local Gross Domestic Product (GDP) between 2007 and 2011.

Table 40: Gross Domestic Product of Itamarati Municipality from 2007 to 2011 (US$)

GDP TOTAL	2007	2008	2009	2010	2011
	18,314	**19,454**	**18,477**	**29,407**	**30,502**
GDP Agribusiness	5,673	4,391	4,401	10,094	8,936
GDP Industry	1,327	1,597	1,518	2,227	2,543
GDP Servicing	10,854	13,090	12,213	16,434	18,441
GDP Taxes	461	376	345	652	581
GDP per capita (US$ 1.00)	**2,264**	**2,344**	**2,231**	**3,657**	**3,805**
Poverty line (US$ 1.00)	1.62	1.77	1.55	2.97	3.17

SOURCE: SEPLAN (2013)

Agriculture (2013)

Table 41 presents the local agricultural production in 2013.

Table 41: Agricultural production of Itamarati Municipality in 2013

Product	Area (ha)	Quantity produced (tonnes)
Açaí Berry	-	200
Rubber	-	1
Pineapple	1	10 (thousand fruits)
Rice	40	80
Yams	10	150
Sugarcane	4	60
Bean	2	3
Cassava	290	2,400
Watermelon	30	430
Melon	4	24
Corn or maize (grain)	150	375
Tomato	2	36
Avocado	3	11
Banana	15	140
Cocoa	40	10
Coconut-from-Bahia	2	4 (thousand fruits)
Orange	2	15
Lemon	1	5
Papaya	4	40
Passion fruit	2	15

SOURCE: IBGE (2013)

Livestock and animal production (2013)

Table 42 presents the livestock composition.

Table 42: Livestock composition of Itamarati Municipality

Description	Amount
Bovine	1,980 heads
Caprine	125 heads
Equine	43 heads
Swine	1,130 heads
Ovine	118 heads
Poultry	980 heads
Chicken egg (1,000 dozens)	8
Fishing (tonnes)	18

SOURCE: IBGE (2013)

Wood

Itamarati produced, in 2013, 1,300 m^3 of firewood and 1,600 m^3 of round wood.

Environment and Preservation

There are is one Indian area in Itamarati, called Kanamari of Jurua River with 596,434 ha that includes part of other two municipalities, Eirunepé and Pauini. According to SEPLAN, in 2013 there were 78 burned areas in Itamarati. The forest covers 18,203 km^2 of the municipality but the deforestation reached 129.1 km^2 in 2013.

IX. Municipality of Santa Isabel do Rio Negro

Physical Geography Aspects

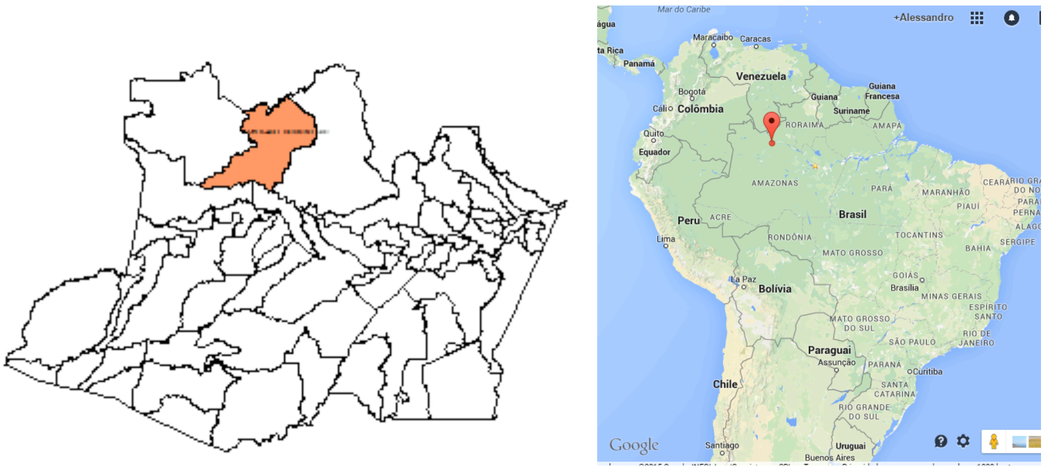

Figure 39: Map of Santa Isabel do Rio Negro, State of Amazonas

Country: Brazil

State: Amazonas

Region: North

Border: Municipalities of Barcelos, Maraã, Japurá, São Gabriel da Cachoeira, and the country of Venezuela.

Area: 62,846 km^2

Population (IBGE, 2010): 18,146

Population Density: 0.29/km^2

Population Rank: 33th (Amazonas State has 62 municipalities)

Urban population (IBGE, 2010): 6,856

Rural population (IBGE, 2010): 11,290

Villages in the Rural Area (IDAM): 48

Elevation: 60 m

Created by: State Law Number 117 of 07/08/1965 (Santa Isabel do Rio Negro was part of Barcelos Municipality)

Distance from State Capital (Manaus): 630 km in straight line or 737 km following the rivers

How to reach Santa Isabel do Rio Negro from Manaus: there is a small airport in the municipality, operated only by charter flights. Usual trips: 2h00h by plane; two days by regional boat; or 18 hours by fast boat. There are no highways linking the municipality to its neighbors. Hence, rivers are the main transportation pathways.

Dry season: between December and February. The dry season has great impact on mobility since it difficult the use of boats

Main Rivers: Negro e Daraá

Temperature (SEPLAN, 2013): Max. 32.6°C, Min. 21.5°C and Mean 27.5°C

Climate: Tropical Rainforest

Human Development Indexes (PNUD, 2010)

HDI-M: 0.479

Rank Amazonas State: 60th (of 62)

Rank Brazil: 5,555th (of 5,565)

Longevity index: 0.737

Education index: 0.323

Income index: 0.461

Gross Domestic Product (US$ 1,000)

Table 43 presents the local Gross Domestic Product (GDP) between 2007 and 2011.

Table 43: Gross Domestic Product of Santa Isabel do Rio Negro Municipality from 2007 to 2011 (US$)

	2007	2008	2009	2010	2011
GDP TOTAL	**24,127**	**30,208**	**28,518**	**42,438**	**51,663**
GDP Agribusiness	2,304	3,075	1,572	6,429	9,507
GDP Industry	2,539	3,098	3,063	4,454	5,288
GDP Servicing	18,772	23,386	23,346	30,626	35,823
GDP Taxes	512	648	537	929	1,045
GDP per capita (US$ 1.00)	**1,420**	**1,699**	**1,541**	**2,340**	**2,758**
Poverty line (US$ 1.00)	1.03	1.29	1.07	1.90	2.29

SOURCE: SEPLAN (2013)

Agriculture (2013)

Table 44 presents the local agricultural production in 2013.

Table 44: Agricultural production of Santa Isabel do Rio Negro Municipality in 2013

Product	Area (ha)	Quantity produced (tonnes)
Açaí Berry	-	1,200
Rubber	-	10
Brazilian Nut	-	20
Banana	28	240
Coconut-from-Bahia	4	16 (thousands of fruits)
Orange	7	154
Lemon	1	8
Papaya	10	250
Passion fruit	3	60
Tangerine	3	12
Pineapple	71	630 (thousand fruits)
Rice	5	15
Bean	50	65
Cassava	813	4,956
Watermelon	50	147
Corn or maize (grain)	62	180
Tomato	1	17 t

SOURCE: IBGE (2013)

Livestock and animal production (2013)

Table 36 presents the livestock composition.

Table 45: Livestock composition of Santa Isabel do Rio Negro Municipality

Description	Amount
Bovine	299 heads
Buffalo	22 heads
Caprine	8 heads
Equine	9 heads
Swine	196 heads
Ovine	78 heads
Poultry	3,500 heads
Chicken egg (1,000 dozens)	24
Fishing (tonnes)	20

SOURCE: IBGE (2013)

Wood

Santa Isabel do Rio Negro do not produced wood in 2013, but produced 890 tonnes of piassava fiber.

Environment and Preservation

According to SEPLAN, in 2013 there were 92 burned areas in Santa Isabel do Rio Negro. The deforestation reached 216.8 km^2 but the forest covers 36,557.3 km^2 of the municipality.

X. Municipality of Ipixuna

Physical Geography Aspects

Figure 40: Map of Ipixuna, State of Amazonas

Country: Brazil

State: Amazonas

Region: North

Border: Municipalities of Eirunepé, Guajará, Atalaia do Norte, Benjamin Constant and the State of Acre

Area: 12,044 km^2

Population (IBGE, 2010): 22,254

Population Density: 1.85/km^2

Population Rank: 30th (Amazonas State has 62 municipalities)

Urban population (IBGE, 2010): 9,499

Rural population (IBGE, 2010): 12,755

Villages in the Rural Area: 17

Elevation: 164m

Created by: State Law Number 96 of 12/19/1955 (Ipixuna was part of Eirunepé Municipality)

Distance from State Capital (Manaus): 1,367 km in straight line or 2,936 km following the rivers

How to reach Ipixuna from Manaus: there is no airport in the municipality. Normally, the usual trip is by plane 4h00m until Cruzeiro do Sul (Acre State) and more 20 hours using a regional boat. There are no highways linking the municipality to its neighbors. Hence, rivers are the main transportation pathways.

Dry season: September. The dry season has great impact on mobility since it difficult the use of boats

Main Rivers: Juruá, Gregório, Liberdade and Campinas

Temperature (SEPLAN, 2013): Max. 30°C, Min. 23°C and Mean 27°C

Climate: Tropical Rainforest

Human Development Indexes (PNUD, 2010)

HDI-M: 0.481

Rank Amazonas State: 59th (of 62)

Rank Brazil: 5,554th (of 5,565)

Longevity index: 0.772

Education index: 0.302

Income index: 0.476

Gross Domestic Product (US$ 1,000)

Table 46 presents the local Gross Domestic Product (GDP) between 2007 and 2011.

Table 46: Gross Domestic Product of Ipixuna Municipality from 2007 to 2011 (US$)

	2007	2008	2009	2010	2011
GDP TOTAL	**29,714**	**45,569**	**42,803**	**55,114**	**52,720**
GDP Agribusiness	6,923	16,890	14,941	13,620	5,716
GDP Industry	2,585	3,097	3,005	5,144	6,043
GDP Servicing	19,519	24,475	23,962	35,278	39,808
GDP Taxes	687	1,107	895	1,072	1,153
GDP per capita (US$ 1.00)	**1,730**	**2,553**	**2,352**	**2,483**	**2,306**
Poverty line (US$ 1.00)	1.23	1.93	1.63	2.01	1.92

SOURCE: SEPLAN (2013)

Agriculture (2013)

Table 47 presents the local agricultural production in 2013.

Table 47: Agricultural production of Ipixuna Municipality in 2013

Product	Area (ha)	Quantity produced (tonnes)
Açaí Berry	-	22
Rubber	-	3
Rice	266	450
Bean	142	164
Corn or maize (grain)	105	200 t
Pineapple	2	36 (thousand fruits)
Sugarcane	36	1.08
Cassava	193	1.17
Watermelon	8	160
Corn or maize (grain)	96	240
Banana	67	360
Cocoa	50	21

SOURCE: IBGE (2013)

Livestock and animal production (2013)

Table 48 presents the livestock composition.

Table 48: Livestock composition of Ipixuna Municipality

Description	Amount
Bovine	14,462 heads
Swine	4,683 heads
Ovine	324 heads
Poultry	8,000 heads
Chicken egg (1,000 dozens)	3
Milk (1,000 liters)	16

SOURCE: IBGE (2013)

Wood

Ipixuna produced in 2013 around 3 m^3 of firewood, 900 m^3 of round wood and 4 tonnes of charcoal.

Environment and Preservation

There are two Indian areas in Ipixuna. One called Campinas/Katurina with 32,624 ha and other called Kulina of Médio Juruá with 730,143 ha which includes part of other two municipalities, Eirunepé and Envira. According to SEPLAN, in 2013 there were 88 burned areas in Ipixuna. The forest covers 12,221 km^2 of the municipality but the deforestation reached 228.7 km^2 in 2013.

XI. Municipality of Santo Antônio do Içá

Physical Geography Aspects

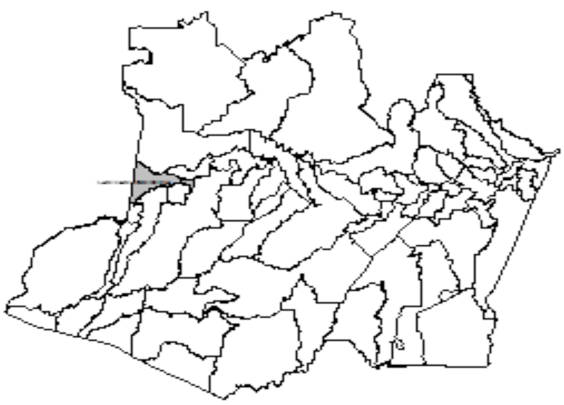

Figure 41: Map of Santo Antônio de Içá, State of Amazonas

Country: Brazil

State: Amazonas

Region: North

Border: Municipalities of Jutaí, Amaturá, São Paulo de Olivença, Tabatinga, Japurá, Tonantis and the country of Colombia

Area: 12,307 km^2

Population (IBGE, 2010): 24,481

Population Density: 1.99/km^2

Population Rank: 31th (Amazonas State has 62 municipalities)

Urban population (IBGE, 2010): 12,947

Rural population (IBGE, 2010): 11,534

Villages in the Rural Area (IDAM): 43

Elevation: 61 m

Created by: State Law Number 96 of 12/19/1955 (Santo Antônio do Içá was part of São Paulo de Olivença Municipality)

Distance from State Capital (Manaus): 880 km in straight line or 1,195 km following the rivers

How to reach Santo Antônio do Içá from Manaus: there is a small airport in the municipality just to charter flights. Normally, the usual trip is by plane 2h15m until Fonte Boa and more 7 hours using a fast boat. From Manaus is possible to take a fast boat and reach the municipality in 50 hours. There are no highways linking the municipality to its neighbors. Hence, rivers are the main transportation pathways.

Dry season: September. The dry season has great impact on mobility since it difficult the use of boats

Main Rivers: Içá and Solimões

Temperature (SEPLAN, 2013): Max. 40°C, Min. 15°C Mean of 25°C

Climate: Tropical Rainforest

Human Development Indexes (PNUD, 2010)

HDI-M: 0.490

Rank Amazonas State: 58th (of 62)

Rank Brazil: 5,541th (of 5,565)

Longevity index: 0.759

Education index: 0.353

Income index: 0.438

Gross Domestic Product (US$ 1,000)

Table 49 presents the local Gross Domestic Product (GDP) between 2007 and 2011.

Table 49: Gross Domestic Product of Santo Antônio do Içá Municipality from 2007 to 2011 (US$)

	2007	2008	2009	2010	2011
GDP TOTAL	**42,038**	**47,314**	**47,081**	**56,333**	**66,418**
GDP Agribusiness	5,202	5,778	5,852	8,862	10,482
GDP Industry	4,344	5,060	4,880	6,087	7,137
GDP Servicing	31,598	35,472	35,373	40,252	47,533
GDP Taxes	894	1,004	976	1,133	1,266
GDP per capita (US$ 1.00)	**1,438**	**1,568**	**1,551**	**2,301**	**2,690**
Poverty line (US$ 1.00)	1.02	1.19	1.08	1.87	2.23

SOURCE: SEPLAN (2013)

Agriculture (2013)

Table 50 presents the local agricultural production in 2013.

Table 50: Agricultural production of Santo Antônio do Içá Municipality in 2013

Product	Area (ha)	Quantity produced (tonnes)
Açaí Berry	-	250
Rubber	-	40
Oilseed		12
Banana	176	2,000
Orange	2	24
Papaya	10	135
Passion fruit	2	30
Pineapple	10	140 (thousand fruits)
Sugarcane	4	160
Cassava	720	7,200
Watermelon	50	700
Corn or maize (grain)	100	250

SOURCE: IBGE (2013)

Livestock and animal production (2013)

Table 51 presents the livestock composition.

Table 51: Livestock composition of Santo Antônio do Içá Municipality

Description	Amount
Bovine	1,400 heads
Buffalo	75 heads
Equine	40 heads
Swine	350 heads
Ovine	500 heads
Poultry	10,000 heads
Chicken egg (1,000 dozens)	22
Fishing (tonnes)	14
Honey (kg)	250

SOURCE: IBGE (2013)

Wood

Santo Antônio do Içá produced, in 2013, 1,000 m^3 of firewood, 3,944 m^3 of round wood and 5 tonnes of charcoal.

Environment and Preservation

There is one Indian area in Santo Antônio do Içá, called Betânia with 122,769 ha. There is also an area of relevant ecological interest of 15,000 ha in the municipality, called Javari Buriti. In addition, an ecological reserve of 288,187 ha called Jutaí Solimões that covers part of another two municipalities, Amaturá e Jutaí. According to SEPLAN, in 2013 there were 34 burned areas in Santo Antônio do Içá. The forest covers 4,046 km^2 of the municipality but the deforestation reached 137.6 km^2 in 2013.

XII. Municipality of Pauini

Physical Geography Aspects

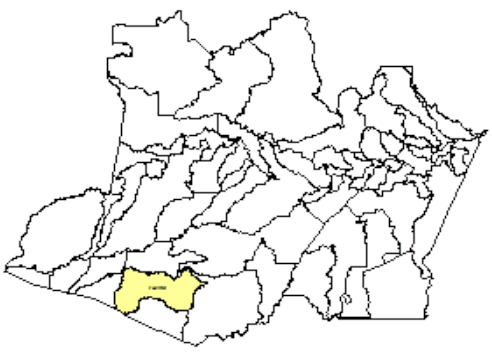

Figure 42: Map of Pauini, State of Amazonas

Country: Brazil

State: Amazonas

Region: North

Border: Municipalities of Lábrea, Boca do Acre, Envira and Itamarati, and Acre State

Area: 41,610 km^2

Population (IBGE, 2010): 18,166

Population Density: 0.44/km^2

Population Rank: 38th (Amazonas State has 62 municipalities)

Urban population (IBGE, 2010): 9,264

Rural population (IBGE, 2010): 8,902

Villages in the Rural Area (IDAM): 90

Elevation: 100m

Created by (IDAM): State Law Number 96 of 12/19/1955 (Pauini was part of Lábrea Municipality)

Distance from State Capital (Manaus): 935 km in straight line or 2,215 km following the rivers

How to reach Pauini from Manaus: there is one airport in the municipality, which is out of order. Normally, the trip lasts about 10 days + 18h by regional boat, by plane from Manaus to Lábrea (1h35m) + 36h by regional boat from Lábrea to Pauini. There are no highways linking the municipality to its neighbors. Hence, rivers are the main transportation pathway.

Dry season: September. The dry season has great impact on mobility since it difficult the use of boats

Main Rivers: Purus and Pauini

Temperature (SEPLAN, 2013): Max. 35.2°C, Min. 16.9°C and Mean 24°C

Climate: Tropical Rainforest

Human Development Indexes (PNUD, 2010)

HDI-M: 0.496

Rank Amazonas State: 57th (of 62)

Rank Brazil: 5,538th (of 5,565)

Longevity index: 0.724

Education index: 0.317

Income index: 0.531

Gross Domestic Product (US$ 1,000)

Table 52 presents the local Gross Domestic Product (GDP) between 2007 and 2011.

Table 52: Gross Domestic Product of Pauini Municipality from 2007 to 2011 (US$)

GDP TOTAL	2007	2008	2009	2010	2011
	31,736	**34,099**	**34,853**	**55,282**	**61,415**
GDP Agribusiness	7,265	4,765	4,849	15,030	16,382
GDP Industry	2,791	3,323	3,275	4,709	5,396
GDP Servicing	20,928	25,292	26,001	34,316	38,439
GDP Taxes	752	719	729	1,228	1,198
GDP per capita (US$ 1.00)	**1,729**	**1,801**	**1,824**	**3,046**	**3,365**
Poverty line (US$ 1.00)	1.24	1.36	1.27	2.47	2.80

SOURCE: SEPLAN (2013)

Agriculture (2013)

Subsistence agriculture is the common practice in Pauini, which is the reason for not registering large production rates. Seeding is done in lowlands due to the fact that land fertility is renewed through every water cycle. This phenomenon occurs annually and it is characterized by a period of six months of flooding and six months of ebb. There is few large-scale farming, from which the produce is destined for sale. However, sowing and harvesting are still rudimentary and based on manual labor. Associated with the regional vision of forest preservation, these large-scale farms are scattered so as to avoid planting in a larger single area. Table 53 presents the local agricultural production in 2013.

Table 53: Agricultural production of Pauini Municipality in 2013

Product	Area (ha)	Quantity produced
Açaí Berry	-	160
Rice	160	387
Brazil nuts	-	30
Orange	6	120
Passion fruit	2	40
Watermelon	35	630
Banana	30	384
Bean	81	90
Cassava	500	6
Pineapple	4	72
Corn or maize (grain)	100	300
Papaya	3	60
Coffee grain	4	8
Coconut-from-Bahia	2	8 (thousand fruits)
Lemon	3	21
Rubber	-	50

SOURCE: IBGE (2013)

Livestock and animal production (2013)

The predominant activity in communities living on the banks of rivers and streams is fishing since it is their main source of food. The quantity of fish can be seen throughout the year, with great abundance from June to September. However, there are few households that have livestock. Table 54 presents the livestock composition.

Table 54: Livestock composition of Pauini Municipality

Description	Amount
Bovine	11,200 heads
Swine	650 heads
Buffalo	5 heads
Ovine	202 heads
Caprine	48 heads
Equine	84 heads
Asinine	-
Mules	-
Poultry	19,600 heads
Chicken egg (1,000 dozens)	98
Milk (1,000 liters)	140
Fishing (tonnes)	15

SOURCE: IBGE (2013)

Wood

Logging is a traditional activity of the municipality but it has collapsed in recent years as a result of the lack of sustainable forest management (SFM) causing the extinction of commercially attractive species. Even with that scenario, Pauini produced in 2013 900 m^3 of firewood and 977 m^3 of round wood.

Environment and Preservation

With regard to environmental issues, Pauini has one of the largest preservation areas of the world regarding the relation between its total area and protected area. There two very important natural reserves in the region: The National Forest of Purus with 256,000 ha and The National Forest of Mapiá / Inauini with 311,000 ha, which together correspond to about 14% of the total municipality. According to SEPLAN, in 2013 there were 154 burned areas in Pauini. The forest covers 39,980 km^2 of the municipality but the deforestation reached 239.7 km^2 in 2013.

XIII. Municipality of Maraã

Physical Geography Aspects

Figure 43: Map of Maraã, State of Amazonas

Country: Brazil

State: Amazonas

Region: North

Border: Municipalities of Santa Isabel do Rio Negro, Barcelos, Coari, Tefé, Alvarães, Uarini, Fonte Boa and Japurá

Area: 16,910 km^2

Population (IBGE, 2010): 17,528

Population Density: 1.04/km^2

Population Rank: 40th (Amazonas State has 62 municipalities)

Urban population (IBGE, 2010): 8,753

Rural population (IBGE, 2010): 8,775

Villages in the Rural Area (IDAM): 96

Elevation: 65 m

Created by (IDAM): State Law Number 96 of 12/19/1955 (Maraã was part of Tefé Municipality)

Distance from State Capital (Manaus): 634 km in straight line or 796 km following the rivers

How to reach Maraã from Manaus: there is no airport in the municipality. The trip can be done by three different ways. The journey can last two days by regional boat; 13h using a fast boat; 1h by plane until Tefé and more 3h of fast boat (or 22h using a regional boat from Tefé to Maraã). There are no highways linking the municipality to its neighbors. Hence, rivers are the main transportation pathways.

Dry season: September. The dry season has great impact on mobility since it difficult the use of boats

Main Rivers: Japurá and Solimões

Temperature (SEPLAN, 2013): Max. 31°C, Min. 11°C and Mean 26°C

Climate: Tropical Rainforest

Human Development Indexes (PNUD, 2010)

HDI-M: 0.498

Rank Amazonas State: 56th (of 62)

Rank Brazil: 5,535th (of 5,565)

Longevity index: 0.763

Education index: 0.348

Income index: 0.466

Gross Domestic Product (US$ 1,000)

Table 55 presents the local Gross Domestic Product (GDP) between 2007 and 2011.

Table 55: Gross Domestic Product of Maraã Municipality from 2007 to 2011 (US$)

GDP TOTAL	2007	2008	2009	2010	2011
	29,807	**53,652**	**54,625**	**47,407**	**50,925**
GDP Agribusiness	5,698	23,927	23,889	10,292	9,540
GDP Industry	2,683	3,144	3,110	4,389	5,024
GDP Servicing	20,855	25,394	26,586	31,817	35,449
GDP Taxes	571	1,187	1,041	908	911
GDP per capita (US$ 1.00)	**1,703**	**2,972**	**3,012**	**2,730**	**2,899**
Poverty line (US$ 1.00)	1.21	2.25	2.09	2.21	2.41

SOURCE: SEPLAN (2013)

Agriculture (2013)

Table 56 presents the local agricultural production in 2013.

Table 56: Agricultural production of Maraã Municipality in 2013

Product	Area (ha)	Quantity produced (tonnes)
Brazilian Nutt	-	2
Açaí Berry	-	120
Banana	9	115
Cocoa	45	10
Coconut-from-Bahia	1	4 (thousand fruits)
Papaya	8	175
Passion fruit	4	80
Pineapple	5	54 (thousand fruits)
Bean	30	27
Cassava	315	3,300
Watermelon	5	97
Corn or maize (grain)	25	62
Tomato	1	16

SOURCE: IBGE (2013)

Livestock and animal production (2013)

Table 57 presents the livestock composition.

Table 57: Livestock composition of Maraã Municipality

Description	Amount
Bovine	797 heads
Caprine	21 head
Equine	5 heads
Swine	98 heads
Ovine	86 heads
Poultry	28,000 heads
Buffalo	288 heads

SOURCE: IBGE (2013)

Wood

Maraã produced, in 2013, 1,930 m^3 of round wood and 2 tonnes of charcoal.

Environment and Preservation

There are four Indian areas in Maraã. Cuiu-Cuiu with 36,310h, Jaquiri with 1,820h, Maraã Urubaxi with 94,406h, and Paraná do Paricá with 7,866h. According to SEPLAN, in 2013 there were 68 burned areas in Maraã. The forest covers 10,215 km^2 of the municipality but the deforestation reached 117.1 km^2 in 2013.

XIV. Municipality of Uiramutã

Physical Geography Aspects

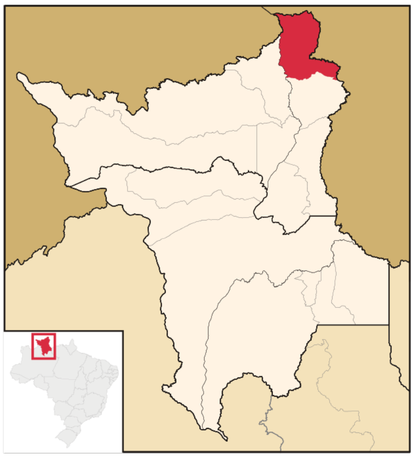

Figure 44: Map of Uiramutã, State of Roraima

Country: Brazil

State: Roraima

Region: North

Border: Municipalities of Pacaraima and Normandia, and the countries of Venezuela and Guiana.

Area: 8,065 km^2

Population (IBGE, 2010): 8,375

Population Density: 1.04/km^2

Population Rank: 12th (Roraima State has 15 municipalities)

Urban population (IBGE, 2010): 1,138

Rural population (IBGE, 2010): 7,237 (86.41% of population, mostly Indians)

Villages in the Rural Area (SEPLAN3): 13

Elevation: 804 m

Created by (SEPLAN2): State Law Number 98 of 10/17/1995 (Uiramutã was part of Normandia Municipality)

Distance from State Capital (Boa Vista): 315 km

How to reach Uiramutã from Boa Vista: there is no airport in the municipality. Four highways, BR-174, BR-433, RR-171 and RR-407, are the common pathways.

Main Rivers: Maú, Cotingo, Canã and Uailã

Temperature (SEPLAN2): Max. 38°C, Min 28°C, and Mean 26°C.

Climate: Tropical Rainforest.

Human Development Indexes (PNUD, 2010)

HDI-M: 0.453

Rank Roraima State: 15th (of 15)

Rank Brazil: 5,560th (of 5,565)

Longevity index: 0.766

Education index: 0.276

Income index: 0.439

Gross Domestic Product (BRL 1,000)

Table 58 presents the local Gross Domestic Product (GDP) between 2008 and 2012.

Table 58: Gross Domestic Product of Uiramutã Municipality from 2008 to 2012 (US$ 1,000)

GDP TOTAL	2008	2009	2010	2011	2012
	24,085	**29,150**	**30,787**	**40,385**	**45,488**
GDP Agribusiness	1,414	1,614	1,436	1,928	2,203
GDP Industry	1,682	2,029	2,426	3,049	3,253
GDP Servicing	20,717	25,293	26,719	35,117	39,697
GDP Taxes	271	214	207	291	334
GDP per capita (US$ 1.00)	**3,111**	**3,674**	**3,676**	**4,711**	**5,190**

SOURCE: SEPLAN1 (2012)

Agriculture (2012)

Table 59 presents the local agricultural production in 2010.

Table 59: Agricultural production of Uiramutã Municipality in 2010

Product	Area (ha)	Quantity produced (tonnes)
Rice	50	55
Sugarcane	1	2
Bean	60	30
Cassava	140	1,400
Watermelon	1	6
Corn or maize (grain)	200	232
Orange	10	42
Papaya	2	4
Banana	20	120

SOURCE: SEPLAN3 (2012)

Livestock and animal production (2010)

Table 60 presents the livestock composition.

Table 60: Livestock composition of Uiramutã Municipality

Description	Amount
Bovine	11,500 heads
Caprine	200 heads
Equine	2,000 heads
Swine	730 heads
Ovine	-
Poultry	8,000 heads
Milk (thousand liters)	48
Eggs (thousand dozen)	9

SOURCE: SEPLAN3 (2012)

Wood

Uiramutã produced, in 2010, 950 m^3 of firewood.

Environment and Preservation

There is one Native reserve in Uiramutã, called Raposa Serra do Sol, with 1,747,464 ha covering as well two more municipalities, Normandia and Pacaraima. That reserve reaches 99.73% of Uiramutã municipality area. There is also a National Forest called Monte Roraima, with 117,147 ha in the municipality.

XV. Municipality of Amajari

Physical Geography Aspects

Figure 45: Map of Amajari, State of Roraima

Country: Brazil

State: Roraima

Region: North

Border: Municipalities of Pacaraima, Alto Alegre, and Boa Vista, and the country of Venezuela.

Area: 28,472 km^2

Population (IBGE, 2010): 9,327

Population Density: 0.33/km^2

Population Rank: 9th (Roraima State has 15 municipalities)

Urban population (IBGE, 2010): 1,219

Rural population (IBGE, 2010): 8,108 (86.93% of population)

Villages in the Rural Area (SEPLAN3): 14

Elevation: 100 m

Created by (SEPLAN2): State Law Number 97 of 10/17/1995 (Amajari was part of Boa Vista Municipality)

Distance from State Capital (Boa Vista): 150 km

How to reach Amajari from Boa Vista: there is no airport in the municipality. Two highways, BR-174 and RR-203, are the common pathways.

Main Rivers: Uraricoera, Parimé and Amajari

Temperature (SEPLAN2): Mean 26°C

Climate: Tropical Rainforest

Human Development Indexes (PNUD, 2010)

HDI-M: 0.484

Rank Roraima State: 14th (of 15)

Rank Brazil: 5,550th (of 5,565)

Longevity index: 0.815

Education index: 0.319

Income index: 0.484

Gross Domestic Product (US$ 1,000)

Table 61 presents the local Gross Domestic Product (GDP) between 2008 and 2012.

Table 61: Gross Domestic Product of Amajari Municipality from 2008 to 2012 (US$ 1,000)

GDP TOTAL	2008	2009	2010	2011	2012
	31,216	**38,824**	**42,433**	**56,638**	**66,656**
GDP Agribusiness	6,245	7,135	6,377	9,187	12,755
GDP Industry	1,851	2,303	3,005	3,865	4,035
GDP Servicing	22,599	28,723	32,124	42,305	48,467
GDP Taxes	521	664	927	1,281	1,399
GDP per capita (US$ 1.00)	**3,912**	**2,733**	**4,549**	**5,877**	**6,709**

SOURCE: SEPLAN1 (2012)

Agriculture (2010)

Table 62 presents the local agricultural production in 2010.

Table 62: Agricultural production of Amajari Municipality in 2010

Product	Area (ha)	Quantity produced (tonnes)
Banana	180	1,030
Pineapple	20	80 (thousand fruits)
Rice	960	5,731
Sugarcane	10	18
Bean	200	99
Cassava	118	1,385
Watermelon	64	428
Corn or maize (grain)	350	732
Orange	16	120
Lemon	27	6
Papaya	65	136
Tomato	10	82

SOURCE: SEPLAN3 (2012)

Livestock and animal production (2010)

Table 63 presents the livestock composition.

Table 63: Livestock composition of Amajari Municipality

Description	Amount
Bovine	65,000 heads
Caprine	960 heads
Equine	4,650 heads
Swine	7,500 heads
Poultry	23,600 heads
Buffalo	288 heads

SOURCE: SEPLAN3 (2012)

Wood

Amajari produced, in 2010, 1,600 m^3 of round wood, 2,000m^3 of firewood and 1 tonne of charcoal.

Environment and Preservation

There are two ecological stations at Amajari: Maracá Island with 103,976 ha and Flona Parima with 149,521 ha (which includes Alto Alegre as well). Amajari has 58.71% of his area belonging to an Indian reserve (16,790 km^2)

XVI. Municipality of Melgaço

Physical Geography Aspects

Figure 46: Map of Melgaço, State of Pará

Country: Brazil

State: Pará

Region: North

Border: Municipalities of Breves, Portel, Bagre, Gurupá and Porto de Moz

Area: 6,774 km^2

Population (IBGE, 2013): 24,808

Population Density: 3.66/km^2

Population Rank: 88th (Pará State has 144 municipalities)

Urban population (IBGE, 2013): 5,503

Rural population (IBGE, 2013): 19,305 (77.8% of population)

Elevation: 12 m

Created in: 1961

Distance from State Capital (Belém): 290 km in a straight line

How to reach Melgaço from Belém: there are no highways, just a small airport in the municipality. The trip can last by helicopter (30 minutes), fast boat (8h) or regional boat (16h)

Main Rivers: Amazonas, Tajapuru, Laguna, Anapu, and Melgaço

Temperature: Mean 28.5°C

Climate: Tropical Rainforest

Human Development Indexes (PNUD, 2010)

HDI-M: 0.418 (least developed municipality of Brazil)

Rank Pará State: 144^{th} (of 144)

Rank Brazil: $5{,}565^{th}$ (of 5,565)

Longevity index: 0.776

Education index: 0.207

Income index: 0.418

Gross Domestic Product (US$ 1,000)

Table 64 presents the local Gross Domestic Product (GDP) between 2008 and 2012.

Table 64: Gross Domestic Product of Melgaço Municipality from 2008 to 2012 (US$ 1,000)

	2008	2009	2010	2011	2012
GDP TOTAL	**23,999**	**26,886**	**36,008**	**45,461**	**55,158**
GDP Agribusiness	4,361	4,976	5,569	6,100	6,626
GDP Industry	2,204	2,210	3,602	4,732	5,348
GDP Servicing	17,079	19,307	26,181	34,068	42,135
GDP Taxes	355	393	655	562	1,049
GDP per capita (US$ 1.00)	**1,334**	**1,523**	**1,451**	**1,811**	**2,174**

SOURCE: IBGE (2013)

Agriculture (2013)

Table 65 presents the local agricultural production in 2013.

Table 65: Agricultural production of Melgaço Municipality in 2013

Product	Area (ha)	Quantity produced (tonnes)
Brazil nut	-	9
Açaí Berry	-	40
Palm tree	-	10
Pequi oil	-	21
Banana	5	50
Rice	20	20
Cassava	150	1,500
Corn or maize (grain)	12	8

SOURCE: IBGE (2013)

Livestock and animal production (2013)

Table 66 presents the livestock composition.

Table 66: Livestock composition of Melgaço Municipality

Description	Amount
Bovine	1,820 heads
Caprine	110 heads
Equine	20 heads
Swine	4,160 heads
Poultry	1,678 heads
Buffalo	382 heads
Ovine	143 heads
Milk (liters)	37,000
Eggs (dozens)	3,000

SOURCE: IBGE (2013)

Wood

Melgaço produced, in 2013, 20,000 m^3 of round wood, 8,000m^3 of firewood, and 120 tonnes of charcoal.

Environment and Preservation

Melgaço municipality has part of its area belonging to Extractive Reserve Gurupá-Melgaço (145,297 ha) and to Caxiuanã National Forest (300,000 ha).

XVII. Municipality of Chaves

Physical Geography Aspects

Figure 47: Map of Chaves, State of Pará

Country: Brazil

State: Pará

Region: North

Border: Municipalities of Afuá, Anajás and Santa Cruz

Area: 13,084 km^2

Population (IBGE, 2010): 21,005

Population Density: 1.61/km^2

Population Rank: 98th (Pará State has 144 municipalities)

Urban population (IBGE, 2010): 2,510

Rural population (IBGE, 2010): 18,495 (88% of population)

Elevation: 6 m

Created in: 1755

Distance from State Capital (Belém): 220 km in straight line

How to reach Chaves from Belém: there are no highways, only a small airport in the municipality. The trip lasts by small planes (1h) and regional boats (50h)

Main Rivers: Amazonas

Temperature: Mean 28.5°C

Climate: Tropical Rainforest

Human Development Indexes (PNUD, 2010)

HDI-M: 0.453

Rank Pará State: 143th (of 144)

Rank Brazil: 5,560th (of 5,565)

Longevity index: 0.769

Education index: 0.234

Income index: 0.516

Gross Domestic Product (BRL 1,000)

Table 67 presents the local Gross Domestic Product (GDP) between 2008 and 2012.

Table 67: Gross Domestic Product of Chaves Municipality from 2008 to 2012 (US$ 1,000)

	2008	2009	2010	2011	2012
GDP TOTAL	**32,958**	**37,278**	**39,028**	**47,018**	**56,683**
GDP Agribusiness	11,743	12,655	13,441	16,368	20,835
GDP Industry	3,713	3,419	4,101	4,771	5,517
GDP Servicing	16,790	20,363	20,650	24,932	28,961
GDP Taxes	711	841	838	946	1,370
GDP per capita (US$ 1.00)	**1,629**	**1,818**	**1,858**	**2,209**	**2,629**

SOURCE: IBGE (2013)

Agriculture (2013)

Table 68 presents the local agricultural production in 2013.

Table 68: Agricultural production of Chaves Municipality in 2013

Product	Area (ha)	Quantity produced (tonnes)
Cassava	70	819
Açaí Berry	-	481
Palm tree	-	141

SOURCE: IBGE (2013)

Livestock and animal production (2013)

Table 69 presents the livestock composition.

Table 69: Livestock composition of Chaves Municipality

Description	Amount
Bovine	73,420 heads
Caprine	1,693 heads
Equine	5,024 heads
Swine	21,400 heads
Poultry	4,200 heads
Buffalo	144,288 heads
Ovine	1,189 heads
Eggs (dozens)	39,000

SOURCE: IBGE (2013)

Wood

Chaves produced, in 2013, 1,553 m^3 of round wood, 6,356 m^3 of firewood, and 4 tonnes of charcoal.

Environment and Preservation

No data available.

XVIII. Municipality of Bagre

Physical Geography Aspects

Figure 48: Map of Bagre, State of Pará

Country: Brazil

State: Pará

Region: North

Border: Municipalities of Breves, Portel, Baião, Oieiras do Pará e Portel

Area: 4,397 km^2

Population (IBGE, 2010): 23,864

Population Density: 5.43/km^2

Population Rank: 83th (Pará State has 144 municipalities)

Urban population (IBGE, 2010): 10,661

Rural population (IBGE, 2010): 13,203 (55% of population)

Elevation: 31 m

Created in: 1961

Distance from State Capital (Belém): 222 km following the rivers

How to reach Bagre from Belém: there is no highways or even airport at the municipality. The trip is done by boat

Main Rivers: Jacundá, Juruparu, Panaúba, Tachi, Mocajuba, Jagurajó, Paraná and Pará

Temperature: Max. 32.4 °C, Min. 24.1°C and Mean of 26.3°C

Climate: Tropical Rainforest

Human Development Indexes (PNUD, 2010)

HDI-M: 0.471

Rank Pará State: 141th (of 144)

Rank Brazil: 5,557th (of 5,565)

Longevity index: 0.777

Education index: 0.280

Income index: 0.481

Gross Domestic Product (US$ 1,000)

Table 70 presents the local Gross Domestic Product (GDP) between 2008 and 2012.

Table 70: Gross Domestic Product of Bagre Municipality from 2008 to 2012 (US$ 1,000)

GDP TOTAL	2008	2009	2010	2011	2012
	21,271	**24,979**	**28,374**	**35,139**	**42,061**
GDP Agribusiness	2,076	2,250	2,348	2,670	2,902
GDP Industry	2,393	2,474	3,329	4,316	4,737
GDP Servicing	16,377	19,739	22,132	27,562	33,490
GDP Taxes	424	516	565	590	932
GDP per capita (US$ 1.00)	**1,075**	**1,225**	**1,189**	**1,426**	**1,656**

SOURCE: IBGE (2013)

Agriculture (2013)

Table 71 presents the local agricultural production in 2013.

Table 71: Agricultural production of Bagre Municipality in 2013

Product	Area (ha)	Quantity produced (tonnes)
Palm tree	-	2
Brazil nut	-	13
Açaí Berry	-	150
Rice	10	12
Pineapple	2	30 (thousand fruits)
Cassava	55	550
Corn or maize (grain)	15	12
Black pepper	8	8 tonnes

SOURCE: IBGE (2013)

Livestock and animal production (2013)

Table 36 presents the livestock composition.

Table 72: Livestock composition of Bagre Municipality

Description	Amount
Bovine	1,811 heads
Caprine	66 heads
Equine	20 heads
Swine	6,710 heads
Poultry	1,158 heads
Buffalo	544 heads
Milk (liters)	36,000
Eggs (dozens)	3,000

SOURCE: IBGE (2013)

Wood

Bagre produced, in 2013, 1,100m^3 of firewood and 18,000 m^3 of round wood.

Environment and Preservation

The vegetation of the municipality is formed by dense forest of low plateaus. Along the edge of Pará river and the lower course of its confluence, can be found the dense forest of the floodplain, the sub-region of Marajó holes (with intense presence of palm trees, especially the Açaí Berry), the riparian forest, occupying the terraces. Where the primary vegetation has been removed by the action of farmers, there is the secondary forest in various stages of regeneration. Small grasslands are found in the most depressed areas subject to flooding by the action of rain.

XIX. Municipality of Cachoeira do Piriá

Physical Geography Aspects

Figure 49: Map of Cachoeira do Piriá, State of Pará

Country: Brazil

State: Pará

Region: North

Border: Municipalities of Viseu, Nova Esperança do Piriá and the State of Maranhão

Area: 2,461 km^2

Population (IBGE, 2010): 26,484

Population Density: 10.76/km^2

Population Rank: 71th (Pará State has 144 municipalities)

Urban population (IBGE, 2010): 5,532

Rural population (IBGE, 2010): 20,952 (79.1% of population)

Elevation: 92.6 m

Created in: 1995

Distance from State Capital (Belém): 217 km in straight line

How to reach Cachoeira do Piriá from Belém: highway BR-316, about 254 km

Main Rivers: Piriá and Gurupi

Temperature: Max. 32 °C; Min. 21 °C; Mean 27 °C

Climate: Tropical Rainforest

Human Development Indexes (PNUD, 2010)

HDI-M: 0.473

Rank Pará State: 141th (of 144)

Rank Brazil: 5,557th (of 5,565)

Longevity index: 0.779

Education index: 0.303

Income index: 0.449

Gross Domestic Product (BRL 1,000)

Table 73 presents the local Gross Domestic Product (GDP) between 2008 and 2012.

Table 73: Gross Domestic Product of Cachoeira do Piriá Municipality from 2008 to 2012 (US$ 1,000)

	2008	2009	2010	2011	2012
GDP TOTAL	**22,718**	**25,796**	**32,761**	**42,327**	**55,167**
GDP Agribusiness	4,172	3,996	4,402	6,034	7,821
GDP Industry	2,483	2,542	3,956	5,053	5,781
GDP Servicing	15,594	18,618	23,657	30,467	40,483
GDP Taxes	468	640	747	773	1,081
GDP per capita (US$ 1.00)	**1,229**	**1,374**	**1,237**	**1,549**	**1,960**

SOURCE: IBGE (2013)

Agriculture (2013)

Table 74 presents the local agricultural production in 2013.

Table 74: Agricultural production of Cachoeira do Piriá Municipality in 2013

Product	Area (ha)	Quantity produced
Mallow	80	75 tonnes
Açaí Berry	-	550 tonnes
Rice	400	296 tonnes
Banana	500	10,080 tonnes
Bean	80	72 tonnes
Cassava	2,200	28,600 tonnes
Black pepper	55	110 tonnes
Corn or maize (grain)	600	390 tonnes

SOURCE: IBGE (2013)

Livestock and animal production (2013)

Table 75 presents the livestock composition.

Table 75: Livestock composition of Cachoeira do Piriá Municipality

Description	Amount
Bovine	46,519 heads
Caprine	652 heads
Equine	1,102 heads
Swine	1,730 heads
Poultry	22,895 heads
Buffalo	6 heads
Ovine	549 heads
Milk (liters)	138,000
Eggs (dozens)	15,000
Honey	10 tonnes

SOURCE: IBGE (2013)

Wood

Cachoeira do Piriá produced, in 2013, 5,210 m^3 of round wood, 7,000m^3 of firewood, and 4 tonnes of charcoal.

Environment and Preservation

No data available.

XX. Municipality of Portel

Physical Geography Aspects

Figure 50: Map of Portel, State of Pará

Country: Brazil

State: Pará

Region: North

Border: Municipalities of Melgaço, Oieiras do Pará, Itupirange, Porto de Moz, Senador José Porfírio and Pacajá

Area: 25,172 km^2

Population (IBGE, 2010): 52,172

Population Density: 2.06/km^2

Population Rank: 31th (Pará State has 144 municipalities)

Urban population (IBGE, 2010): 24,852

Rural population (IBGE, 2010): 27,320 (52.4% of population)

Elevation: 19 m

Created in: 1758

Distance from State Capital (Belém): 270 km in straight line

How to reach Portel from Belém: there is no highways but a small airport in the municipality. The trip can be done by small planes and boats (326 km through the rivers).

Main Rivers: Anapu, Camaraipe

Temperature: Max. 35 °C, Min. 23 °C, and Mean of 29°C

Climate: Tropical Rainforest

Human Development Indexes (PNUD, 2010)

HDI-M: 0.483

Rank Pará State: 140th (of 144)

Rank Brazil: 5,553^{h} (of 5,565)

Longevity index: 0.767

Education index: 0.286

Income index: 0.513

Gross Domestic Product (US$ 1,000)

Table 76 presents the local Gross Domestic Product (GDP) between 2008 and 2012.

Table 76: Gross Domestic Product of Portel Municipality from 2008 to 2012 (US$ 1,000)

GDP TOTAL	2008	2009	2010	2011	2012
	79,446	**91,093**	**95,343**	**108,332**	**147,444**
GDP Agribusiness	7,668	9,017	11,532	14,336	31,772
GDP Industry	16,011	12,812	14,282	13,637	15,697
GDP Servicing	51,997	65,342	65,551	76,471	94,769
GDP Taxes	3,770	3,922	3,977	3,888	5,206
GDP per capita (US$ 1.00)	**1,656**	**1,861**	**1,827**	**2,034**	**2,715**

SOURCE: IBGE (2013)

Agriculture (2013)

Table 77 presents the local agricultural production in 2013.

Table 77: Agricultural production of Portel Municipality in 2013

Product	Area (ha)	Quantity produced (tonnes)
Brazil nut	-	270
Açaí Berry	-	600
Palm tree	-	18
Pequi	-	450
Rice	50	65
Pineapple	10	150 (thousand fruits)
Cassava	4,000	48,000
Corn or maize (grain)	140	84
Banana	50	500
Black pepper	25	75

SOURCE: IBGE (2013)

Livestock and animal production (2013)

Table 78 presents the livestock composition.

Table 78: Livestock composition of Portel Municipality

Description	Amount
Bovine	10,390 heads
Caprine	150 heads
Equine	186 heads
Swine	6,740 heads
Poultry	4,753 heads
Buffalo	1,212 heads
Ovine	114 heads
Milk (liters)	270,000
Eggs (dozens)	9,000

SOURCE: IBGE (2013)

Wood

Portel produced, in 2013, 1,000,000 m^3 of round wood, 3,800m^3 of firewood, and 65 tonnes of charcoal.

Environment and Preservation

No data available.

XXI. Municipality of Anajás

Physical Geography Aspects

Figure 51: Map of Anajás, State of Pará

Country: Brazil

State: Pará

Region: North

Border: Municipalities of Breves, Afuá, São Sebastião de Boa Vista, Chaves, Ponta de Pedras, and Muaná

Area: 6,921 km^2

Population (IBGE, 2010): 24,759

Population Density: 3.58/km^2

Population Rank: 86th (Pará State has 144 municipalities)

Urban population (IBGE, 2010): 9,494

Rural population (IBGE, 2010): 15,265 (61.6% of population)

Elevation: 10 m

Created in: 1870

Distance from State Capital (Belém): 170 km in straight line

How to reach Anajás from Belém: there is no highways or airport in the municipality. The trip can be done by boat

Main Rivers: Anajás, Mocoões, Guajará, Cururu Anamã, and Jacaré

Temperature: Max. 36 °C, Min. 18 °C, and Mean of 27°C

Climate: Tropical Rainforest

Human Development Indexes (PNUD, 2010)

HDI-M: 0.484

Rank Pará State: 139th (of 144)

Rank Brazil: 5,550th (of 5,565)

Longevity index: 0.774

Education index: 0.290

Income index: 0.506

Gross Domestic Product (US$ 1,000)

Table 79 presents the local Gross Domestic Product (GDP) between 2008 and 2012.

Table 79: Gross Domestic Product of Anajás Municipality from 2008 to 2012 (US$ 1,000)

GDP TOTAL	2008	2009	2010	2011	2012
	28,754	**34,168**	**34,209**	**43,685**	**51,604**
GDP Agribusiness	2,301	2,672	3,258	3,954	5,630
GDP Industry	4,263	4,544	4,916	6,807	7,811
GDP Servicing	21,358	25,877	24,892	31,069	35,998
GDP Taxes	833	1,075	1,142	1,854	2,165
GDP per capita (US$ 1.00)	**1,082**	**1,248**	**1,382**	**1,730**	**2,006**

SOURCE: IBGE (2013)

Agriculture (2013)

Table 80 presents the local agricultural production in 2013.

Table 80: Agricultural production of Anajás Municipality in 2013

Product	Area (ha)	Quantity produced (tonnes)
Banana	60	600
Açaí Berry	-	980
Palm tree	-	800
Cassava	150	1,500
Rubber	-	2
Pineapple	1	10 (thousand fruits)

SOURCE: IBGE (2013)

Livestock and animal production (2013)

Table 81 presents the livestock composition.

Table 81: Livestock composition of Anajás Municipality

Description	Amount
Bovine	990 heads
Caprine	102 heads
Equine	482 heads
Swine	8,048 heads
Poultry	5,930 heads
Buffalo	7,424 heads
Ovine	181 heads
Milk (liters)	83,000
Eggs (dozens)	15,000

SOURCE: IBGE (2013)

Wood

Anajás produced, in 2013, 80,000 m^3 of round wood and 16,000m^3 of firewood.

Environment and Preservation

No data available.

XXII. Municipality of Afuá

Physical Geography Aspects

Figure 52: Map of Afuá, State of Pará

Afuá is know as “Venetian of Marajó Island” because the headquarter of the municipality was built on wooden platforms, in an area of lowlands, so as not to be flooded by the floods of the three rivers that surround it, Afuá is probably the only Brazilian city where cars and motorcycles are prohibited in all its extension.

Country: Brazil

State: Pará

Region: North

Border: Municipalities of Chaves, Anajás, Breves, Gurupá in Pará, and Macapá and Santana in Amapá State

Area: 8,372 km^2

Population (IBGE, 2010): 35,042

Population Density: 4.19/km^2

Population Rank: 60th (Pará State has 144 municipalities)

Urban population (IBGE, 2010): 9,478

Rural population (IBGE, 2010): 25,564 (72.9% of population)

Elevation: 8 m

Created in: 1890

Distance from State Capital (Belém): 255 km in straight line

How to reach Afuá from Belém: there is no highways but a small airport in the municipality. The trip can be done by small planes or boats

Main Rivers: Amazonas, Anajás, Afuá, Cajuuna and Marajozinho

Temperature: Max. 36 °C, Min 18 °C, and Mean of 27°C

Climate: Tropical Rainforest

Human Development Indexes (PNUD, 2010)

HDI-M: 0.489

Rank Pará State: 138th (of 144)

Rank Brazil: 5,543th (of 5,565)

Longevity index: 0.774

Education index: 0.311

Income index: 0.489

Gross Domestic Product (US$ 1,000)

Table 34 presents the local Gross Domestic Product (GDP) between 2008 and 2012.

Table 82: Gross Domestic Product of Afuá Municipality from 2008 to 2012 (US$ 1,000)

GDP TOTAL	2008	2009	2010	2011	2012
	46,104	**54,599**	**57,182**	**70,711**	**92,088**
GDP Agribusiness	7,820	9,258	9,225	10,527	12,191
GDP Industry	4,840	4,996	6,258	9,407	11,218
GDP Servicing	32,489	39,233	40,496	48,914	65,853
GDP Taxes	955	1,112	1,202	1,863	2,826
GDP per capita (US$ 1.00)	**1,424**	**1,673**	**1,632**	**1,994**	**2,567**

SOURCE: IBGE (2013)

Agriculture (2013)

Table 83 presents the local agricultural production in 2013.

Table 83: Agricultural production of Afuá Municipality in 2013

Product	Area (ha)	Quantity produced (tonnes)
Banana	40	427
Açaí Berry		5,889
Palm tree	-	126
Cassava	100	1,100

SOURCE: IBGE (2013)

Livestock and animal production (2013)

Table 84 presents the livestock composition.

Table 84: Livestock composition of Afuá Municipality

Description	Amount
Bovine	1,904 heads
Caprine	35 heads
Equine	30 heads
Swine	38,400 heads
Poultry	14,200 heads
Buffalo	4,275 heads
Ovine	34 heads
Milk (liters)	112,000
Eggs (dozens)	25,000

SOURCE: IBGE (2013)

Wood

Afuá produced, in 2013, 39,904 m^3 of round wood, 6,882m^3 of firewood, and 3 tonnes of charcoal.

Environment and Preservation (Municipality of Afuá, 2015)

The municipality of Afuá has typical coastal vegetation of the Amazon River delta region, predominantly wetlands and flooded areas. The Charapucu State Park is a state protected area covering about 65,000 hectares of natural environment of great scenic beauty.

XXIII. Municipality of Ipixuna do Pará

Physical Geography Aspects

Figure 53: Map of Ipixuna do Pará, State of Pará

Country: Brazil

State: Pará

Region: North

Border: Municipalities of Paragominas, Goianésia, Breu Branco, Tailândia, Tomé-Açu, Autora do Pará, Capitão Poço and Nova Esperança do Piriá

Area: 5,215 km^2

Population (IBGE, 2010): 51,309

Population Density: 9.84/km^2

Population Rank: 32th (Pará State has 144 municipalities)

Urban population (IBGE, 2010): 12,227

Rural population (IBGE, 2010): 39,082 (76.2% of population)

Elevation: 50 m

Created in: 1991

Distance from State Capital (Belém): 165 km in straight line

How to reach Ipixuna do Pará from Belém: highway BR-010 and BR-010 (255 km) or by boat through the Capim River

Main Rivers: Rio Ipixuna do Pará and Capim

Temperature: Max. 32 °C, Min. 21 °C, and Mean 26°C

Climate: Tropical Rainforest

Human Development Indexes (PNUD, 2010)

HDI-M: 0.489

Rank Pará State: 138th (of 144)

Rank Brazil: 5,543th (of 5,565)

Longevity index: 0.757

Education index: 0.304

Income index: 0.508

Gross Domestic Product (US$ 1,000).

Table 85 presents the local Gross Domestic Product (GDP) between 2008 and 2012.

Table 85: Gross Domestic Product of Ipixuna do Pará Municipality from 2008 to 2012 (US$ 1,000)

GDP TOTAL	2008	2009	2010	2011	2012
	116,788	**120,554**	**158,978**	**217,055**	**209,262**
GDP Agribusiness	28,451	31,089	26,004	37,264	43,291
GDP Industry	45,521	36,322	71,572	102,434	80,243
GDP Servicing	39,503	49,518	57,571	72,818	80,484
GDP Taxes	3,314	3,625	3,832	4,539	5,244
GDP per capita (US$ 1.00)	**2,739**	**2,715**	**3,098**	**4,071**	**4,058**

SOURCE: IBGE (2013)

Agriculture (2013)

Table 86 presents the local agricultural production in 2013.

Table 86: Agricultural production of Ipixuna do Pará Municipality in 2013

Product	Area (ha)	Quantity produced (tonnes)
Coconut-from-Bahia	10	80 (thousand fruits)
Watermelon	60	900
Rice	2,000	4,000
Black pepper	400	800
Bean	500	500
Cassava	9,000	135,000
Cashew nut	1,600	640
Corn or maize (grain)	5,500	14,437

SOURCE: IBGE (2013)

Livestock and animal production (2013)

Table 87 presents the livestock composition.

Table 87: Livestock composition of Ipixuna do Pará Municipality

Description	Amount
Bovine	85,387 heads
Caprine	227 heads
Equine	1,035 heads
Swine	2,349 heads
Poultry	29,866 heads
Buffalo	1,082 heads
Ovine	1,108 heads
Milk (liters)	5,674,000
Eggs (dozens)	153,000

SOURCE: IBGE (2013)

Wood

Ipixuna do Pará produced, in 2013, 135,357 m^3 of round wood and 3,320m^3.

Environment and Preservation

No data available.

Selected Municipalities in the Northeast Region

CBEM prepared these profiles.

I. Municipality of Satubinha

Physical Geography Aspects

Figure 54: Map of Satubinha, State of Maranhão

Maranhão is the only state in the Northeast that slightly identified with the hydrological characteristics of the region, because there is no drought and no shortage of water resources, both surface and underground, in their territory. In the region, there are many native trees and other natural resources. Most of population lives in rural areas, about 70%.

Country: Brazil

State: Maranhão

Region: Northeast

Border: Municipalities of Pio XII, Vitorino Freire, and Bela Vista do Maranhão.

Area: 441,881 km^2

Population (IBGE, 2010): 11,990

Population Density: 27.14/km^2

Population Rank: 151th (Maranhão State has 217 municipalities)

Urban population (IBGE, 2010): 3,634

Rural population (IBGE, 2010): 8,356 (69.69% of population)

Elevation: 38 m

Created by: State Law Number 6172 of 11/10/1994 (Satubinha was part of Pio XII Municipality)

Distance from State Capital (São Luís): 274 km

How to reach Satubinha from São Luís: 137 km by highway (BR-135) until Miranda do Norte municipality, 115 km by BR's-222/316 until Pio XII, 22 km by a secondary road until Satubinha. The closest airport (Pinheiro) is 160.4 kilometers away. There is also an international one (Marechal Cunha Machado) - 185.5 km away.

Average Temperature: 26°C

Climate: Tropical

Human Development Indexes (PNUD, 2010)

HDI-M: 0.493

Rank Maranhão State: 214th (of 217)

Rank Brazil: 5,539th (of 5,565)

Longevity index: 0.720

Education index: 0.369

Income index: 0.450

Gross Domestic Product (US$ 1,000)

Table 88 presents the local Gross Domestic Product (GDP) between 2008 and 2012.

Table 88: Gross Domestic Product of Satubinha Municipality from 2008 to 2012 (US$ 1,000)

GDP TOTAL	2008	2009	2010	2011	2012
	16,626	**16,598**	**19,748**	**24,702**	**30,433**
GDP Agribusiness	7,973	5,626	6,564	9,415	10,425
GDP Industry	993	1,261	1,623	2,223	2,599
GDP Servicing	7,434	9,457	11,276	12,765	16,920
GDP Taxes	226	254	285	299	489
GDP per capita (US$ 1.00)	**1,352**	**1,905**	**1,647**	**2,008**	**2,415**

SOURCE: IBGE (2013)

Agriculture (2013)

Table 89 presents the local agricultural production in 2013.

Table 89: Agricultural production of Satubinha Municipality in 2013

Product	Area (ha)	Quantity produced (tonnes)
Rice	864	1,123
Bean	315	158
Cassava	220	1,760
Corn (grain)	494	593
Almond	-	840

SOURCE: IBGE (2013)

Livestock and animal production (2013)

Table 90 presents the livestock composition.

Table 90: Livestock composition of Satubinha Municipality

Description	Amount
Bovine	19,200 heads
Caprine	185 heads
Equine	500 heads
Swine	1,260 heads
Poultry	22,652 heads
Buffalo	32 heads
Ovine	205 heads
Milk (liters)	332,000
Eggs (dozens)	23,000

SOURCE: IBGE (2013)

Wood

Satubinha produced, in 2013, 2,810m^3 of firewood, and 800 tonnes of charcoal.

Environment and Preservation

In small patches, in the process of extinction, there are tropical rainforests where some species such as the Angelim, the Maçaranduba, the Camaru, Cedar, the Sapucaia, the Tatajuba, the Copaíba and other less noble species.

II. Municipality of Jenipapo dos Vieiras

Physical Geography Aspects

Figure 55: Map of Jenipapo dos Vieiras, State of Maranhão

The economy of Jenipapo dos Vieiras is based mainly in agribusiness, livestock and animal production. Most of population lives in rural areas, about 85%.

Country: Brazil

State: Maranhão

Region: Northeast

Border: Municipalities of Itaipava do Grajaú, Barra do Corda, and Lagoa Grande do Maranhão.

Area: 1,962,898 km^2

Population (IBGE, 2010): 15,440

Population Density: 7.87/km^2

Population Rank: 121th (Maranhão State has 217 municipalities)

Urban population (IBGE, 2010): 2,536

Rural population (IBGE, 2010): 12,861 (83.53% of population)

Elevation: 150 m

Created by: State Law Number 620 of 11/10/1994 (Jenipapo dos Vieiras was part of Barra do Corda Municipality)

Distance from State Capital (São Luís): 499 km

How to reach Jenipapo dos Vieiras from São Luís: 347 km by highway (BR-135) until Presidente Dutra municipality, and 152 km by BR-226 until Jenipapo dos Vieiras.

Average Temperature: 26°C

Climate: Tropical

Human Development Indexes (PNUD, 2010)

HDI-M: 0.490

Rank Maranhão State: 215th (of 217)

Rank Brazil: 5,541th (of 5,565)

Longevity index: 0.766

Education index: 0.346

Income index: 0.445

Gross Domestic Product (US$ 1,000)

Table 91 presents the local Gross Domestic Product (GDP) between 2008 and 2012.

Table 91: Gross Domestic Product of Jenipapo dos Vieiras from 2008 to 2012 (US$ 1,000)

GDP TOTAL	2008	2009	2010	2011	2012
	24,527	**28,170**	**25,780**	**32,242**	**37,213**
GDP Agribusiness	11,526	10,765	8,165	10,052	12,300
GDP Industry	1,664	2,182	2,264	3,175	3,307
GDP Servicing	10,871	14,752	14,867	18,298	20,968
GDP Taxes	466	470	484	718	637
GDP per capita (US$ 1.00)	**1,573**	**1,825**	**1,670**	**2,068**	**2,365**

SOURCE: IBGE (2013)

Agriculture (2013)

Table 92 presents the local agricultural production in 2013.

Table 92: Agricultural production of Jenipapo dos Vieiras Municipality in 2013

Product	Area (ha)	Quantity produced (tonnes)
Banana	65	488
Cashew nut	50	17
Rice	2,720	2,829
Sugarcane	25	875
Bean	643	279
Cassava	220	1,980
Corn (grain)	833	1,041
Coconut-of-Bay	6	19 (thousand fruits)
Almond	-	2

SOURCE: IBGE (2013)

Livestock and animal production (2013)

Table 93 presents the livestock composition.

Table 93: Livestock composition of Jenipapo dos Vieiras Municipality

Description	Amount
Bovine	64,243 heads
Caprine	417 heads
Equine	811 heads
Swine	6,011 heads
Poultry	31,122 heads
Ovine	923 heads
Milk (liters)	1,927
Eggs (dozens)	28,000
Honey (kilograms)	788

SOURCE: IBGE (2013)

Wood

Jenipapo dos Vieiras produced, in 2013, 60 m^3 of round wood, 5,500m^3 of firewood, and 76 tonnes of charcoal.

Environment and Preservation

According to studies, deforestation to plant extraction, fires and illegal fishing do not exist in the city or do not constitute significant environmental impacts.

III. Municipality of Marajá do Sena

Physical Geography Aspects

Figure 56: Map of Marajá do Sena, State of Maranhão

Most of population lives in rural areas, about 86%. Marajá do Sena is the second poorest city in Brazil. According to data from National Confederation of Municipalities - CNM (2000), “the city does not make the collection of household waste. 99.13% of households throw their wastes directly into the ground or burn them and 0.86% throw trash in lakes or other destinations.”

Country: Brazil

State: Maranhão

Region: Northeast

Border: Municipalities of Paulo Ramos, Arame, Lago da Pedra and Lagoa Grande do Maranhão, and Santa Luzia.

Area: 1,402,594 km^2

Population (IBGE, 2010): 8,051

Population Density: 5.56/km^2

Population Rank: 187th (Maranhão State has 217 municipalities)

Urban population (IBGE, 2010): 1,155

Rural population (IBGE, 2010): 6,890 (85.64% of population)

Elevation: Sea level

Created by: State Law Number 6186 of 11/10/1994 (Marajá do Sena was part of Paulo Ramos Municipality)

Distance from State Capital (São Luís): 400 km

How to reach Marajá do Sena from São Luís: 137 km by highway (BR-135) until Miranda do Norte municipality, 102 km by BR-222 until Bela Vista do Maranhão, and 161 km by BR-316 and state highway MA-008 until Marajá do Sena.

Average Temperature: 26°C

Climate: Tropical

Human Development Indexes (PNUD, 2010)

HDI-M: 0.452

Rank Maranhão State: 216th (of 217)

Rank Brazil: 5,562th (of 5,565)

Longevity index: 0.774

Education index: 0.299

Income index: 0.400

Gross Domestic Product (US$ 1,000)

Table 94 presents the local Gross Domestic Product (GDP) between 2008 and 2012.

Table 94: Gross Domestic Product of Marajá do Sena Municipality from 2008 to 2012 (US$ 1,000)

GDP TOTAL	2008	2009	2010	2011	2012
	26,627	**19,642**	**20,933**	**27,663**	**28,746**
GDP Agribusiness	19,401	11,108	11,161	14,799	14,439
GDP Industry	702	899	1,070	1,550	1,642
GDP Servicing	6,420	7,538	8,555	11,120	12,367
GDP Taxes	105	98	148	194	299
GDP per capita (US$ 1.00)	**3,426**	**2,825**	**2,600**	**3,559**	**3,709**

SOURCE: IBGE (2013)

Agriculture (2013)

Table 95 presents the local agricultural production in 2013.

Table 95: Agricultural production of Marajá do Sena Municipality in 2013

Product	Area (ha)	Quantity produced (tonnes)
Rice	4,680	5,616
Bean	765	387
Cassava	320	3,200
Corn (grain)	2,200	3,080
Almond	-	35

SOURCE: IBGE (2013)

Livestock and animal production (2013)

Table 96 presents the livestock composition.

Table 96: Livestock composition of Marajá do Sena Municipality

Description	Amount
Bovine	25,900 heads
Caprine	928 heads
Equine	825 heads
Swine	8,820 heads
Poultry	42,910 heads
Buffalo	80 heads
Ovine	880 heads
Milk (liters)	373,000
Eggs (dozens)	33,000

SOURCE: IBGE (2013)

Wood

Marajá do Sena produced, in 2013, 1,380 m^3 of round wood, 1,450m^3 of firewood, and 919 tonnes of charcoal.

Environment and Preservation

In the region of the River Plains, the dominant vegetation is the Pioneer Formations with fluvial influence, and forest galleries, occurring in major rivers.

IV. Municipality of Fernando Falcão

Physical Geography Aspects

Figure 57: Map of Fernando Falcão, State of Maranhão

The municipality of Fernando Falcão belongs to the watershed of Itapecuru and Mearim rivers. Most of population lives in rural areas, about 84%.

Country: Brazil

State: Maranhão

Region: Northeast

Border: Municipalities of Barra do Corda, Mirador, Tuntum, and Formosa da Serra Negra.

Area: 5,086,584 km^2

Population (IBGE, 2010): 9,241

Population Density: 1.82/km^2

Population Rank: 182th (Maranhão State has 217 municipalities)

Urban population (IBGE, 2010): 1,511

Rural population (IBGE, 2010): 7,669 (83.54% of population)

Elevation: 210 m

Created by: State Law Number 6201 of 01/10/1994 (Fernando Falcão was part of Barra do Corda Municipality)

Distance from State Capital (São Luís): 540 km

How to reach Fernando Falcão from São Luís: 346 km by highway (BR-135) until Presidente Dutra municipality, 90 km by BR-226 until Barra do Corda, and 104 km by state highway MA-272 and MA-132 until Fernando Falcão.

Average Temperature: 25°C

Climate: Tropical

Human Development Indexes (PNUD, 2010)

HDI-M: 0.443

Rank Maranhão State: 217th (of 217)

Rank Brazil: 5,564th (of 5,565)

Longevity index: 0.728

Education index: 0.286

Income index: 0.417

Gross Domestic Product (US$ 1,000)

Table 97 presents the local Gross Domestic Product (GDP) between 2008 and 2012.

Table 97: Gross Domestic Product of Fernando Falcão Municipality from 2008 to 2012 (US$ 1,000)

GDP TOTAL	2008	2009	2010	2011	2012
	20,060	**20,140**	**21,098**	**24,054**	**27,116**
GDP Agribusiness	11,500	9,587	9,879	9,121	10,974
GDP Industry	940	1,210	1,301	1,922	1,988
GDP Servicing	7,408	9,117	9,603	12,688	13,738
GDP Taxes	212	226	315	324	416
GDP per capita (US$ 1.00)	**2,131**	**2,298**	**2,283**	**2,555**	**2,845**

SOURCE: IBGE (2013)

Agriculture (2013)

Table 98 presents the local agricultural production in 2013.

Table 98: Agricultural production of Fernando Falcão Municipality in 2013

Product	Area (ha)	Quantity produced (tonnes)
Banana	16	105
Cashew nut	30	8
Coconut-of-Bay	11	26 (thousand fruits)
Rice	1,116	1,211
Sugarcane	55	1,210
Bean	431	194
Cassava	1,080	8,640
Corn (grain)	924	1,294
Pineapple	4	100 (thousand fruits)
Orange	10	80
Almond	-	93

SOURCE: IBGE (2013)

Livestock and animal production (2013)

Table 99presents the livestock composition.

Table 99: Livestock composition of Fernando Falcão Municipality

Description	Amount
Bovine	14,640 heads
Caprine	321 heads
Equine	307 heads
Swine	4,815 heads
Poultry	35,713 heads
Ovine	324 heads
Milk (liters)	201,000
Eggs (dozens)	23,000

SOURCE: IBGE (2013)

Wood

Fernando Falcão produced, in 2013, 95 m^3 of round wood, 48,500m^3 of firewood, and 1,184 tonnes of charcoal.

V. Municipality of Assunção do Piauí

Physical Geography Aspects

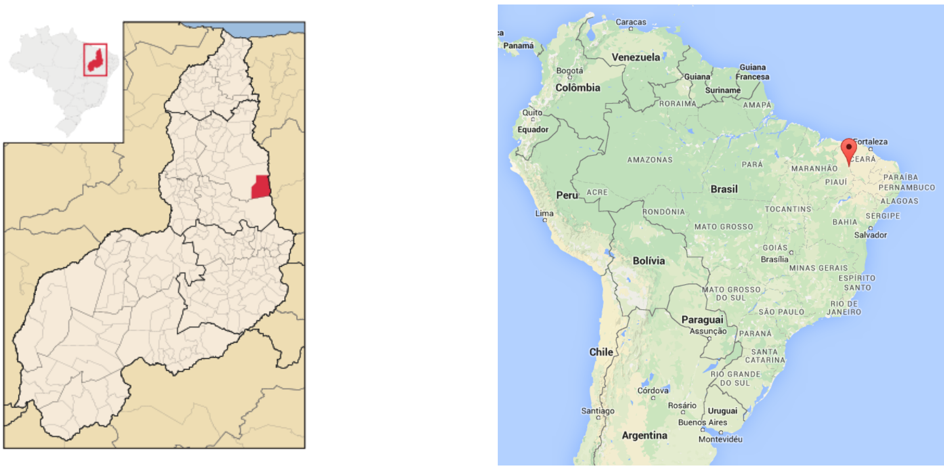

Figure 58: Map of Assunção do Piauí, State of Piauí

The economy of Assunção do Piauí is based mainly in agribusiness, livestock and animal production. Most of population lives in rural areas, about 84%.

Country: Brazil

State: Piauí

Region: Northeast

Border: Municipalities of São Miguel do Tapuio and the state of Ceará.

Area: 1,690,704 km^2

Population (IBGE, 2010): 7,503

Population Density: 4.44/km^2

Population Rank: 82th (Piauí State has 224 municipalities)

Urban population (IBGE, 2010): 3378

Rural population (IBGE, 2010): 4,125 (59.98% of population)

Elevation: 532 m

Created by: State Law Number 4,680 of 1/26/1994 (Assunção do Piauí was part of São Miguel do Tapuio municipality)

Distance from State Capital (Teresina): 281 km

How to reach Assunção do Piauí from Teresina: The trip is done by state highway (PI-221 e PI-115) until Tarauacá and then by boat through Tarauacá River.

Average Temperature: 25°C

Climate: Tropical

Human Development Indexes (PNUD, 2010)

HDI-M: 0.499

Rank Piauí State: 159th (of 224)

Rank Brazil: 5,534th (of 5,565)

Longevity index: 0.706

Education index: 0.382

Income index: 0.462

Gross Domestic Product (US$ 1,000)

Table 100 presents the local Gross Domestic Product (GDP) between 2008 and 2012.

Table 100: Gross Domestic Product of Assunção do Piauí Municipality from 2008 to 2012 (US$ 1,000)

GDP TOTAL	2008	2009	2010	2011	2012
	11,740	**12,544**	**11,994**	**15,681**	**16,431**
GDP Agribusiness	3,121	1,969	1,259	1,687	1,063
GDP Industry	573	859	1,110	1.575	1,956
GDP Servicing	7,686	9,407	9,245	11.973	12,858
GDP Taxes	360	309	380	447	554
GDP per capita (US$ 1.00)	**1,556**	**1,499**	**1,599**	**2,078**	**2,165**

SOURCE: IBGE (2013)

Agriculture (2013)

Table 101 presents the local agricultural production in 2013.

Table 101: Agricultural production of Assunção do Piauí Municipality in 2013

Product	Area (ha)	Quantity produced (tonnes)
Cashew nut	180	9
Rice	45	5
Sugarcane	20	800
Bean	4,886	680
Cassava	200	200
Watermelon	10	230
Corn (grain)	2,670	80
Carnauba	-	15

SOURCE: IBGE (2013)

Livestock and animal production (2013)

Table 102 presents the livestock composition.

Table 102: Livestock composition of Assunção do Piauí Municipality

Description	Amount
Bovine	7,853 heads
Caprine	2,440 heads
Equine	133 heads
Swine	3,224 heads
Poultry	21,385 heads
Ovine	1,212 heads
Milk (liters)	198,000
Eggs (dozens)	34,000

SOURCE: IBGE (2013)

Wood

Assunção do Piauí produced, in 2013, 49,310m^3 of firewood, and 48 tonnes of charcoal.

Environment and Preservation

Piauí was the State that more deforested between the years 2013 and 2014.

VI. Municipality of Cocal dos Alves

Physical Geography Aspects

Figure 59: Map of Cocal dos Alves, State of Piauí

The economy of Cocal dos Alves is based mainly in agribusiness, livestock and animal production. The agriculture in the city is based on seasonal production of rice, beans, cassava and corn. Most of population lives in rural areas, about 68%.

Country: Brazil

State: Piauí

Region: Northeast

Border: Municipalities of Cocal, Piracuruca, and Ceará State.

Area: 357,689 km^2

Population (IBGE, 2010): 5,572

Population Density: 15.58/km^2

Population Rank: 122th (Piauí State has 224 municipalities)

Urban population (IBGE, 2010): 1,782

Rural population (IBGE, 2010): 3,790 (68.02% of population)

Elevation: 100 m

Created by: State Law Number 4,811 of 12/27/1995 (Cocal dos Alves was part of Cocal Municipality)

Distance from State Capital (Teresina): 262 km

How to reach Cocal dos Alves from Teresina: The trip is done by highway (BR-343) until state highway PI-110 until Cocal dos Alves.

Climate: Tropical

Human Development Indexes (PNUD, 2010)

HDI-M: 0.498

Rank Piauí State: 213th (of 224)

Rank Brazil: 5,535th (of 5,565)

Longevity index: 0.779

Education index: 0.315

Income index: 0.504

Gross Domestic Product (US$ 1,000)

Table 103 presents the local Gross Domestic Product (GDP) between 2008 and 2012.

Table 103: Gross Domestic Product of Cocal dos Alves Municipality from 2008 to 2012 (US$ 1,000)

GDP TOTAL	2008	2009	2010	2011	2012
	8,261	**9,511**	**9,696**	**13,444**	**13,528**
GDP Agribusiness	2,257	2,181	1,191	2,419	1,315
GDP Industry	369	547	753	1,066	1,290
GDP Servicing	5,329	6,464	7,372	9,462	10,340
GDP Taxes	306	320	380	497	584
GDP per capita (US$ 1.00)	**1,474**	**1,722**	**1,740**	**2,399**	**2,401**

SOURCE: IBGE (2013)

Agriculture (2013)

Table 104 presents the local agricultural production in 2013.

Table 104: Agricultural production of Cocal dos Alves Municipality in 2013

Product	Area (ha)	Quantity produced (tonnes)
Cashew nut	3,436	171
Rice	20	-
Bean	742	67
Cassava	720	4,320
Corn or maize (grain)	742	-
Carnauba (powder)	-	59
Almond	-	77

SOURCE: IBGE (2013)

Livestock and animal production (2013)

Table 105 presents the livestock composition.

Table 105: Livestock composition of Cocal dos Alves Municipality

Description	Amount
Bovine	1,256 heads
Caprine	4,588 heads
Equine	153 heads
Swine	5,816 heads
Poultry	31,029 heads
Ovine	2,285 heads
Milk (liters)	32,000
Eggs (dozens)	38,000
Fishing (tonnes)	13,649

SOURCE: IBGE (2013)

Wood

Cocal dos Alves produced, in 2013, 9,574m^3 of firewood, and 28 tonnes of charcoal.

VII. Municipality of Cocal

Physical Geography Aspects

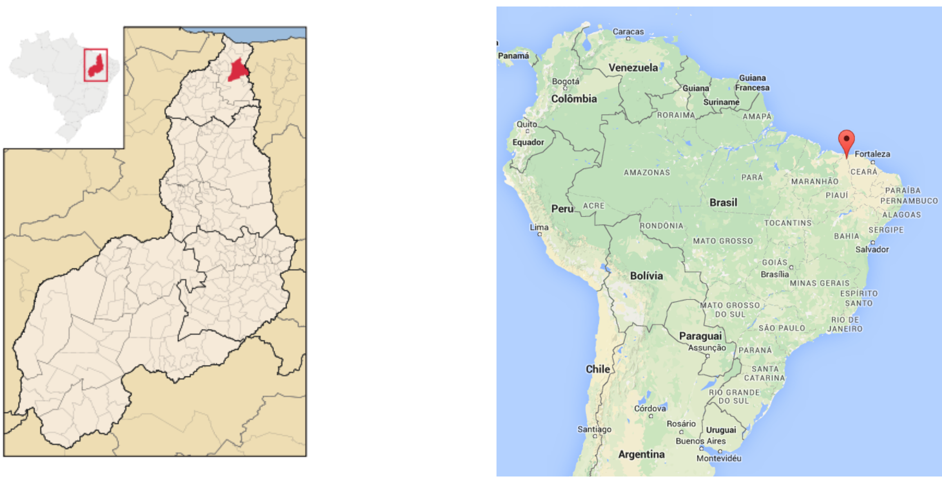

Figure 60: Map of Cocal, State of Piauí

The name of Cocal is based on a palm tree named babassu coconut. The origin of the city was due to the construction of the railway linking the coast to the capital, Teresina, and a major railway station. Most of population lives in rural areas.

Country: Brazil

State: Piauí

Region: Northeast

Border: Municipalities of Luís Correia e Bom Princípio do Piauí, Piracuruca e Cocal dos Alves, Buriti dos Lopes e Caraúbas do Piauí.

Area: 1,303,685 km^2

Population (IBGE, 2010): 26,036

Population Density: 20.51/km^2

Population Rank: 17th (Piauí State has 224 municipalities)

Urban population (IBGE, 2010): 12,021

Rural population (IBGE, 2010): 14,023 (53.84% of population)

Elevation: 160 m

Created by: State Law Number 160 of 07/28/1937

Distance from State Capital (Teresina): 268 km

How to reach Cocal from Teresina: The trip is done by highway (BR-226/343) until state highway PI-213 and until Cocal.

Average Temperature: 30°C

Climate: Tropical

Human Development Indexes (PNUD, 2010)

HDI-M: 0.497

Rank Piauí State: 186th (of 224)

Rank Brazil: 5,537th (of 5,565)

Longevity index: 0.712

Education index: 0.334

Income index: 0.516

Gross Domestic Product (US$ 1,000)

Table 106 presents the local Gross Domestic Product (GDP) between 2008 and 2012.

Table 106: Gross Domestic Product of Cocal Municipality from 2008 to 2012 (US$ 1,000)

GDP TOTAL	2008	2009	2010	2011	2012
	42,550	**43,338**	**47,263**	**62,820**	**66,598**
GDP Agribusiness	8,927	5,274	4,630	8,768	4,440
GDP Industry	2,488	3,600	4,824	6,499	8,148
GDP Servicing	29,001	32,535	35,534	44,833	50,858
GDP Taxes	2,135	1,930	2,275	2,720	3,152
GDP per capita (US$ 1.00)	**1,580**	**1,592**	**1,815**	**2,333**	**2,461**

SOURCE: IBGE (2013)

Agriculture (2013)

Table 107 presents the local agricultural production in 2013.

Table 107: Agricultural production of Cocal Municipality in 2013

Product	Area (ha)	Quantity produced (tonnes)
Banana	10	80
Cashew nut	4,402	220
Rice	477	-
Sugarcane	20	600
Bean	4,396	198
Cassava	3,488	17,440
Corn (grain)	4,671	-
Mango	15	150
Coconut-the-Bay	12	72 (thousand fruits)
Orange	10	50
Carnauba (powder)	-	39
Almond	-	114

SOURCE: IBGE (2013)

Livestock and animal production (2013)

Table 108 presents the livestock composition.

Table 108: Livestock composition of Cocal Municipality

Description	Amount
Bovine	7,077 heads
Caprine	13,172 heads
Equine	792 heads
Swine	6,122 heads
Poultry	96,346 heads
Ovine	5,905 heads
Milk (liters)	505,000
Eggs (dozens)	150,000
Honey (tonnes)	6,575

SOURCE: IBGE (2013)

Wood

Cocal produced, in 2013, 2,091 m^3 of round wood, 18,218m^3 of firewood, and 471 tonnes of charcoal.

VIII. Municipality of Betânica do Piauí

Physical Geography Aspects

Figure 61: Map of Betânica do Piauí, State of Piauí

The economy of Betânia do Piauí is based mainly in animal production, especially bovine and caprine. Most of population lives in rural areas, about 72%.

Country: Brazil

State: Piauí

Region: Northeast

Border: Municipalities of Curral Novo do Piauí, Simões and Jacobina do Piauí, Acauã, Paulistana, and the State of Pernambuco**.**

Area: 564,707 km^2

Population (IBGE, 2010): 6,015

Population Density: 10.65/km^2

Population Rank: 113^{th} (Piauí State has 224 municipalities)

Urban population (IBGE, 2010): 1,678

Rural population (IBGE, 2010): 4,337 (72.10% of population)

Elevation: 480 m

Created by: State Law Number 4,680 of 01/26/1994

Distance from State Capital (Teresina): 499 km

How to reach Betânia do Piauí from Teresina: The trip is done by highway (BR-226/343). Then, following BR-316 until BR-407, state highway PI-243 and PI-456 until Betânia do Piauí.

Average Temperature: 27°C

Human Development Indexes (PNUD, 2010)

HDI-M: 0.489

Rank Piauí State: 217th (of 224)

Rank Brazil: 5,543th (of 5,565)

Longevity index: 0.702

Education index: 0.342

Income index: 0.486

Gross Domestic Product (US$ 1,000)

Table 109 presents the local Gross Domestic Product (GDP) between 2008 and 2012.

Table 109: Gross Domestic Product of Betânica do Piauí Municipality from 2008 to 2012 (US$ 1,000)

GDP TOTAL	2008	2009	2010	2011	2012
	9,493	**11,273**	**10,998**	**14,579**	**14,416**
GDP Agribusiness	2,477	2,602	1,926	2,396	1,108
GDP Industry	398	624	846	1,221	1,481
GDP Servicing	6,283	7,703	7,763	10,284	11,054
GDP Taxes	335	345	463	678	774
GDP per capita (US$ 1.00)	**1,575**	**1,750**	**1,828**	**2,418**	**2,386**

SOURCE: IBGE (2013)

Agriculture (2013)

Table 110 presents the local agricultural production in 2013.

Table 110: Agricultural production of Betânica do Piauí Municipality in 2013

Product	Area (ha)	Quantity produced (tonnes)
Bean	1,050	9
Cassava	8	10
Corn (grain)	3,600	-
Cotton	230	

SOURCE: IBGE (2013)

Livestock and animal production (2013)

Table 111 presents the livestock composition.

Table 111: Livestock composition of Betânica do Piauí Municipality

Description	Amount
Bovine	4,859 heads
Caprine	3,573 heads
Equine	581 heads
Swine	1,876 heads
Poultry	13,355 heads
Ovine	16,959 heads
Milk (liters)	241,000
Eggs (dozens)	16,000

SOURCE: IBGE (2013)

Wood

Betânica do Piauí produced, in 2013, 883 m^3 of round wood, and 23,581m^3 of firewood.

IX. Municipality of Caxingó

Physical Geography Aspects

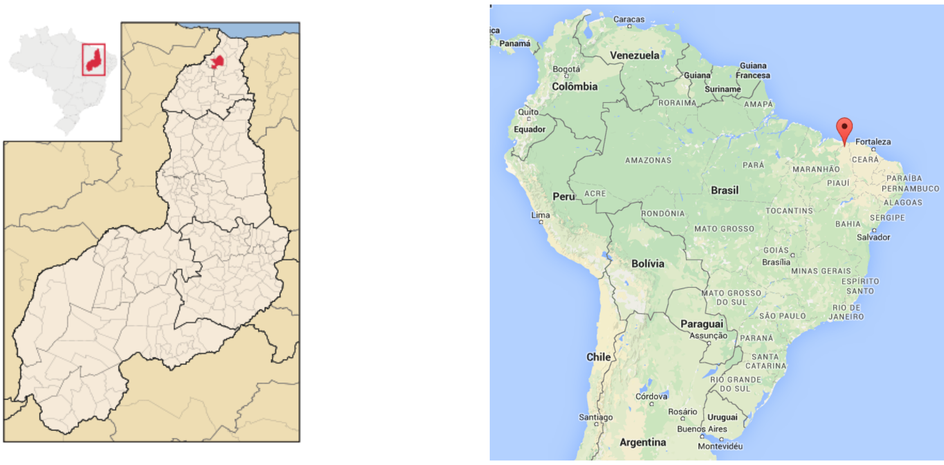

Figure 62: Map of Caxingó, State of Piauí

The agriculture practiced in the city is based on seasonal production of beans, rice, cassava and corn. Most of population lives in rural areas, about 81%.

Country: Brazil

State: Piauí

Region: Northeast

Border: Municipalities of Buriti dos Lopes and Murici dos Portelas, Caraúbas do Piauí and Joaquim Pires.

Area: 488,169 km^2

Population (IBGE, 2010): 5,039

Population Density: 10.32/km^2

Population Rank: 141th (Piauí State has 224 municipalities)

Urban population (IBGE, 2010): 966

Rural population (IBGE, 2010): 4,073 (80.83% of population)

Elevation: 13 m

Created by: State Law Number 4811 of 12/27/1995 (Caxingó was part of Buriti dos Lopes Municipality)

Distance from State Capital (Teresina): 264 km

How to reach Caxingó from Teresina: The trip is done by highway (BR-226/343) until state highway PI-213. Then, Felino Tomaz Avenue until Antonio Joaquim avenue until Caxingó.

Average Temperature: 30°C

Climate: Tropical

Human Development Indexes (PNUD, 2010)

HDI-M: 0.488

Rank Piauí State: 216th (of 224)

Rank Brazil: 5,546th (of 5,565)

Longevity index: 0.708

Education index: 0.329

Income index: 0.498

Gross Domestic Product (US$ 1,000)

Table 112 presents the local Gross Domestic Product (GDP) between 2008 and 2012.

Table 112: Gross Domestic Product of Caxingó Municipality from 2008 to 2012 (US$ 1,000)

GDP TOTAL	2008	2009	2010	2011	2012
	9,245	**10,605**	**11,372**	**14,456**	**15,210**
GDP Agribusiness	2,078	2,271	2,084	2,815	2,202
GDP Industry	554	726	980	1,320	1,627
GDP Servicing	6,296	7,243	7,830	9,766	10,545
GDP Taxes	316	365	478	556	836
GDP per capita (US$ 1.00)	**1,810**	**2,012**	**2,257**	**2,830**	**2,940**

SOURCE: IBGE (2013)

Agriculture (2013)

Table 113 presents the local agricultural production in 2013.

Table 113: Agricultural production of Caxingó Municipality in 2013

Product	Area (ha)	Quantity produced (tonnes)
Cashew nut	50	5
Rice	441	1,764
Bean	280	11
Cassava	221	1,060
Watermelon	15	300
Corn (grain)	515	41
Carnauba (powder)	-	193

SOURCE: IBGE (2013)

Livestock and animal production (2013)

Table 114 presents the livestock composition.

Table 114: Livestock composition of Caxingó Municipality

Description	Amount
Bovine	5,330 heads
Caprine	2,379 heads
Equine	368 heads
Swine	2,223 heads
Poultry	17,803 heads
Ovine	2,144 heads
Milk (liters)	345,000
Eggs (dozens)	23,000

SOURCE: IBGE (2013)

Wood

Caxingó produced, in 2013, 4,275m^3 of firewood, and 30 tonnes of charcoal.

X. Municipality of São Francisco de Assis do Piauí

Physical Geography Aspects

Figure 63: Map of São Francisco de Assis do Piauí, State of Piauí

Most of population lives in rural areas, about 75%. Some of them still without electricity access, according to the news at least 400 families.

Country: Brazil

State: Piauí

Region: Northeast

Border: Municipalities of Jacobina do Piauí, Queimada Nova and Lagoa do Barro do Piauí, Paulistana, and Conceição do Canindé.

Area: 1,340,665 km^2

Population (IBGE, 2010): 5,567

Population Density: 5,06/km^2

Population Rank: 121th (Piauí State has 224 municipalities)

Urban population (IBGE, 2010): 1,429

Rural population (IBGE, 2010): 4,146 (74.37% of population)

Elevation: 158 m

Created by: State Law Number 1453 of 11/30/1956 (São Francisco de Assis do Piauí was part of Oeiras Municipality)

Distance from State Capital (Teresina): 513 km

How to reach São Francisco de Assis do Piauí from Teresina: The trip is done from Miguel Rosa Avenue until highway (BR-226/343), then following BR-343, state highways PI-236 and PI-143. From Prof. Vicente Gualberto Ribeiro Avenue to São Francisco de Assis do Piauí.

Average Temperature: 30°C

Human Development Indexes (PNUD, 2010)

HDI-M: 0.485

Rank Piauí State: 208th (of 224)

Rank Brazil: 5,549th (of 5,565)

Longevity index: 0.734

Education index: 0.336

Income index: 0.462

Gross Domestic Product (US$ 1,000)

Table 115 presents the local Gross Domestic Product (GDP) between 2008 and 2012.

Table 115: Gross Domestic Product of São Francisco de Assis do Piauí Municipality from 2008 to 2012 (US$ 1,000)

GDP TOTAL	2008	2009	2010	2011	2012
	6,652	**7,907**	**8,865**	**11,599**	**13,184**
GDP Agribusiness	1,042	1,217	877	1,064	512
GDP Industry	337	500	894	1,345	1,726
GDP Servicing	5,054	5,950	6,784	8.829	10,455
GDP Taxes	220	240	309	360	490
GDP per capita (US$ 1.00)	**1,182**	**1,514**	**1.592**	**2,061**	**2,319**

SOURCE: IBGE (2013)

Agriculture (2013)

Table 116 presents the local agricultural production in 2013.

Table 116: Agricultural production of São Francisco de Assis do Piauí Municipality in 2013

Product	Area (ha)	Quantity produced (tonnes)
Cashew nut	32	-
Bean	384	35
Corn (grain)	299	9

SOURCE: IBGE (2013)

Livestock and animal production (2013)

Table 117 presents the livestock composition.

Table 117: Livestock composition of São Francisco de Assis do Piauí Municipality

Description	Amount
Bovine	5,691 heads
Caprine	12,593 heads
Equine	477 heads
Swine	2,504 heads
Poultry	9,545 heads
Ovine	7,896 heads
Milk (liters)	125,000
Eggs (dozens)	10,000
Honey (tonnes)	10,17

SOURCE: IBGE (2013)

Wood

São Francisco de Assis do Piauí produced, in 2013, 10 m^3 of round wood, and 7,540m^3 of firewood.

XI. Municipality of Manari

Physical Geography Aspects

Figure 64: Map of Manari, State of Pernambuco

The main economic activities of Manari municipality are agriculture, livestock and trade. Most of population lives in rural areas, about 80%. The municipality has the worst HDI of Pernambuco State.

Country: Brazil

State: Pernambuco

Region: Northeast

Border: Municipalities of Ibimirim, Inajá, Itaíba, and the State of Alagoas

Area: 359,240 km^2

Population (IBGE, 2010): 18,083

Population Density: 47.56/km^2

Population Rank: 107th (Pernambuco State has 185 municipalities)

Urban population (IBGE, 2010): 3,844

Rural population (IBGE, 2010): 14,343 (78.91% of population)

Elevation: 570 m

Created by: State Law Number 11,229 of 07/12/1995 (Manari was part of Inajá Municipality)

Distance from State Capital (Recife): 330 km

How to reach Manari from Recife: The trip is by highway BR-232 until Arco Verde municipality, then following state highways PE-270 for 77 km until the municipality of Itaíba. Then, PE-300 for 46 km until Manari.

Average Temperature: 25°C

Climate: Semi-arid

Human Development Indexes (PNUD, 2010)

HDI-M: 0.487

Rank Pernambuco State: 185th (of 185)

Rank Brazil: 5,547th (of 5,565)

Longevity index: 0.682

Education index: 0.354

Income index: 0.477

Gross Domestic Product (US$ 1,000)

Table 118 presents the local Gross Domestic Product (GDP) between 2008 and 2012.

Table 118: Gross Domestic Product of Manari Municipality from 2008 to 2012 (US$ 1,000)

GDP TOTAL	2008	2009	2010	2011	2012
	26,178	**33,517**	**34,552**	**44,957**	**49,047**
GDP Agribusiness	4,949	6,879	5,696	6,250	3,577
GDP Industry	1,695	2,205	2,582	4,365	5,612
GDP Servicing	18,981	23,873	25,608	33,431	38,765
GDP Taxes	553	560	666	911	1,093
GDP per capita (US$ 1.00)	**1,484**	**1,852**	**1,911**	**2,434**	**2,602**

SOURCE: IBGE (2013)

Agriculture (2013)

Table 119 presents the local agricultural production in 2013.

Table 119: Agricultural production of Manari Municipality in 2013

Product	Area (ha)	Quantity produced (tonnes)
Bean	1,200	720
Corn (grain)	1,000	480
Umbu	-	4
Angico	-	3

SOURCE: IBGE (2013)

Livestock and animal production (2013)

Table 120 presents the livestock composition.

Table 120: Livestock composition of Manari Municipality

Description	Amount
Bovine	10,200 heads
Caprine	19,000 heads
Equine	1,500 heads
Swine	2,100 heads
Poultry	36,000 heads
Ovine	20,000 heads
Milk (liters)	3,510
Eggs (dozens)	40,000

SOURCE: IBGE (2013)

Wood

Manari produced, in 2013, 8,000m^3 of firewood, and 14 tonnes of charcoal.

Environment and Preservation

The typical vegetation of Pernambuco and consequently Manari municipality is Caatinga. This kind of vegetation occupies an area of 844,453 square kilometers, equivalent to 11% of the country. However, the deforestation reaches more than 40% of the biome, according to the Ministry of Environment (MMA).

XII. Municipality of Olivença

Physical Geography Aspects

Figure 65: Map of Olivença, State of Alagoas

The main agricultural product produced in Olivença is bean. The municipality also produces corn, cassava and cashew nuts. Most of population lives in rural areas, about 72%.

Country: Brazil

State: Alagoas

Region: Northeast

Border: Municipalities of Santana do Ipanema, Olho d'Água das Flores, and Major Isidoro

Area: 175,709 km^2

Population (IBGE, 2010): 11,047

Population Density: 63.87/km^2

Population Rank: 66th (Alagoas State has 102 municipalities)

Urban population (IBGE, 2010): 3,147

Rural population (IBGE, 2010): 7,910 (71.54% of population)

Elevation: 278 m

Created by: State Law Number 1785 of 04/05/1954 (Named Capim), changed to Olivença by State Law 2092 of 04/24/1958.

Distance from State Capital (Maceió): 231 km

How to reach Olivença from Maceió: The trip is done by state highway AL-101, AL-220 and AL-125 until Dr. José R Torres street. Then José Corrêa Bulhões street until Olivença.

Climate: Arid

Human Development Indexes (PNUD, 2010)

HDI-M: 0.493

Rank Alagoas State: 91th (of 102)

Rank Brazil: 5,539th (of 5,565)

Longevity index: 0.677

Education index: 0.345

Income index: 0.513

Gross Domestic Product (US$ 1,000)

Table 121 presents the local Gross Domestic Product (GDP) between 2008 and 2012.

Table 121: Gross Domestic Product of Olivença Municipality from 2008 to 2012 (US$ 1,000)

GDP TOTAL	2008	2009	2010	2011	2012
	16,083	**18,242**	**20,035**	**25,249**	**28,209**
GDP Agribusiness	2,537	2,162	2,043	1,758	1,953
GDP Industry	1,175	1,637	1,625	2,265	2,347
GDP Servicing	11,957	14,015	15,681	20,247	22,632
GDP Taxes	414	428	685	980	1,278
GDP per capita (US$ 1.00)	**1,485**	**1,679**	**1,814**	**2,275**	**2,530**

SOURCE: IBGE (2013)

Agriculture (2013)

Table 122 presents the local agricultural production in 2013.

Table 122: Agricultural production of Olivença Municipality in 2013

Product	Area (ha)	Quantity produced (tonnes)
Cashew nut	250	31
Bean	602	67
Cassava	20	50
Corn (grain)	649	94
Umbu	-	1
Licuri	-	2

SOURCE: IBGE (2013)

Livestock and animal production (2013)

Table 123 presents the livestock composition.

Table 123: Livestock composition of Olivença Municipality

Description	Amount
Bovine	10,789 heads
Caprine	109 heads
Equine	350 heads
Swine	872 heads
Poultry	10,090 heads
Ovine	2,333 heads
Milk (liters)	3,072
Eggs (dozens)	25,000
Honey (kilograms)	240

SOURCE: IBGE (2013)

Wood

Olivença produced, in 2013, 16 m^3 of round wood, and 49m^3 of firewood.

Environment and Preservation

The typical vegetation of Alagoas is also Caatinga.

XIII. Municipality of Inhapi

Physical Geography Aspects

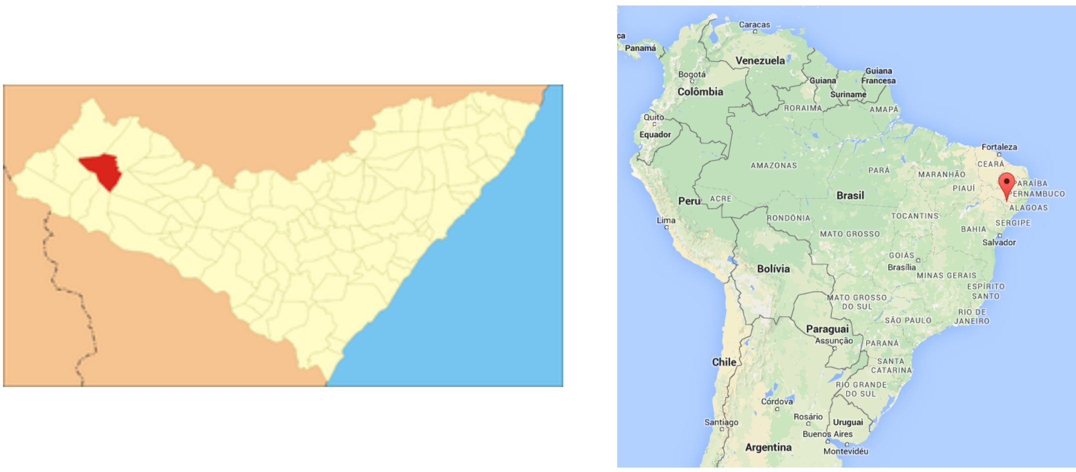

Figure 66: Map of Inhapi, State of Alagoas

The economy of Inhapi is based mainly in agribusiness (especially bean and cassava), livestock and animal production (bovine and poultry). Most of population lives in rural areas, about 63%.

Country: Brazil

State: Alagoas

Region: Northeast

Border: Municipalities of Mata Grande and Canapi, Piranhas and São José da Tapera, Senador Rui Palmeira, Água Branca, and Olho D' Água do Casado.

Area: 373,388 km^2

Population (IBGE, 2010): 17,898

Population Density: 47,49/km^2

Population Rank: 45th (Alagoas State has 102 municipalities)

Urban population (IBGE, 2010): 6,699

Rural population (IBGE, 2010): 11,203 (62.58% of population)

Elevation: 400 m

Created by: State Law Number 2460 of 06/22/1962 (Inhapi was part of Mata Grande Municipality)

Distance from State Capital (Maceió): 271 km

How to reach Inhapi from Maceió: The trip is done by highway BR-316, BR-423 until Inhapi.

Human Development Indexes (PNUD, 2010)

HDI-M: 0.484

Rank Alagoas State: 95th (of 102)

Rank Brazil: 5,550th (of 5,565)

Longevity index: 0.718

Education index: 0.316

Income index: 0.501

Gross Domestic Product (US$ 1,000)

Table 124 presents the local Gross Domestic Product (GDP) between 2008 and 2012.

Table 124: Gross Domestic Product of Inhapi Municipality from 2008 to 2012 (US$ 1,000)

GDP TOTAL	2008	2009	2010	2011	2012
	22,249	**26,762**	**29,255**	**33,967**	**39,562**
GDP Agribusiness	4,131	3,447	3,032	2,692	2,511
GDP Industry	1,625	2,381	2,404	3,266	5,314
GDP Servicing	15,901	20,335	23,109	27,010	30,410
GDP Taxes	592	598	710	999	1.327
GDP per capita (US$ 1.00)	**1,226**	**1,473**	**1,635**	**1,897**	**2,218**

SOURCE: IBGE (2013)

Agriculture (2013)

Table 125 presents the local agricultural production in 2013.

Table 125: Agricultural production of Inhapi Municipality in 2013

Product	Area (ha)	Quantity produced (tonnes)
Bean	936	28
Cassava	80	800
Corn (grain)	645	-

SOURCE: IBGE (2013)

Livestock and animal production (2013)

Table 126 presents the livestock composition.

Table 126: Livestock composition of Inhapi Municipality

Description	Amount
Bovine	16,970 heads
Caprine	1,130 heads
Equine	774 heads
Swine	1,880 heads
Poultry	36,590 heads
Ovine	8,990 heads
Milk (liters)	2,260
Eggs (dozens)	50,000
Fishing (tonnes)	18,6
Honey (kilograms)	280

SOURCE: IBGE (2013)

Wood

Inhapi produced, in 2013, 257 m^3 of round wood, 7,300m^3 of firewood, and 6 tonnes of charcoal.

XIV. Municipality of Itapicuru

Physical Geography Aspects

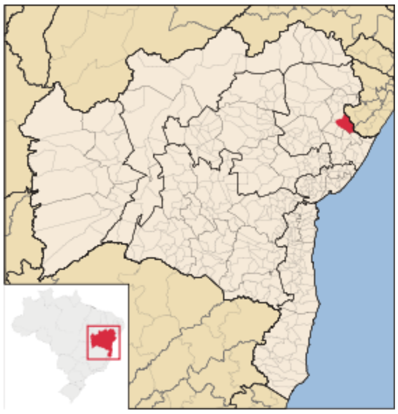

Figure 67: Map of Itapicuru, State of Bahia

Itapicuru is one of the oldest municipalities in Bahia. It is highly visited by tourists because of the presence of thermal waters. The economy of Itapicuru is based mainly in agribusiness, livestock and animal production. Most of population lives in rural areas, about 80%.

Country: Brazil

State: Bahia

Region: Northeast

Border: Municipalities of Olindina, Crisópolis, Nova Soure, Ribeira do Amparo, Cipó and Rio Real, and the state of Sergipe.

Area: 1,585,591 km^2

Population (IBGE, 2010): 32,261

Population Density: 20.35/km^2

Population Rank: 77th (Bahia State has 417 municipalities)

Urban population (IBGE, 2010): 6,675

Rural population (IBGE, 2010): 25,603 (79.32% of population)

Elevation: 155 m

Created by: State Law Number 8447 of 05/27/1933 (Itapicuru was part of Inhambupe e Rio Real Municipality).

Distance from State Capital (Salvador): 251 km

How to reach Itapicuru from Salvador: The trip is done by highway (BR-324) following through BR-110/BR-420 and BR-349 until Itapicuru.

Climate: Semi-Arid

Human Development Indexes (PNUD, 2010)

HDI-M: 0.486

Rank Bahia State: 415th (of 417)

Rank Brazil: 5,548th (of 5,565)

Longevity index: 0.711

Education index: 0.319

Income index: 0.505

Gross Domestic Product (US$ 1,000)

Table 127 presents the local Gross Domestic Product (GDP) between 2008 and 2012.

Table 127: Gross Domestic Product of Itapicuru Municipality from 2008 to 2012 (US$ 1,000)

GDP TOTAL	2008	2009	2010	2011	2012
	53,022	**65,082**	**66,942**	**81,326**	**92,715**
GDP Agribusiness	12,851	15,764	12,569	12,539	12,080
GDP Industry	4,899	6,373	7,725	10,058	12,125
GDP Servicing	33,675	41,164	44,362	55,903	64,862
GDP Taxes	1,598	1,781	2,286	2,826	3,648
GDP per capita (US$ 1.00)	**1,652**	**1,999**	**2,075**	**2,492**	**2,809**

SOURCE: IBGE (2013)

Agriculture (2013)

Table 128 presents the local agricultural production in 2013.

Table 128: Agricultural production of Itapicuru Municipality in 2013

Product	Area (ha)	Quantity produced (tonnes)
Banana	10	110
Cashew nut	1,000	200
Bean	700	262
Cassava	1,500	22,500
Watermelon	50	400
Corn (grain)	600	504
Coconut-of-Bay	200	800 (thousand fruits)
Passion fruit	160	960
Orange	12,800	192,000
Peanut	30	17

SOURCE: IBGE (2013)

Livestock and animal production (2013)

Table 129 presents the livestock composition.

Table 129: Livestock composition of Itapicuru Municipality

Description	Amount
Bovine	21,500 heads
Caprine	835 heads
Equine	1,750 heads
Swine	1,250 heads
Poultry	56,000 heads
Ovine	5,750 heads
Milk (liters)	746,000
Eggs (dozens)	118,000
Fishing (tonnes)	18,21
Honey (tonnes)	3

SOURCE: IBGE (2013)

Wood

Itapicuru produced, in 2013, 54,000m^3 of firewood, and 10 tonnes of charcoal.

Environment and Preservation

The municipality currently notified bakeries and factories in order to replace the wood by gas. The goal is to reduce deforestation and air pollution.

Annex II: Profiles of selected municipalities in Colombia

Universidad de La Sabana prepared these profiles.

Selected Municipalities with low Basic Unsatisfied NBI

Colombia is a South American country located in the northwest of the continent, the only in South America with access to the Atlantic and Pacific Oceans. The country shares borders with Venezuela, Ecuador, Peru, Brazil and Panama. It has an area of 2.129.749 km^2 from which 1.141748 km^2 are continental territory and the rest are maritime territory. It is organized in 32 decentralized departments and one capital district which is Bogotá. The population is about 48 million. Colombia has an emergent economy defined by activities such as agriculture, animal husbandry, industry, mining, energy production, international trade, and tourism. In agriculture, Colombia has as primary products sugar cane, coffee, flowers, cotton, plantain, bananas, rice, maize, and potatoes. In relation to mining, the most exploited minerals are gold, silver, emeralds, cooper, platinum, nickel and carbon.

The country has an installed electricity generation capacity of about 15.5 GW, almost 70% derived from hydropower, about 11% from natural gas, and around 7% from coal. Biomass-based and wind power generation account together for less than 1% of the national power generation (UPME, 2015). Contribution of renewable energy to the national power generation system is still low. Yet, the national government considers, within its energy plan 2014-2018, options to diversify the electricity generation matrix. In this sense, this plan proposes the inclusion of intermittent renewable sources. Preliminary simulations show that non-conventional renewable energy can reduce the marginal cost of electricity, that is, it has the potential to replace more expensive power generation (UPME, 2013).

Colombia is generally recognized by its natural resources and enormous biodiversity. However, those are not the only factors that capture international attention. According to the World Bank, for the first time in Colombia history, three development objectives - sustainable peace, poverty eradication, and shared prosperity - seem within realistic reach (World Bank, 2014). In fact, the Human Development Index shows an average annual increase of about 0.74 % for the period 1980-2013 (see Figure 68). The HDI gives an indication of performance in terms of life quality achieved in a given locality, which is a prerequisite for human development in general. It combines health, educational achievement and income indicators into a composite index that includes (i) health, expressed as longevity, measured by life expectancy at birth; (ii) educational level, measured by the combination of mean years of schooling and expected years of schooling; and (iii) income, measured through the Gross National Income (GNI) in Purchasing Parity Power (Klugman, Rodríguez, & Choi, 2011). Today, after some modifications in the methodology for HDI calculation, the index is calculated as the geometric average of normalized indices measuring achievements in each dimension. Such updates demonstrate that HDI is a flexible tool, which can be adapted to measure progress on different levels. Countries with a HDI higher than 0.8 are considered to be highly developed, countries with HDI values between 0.5 and 0.8 are included in the medium development category and those with HDI lower than 0.5 are included in the low development category (UNDP, 2011b).

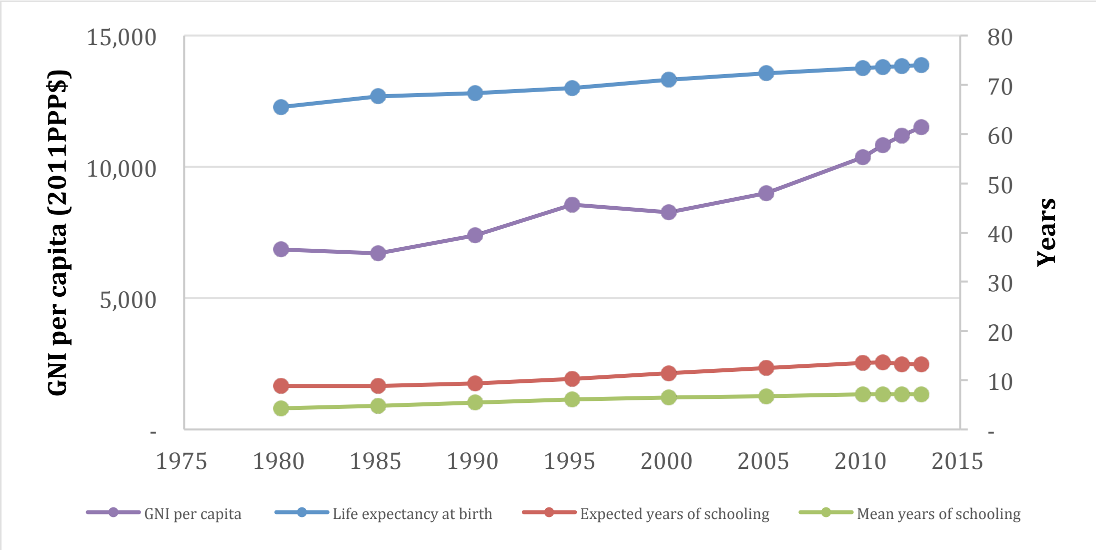

Figure 68: Trends in Colombia´s HDI component indices 1980-2013

Source: (UNDP, 2015)

In spite of significant achievements in the national HDI, there are more than 1.5 million people who have no access to modern energy services in the country. Modern energy services include not only electricity but also clean fuels especially for cooking, which are widely recognized as critical to achieve human wellbeing and development. Population without access to these services is primarily located in rural and sub-urban areas and belongs to the poorest group of inhabitants in the country. As a result, the national government face difficult challenges when aiming at extending energy services – actions needed include defining explicit targets, deciding on implementation strategies, and allocating funds either nationally or internationally (IEA, 2011). Aware of the importance modern energy services have on promoting the country's development, the Colombian government has recently launched the law 1715 of May 13, 2014. This law opens an opportunity window to achieve development goals through the use of non-conventional sources of energy. The law establishes the framework and the instruments to enhance sustainable use of renewable resources and development of the current electricity system. In regards to forestry biomass, it states that silviculture industry must consider alternative uses of byproducts or waste resulting from its activities instead of just leaving them in exploitation areas. Alternative uses include power generation. Regarding residual agricultural biomass, the National Government in coordination with the Regional Environmental Authorities must establish action plans aimed at promoting the use of such residues for energy purposes. Uncontrolled burning and on-field disposal must be avoided. The law also states that solid residues that are not possibly recycled or re-used, are considered as non-conventional sources of energy. According to the law, the Ministry of Mines and Energy regulates the technical standards to define the quality parameters for recovered solid fuels obtained from different waste. Also, the Ministry of the Environment and Sustainable Development together with the Ministry of Agriculture and Rural Development and the Ministry of Housing, City and Territory shall develop joint strategies so that recovered fuels meeting the parameters required by such standards be destined to energy valuation. Said technical standards shall be defined taking into account the community guidelines, including among other aspects, categories and qualities and areas of applicability as well as systems that allow the quality control or certification of said fuels (Colombian Congress, 2014).

I. Municipality of La Primavera

Physical Geography Aspects

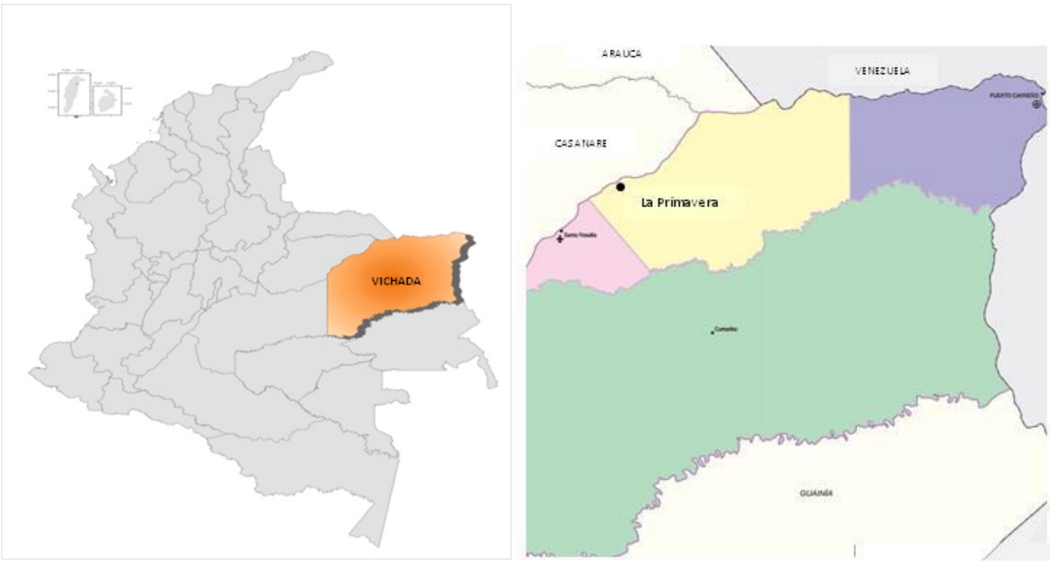

Figure 69. Map of La Primavera, Vichada department

Country: Colombia

Department: Vichada

Border: Casanare, Arauca, Guainía, Guaviare, and Meta Departments, Venezuela.

Area: 21,420 km^2

Population (2014,p): 14,810

Population Density: 0.73/km^2

Urban population (2014,p): 8,104

Rural population (2014,p): 6,706

Villages: 6 villages plus 3 indigenous and community conserved areas.

Elevation: 140m

Created by: Decree 676, April 13th 1987

Distance from Department Capital (Puerto Carreño): 400 km

How to reach La Primavera: By plane or road from Villavicencio (Capital City of Meta Department). It is important to mention that he road infrastructure is made up of a precarious network that lacks conditions for suitable transportation of goods and passengers. By river from Puerto Gaitán (Meta)

Main rivers: Vichada and Meta

Average Temperature: 28°C

Basic Unsatisfied Needs: 100

Gross Domestic Product (USD$1,000)

Table 130 presents the local Gross Domestic Product (GDP) between 2007 and 2013.

Table 130: Gross Domestic Product of La Primavera Municipality from 2007 to 2013 (USD$ 1,000)

	2007	2008	2009	2010	2011	2012	2013
GDP TOTAL	48,564	66,434	20,832	37,150	41,464	32,924	26,680
GDP Agro-industry	4,509	5,942	1,720	2,841	3,331	2,601	1,787
GDP Mining	173	212	61	4,209	123	89	66
GDP Manufacture Industry	3,295	4,669	1,843	526	493	448	331
GDP Public services (electricity, gas and water)	346	636	245	420	493	358	331
GDP construction	3,122	4,457	1,720	2,736	3,702	3,139	2,581
GDP commerce	6,590	8,914	2,580	4,735	6,170	4,754	3,773
GDP services	27,294	38,841	11,737	20,627	25,791	20,274	16,749
Taxes	2,601	2,759	921	1,052	1,357	1,255	1,059
GDP per capita (USD)	4,236	5,579	1,685	2,896	3,117	2,387	1,866

Source: Estimated by authors based on (DANE, 2014)

Agriculture

Subsistence farming consisting of cassava, corn, banana and cacao is a common practice in La Primavera. Yet, there are also large soya and corn agro-industrial projects. About 5660 hectares, equivalent to 73% of total hectares, which are established in the department of Vichada for agro-industrial production, are located in La Primavera. To a lesser extent, palm and timber production is also developed in this municipality (La Primavera Municipality, 2011)

According to Juan Antonio Nieto Escalante, Director of Geographical Institute Agustin Codazzi, La Primavera and generally the Orinoco and the Amazon Regions, comprise very extensive areas with a great but still unexplored potential. Locals should benefit from these opportunities but unfortunately, farmers prefer to sell their land rather than grow their own crops. This is due to lack of productive alternatives at small scale and the undeniable chemical limitations of the soil. Large-scale agro-industrial projects have settled in the region to explore business opportunities that in many cases are not connected to the development of La Primavera (Redacción Llano 7 días, 2014). Table 2 indicates the most relevant crops in La Primavera.

Table 131: Permanent and temporary crops production in La Primavera, Vichada (Tonnes/year). 2013

Municipality: La Primavera, Vichada	Temporary crops			Permanent crops		
	Rice	**Corn**	**Soja**	**Palm oil**	**Cassava**	**Plantain**
Cultivated area (Ha)	244	406	1,575	202	176	82
Production (t)	987	505	4,290	620	720	383
Productivity (t/Ha)	4.0	1.2	2.7	3.1	4.1	4.7

Source: Estimated by authors based on (Colombian Ministry of Agriculture and Rural Development, 2013)

Livestock and animal production

The main economic activity in the municipality is cattle rising. Recently, some foreign investors introduced processes of modernization and improvement, which are being progressively reproduced by local inhabitants. About 90% of the municipal land is dedicated to cattle industry (La Primavera Municipality, 2011). Table 132 shows the evolution of cattle industry in la Primavera for the period 2011-2014.

Table 132: Cattle production in La Primavera, Vichada (Number of heads)

Department	Municipality	Year			
		2011	2012	2013	2014
Vichada	La Primavera	118,670	118,670	125,980	125,750

Source: (FEDEGAN, 2015)

Wood

The second economic activity in importance, preceded by cattle rising, is silviculture. The Municipality has the largest number of hectares of forest in the department of Vichada, amounting to about 26900 Ha. Commercial forestry projects include species such as Acacia mangium, Pinus caribaea, Eucalyptus grandis, Eucalyptus pellita, Eucalyptus tereticornis, orocarpa Pine, Teak (Tectona grandis), Rubber (Hevea brasiliensis) and palm oil (Elaeis guineensis). This activity has markedly contributed to improve employment indicators (La Primavera Municipality, 2011)

Public services

In regard to heath and sanitation services, only 40% of the population has access to clean water and sewage. On average, each person produces between 0.3 and 0.9 kilograms of waste per day, depending on their socioeconomic characteristics but, according to the Sanitary Services Inventory for Rural Areas, about 98% of rural population does not have access to waste collection services and use alternatives such as burning or disposal in open fields (Colombian Ministry of Environment and Rural Development, 2006). Regarding electicity services, diesel-based power plants supply the service to about 55% of the population. Despite the existence of abundant bioenergy resources (See Table 133), it is important to mention that one of the strategic goals of the local government is to increase the coverage of electricity service through the expansion of grid and upgrading of power generators which actually provide electricity in the municipality (La Primavera Municipality, 2011)

Table 133: Electricity coverage and demand in La Primavera, Vichada

Municipality	Electricity coverage (%)	Electricity demand per capita, 2014 (kWh/person/year)
La Primavera	54.49	226

Source: (DANE, 2011; SIEL, 2012)

Environment

The Regional Autonomous Corporation of the Orinoco (CORPORINOQUIA) classified La Primavera as one of the strategic environmental areas of the department of Vichada. That is, La Primavera has an important environmental capital, which is crucial for the development of the community. Yet, this structure is in danger due to common practices such as open burnings and wrong inappropriate disposal of waste.

II. Municipality of Cumaribo

Physical Geography Aspects

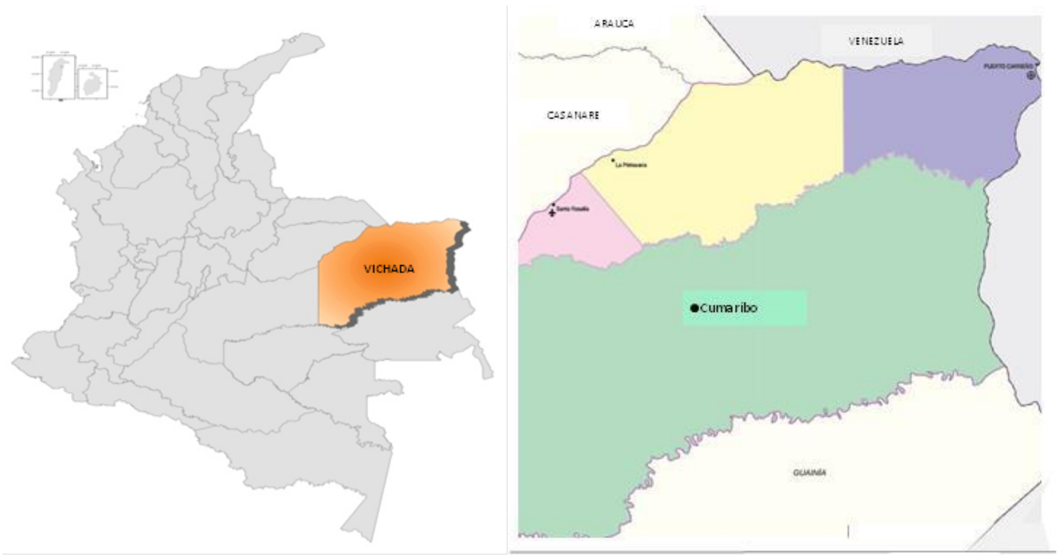

Figure 70: Map of Cumaribo, Vichada department

Country: Colombia

Department: Vichada

Border: Casanare, Arauca, Guainía, Guaviare, and Meta Departments, Venezuela.

Area: 65,163 km^2

Population (2014,p): 35,999

Population Density: 0,6/km^2

Urban population (2014,p): 6,573

Rural population (2014,p): 29,426

Villages: 4 districts (Santa Rita, San José de Ocuné, Guerima, y El Viento) with at least 60 locations between indigenous communities, shelters and municipal divisions.

Elevation: 125m.

Distance from Department Capital (Puerto Carreño): 753 km.

How to reach the municipality: By plane and road from Villavicencio (Capital City of Meta Department). It is important to mention that for road trip, the way is able just diring summer (from December to March). By the rivers in Orinoco basin.

Main rivers: Orinoco basin, Vichada, Guaviare, Tomo, Tuparro.

Average Temperature: 28,5 °C

Basic Unsatisfied Needs: 82.43%

Gross Domestic Product (USD$1,000)

Table 134 presents the local Gross Domestic Product (GDP) between 2007 and 2013.

Table 134: Gross Domestic Product of Cumaribo Municipality from 2007 to 2013 (USD$ 1,000)

	2007	2008	2009	2010	2011	2012p	2013pr
GDP TOTAL	128,011	173,289	53,694	94,618	104,370	81,904	65,602
GDP Agro-industry	11,887	15,502	4,435	7,237	8,387	6,472	4,395
GDP Mining	457	554	158	10,722	311	223	163
GDP Manufacture Industry	8,686	12,180	4,752	1,340	1,242	1,116	814
GDP Public services (electricity, gas and water)	914	1,661	634	1,072	1,242	893	814
GDP construction	8,229	11,626	4,435	6,969	9,319	7,811	6,349
GDP commerce	17,373	23,253	6,652	12,062	15,531	11,828	9,279
GDP Transport, storage and communications	11,430	16,609	4,752	5,093	5,902	4,910	3,581
GDP financial instituions, real state, insurance, service to companies	6,401	8,305	2,534	4,825	5,902	5,133	4,395
GDP services	55,776	76,402	22,967	42,618	53,117	40,394	33,208
Taxes	6,858	7,197	2,376	2,680	3,417	3,124	2,605
GDP per capita (USD)	4,236	5,580	1,686	2,897	3,117	2,387	1,867

Source: Estimated by authors based on (DANE, 2014)

Agriculture

In Cumaribo, agricultural systems are developed at large, medium, and small scale. Large-scale systems are more profitable thanks not only to an extensive area but also to a chemically rich soil. This applies particularly for rice, soybeans, corn and sorghum crops. These crops are produced for commercialization within the country but also for exportation purposes. In the medium scale, the main crops are cassava, corn, watermelon, cacao, and banana. Finally, small-scale subsistence agriculture prevails for cassava, corn and banana. All crops have an area not exceeding three acres. Another activity is the extraction of timber and non-timber products for building purposes. However, this extraction of products is performed improperly Subsistence hunting and fishing are also common practices in this municipality (Cumaribo Municipality, 2012). Table 135 shows permanent and temporary crops production based on information available at department level.

Table 135: Permanent and temporary crops production in Cumaribo, Vichada (Tonnes/year). 2013

Municipality: Cumaribo, Vichada	Temporary crops			Permanent crops		
	Rice	**Corn**	**Soja**	**Palm oil**	**Cassava**	**Plantain**
Cultivated area (Ha)	742	1,236	4,791	615	176	249
Production (t)	3,003	1,535	13,050	1,886	720	1,164
Productivity (t/Ha)	4.0	1.2	2.7	3.1	4.1	4.7

Source: Estimated by authors based on (Colombian Ministry of Agriculture and Rural Development, 2013)

Livestock and animal production

Cumaribo is the most extended municipality in Colombia, with more than 65,000 km^2. While approximately 40% of the municipality territory is covered by grass, enhancing livestock development, about 60% of the land corresponds to forest. In spite of wide availability of land for livestock, the livestock production sector faces significant challenges related to the high costs of production due to lack of appropriate technologies, and absence of funding programs particularly for small producers, poor conditions of roads and transport infrastructure that prevent proper commercialization of local products. Yet, Cumaribo is considered as an strategic place to develop livestock sector (Cumaribo Municipality, 2012). Table 136 shows cattle production in Cumaribo for the period 2010-2013.

Table 136: Cattle production in Cumaribo, Vichada (Number of heads)

Department	Municipality	Year			
		2011	2012	2013	2014
Vichada	Cumaribo	28,380	27,380	29,846	41,825

Source: (FEDEGAN, 2015)

Wood

About 22,113 hectares in the municipality are dedicated to forestry projects. Species such as Caribbean pine have been developed with the purpose of obtaining commercial oil and resins. Acacia (Acacia mangium Willd), Teca (tectona grandis), Eucalyptus pellita, Eucalyptus tereticornis, and Eucalyptus orophylla have been developed for wood commercialization. In addition, mixed forestry projects comprising palm oil and rubber, cover approximately 4,714 hectares (Cumaribo Municipality, 2012).

Public services

The municipality has two sewage systems that benefit about 470 people in urban areas, out of 600 potential users. This implies coverage of 78.3%.

About 19.3% of the users have their own wastewater system, and the remaining 2.4% of the population has no access either to the sewage system or to individual solutions. Water is provided in the urban area to about 564 users through a sectoring system, according to which, the service is provided to a particular area of the municipality on previously defined days (two per week). The system pressure is not enough. As a result, some households do not fully benefit from the service. In addition, distributed water is not drinkable, which is of great risk to public health Municipality. The Water Treatment Plant is not working at the moment. Regarding electricity services, the municipality is provided with electricity by a CUMMINS 1000 KVA diesel-based power plant. Electricity coverage and demand in Cumaribo are indicated in Table 137

Table 137: Electricity coverage and demand in Cumaribo, Vichada

Municipality	Electricity coverage (%)	Electricity demand per capita, 2014 (kWh/person/year)
Cumaribo	37,38	38,93

Source: (DANE, 2011; SIEL, 2012)

Environment

There are two areas that are part of strategic national ecosystems due to their biodiversity, and cultural heritage. These areas, the National Natural Park Tuparro, and the Matavén Forest, provide an opportunity for eco-tourism, one of the strategic areas included in the current development plan for the municipality.

III. Municipality of Puerto Carreño

Physical Geography Aspects

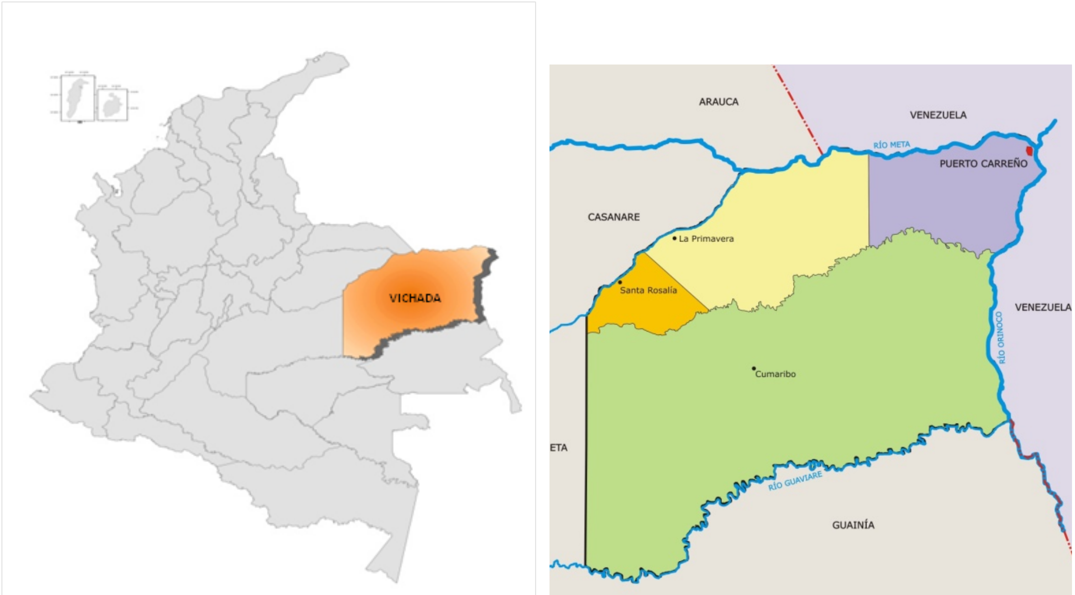

Figure 71: Map of Puerto Carreño, Vichada department

Country: Colombia

Department: Vichada

Border: Meta, Puerto Páez, Casuarito, Puerto Ayacucho (Venezuela).

Area: 12,409 km^2

Population (2014,p): 15,505

Population Density: 1.3 Inhab/km^2

Urban population (2014,p): 12,943

Rural population (2014,p): 2,562

How to reach the municipality: Rivers allow communication with Puerto Lopez, Puerto Ayacucho , Puerto Paez , Ciudad Bolivar , and Puerto Ayacucho in Venezuela.

Elevation: 51 m

Created: in 1972

Main Rivers: Orinoco, Meta, Bita and Calo Negro

Average Temperature: 36°C

Basic Unsatisfied Needs: 45.35%

Gross Domestic Product (USD$1,000)

Agriculture is an important sector, contributing more than 7% to municipal GDP in the primary sector. Even though Puerto Nariño is located close to the border with Venezuela, commerce with this country is very poor due to lack of infrastructure. Yet, there is some trade of timber, fish, cassava, and handicrafts, particularly with Puerto Ayaucho in Venezuela. Table 138 presents the local Gross Domestic Product (GDP) between 2007 and 2013.

Table 138: Gross Domestic Product of Puerto Carreño from 2007 to 2013 (USD$ 1,000)

	2007	2008	2009	2010	2011	2012p	2013pr
GDP TOTAL	**58,388**	**78,2857**	**24,0635**	**42,0658**	**46,0343**	**35,8393**	**28,4797**
GDP Agro-industry	5,422	7,003	1,987	3,217	3,699	2,832	1,908
GDP Mining	209	250	71	4,768	137	98	71
GDP Manufacture Industry	3,962	5,502	2,129	596	548	488	353
GDP Public services (electricity, gas and water)	417	750	284	477	548	391	353
GDP construction	3,753	5,252	1,987	3,098	4,110	3,417	2,756
GDP commerce	7,924	10,504	2,981	5,362	6,850	5,176	4,028
GDP Transport, storage and communications	5,213	7,503	2,129	2,264	2,603	2,148	1,554
GDP financial instituions, real estate, insurance, service to companies	2,919	3,752	1,136	2,145	2,603	2,246	1,908
GDP services	25,441	34,516	10,293	18,947	23,428	17,675	14,416
Taxes	3,128	3,251	1,069	1,192	1,507	1,367	1,130
GDP per capita (USD)	**4,236**	**5,580**	**1,686**	**2,897**	**3,117**	**2,387**	**1,867**

Source: Estimated by authors based on (DANE, 2014)

Agriculture

Agriculture is one of the main economic activities in the municipality. The principal products are rice, cotton, cassava and plantain. Cassava and plantain crops have a higher productivity than that measured at national level. Yet, these products are basically used for internal consumption. Agriculture is also very important for the municipality as it represents an opportunity for labor development. However, the remuneration for agricultural activities is low, particularly in Puerto Carreño surroundings where the overall low income of indigenous people is widely acknowledged.

Inadequate land use, and high costs of production and transportation create barriers for the development of agriculture technology. There is also a significant need for soil adaptation. These needs are linked to an important investment that unfortunately has not been assigned yet to the department. Table 139 shows permanent and temporary crops production based on information available at department level.

Table 139: Permanent and temporary crops production in Puerto Carreño, Vichada (Tonnes/year). 2013

Municipality: Puerto Carreño, Vichada	Temporary crops			Permanent crops		
	Rice	**Corn**	**Soja**	**Palm oil**	**Cassava**	**Plantain**
Cultivated area (Ha)	141	235	912	117	102	47
Production (t)	572	292	2,485	359	417	222
Productivity (t/Ha)	4.0	1.2	2.7	3.1	4.1	4.7

Source: Estimated by authors based on (Colombian Ministry of Agriculture and Rural Development, 2013)

Wood

Timber exploitation as well as trade of ornamental fish, and natural fibers, are profitable activities for large-scale enterprises and not for small producers. This has influenced corporative decisions and some entities started to grow some species for wood production. For example, companies such as Pizano S.A., Refocosta, Reforestadora Madetec, Centro Las Gaviotas, and Pinares de la Orinoquía S.A. have settled in the region with specific projects. The Caribbean Pine has been identified as being highly adaptable to acid soils. For this reason this specie has been promoted and it has created great expectations in relation to the creation of productive areas and benefits for the entire region (ESAP, 2015).

Livestock and animal production

The grassy savanna of the municipality is dedicated to cattle and beef production. Table 140 shows the evolution of cattle industry in Puerto Carreño for the period 2010-2013

Table 140: Cattle production in Puerto Carreño, Vichada (Number of heads)

Department	Municipality	Year			
		2011	2012	2013	2014
Vichada	Puerto Carreño	24,375	24,284	24,284	23,600

Source: (FEDEGAN, 2015)

Public services

About 35% of the population has no access to clean water services and about 94% has no sewage service. Efforts to provide clean water supply have been focused on providing the service leaving aside quality issues (Puerto Carreño Municipalty, 2015). Regarding electricity services, the municipality has coverage higher than 90%. Electricity coverage and demand in Puerto Carreño are indicated in Table 141.

Table 141: Electricity coverage and demand in Puerto Carreño, Vichada

Municipality	Electricity coverage (%)	Electricity demand per capita, 2014 (kWh/person/year)
Puerto Carreño	90.36	1,342

Source: (DANE, 2011; SIEL, 2012)

Environment

Inappropriate use of resources has negatively impacted diverse ecosystems, increasing risks for species that are already in danger of extinction. There is a need for controlling practices such as open burnings; illegal mining, phishing, and hunting that directly affect a very sensitive and bio-diverse system.

IV. Municipality of Mosquera

Physical Geography Aspects

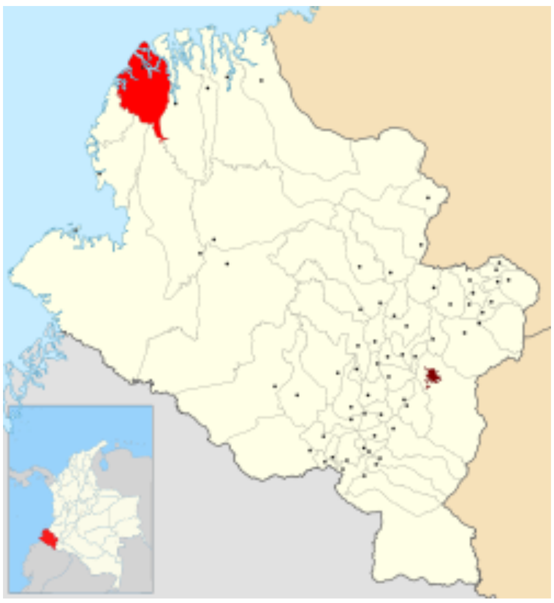

Figure 72: Map of Mosquera, Nariño department

Country: Colombia

Department: Nariño

Borders: Cauca and Putumayo departments and Ecuador

Area: 1,770 km^2

Population (2014,p): 13,161

Population Density: 19.41/km^2

Urban population (2014,p): 4,327

Rural population (2014,p): 8,834

Villages: 8 neighbourhoods (Brisas de Mar, Samaritana, El Carmen, Las Mercedes, Avenida Los Estudiantes, Aeropuerto, La Esperanza, Las Flores) plus 34 corregimientos (smaller villages)

Elevation: 10 m

Created by: Tomas Cipriano de Mosquera, May 24th 1824

Distance from Department Capital (Pasto): 517 km

How to reach the municipality: By either road or river from Pasto (Capital city of Nariño Department). There is also access from Tumaco, Buenaventura, Guapi, Barbacoas, and El Charco

Average Temperature: 28 °C

Basic Unsatisfied Needs: 84.32%

Gross Domestic Product (USD$1,000)

Table 142: Gross Domestic Product of Mosquera from 2007 to 2013 (USD$ 1,000)

	2007	2008	2009	2010	2011	2012p	2013p
GDP TOTAL	**53,132**	**70,805**	**22,610**	**40,862**	**54,396**	**44,108**	**19,436**
GDP Agro-industry	8,587	10,911	3,208	5,917	7,984	6,316	2,712
GDP Mining	330	383	151	424	628	1,052	393
GDP Manufacture Industry	3,491	4,160	1,210	2,097	2,724	2,189	920
GDP Public services (electricity, gas and water)	1,101	1,442	455	854	1,093	801	331
GDP construction	3,916	5,151	2,093	3,310	4,723	3,930	2,101
GDP commerce	10,034	13,207	4,102	7,690	10,273	8,070	3,500
GDP Transport, storage and communications	4,160	5,318	1,607	2,754	3,394	2,619	1,094
GDP financial institutions, real state, insurance, service to companies	5,363	7,585	2,440	4,492	5,780	4,651	2,034
GDP services	13,320	19,104	6,256	11,323	14,887	12,291	5,407
Taxes	2,831	3,542	1,088	2,001	2,911	2,189	945
GDP per capita (USD)	**4,162**	**5,380**	**1,666**	**2,921**	**3,771**	**2,965**	**1,268**

Source: Estimated by authors based on (DANE, 2014)

Agriculture

Crops such as plantain, sugar cane, cacao, and coconut are still developed in. Table 143 shows permanent and temporary crops production based on information available at department level.

Table 143: Permanent and temporary crops production in Mosquera, Nariño (Tonnes/year). 2013

Municipality: Mosquera, Nariño	Permanent crops			
	Sugar cane	**Coconut**	**Cacao**	**Plantain**
Cultivated area (Ha)	806	323	725	1,385
Production (t)	5,541	2,057	242	8,644
Productivity (t/Ha)	6.9	6.4	0.3	6.2

Source: Estimated by authors based on (Colombian Ministry of Agriculture and Rural Development, 2013)

Aquiculture

Fishing and mollusk extraction are the most important activities of the municipal economy. About 99.4 % of the rural population income depends on these activities. Subsistence agriculture is also developed in this region. Other sources of income include forestry activities. Mosquera is located by the Pacific Coast. This implies a great potential for tourism activities. However, there is no infrastructure necessary to enable this possibility. For example, rural bridges, roads, and improvement and maintenance of village roads are needed (Mosquera Municipality, 2012). Table 142 shows the Gross Domestic product 2007-2013.

Public services

The municipality has no access to clean water supply. This is because there are no close sources of water for the aqueduct feed. In addition, the municipality can´t use water from soil wells because of the soil conditions. A desalination plant was built some years ago but it is currently out of service due to lack of maintenance. Nowadays, about 11,400 people collect rainwater during winter but during summer lack of potable water increases risk for stomach diseases and children mortality. Only 67 household have access to water wells. In terms of sanitation and sewage management, the municipality is also under national standards. There is no system for garbage disposal and there is no aqueduct providing services to the community. As a result, residues are often thrown into the rivers, into the ocean or into open fields. About $USD 520 million are required to build and put in place a system for solid residues management. Regarding electricity services, the coverage in rural and urban areas is low. In spite of a coverage level of 96.59%, EnerMosquera, the local electricity company has neither institutional nor technologic capacity to fully attend the demand. Electricity coverage and demand in Mosquera are indicated in Table 144 (Mosquera Municipality, 2012).

Table 144: Electricity coverage and demand in Mosquera, Nariño

Municipality	Electricity coverage (%)	Electricity demand per capita, 2014 (kWh/person/year)
Mosquera	96.59	56

Source: (DANE, 2011; SIEL, 2012)

V. Municipality of La Tola

Physical Geography Aspects

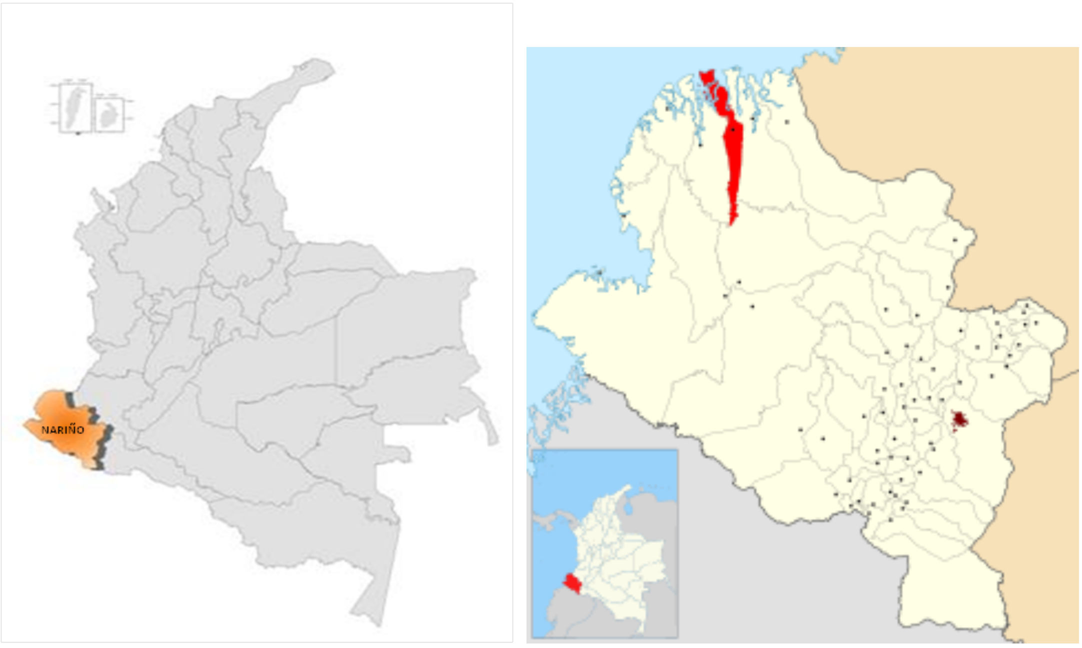

Figure 73: Map of la Tola, Nariño department

Country: Colombia

Department: Nariño

Borders: North: Pacific Ocean, South: Roberto Payan Municipality; East: El Charco Municipality; West: Olaya Herrera Municipality

Area: 459 km^2

Population (2014,p): 12,073

Population Density: 26.31/km^2

Urban population (2014,p): 8,916

Rural population (2014,p): 3,157

Elevation: 20 m

Created by: Ordinance N°. 013 16-11-1988

Distance from Department Capital (Pasto): 460 km

How to reach the municipality: Only by river from Buenaventura.

Main Rivers: La Tola

Average Temperature: 29 °C

Basic Unsatisfied Needs: 91.46%

Gross Domestic Product (USD$1,000)

The most important economic activity at the municipality is related to wood extraction. The second activity is fishing and mollusk collection. Local commerce also contributes to income generation. Also, artisanal fishing activities are performed in the Pacific Ocean and mangrove area. Livestock is less important for the economy and developed a t small scale. Table 145 shows the Gross Domestic product 2007-2013.

Table 145: Gross Domestic Product of La Tola from 2007 to 2013 (USD$ 1,000)

	2007	2008	2009	2010	2011	2012p	2013p
GDP TOTAL	**37.859**	**50.974**	**16.434**	**29.943**	**40.287**	**33.005**	**14.697**
GDP Agro-industry	6.118	7.855	2.331	4.336	5.913	4.726	2.051
GDP Mining	235	275	109	311	465	787	297
GDP Manufacture Industry	2.488	2.995	880	1.537	2.017	1.638	695
GDP Public services (electricity, gas and water)	784	1.038	330	626	810	600	250
GDP construction	2.790	3.709	1.521	2.425	3.498	2.941	1.589
GDP commerce	7.149	9.508	2.982	5.635	7.608	6.039	2.647
GDP Transport, storage and communications	2.964	3.829	1.168	2.018	2.514	1.959	827
GDP financial instituions, real state, insurance, service to companies	3.821	5.461	1.774	3.292	4.280	3.480	1.538
GDP services	9.491	13.754	4.547	8.298	11.025	9.198	4.089
Taxes	2.017	2.550	791	1.466	2.156	1.638	715
GDP per capita (USD)	**4.162**	**5.380**	**1.666**	**2.921**	**3.771**	**2.965**	**1.268**

Source: Estimated by authors based on (DANE, 2014)

Agriculture

During the last decade, agriculture productivity has been affected by the use of glyphosate to eradicate illegal crops. Yet, subsistence agriculture with crops such as plantain, sugar cane, cacao, and coconut is still developed in the municipality. Table 146 shows permanent and temporary crops production based on information available at deparment level.

Table 146: Permanent and temporary crops production in La Tola, Nariño (Tonnes/year). 2013

Municipality: La Tola, Nariño	Permanent crops			
	Sugar cane	**Coconut**	**Cacao**	**Plantain**
Cultivated area (Ha)	209	84	188	359
Production (t)	1.437	533	63	2,241
Productivity (t/Ha)	6.9	6.4	0.3	6.2

Source: Estimated by authors based on (Colombian Ministry of Agriculture and Rural Development, 2013)

Public services

Regarding public services, only 4.95% of rural households and 55.41% of urban areas have access to water services. Only 3 households out of 1383 have access to the aqueduct system. Municipal wastewater is discharged into the sea. Besides, the municipality does not have a plan for disposal of solid residues. Lack of access to potable water and incorrect disposal of residues negatively impact the ecosystem. For example, in municipalities such as La Tola, Magüí, Mallama, Olaya Herrera, Ricaurte y Roberto Payán, about 306 t/month are generated un urban areas. About 79,8% of these residues are disposed in a dump and only 62 t/month are technically disposed. (MIDEROS LÓPEZ, 2012; La Tola Municipality, 2015). Electricity is provided by a diesel-based system. Table 147 shows the electricity coverage and demand in the municipality. In spite of a 100% coverage reported by the national statistics department, less than 10% of the population has access to electricity in urban areas and only 4% in rural areas (La Tola Municipality, 2015).

Table 147: Electricity coverage and demand in La Tola, Nariño

Municipality	Electricity coverage (%)	Electricity demand per capita, 2014 (kWh/person/year)
La Tola	100	105

Source: (DANE, 2011; SIEL, 2012)

Environment

The municipality is extremely rich in forest species. Unfortunately, deforestation has expanded its indiscriminately, causing irreversible damage to the ecosystem. Logging industry has also contributed to this damage, as exploitation of wood resources is often uncontrolled. In addition, illegal crops have endangered the local ecosystem because of continuous use of glyphosate.

VI. Municipality of Solano

Physical Geography Aspects

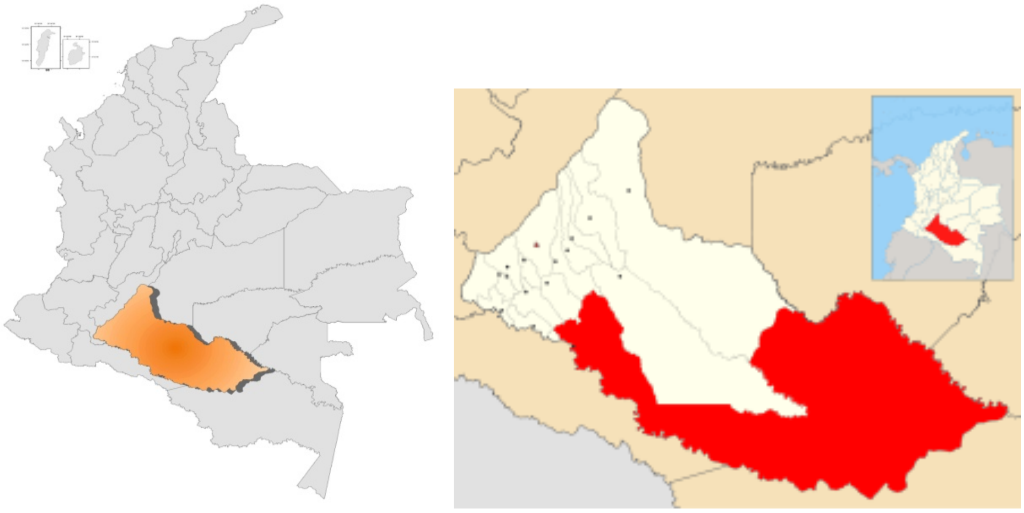

Figure 74: Map of Solano, Caquetá Department

Country: Colombia

Department: Caquetá

Borders: In the North, Solita, Valparaíso, Milán, Montañita, Cartagena del Chaira, San Vicente del Caguan, Calamar, and Miraflores (Guaviare Department). In the East, Pacoa (Vaupés Department), and Mirití, Paraná, and la Victoria (Amazonas department). In the South, Santander and la Chorrera. In the West, Puerto Leguízamo and Puerto Guzmán (Putumayo).

Area: 42,178 km^2

Population (2014,p): 23,210

Population Density: 0.5 Inhab. /km^2

Urban population (2014,p): 1,939

Rural population (2014,p): 21,271

Elevation: 200 m

Created by: Decree No. 23, July 1931

Distance from Department Capital (Florencia): 170 kilometers

How to reach the municipality: There is a road from Florencia that covers 16 km to Puerto Arango. From there, the route to Solano has to continue by river.

Main rivers: Caquetá, Orteguaza, Caguán, Coemaní, Yarí, Apaporis

Average Temperature: 27 °C

Basic Unsatisfied Needs: 100%

Gross Domestic Product (USD$1,000)

Agriculture is important within the primary sector in Solano. Yet, low levels of productivity and technological development characterize it, and lack of value added to their products. In spite of illegal crops reduction, agriculture keeps on being the main source for jobs. Agriculture is followed by livestock production and fishing, the latter is not industrialized. There is a number of productive organizations that comprise sugar cane, cacao, and milk and beef producers (Solano Municipality, 2015a).

Table 148 shows the local Gross Domestic Product (GDP) between 2007 and 2013.

Table 148: Domestic Product of Solano Municipality from 2007 to 2013 (USD$ 1,000)

	2007	2008	2009	2010	2011	2012p	2013pr
GDP TOTAL	**76,791**	**104,603**	**32,620**	**57,5275**	**72,905**	**61,716**	**49,191**
GDP Agro-industry	14,255	18,190	5,138	8,157	10,836	8,605	6,335
GDP Mining	167	306	88	200	263	317	264
GDP Manufacture Industry	3,344	4,636	1,439	2,102	2,716	2,157	1,708
GDP Public services (electricity, gas and water)	1,4213	1,9361	602	1,1260	1,4312	1,1206	885
GDP construction	4,556	8,407	2,555	5,580	6,835	8,986	7,966
GDP commerce	9,238	12,075	3,714	6,856	8,733	6,914	5,497
GDP Transport, storage and communications	4,556	8,407	2,554	5,580	6,835	8,986	7,966
GDP financial instituions, real state, insurance, service to companies	6,061	8,407	2,672	4,879	6,104	4,842	3,773
GDP services	27,798	37,806	12,067	22,020	27,514	22,454	17,888
Taxes	3,177	4,330	1,247	2,277	3,213	2,537	2,018
GDP per capita (USD)	**3,797**	**5,072**	**1,551**	**2,683**	**3,333**	**2,765**	**2,162**

Source: Estimated by authors based on (DANE, 2014)

Agriculture

Agriculture production includes crops such as plantain, cassava, sugar cane, cacao, corn, chontaduro and Amazonian guava (Solano Municipality, 2015a). Besides, rubber crops are reported but do not represent the main activity (Corpoamazonía, 2015a). Table 149 shows permanent and temporary crops production based on information available at department level. Corn is a relevant crop but is not included in the table due to lack of information. Rubber crops found in the municipality have a total area of 204 hectares, of which 104 are 2-9 years old, 45 hectares of 9-12 years, and 55 older than 12 years. Production levels have not been reported yet (Solano Municipality, 2015b).

Table 149: Permanent crops production in Solano, Caquetá (Tonnes/year) in 2013

Municipality: Solano, Caquetá	Permanent crops		
	Sugar cane	**Cassava**	**Plantain**
Cultivated area (Ha)	1,718	2,978	5,295
Production (t)	8,717	22,134	32,272
Productivity (t/Ha)	5.1	7.4	6.1

Source: Estimated by authors based on (Colombian Ministry of Agriculture and Rural Development, 2013)

Livestock and animal production

Livestock consists of double purpose cattle, mainly composed by 5824 of livestock and a minor activity of raising hogs, poultry and fish farming (Corpoamazonía, 2015a). The rural sector recognizes 7000 hectares for cattle grazing and 5000 hectares of grasslands (Solano Municipality, 2015b). Craft fishing is also an important activity mainly practiced by the indigenous and the main species are river ones. The fishing season is the first three months of the year where the production reaches 20 ton/week and is commercialized in Bogotá D.C. through Savelca Company that has offices in Villavicencio, Aerovanguardia and Viarco (Solano Municipality, 2015b).

Table 150: Cattle production in Solano, Caquetá (Number of heads)

Department	Municipality	Year			
		2011	2012	2013	2014
Caquetá	Solano	8,902	9,243	9,876	12,792

Source: (FEDEGAN, 2015)

Wood

Logging is mainly found in the south and southeast region where wide areas of primary forests still exist. Estimates indicate that about 2000 to 2500 m^3 of wood are extracted monthly. The main local exploited species are *perillo, achapo, sangretoro, marfil, tamarindo, arracacho* and *granadillo* (Solano Municipality, 2015b).

Public services

Regarding sanitary services, lack of a proper sewage system implies serious health risks. Most of the households have latrines or septic tanks, which are discharged, into the rivers. As a result, there is proliferation of mosquitoes and increased risk for diseases. Concerning electricity services, a diesel-based power plant provide electricity to about 36% of the population during 4 hours per day to, including rural and urban areas. According to the Municipality’s development program, coverage in the urban area is 100% but the service is provided only between 6pm and 10pm. Table 151 shows the electricity demand of the municipality (Solano Municipality, 2015b).

Table 151: Electricity coverage and demand in Solano, Caqueta

Municipality	Electricity coverage (%)	Electricity demand per capita, 2014 (kWh/person/year)
Solano	36.63	27

Source: (DANE, 2011; SIEL, 2012)

Environment

Unplanned agricultural expansion, deforestation in the national reserves, and illegal mining resulted in degraded and polluted water sources. The municipality looks forward to apply deforestation control programs that bring to an end practices that are negatively impacting the ecosystem. Another important issue the municipality is facing is the erosion of the Caguan, Orteguaza and Caqueta rivers and in the Amazonia (Corpoamazonía, 2015a)

VII. Municipality of Mitú

Physical Geography Aspects

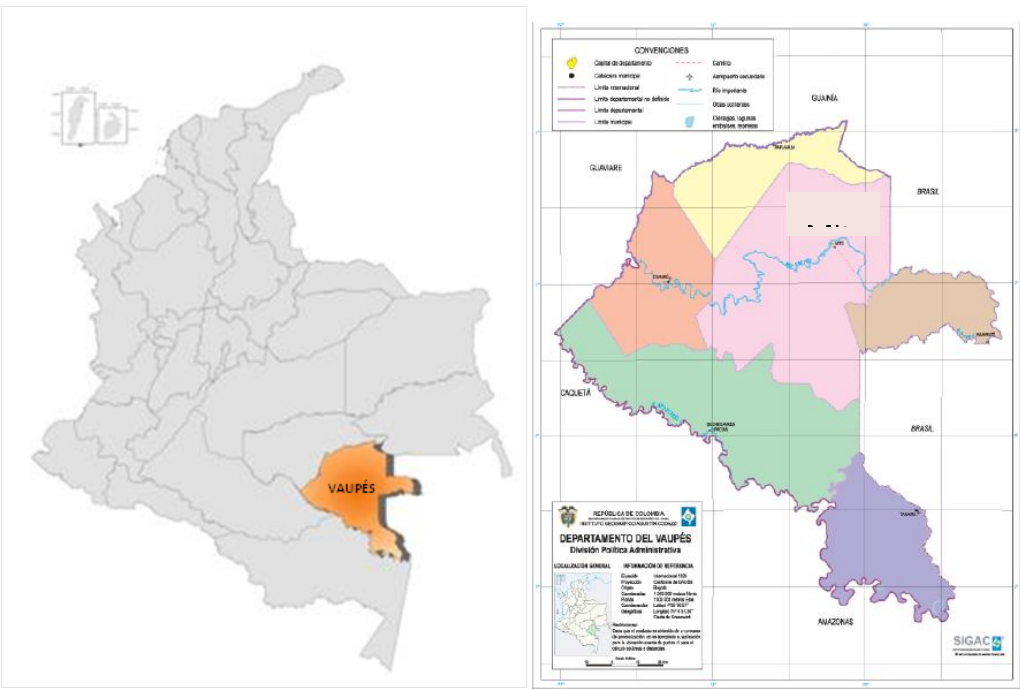

Figure 75: Map of Mitú, Vaupés department

Country: Colombia

Department: Vaupés

Borders: In the North, Arrecifal and Sapuara; In the South, Puerto Colombia and Sejal, In the East, Cacahual and Venezuela; In the West, Morichal and Barranco Minas.

Area: 16,455 km^2

Population (2014,p): 31,265

Population Density: 1.8 inhab/km^2

Urban population (2014,p): 15,752

Rural population (2014,p): 15,513

Elevation: 200 m

Created by: Decree No. 166, 06-08-1974

Distance from Bogotá: 660 km

How to reach the municipality: Mitú can be accessed through navigable routes from Carurú and other towns located by Vaupés River. Flights departure from Alberto León Bentley local airport and communicate the city with Bogotá and other cities. There is a road between Mitú and Monfort with only 54km paved.

Main Rivers: Vaupés

Average Temperature: 27 °C

Basic Unsatisfied Needs: 51.78%

Gross Domestic Product (USD$1,000)

Mitú is the capital city of Vaupés Department. Most of the territory corresponds to virgin jungle and forest with a vast biodiversity that is protected by law. Less than 1% (about 4 km^2) of the municipality are dedicated to urban areas; the remaining land corresponds to the Amazon forest reserve. The main activities are agriculture and fishing but not at commercial level due to restrictions in protected areas. Cattle raising activities are not significant due to local topography. According to Fedegan, only 1043 heads are part of the livestock inventory in the municipality (FEDEGAN, 2015). In addition, there are some natural and recreational areas in the surroundings of Mitú that may produce some income to the municipality. However, lack of infrastructure prevents the development of tourism. Table 152 shows the local Gross Domestic Product (GDP) between 2007 and 2013.

Table 152: Domestic Product of Mitú Municipality from 2007 to 2013 (USD$ 1,000)

	2007	2008	2009	2010	2011	2012p	2013pr
GDP TOTAL	**72,131**	**94,347**	**29,683**	**53,275**	**70,084**	**53,203**	**42,260**
GDP Agro-industry	2,576	3,899	893	1,134	1,314	1,889	1,148
GDP Manufacture Industry	644	780	223	378	438	315	230
GDP Public services (electricity, gas and water)	1,288	1,559	446	756	876	630	459
GDP construction	5,152	5,458	2,232	3,778	6,132	4,093	3,445
GDP commerce	12,237	15,595	4,687	8,690	10,951	8,500	6,661
GDP Transport, storage and communications	7,084	10,136	2,901	6,423	7,446	5,037	3,904
GDP financial instituions, real estate, insurance, service to companies	5,152	6,238	2,009	3,401	4,380	3,778	2,986
GDP services	36,066	48,343	15,399	26,448	35,042	26,444	21,360
Taxes	1,932	2,339	893	2,267	3,504	2,518	2,067
GDP per capita (USD)	**2,482**	**3,210**	**999**	**1,774**	**2,309**	**1,735**	**1,365**

Source: Estimated by authors based on (DANE, 2014)

Agriculture

Only indigenous populations are allowed to practice subsistence agriculture. Agriculture is developed through a small-scale system called chagra, which is responsibility of women. Chagras are located in rural areas, close to the main road that leads to the city where surplus production is commercialized. The main subsistence crops are cassava, maize, coca, banana, sugarcane, sweet potatoes, and yams. Fruits grown in the region include *lulo, borojo, araza*, papaya, *zapayo*, watermelon, *zapote*, and cacao. In the early 1990´s the main economic activity was rubber production. However, this crop was gradually eradicated as the municipality was declared a natural protected area. Table 153 shows an estimate of cassava and plantain production in Mitú.

Table 153: Permanent crops production in Mitú, Vaupés (Tonnes/year) in 2013

Municipality: Mitú, Vaupés	Permanent crops	
	Cassava	**Plantain**
Cultivated area (Ha)	255	15
Production (t)	2,596	96
Productivity (t/Ha)	10.2	6.2

Source: Estimated by authors based on (Colombian Ministry of Agriculture and Rural Development, 2013)

Public services

The Municipality of Mitú is in charge of the provision of public services, including water, sewerage and sanitation. Despite the fact that the development plan considers the construction of a landfill, residues are still thrown in a dump. There is no access to potable water. The service is provided only in urban areas, with coverage of about 85% during limited periods (usually twice per week, for 16 hours). The sewage system was recently built but it is not operative, as the households are not yet connected. Regarding electricity, the municipality has an average 24-hours of energy service delivery daily. However, about 69.43 % of the households are connected to the local electricity network (DANE, 2011). This implies a coverage level higher than 95% in urban areas and lower than 16% in rural areas where inhabitants that have access to the service, are supplied with electricity only for two hours during the day (Mitú Municipality, 2015). Table 154 shows the electricity demand of the municipality.

Table 154: Electricity coverage and demand in Mitú, Vaupés

Municipality	Electricity coverage (%)	Electricity demand per capita, 2014 (kWh/person/year)
Mitú	69.43	289

Source: (DANE, 2011; SIEL, 2012)

There are fifteen wetlands that used to be interconnected. Unfortunately, most of these wetlands are contaminated and not interconnected due to incorrect agriculture practices, residential development; residues disposal, and wastewater discarding. The situation creates a risk to the population, not only because of disease transmission, but also because of floods (Mitú Municipality, 2015).

VIII. Municipality of Taraira

Physical Geography Aspects

Figure 76: Map of Taraira, Vaupés Department

Country: Colombia

Department: Vaupés

Borders: East: Japurá (Brasil), South and west: La Pedrera (Amazonas), North: Pacoa and Japurá (Brasil).

Area: 6,619 km^2

Population (2014,p): 984

Population Density: 0.15 inhab./km^2

Urban population (2014,p): 148

Rural population (2014,p): 836

Villages: 15 communities: La Pista, Cerro Rojo, San Victorino, Puerto Alegría, Puerto López, Puerto Caimán, Bocas del Taraira, Puerto Ñumi, Vista Hermosa, Bocas de Ugá, Puerto Curúpira, Campo Alegre, Aguas Blancas, Santa Clara, and Jotabeyá.

Elevation: 100m

Created by: Ordinance No.022, November 27, 1987

Distance from Department Capital (Mitu): 179 km

How to reach Taraira: Taraira is accessible by air and by river. It has an airport runway of 600 meters, entering aircraft carrying up to 500 kilos. Rivers are also used as a mean for transportation.

Main rivers: Apaporis, Taraira and Ujca vica

Average Temperature: 27°C

Basic Unsatisfied Needs: 82.07%

Gross Domestic Product (USD$1,000)

Subsistence agriculture and small-scale gold mining are the main economic activities in the municipality. Table 155 presents the local Gross Domestic Product (GDP) between 2007 and 2013.

Table 155: Gross Domestic Product of Taraira Municipality from 2007 to 2013 (USD$ 1,000)

	2007	2008	2009	2010	2011	2012p	2013pr
GDP TOTAL	**2,713**	**3,509**	**1,092**	**1,939**	**2,524**	**1,897**	**1,492**
GDP Agro-industry	97	145	33	41	47	67	41
GDP Manufacture Industry	24	29	8	14	16	11	8
GDP Public services (electricity, gas and water)	48	58	16	27	32	22	16
GDP construction	194	203	82	137	221	146	122
GDP commerce	460	580	172	316	394	303	235
GDP Transport, storage and communications	266	377	107	234	268	180	138
GDP financial instituions, real state, insurance, service to companies	194	232	74	124	158	135	105
GDP services	1,357	1,798	566	962	1,262	943	754
Taxes	73	87	33	82	126	90	73
GDP per capita (USD)	**2,482**	**3,210**	**999**	**1,774**	**2,309**	**1,735**	**1,365**

Source: Estimated by authors based on (DANE, 2014)

Agriculture

Subsistence agriculture is the most frequent economic activity. Indigenous people living in *chagras* are dedicated to grow cassava, maize, coca, plantain, sugarcane, sweet potatoes, and yams. Table 156 shows an estimate of cassava and plantain production in Taraira.

Table 156: Permanent crops production in Taraira, Vaupés (Tonnes/year) in 2013

Municipality: Taraira, Vaupés	Permanent crops	
	Cassava	**Plantain**
Cultivated area (Ha)	103	39
Production (t)	1,046	237
Productivity (t/Ha)	10.2	6.2

Source: Estimated by authors based on (Colombian Ministry of Agriculture and Rural Development, 2013)

Public services

Electricity services are provided by a diesel-based power system. In average, the service is provided during 4 hours per day. Coverage is about 95% (See Table 157). Regarding sanitation, even though the municipality has a water treatment plant, lack of spare parts has forced the distribution of non-potable water. The service is provided in some areas only during night. According to the current development plan, the municipality has coverage of clean water and sewage services of less than 30% (Taraira Municipality, 2015).

Table 157: Electricity coverage and demand in Taraira, Vaupés

Municipality	Electricity coverage (%)	Electricity demand per capita, 2014 (kWh/person/year)
Mitú	95.66	137

Source: (DANE, 2011; SIEL, 2012)

Environment

As in other municipalities, lack of aqueduct and proper management of residues have negatively impacted the ecosystem. The situation creates a risk to the population, not only because of disease transmission, but also because of floods. In line with this situation, the current development plant includes the construction of a landfill (Taraira Municipality, 2015).

IX. Municipality of Guapi

Physical Geography Aspects

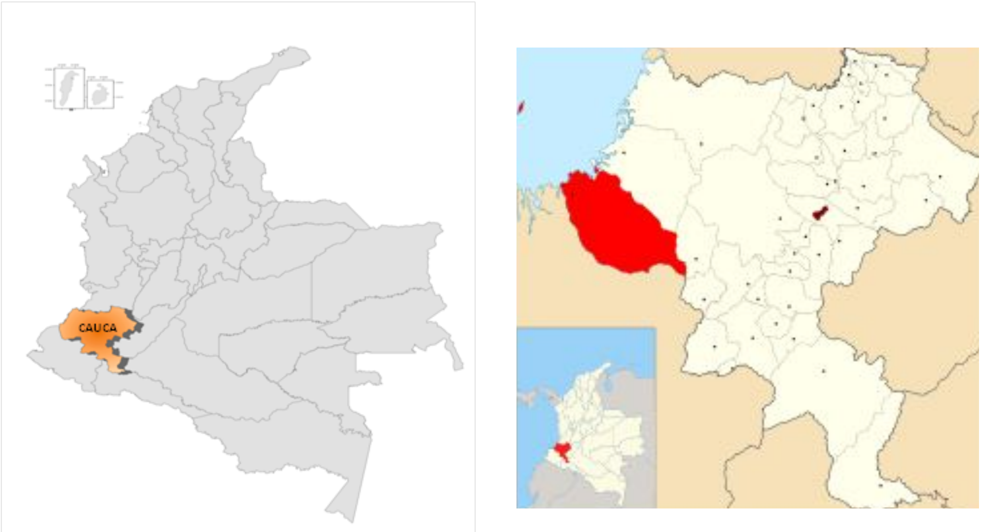

Figure 77: Map of Guapi, Cauca department

Country: Colombia

Department: Cauca

Borders: North: Pacific Ocean and the municipality of Timbiquí. West:Pacific Ocean and the Island of Gorgona. West: The municipalities of Argelia and Timbiquí. South: the municipality of Santa Bárbara de Iscuandé, department of Narino

Area: 2,688 km^2

Population (2014,p): 29,641

Population Density: 9,9 /km^2

Urban population (2014,p): 18010

Rural population (2014,p): 11631

Villages: *Corregimientos*: Balsitas, Las Juntas, EL Naranjo, San Vicente, Santa Clara, El Rosario, Boca de Napi, Temuey, Chamon, Soledad, Belen, San Agustin, Calle Larga, Chuare, Cascajero, Santa Ana. La Calle, Concepcion, San Antonio, San Jose de Guare, EL Carmelo, Limones, Quiroga, Gorgona – Gorgonilla. *Veredas*: San Agustín, rio Yantin (Hojarascal, Chiguero), Caimito, Calle Honda, Partidero, La Pampa, Codicia, Sansón, Penitente, El Carmen, Santa Rosa, Chamoncito, Parcelas, Playa Obregones. La Sabana, Boca de San Francisco, Playa del Medio, Isla de Tomas, Santa Gertrudis, Pinulpi, San Antonio,El Roble, Pascualero, Obregones, Madre vieja, Santa Rosa, Cantil, Joanico, Playa Blanca.

Elevation: 5m above sea level

Founded by: Manuel Valverde in 1772 by Ordenance 103/1911

Distance from Department Capital (Popayan): 144 km

How to reach the municipality: Guapí can be accessed through navigable routes from Buenaventura port or by plane from Cali or Popayán, there are not earthbound routes to Guapí due to lack of infrastructure in the region.

Main rivers: Guapi, Napi, San Francisco, Guajui

Average Temperature: 29°C

Basic Unsatisfied Needs: 87.42%

Gross Domestic Product (USD$1,000)

Table 158 presents the local Gross Domestic Product (GDP) between 2007 and 2013.

Table 158: Gross Domestic Product of Guapi Municipality from 2007 to 2013 (USD$ 1,000)

	2.007	2.008	2.009	2.010	2.011	2012p	2013p
GDP TOTAL	**121,403**	**165,548**	**50,491**	**94,667**	**118,670**	**94,233**	**76,255**
GDP Agro-industry	16,846	20,561	5,138	9,851	12,951	8,664	6,721
GDP Mining	1,360	2,027	887	1,182	1,818	2,388	2,231
GDP Manufacture Industry	18,807	25,846	9,148	16,087	19,299	14,395	10,151
GDP Public services (electricity, gas and water)	4,462	6,419	1,733	3,280	4,116	2,971	2,203
GDP construction	7,443	11,897	3,219	7,232	8,634	9,581	10,782
GDP commerce	10,904	14,359	4,388	8,136	10,291	8,177	6,396
GDP Transport, storage and communications	6,782	8,470	2,455	4,323	5,065	3,802	2,876
GDP financial instituions, real estate, insurance, service to companies	17,526	24,422	7,456	14,047	17,602	13,612	10,664
GDP services	27,390	37,888	11,933	22,403	28,294	22,582	17,981
Taxes	9,883	13,659	4,134	8,125	10,599	8,062	6,250
GDP per capita (USD)	**4,198**	**5,701**	**1,732**	**3,235**	**4,041**	**3,198**	**2,580**

Source: Estimated by authors based on (DANE, 2014)

Agriculture

Agriculture is the most significant productive activity in the municipality; the harvest of products such as coconut, 'chontaduro', corn, rice, and potatoes includes most of the family basic budget needs. Table 159 shows an estimate of rice and plantain production in Guapi.

Table 159: Permanent crops production in Guapi, Cauca (Tonnes/year) in 2013

Municipality: Guapi, Cauca	Temporary crops	Permanent crops	
	Rice	**Plantain**	**Coconut**
Cultivated area (Ha)	38	1,284	168
Production (t)	54	9,013	1,589
Productivity (t/Ha)	1.4	7.0	9.4

Source: Estimated by authors based on (Colombian Ministry of Agriculture and Rural Development, 2013)

Animal production

Fishing was an unregulated activity for years. Currently, there are programs to improve the breeding and repopulation of shrimp. Local fishing activities grasp most of the economic activities in the region; mollusk and crustacean, and shrimp collection provide valuable resources for the local economy. Along with home crops, breeding of chicken and pigs plays an important role in the diet of the locals.

Wood

Traditional timber industry is the most common activity performed by the natives who selectively cut certain species of trees. There are no industrial techniques implemented – machete, chains saw, measuring tape- which is affecting the natural trees regeneration. Wood waste is high due to lack of modern machinery, thus a significant amount of wood remains in the forest. Also, transportation throughout the river to Buenaventura causes a 20-30% lost. Some lumber mills like Triplex Braun, Madecen, Prochapas and Triplex de Madera commercialize then wood. Illegal commercialization of the wood (trees are cut down in Guapi and legalized in another jurisdiction) makes it difficult to know the amount of wood extracted from this municipality.

Mining

Mining activity is an important source of economic exploitation, mainly in the high and central areas of the rivers, being gold and platinum the minerals extracted.

Public Services

Guapi has 100% coverage of electricity service (See Table 160) and a daily average service of 23 hours. The electricity is produced by diesel power plants that create a significant impact on the local environment. This indicates the urgent evaluation of alternative sources of energy in order to supply local demand. Access to clean water is limited; Guapi does not have an efficient aqueduct. Also, there is no available system for final disposal and treatment of solid residues (Guapi Municipality, 2015).

Table 160: Electricity coverage and demand in Guapi, Cauca

Municipality	Electricity coverage (%)	Electricity demand per capita, 2014 (kWh/person/year)
Guapi	100	307

Source: (DANE, 2011; SIEL, 2012)

Environment

Wood production and commercialization is one of the main causes of deforestation. Also, the expansion of illegal crops and the agricultural borders are creating pressure on the ecosystem. Fishing was an unregulated activity for years. Currently, there are programs to increase shrimp production. Due to the special characteristics of the region and its high biodiversity, ecoturism could be an important source of income for the region.

X. Municipality of Timbiquí

Physical Geography Aspects

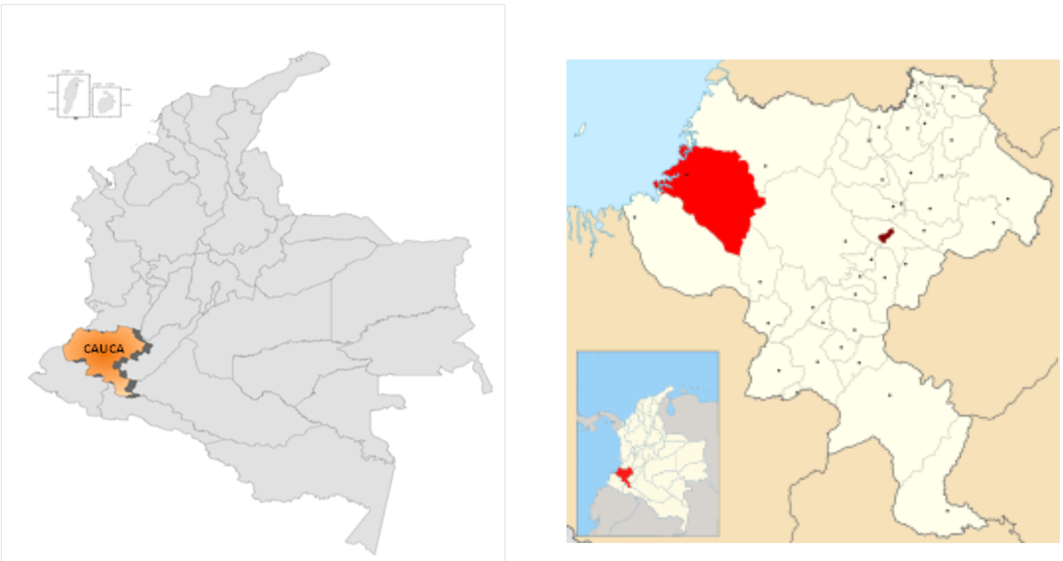

Figure 78: Map of Timbiquí, Cauca Department

Country: Colombia

Department: Cauca

Border: North: Municipality of Lopez de Micay. East: Municipalities of El Tambo and Argelia, South: Municipality of Guapi, West: Pacific Ocean

Area: 1,813 km^2

Population (2014,p): 21,490

Population Density: 8,5/km^2

Urban population (2014,p): 4141

Rural population (2014,p): 17349

Villages: *28 corregimientos* (Santa Maria, San Jose, Coteje, Corozal, Chete, Realito, El Charco, Cuerval, Chacon, Brazo Corto, San Miguel del Rio, Puerto Saija, Santa Rosa, San Bernardo, Pete, Boca de Patia, Los Brazos, Guangui, Soledad de Yantin, Cuip, Camarones, San Infi, Angostura, Cabecital, Pizares, La Brea, San Isidro, Bubuey), *48 veredas* and *12 neighborhoods*.

Elevation: 5 m above sea level

Created by: Francisco Antonio de Mosquera and Andrés Saa in 1772

Distance from Department Capital (Popayan): 580 km

How to reach the municipality: The 3 rivers and the Pacific Ocean are the main transportation for the natives. There is an airline that flies 3 times per week from Cali, the capital city, to Timbiquí.

Main rivers: Timbiquí, Saija, and Bubuey

Average Temperature: 28°C

Basic Unsatisfied Needs: 73.19

Gross Domestic Product (USD$1,000)

Table 161 presents the local Gross Domestic Product (GDP) between 2007 and 2013.

Table 161: Gross Domestic Product of Timbiquí Municipality from 2007 to 2013 (USD$ 1,000)

	2,007	2,008	2,009	2,010	2,011	2012p	2013pr
GDP TOTAL	87,974	119,696	36,452	68,284	85,629	68,077	55,173
GDP Agro-industry	12,207	14,866	3,709	7,106	9,345	6,259	4,863
GDP Mining	986	1,466	641	853	1,312	1,725	1,614
GDP Manufacture Industry	13,628	18,687	6,604	11,604	13,926	10,400	7,345
GDP Public services (electricity, gas and water)	3,233	4,641	1,251	2,366	2,970	2,146	1,594
GDP construction	5,393	8,602	2,324	5,217	6,230	6,922	7,801
GDP commerce	7,901	10,382	3,168	5,869	7,426	5,907	4,627
GDP Transport, storage and communications	4,915	6,124	1,773	3,118	3,655	2,747	2,081
GDP financial instituions, real state, insurance, service to companies	12,700	17,658	5,383	10,132	12,701	9,834	7,716
GDP services	19,848	27,394	8,615	16,160	20,416	16,314	13,010
Taxes	7,162	9,876	2,984	5,860	7,648	5,824	4,522
GDP per capita (USD)	4,198	5,701	1,732	3,235	4,041	3,198	2,580

Source: Estimated by authors based on (DANE, 2014)

Agriculture

Representative agricultural products of the region include rice, corn, sugar cane, coconut, and plantain. Of these, coconut is the most profitable for the natives; sugar cane is transformed into honey, *cany* and alcoholic beverages. Table 162 shows an estimate of rice and plantain production in Timbiquí.

Table 162: Permanent crops production in Timbiquí, Cauca (Tonnes/year) in 2013

Municipality: Timbiquí, Cauca	Temporary crops	Permanent crops	
	Rice	**Plantain**	**Coconut**
Cultivated area (Ha)	26	868	114
Production (t)	37	6,095	1,075
Productivity (t/Ha)	1.4	7.0	9.4

Source: Estimated by authors based on (Colombian Ministry of Agriculture and Rural Development, 2013)

Animal production

Fishing is done in a traditional way, and under precarious conditions, as fishermen have no equipment of their own and they have to rent it. Shrimp and white fish are important products; fish is classified by size, the small stays in town and the big one goes to the closest cities. Besides being a source of job, fishing is also a source of food for the natives.

Wood

The forest exploitation is one of the main activities in the economy of Timbiquí. Although wood has been extracted from the area close to the rivers Timbiquí, Bubuey and Saija, there is still a big potential to be exploited and there are programs oriented to the achieve sustainable processes for the extraction of this resource. Besides industrial uses, wood is used as a fuel to process sugar cane into honey and other products like '*biche*', an alcoholic beverage.

Mining

Gold and platinum extraction is an important part of the economy of many families in the region.

Public services

Quality of water in urban area is low and the aqueduct and sewage system is insufficient for the inhabitants of the municipality, which makes it difficult to know about the consumption, production or losses of water in Timbiquí. In the rural areas, contamination of water is significant. Liquid and solid waste, mining residues such as heavy metals, and agrochemicals residues are present in high quantities.

In Timbiquí, about 73% of households have energy service (See Table 163). Sewage service in the municipality covers of 18% of the population and waste disposal covers 12%. There is no water treatment plant and most of the residues are discharged into rio Timbiquí.

Table 163: Electricity coverage and demand in Timbiquí, Cauca

Municipality	Electricity coverage (%)	Electricity demand per capita, 2014 (kWh/person/year)
Solano	98.52	157

Source: (DANE, 2011; SIEL, 2012)

Environment

There is a type of transitional forest between the mangrove and the alluvial region, which is the forest of '*guandal*' with tree species like *sajo, cuángare, machare* and *palma naidí*. There are also terraces and hills where a lot of species exist, many of these of a high commercial value. Deforestation in Timbiquí has been caused by the wood industry, by the expansion of agricultural activities, colonization and consumption of firewood, being the latter essential for cooking purposes. Contamination of water is caused by mining, agrochemicals, deforestation, solid and liquid wastes from animals and human due to the absence of septic wells in the rural area.

XI. Municipality of Juradó

Physical Geography Aspects

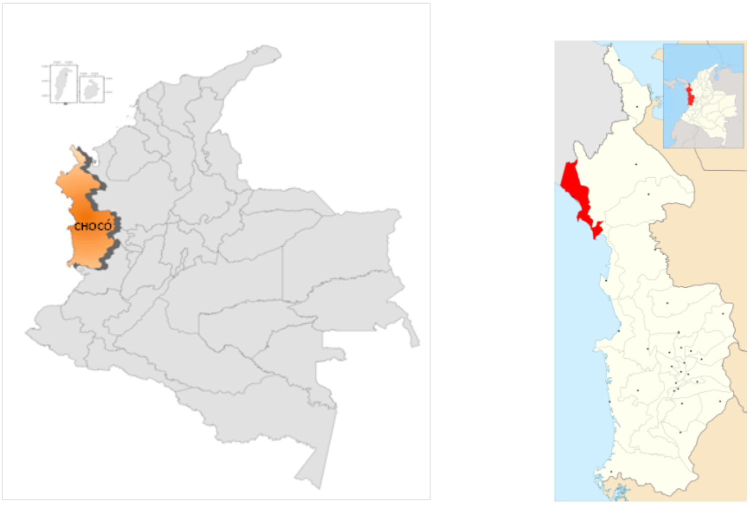

Figure 79: Map of Juradó, Chocó Department

Country: Colombia

Department: Chocó

Border: North: Republic of Panama, West: Municipality of Rio Sucio, South: Municipality of Bahia Solano, West: Pacific Ocean.

Area: 1,352 km2

Population (2014,p): 3,353

Population Density: 2.48 Inhab./km2

Urban population (2014,p): 1,631

Rural population (2014,p): 1,722

Villages: 6 *corregimientos* (Punta Ardita, Guarin, Curiche, Punta Pina, Coredo and Cabo Marzo) and 11 *veredas*.

Elevation: 5 m

Created by: Gregorio Ballesteros – Toribia Alegria. Decree 14, December 13th 1956

Distance from Department Capital (Quibdó): 320 km

How to reach the municipality: A private airline company is providing the service of flights only on Tuesdays and Fridays, with itineraries to the nearest city Quibdó (Capital City of the Department). There are navigable routes like the Jiguado river (Chocó).There are not earthbound routes to Juradó due to the lack of infrastructure in the region.

Main rivers: Juradó, Partado, Jiguiado, Jampabado, Totumia and Curiche.

Average Temperature: 27°C

Basic Unsatisfied Needs: 86.21%

Gross Domestic Product (USD$1,000)

Agriculture and wood extraction are important economic activities in this municipality. In addition, due to their high fluvial activity, fishing is a common practice. Local government is currently promoting commerce with Panamá (Juradó Municipality, 2015). Table 164 presents the local Gross Domestic Product (GDP) between 2007 and 2013.

Table 164: Gross Domestic Product of Juradó Municipality from 2007 to 2013 (USD$ 1,000)

	2007	2008	2009	2010	2011	2012p	2013pr
GDP TOTAL	10,293	13,744	4,719	10,274	14,246	10,245	6,653
GDP Agro-industry	2,229	2,945	801	1,225	1,524	1,164	830
GDP Mining	1,350	1,688	1,065	3,768	6,348	4,056	1,820
GDP Manufacture Industry	184	235	78	136	168	128	92
GDP Public services (electricity, gas and water)	164	203	64	114	143	107	83
GDP construction	511	600	251	379	497	397	376
GDP commerce	1,097	1,436	431	800	998	782	607
GDP Transport, storage and communications	634	746	205	379	440	333	251
GDP financial instituions, real state, insurance, service to companies	429	576	176	322	389	305	232
GDP services	3,408	4,957	1,535	2,942	3,442	2,743	2,189
Taxes	286	357	114	209	298	229	173
GDP per capita (USD)	2,908	3,911	1,354	2,974	4,156	3,007	1,972

Source: Estimated by authors based on (DANE, 2014)

Agriculture

Agricultural activity in Juradó includes crops such as plantain, coconuts, cassava, and rice. These products are traded locally due to lack of adequate road conditions. Table 165 shows an estimate of rice, coconut, cassava, and plantain production in Juradó.

Table 165: Temporary and permanent crops production in Juradó, Chocó (Tonnes/year) in 2013

Municipality: Juradó	Temporary crops	Permanent crops		
	Rice	**Plantain**	**Coconut**	**Cassava**
Cultivated area (Ha)	594	868	15	157
Production (t)	1,025	6,095	185	1,384
Productivity (t/Ha)	1.7	7.0	12.5	8.8

Source: Estimated by authors based on (Colombian Ministry of Agriculture and Rural Development, 2013)

Wood

Timber industry is an important part of the economy of the region. There is an immense variety of species in a vast area of natural forest with valuable species like roble, abarco, cedro, insive, caracoli, almendro, jiguanegro, clavellino, peinemono, higueron, mora, sande, huina and the precious caobo. Timber is exported to Panamá.

Public Services

Juradó has about 94% coverage of electricity service (See Table 168). Yet, the service is provided during 13 hour per day in average. The electricity is produced by diesel power plants and this creates a significant impact on the local environment. Access to clean water is limited and Juradó does not have an efficient aqueduct that provides the service to rural areas. It is limited to the urban population, where the coverage is about 90% (Juradó Municipality, 2015).

Table 166: Electricity coverage and demand in Juradó, Chocó

Municipality	Electricity coverage (%)	Electricity demand per capita, 2014 (kWh/person/year)
Mitú	93.79	214

Source: (DANE, 2011; SIEL, 2012)

Environment

The territory is covered by uneven and humid jungle; weather is usually affected by ‘winter and summer seasons’ as they interfere with the wind and ocean movements. That is why there is permanent relative humidity of 95% and annual average precipitation of 4980mm.

XII. Municipality of Unguía

Physical Geography Aspects

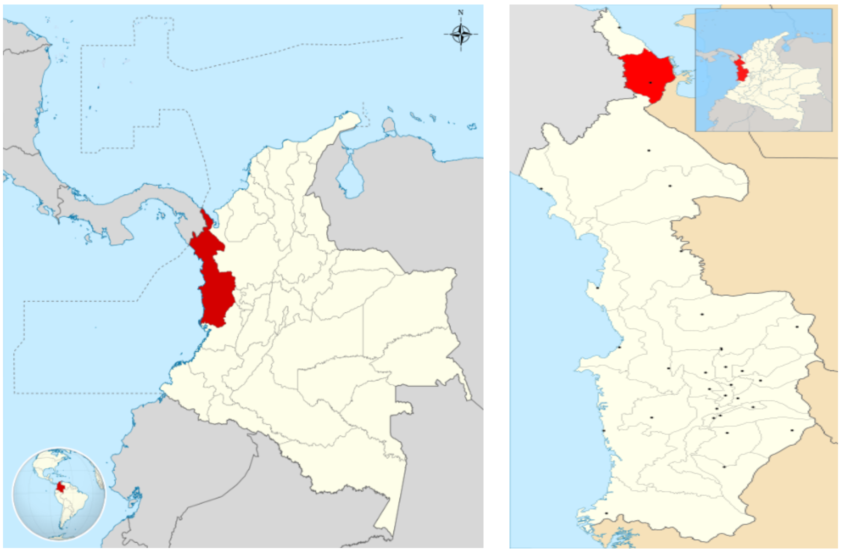

Figure 80: Map of Unguía, Chocó Department

Country: Colombia

Department: Chocó

Border: North: Municipality of Acandi and the Uraba Gulf, West: River Atrato, South: Municipality of Riosucio, West: Republic of Panama

Area: 1,307 km^2

Population (2014,p): 15,077

Population Density: 12.67/km^2

Urban population (2014,p): 4,674

Rural population (2014,p): 10,403

Villages: 30 *corregimientos*: Unguia (cabecera), Santa Maria, Titumate, Gilgal, Raicero, Quebrada Bonita, Ticole, El Corazón, Cuque Minas, Cuque Peniel, Cañitas, Tigre Medio, Horizonte, Pasa Mano, Tanela Platanera, Capitan Viejo, Taparti, Tisló, Marcelia, Tanelandia, Quebrada Grande, Tanelita, Natí, Las Parcelas, Tarena, Tumaradó, Marriaga, El Roto, Balboa, Hipeti. Several veredas and neighborhoods.

Elevation: 5 m

Created by: Ordinance No. 0014 of October 30, 1979. By Higinio de La Rosa

Distance from Department Capital (Quibdó): 478 km

How to reach the municipality: There used to be airports in Gilgal, Santa Maria and Balboa. The one that is currently working in the head of the municipality is not efficient. There are no main roads that connect the municipality with the National highways, which makes the communication with the rest of the country almost inexistent. The main via of access to

Unguia is by water as the rivers connect Unguia with several municipalities, including Quibdó.

Average Temperature: 28°C

Basic Unsatisfied Needs: 60.63%

Gross Domestic Product (USD$1,000)

While the main economic activity in Unguía is cattle raising, agriculture takes the second place with crops such as rice, cassava, and plantains. Table 167 presents the local Gross Domestic Product (GDP) between 2007 and 2013.

Table 167: Gross Domestic Product of Unguía Municipality from 2007 to 2013 (USD$ 1,000)

	2007	2008	2009	2010	2011	2012p	2013pr
GDP TOTAL	42,688	57,641	20,040	44,194	61,961	45,023	29,628
GDP Agro-industry	9,244	12,352	3,400	5,267	6,630	5,114	3,697
GDP Mining	5,598	7,077	4,523	16,210	27,609	17,827	8,105
GDP Manufacture Industry	763	987	329	587	732	564	409
GDP Public services (electricity, gas and water)	678	851	271	489	620	470	370
GDP construction	2,120	2,518	1,065	1,631	2,160	1,745	1,674
GDP commerce	4,552	6,023	1,831	3,441	4,339	3,436	2,705
GDP Transport, storage and communications	2,629	3,130	872	1,631	1,916	1,463	1,119
GDP financial instituions, real state, insurance, service to companies	1,781	2,416	746	1,386	1,690	1,342	1,031
GDP services	14,135	20,790	6,518	12,655	14,969	12,055	9,750
Taxes	1,187	1,497	484	897	1,296	1,007	769
GDP per capita (USD)	2,908	3,911	1,354	2,974	4,156	3,007	1,972

Source: Estimated by authors based on (DANE, 2014)

Agriculture

Agriculture consists of crops such as rice, corn, cassava, and plantain. There are about 620 Ha in the village Tanela which are cultivated with plantain; part of this production is exported to Europe and North America. There are other products that are commercialized in the main markets of the country, such as palm oil and plantations of fruits such as lime, papaya, and *borojó* (Unguía Municipality, 2015).

Table 165 shows an estimate of rice, plantain, and cassava, production in Juradó.

Table 168: Temporary and permanent crops production in Unguía, Chocó (Tonnes/year) in 2013

Municipality: Unguía, Chocó	Temporary crops	Permanent crops	
	Rice	**Plantain**	**Cassava**
Cultivated area (Ha)	574	700	152
Production (t)	991	3,990	1,388
Productivity (t/Ha)	1.7	5.7	8.8

Source: Estimated by authors based on (Colombian Ministry of Agriculture and Rural Development, 2013)

Livestock and animal production

According to Fedegan, there are about 53,557 cattle heads in the municipaliy (FEDEGAN, 2015). There exist artisanal fisheries in the swamps of Unguía, Tumarado, Marriaga and rivers Unguía, Arquía and Tanela are: *bocachico*, *moncholo*, *róbalo*, *mojarra* y *guacuco*.

Public services

In regard to health and sanitation services, only 28.20% of the population has access to clean water and sewage service (Unguía Municipality, 2015). Regarding electricity services, diesel-based power plants supply the service to about 71% of the population(See Table 169). Despite the existence of abundant bioenergy resources, it is important to mention that one of the strategic goals of the local government is to increase the coverage of electricity service through the expansion of grid and upgrading of power generators that currently provide electricity to the municipality.

Table 169: Electricity coverage and demand in Unguía, Chocó

Municipality	Electricity coverage (%)	Electricity demand per capita, 2014 (kWh/person/year)
Mitú	70,91	81

Source: (DANE, 2011; SIEL, 2012)

Environment

Unguía has a wide range of environmental sensitive areas, such as the Gulf of Uraba Coast, the swamps of Marriaga and Unguía and different rivers and streams. There are hot springs in the village of Balboa, and the buffer zone of the Natural Park Katíos ranging from the southern part the Municipality. These areas and historical places such as historic places, such as Santa María la Antigua del Darién could provide the basis for ecoturism projects. There is not a good hotel infrastructure, except for the village of Titumate where there are cabins for the shelter of tourists. Yet, there is a project that has already been approved by the Government secretariat. This project is expected to build capacity and promote the design, formulation, socialization, monitoring, and evaluation of a Municipal Environmental Education Plan.

XIII. Municipality of Inírida

Physical Geography Aspects

Figure 81: Map of Inírida, Guainía Department

Country: Colombia

Department: Guainía

Border: North: Department of Vichada and Corregimiento Barranco Minas; East: Municipality Fernando de Atabapo, Amazonas and Cachual (Venezuela); South: Corregimientos Puerto Colombia and Pana Pana; West: Corregimientos Barranco Minas and Morichal Nuevo.

Area: 17,000 km^2

Population (2014,p): 19,641

Population Density: 1.2 $/km^2$

Urban population (2014,p): 12,539

Rural population (2014,p): 7,102

Elevation: 95m above sea level

Created by: Decree 003/1965

Distance from Department Capital (Villavicencio): 600 km

How to reach the municipality: There are no current roads that communicate the city with the rest of the country. Inírida can be accessed through navigable routes from Villavicencio and many others towns next to local river. Flights departure especially from Bogotá, and Villavicencio and arrive to Cesar Gaviria Trujillo local airport.

Main Rivers: Guaviare, Inirida, Atabapo

Average Temperature: 29°C

Basic Unsatisfied Needs: 57.53%

Gross Domestic Product (USD$1,000)

Agriculture, mining and fishing are the most significant productive activities. Some products of daily consumption such as, maize, yuca, plantain and grapes have been introduced in the rural areas of the municipally. Moreover, Inírida as a capital city cooperates with Villavicencio in order to deliver some basics services to other minor municipalities around the region, distributing considerable loads of raw material coming from San Felipe, Santa Rita, San Fernando and Ayacucho (Venezuela) ports (Inírida Municipality, 2015). Table 170 presents the local Gross Domestic Product (GDP) between 2007 and 2013.

Table 170: Gross Domestic product of Inírida Municipality from 2007 to 2013 (USD$ 1,000)

	2007	2008	2009	2010	2011	2012p	2013p
GDP TOTAL	54,776	74,786	22,669	41,123	49,476	40,618	31,517
GDP Agro-industry	2,819	3,835	1,484	2,697	2,564	1,813	1,302
GDP Mining	-	479	-	225	256	1,269	1,042
GDP Manufacture Industry	1,208	1,438	540	899	1,025	907	651
GDP Public services (electricity, gas and water)	403	479	270	449	513	363	260
GDP construction	5,236	8,629	2,564	4,719	5,383	4,352	3,126
GDP commerce	6,444	8,629	2,564	4,719	5,640	4,715	3,516
GDP Transport, storage and communications	4,430	6,712	1,889	2,472	3,076	2,176	1,563
GDP financial instituions, real state, insurance, service to companies	3,222	4,794	1,484	2,697	3,076	2,720	2,084
GDP services	28,999	36,914	11,065	20,674	25,635	20,309	16,410
Taxes	2,014	2,876	810	1,573	2,307	1,995	1,563
GDP per capita (USD)	3,829	5,317	1,639	3,022	3,695	3,082	2,429

Source: Estimated by authors based on (DANE, 2014)

Agriculture

The municipality compromises from large valleys to mountains and numerous rivers. These features have given the soil a significant percentage of clay and minerals making the land considerably fertile. Corn, cassava, plantain and grapes are some of the main products to be commercialized and the production of fiber from diverse palm species are used to make rope, furniture and baskets. Table 171 shows an estimate of cassava and plantain production and productivity in Inírida.

Table 171: Temporary and permanent crops production in Inírida, Guainía (Tonnes/year) in 2013

Municipality: Inírida, Guainía	Permanent crops	
	Plantain	**Cassava**
Cultivated area (Ha)	75	281
Production (t)	512	1,275
Productivity (t/Ha)	6.8	4.5

Source: Estimated by authors based on (Colombian Ministry of Agriculture and Rural Development, 2013)

Livestock

Cattle rising cover needs for meet in the municipality. As a result, there is no need for importing meet. Yet, practices related to this activity are still rudimentary. Table 172 shows the number of heads for 2011-2014.

Table 172: Cattle production in Inírida, Guainía (Number of heads)

Department	Municipality	Year			
		2011	2012	2013	2014
Guainía	Inírida	2,530	2,530	3,820	4,193

Source: (FEDEGAN, 2015)

Wood

Wood is extracted to cover the needs of the municipality although native species such as *sasafrás, chicle, pavito, parature,* and *laurel* have a significant potential for large-scale business (Inírida Municipality, 2015).

Mining

In Inírida the main source of mining activity is the river Inirida. Gold and other minerals are extracted in an artisanal and low scale process. There are two types of exploitation: dredging and barrage mining. The first one uses barges and suction pumps in the rivers, which directly affect the ecosystem causing erosion and redistribution of sediments, growth or narrowing of the beaches. According to the natives, the noise and vibration of the barges have caused the disappearance of fish in the area. The barrage cause a negative impact to the ecosystem as camps and solid residues are left in the area. The use of mercury in the process of foundry of gold is dangerous for the natives who absorb its gases. Also, because of the way it is disposed in the soil, gold ends up in the rivers where fish uptake it, incorporating the metal to the food chain.

Public services

The municipality has an average of 24 hours of energy service daily delivery. In spite of a coverage level of 99%, the municipality relies on diesel-based electricity that affects the local ecosystem. Table 173 shows the electricity coverage and electricity demand in Inírida. Aqueduct, sewerage and telephone services are undersupplied. Access to clean water is limited. In rural areas there are neither sewage nor aqueduct services. The water is taken in three ways: directly from the rivers and drunk untreated, pumped from deep wells or stored in tanks. There are no septic wells for waterwaste disposal. The government has created a project to improve or implement the aqueduct, sewage and waste disposal services for the urban area by reconditioning and remodeling a water treatment plant, its replacement and installation of materials and a distribution system for several neighborhoods by constructing storage cisterns for several neighborhoods.

Table 173: Electricity coverage and demand in Inírida, Guainía

Municipality	Electricity coverage (%)	Electricity demand per capita, 2014 (kWh/person/year)
Inírida	99.36	778

Source: (DANE, 2011; SIEL, 2012)

Environment

Biodiversity in Inírida is unique among Colombian ecosystems, endemic species such as the Inírida flower that only grows in these valleys, and the iconic pink dolphin can be founded from the Orinoco region to the Amazon. Numerous plant species as Melastomatacea, Aracaceae, Araceae, Bromeliacea, Ciperaceae, among others dominate the land.

XIV. Municipality of Puerto Nariño

Physical Geography Aspects

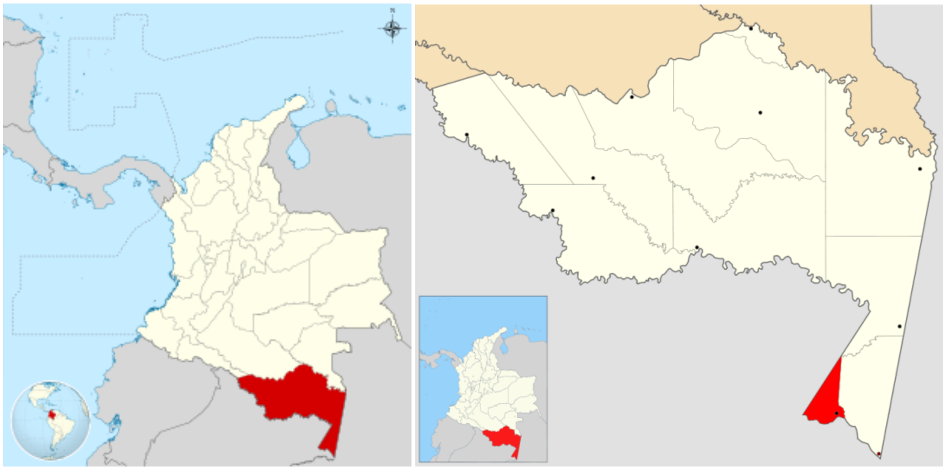

Figure 82: Map of Puerto Nariño, Amazonas Department

Country: Colombia

Department: Amazonas

Border: Putumayo, Caquetá, Guaviare, and Vaupés Departments, Peru and Brazil.

Area: 1,876 km^2

Population (2014,p): 8,043

Population Density: 4,29 /km^2

Urban population (2014,p): 2,139

Rural population (2014,p): 5,904

Villages: 6 districts and 22 indigenous communities.

Elevation: 40 to 150 m

Created by: José Humberto Espejo on August 18^{th} 1961

Distance from Department Capital (Leticia): 87 km

How to reach La Primavera: By plane or road from Leticia (Capital City of Amazonas Department). It is important to mention that he road infrastructure is made up of a precarious network that lacks conditions for suitable transportation of goods and passengers. Roads in the village are trails that communicate the urban center of Puerto Nariño with indigenous communities. The only means of transport between Puerto Nariño and Leticia is by the Amazonas river from Leticia or caballococha (municipality of Mariscal Ramón Castilla, Peru) and by Loretoyaco river to indigenous communities.

Main rivers: Loretoyaco, Vichada, Amazonas.

Average Temperature: 38°C

Basic Unsatisfied Needs: 58,35%

Gross Domestic Product (USD$1,000)

The main economic activity is subsistence agriculture. Fishing, wood extraction and, to a lesser extent, ecoturism are also sources of income for local communities. Table 174 presents the local Gross Domestic Product (GDP) between 2007 and 2013

Table 174: Gross Domestic product of Puerto Nariño Municipality from 2007 to 2013 (USD$ 1,000)

	2007	2008	2009	2010	2011	2012p	2013pr
GDP TOTAL	27,868	37,253	11,479	20,990	26,150	20,338	15,635
GDP Agro-industry	3,055	4,052	1,520	2,912	3,197	2,352	1,621
GDP Manufacture Industry	741	788	226	440	575	415	304
GDP Public services (electricity, gas and water)	463	563	194	385	448	323	236
GDP construction	93	113	-	-	-	-	-
GDP commerce	5,925	7,766	2,263	4,011	5,115	4,058	3,140
GDP Transport, storage and communications	3,148	4,164	1,293	2,198	2,685	1,891	1,384
GDP financial instituions, real state, insurance, service to companies	1,574	2,476	776	1,484	1,790	1,522	1,148
GDP services	11,666	15,869	4,818	8,682	11,061	8,855	7,057
Taxes	1,204	1,463	388	879	1,279	922	743
GDP per capita (USD)	**3,860**	**5,077**	**1,540**	**2,771**	**3,400**	**2,605**	**1,973**

Source: Estimated by authors based on (DANE, 2014)

Agriculture

Indigenous communities grow crops such as cassava, rice, corn, plantain, beans, and some fruits such as watermelon. Agriculture is developed at small scale with the main purpose of covering the needs of the municipality. Agricultural practices revolve around seasonal changes in water level. Large seasonal fluctuations occur between high and low water seasons, forcing farmers to plan their crops according to flooding. Rice and cassava are the main crops. Table 175 shows an estimate of rice, cassava and plantain production and productivity in Leticia.

Table 175: Permanent crops production in Puerto Nariño, Amazonas (Tonnes/year) in 2013

Municipality: Puerto Nariño, Amazonas	Permanent crops	
	Cassava	**Plantain**

Cultivated area (Ha)	5	2
Production (t)	17	8
Productivity (t/Ha)	3.8	3.6

Source: Estimated by authors based on (Colombian Ministry of Agriculture and Rural Development, 2013).

Livestock and animal production

Cattle rising are not a significant activity for the local economy. Fedegan informs of only 95 heads in 2014 (FEDEGAN, 2015). Hunting is an important economic activity for rural and indigenous communities who use it almost entirely for their consumption, as trade is not allowed.

Wood

Puerto Nariño is located in the southwestern part of the Colombian Amazon, which is considered the second timber producing area in the department. Due to the location of the municipality, forestry is important for the local economy. For example, during the period January 1997 - December 2004, about 41,042 m3 of timber were traded. From 2002 to 2007, the municipality reached a wood production of about 63,298 m^3 (CORPOAMAZONIA, 2015b). Besides commercial use, wood is also important for housing, mobility (boat building) and cooking purposes (Rodriguez & Maldonado, 2009).

Public services

Inhabitants of rural areas (over 73%) lack basic services of clean water, sewerage, and residues collection. Water supply in the urban area is deficient despite the fact that there is a plant of potable water. In rural areas, water is provided through a floating barge equipped with a pump. There is no water purification system. Regarding sewerage, only 116 users are supplied with an inefficient service. Residual water is discharged into the Amazon River and Salto. In rural areas, only 40% of the population has septic wells. Solid waste is disposed in a dump without appropriate techniques for evacuation of gases and disposal of leachate (Puerto Nariño Municipality, 2015). Regarding electricity services, about 73% of the population has access to diesel-based electricity. Table 176 shows electricity coverage and demand in the municipality.

Table 176: Electricity coverage and demand in Puerto Nariño, Amazonas

Municipality	Electricity coverage (%)	Electricity demand per capita, 2014 (kWh/person/year)
Puerto Nariño	74.13	103

Source: (DANE, 2011; SIEL, 2012)

Environment

Puerto Nariño has about 298 km^2 of forest reserve that was declared in 1959. The National Park Amacayacu and indigenous reserves are also of environmental interest for the country. The current development plan includes goals for preserving the local cultural heritage as well as local traditions. There are efforts to regulate and control the expansion of the agricultural frontier, boosting research and innovation for sustainable use of biodiversity in the municipality.

XV. Municipality of Leticia

Physical Geography Aspects

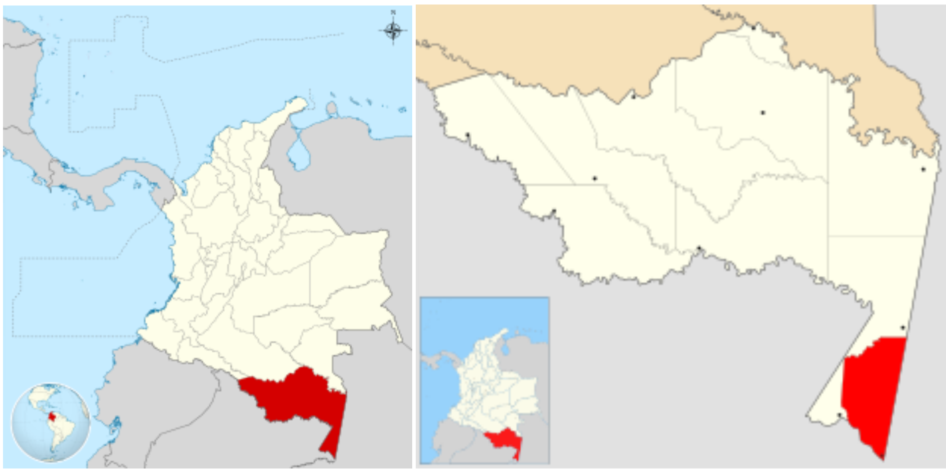

Figure 83: Map of Leticia, Amazonas Department

Country: Colombia

Department: Amazonas

Borders: North: *corregimiento* Tarapacá, East: Brasil (Tabatinga, Amazonas); South: Perú (Santa Rosa, Iquitos) ; West: Puerto Nariño.

Area: 5,968 km^2

Population (2014,p): 41,000

Population Density: 6.7 /km^2

Urban population (2014,p): 26,024

Rural population (2014,p): 14,976

Elevation: 0 to 80 m

Created by: Benigno Bustamante on April 25, 1867

Distance from Bogotá (Capital city of the country): 1,100 km

How to reach the municipality: Leticia is isolated from the rest of the country, surrounded by dense forest. It can be accessed by plane or through the rivers that irrigate the area.

Main Rivers: Amazonas, Gran río.

Average Temperature: 25°C

Basic Unsatisfied Needs: 58,35%

Gross Domestic Product (USD$1,000)

The main economic activity is agriculture. Fishing is not developed in the municipality but fish is commercialized there. Wood extraction, commerce and, to a lesser extent, ecotourism are also sources of income for local population presents the local Gross Domestic Product (GDP) between 2007 and 2013.

Table 177: Gross Domestic product of Leticia Municipality from 2007 to 2013 (USD$ 1,000)

	2007	2008	2009	2010	2011	2012p	2013p
GDP TOTAL	**44,250**	**60,444**	**19,027**	**35,543**	**45,225**	**35,922**	**28,199**
GDP Agro-industry	4,851	6,574	2,519	4,931	5,529	4,154	2,923
GDP Manufacture Industry	1,176	1,278	375	744	995	733	548
GDP Public services (electricity, gas and water)	735	913	322	651	774	570	426
GDP construction	147	183	-	-	-	-	-
GDP commerce	9,409	12,600	3,752	6,792	8,846	7,168	5,664
GDP Transport, storage and communications	4,998	6,757	2,144	3,722	4,644	3,340	2,497
GDP financial instituions, real estate, insurance, service to companies	2,499	4,017	1,286	2,512	3,096	2,688	2,071
GDP services	18,523	25,748	7,986	14,701	19,129	15,640	12,729
Taxes	1,911	2,374	643	1,489	2,211	1,629	1,340
GDP per capita (USD)	**3,860**	**5,077**	**1,540**	**2,771**	**3,400**	**2,605**	**1,973**

Source: Estimated by authors based on (DANE, 2014)

Agriculture

Local economy is based on crops such as cassava, rice, corn, and plantain. Agricultural practices revolve around seasonal changes in water level. Large seasonal fluctuations occur between high and low water seasons, forcing farmers to plan their crops according to flooding. Table 175 shows an estimate of cassava and plantain production and productivity in Leticia. These two crops are the most important for the economy. Rice has lost relevance since imports from Brazil offer a better price (Leticia Municipality, 2015).

Table 178: Permanent crops production in Leticia, Amazonas (Tonnes/year) in 2013

Municipality: Leticia, Amazonas	Permanent crops	
	Cassava	**Plantain**
Cultivated area (Ha)	14	7
Production (t)	55	25
Productivity (t/Ha)	3.8	3.6

Source: Estimated by authors based on (Colombian Ministry of Agriculture and Rural Development, 2013)

Livestock and animal production

Leticia has an incipient practice of cattle rising. The soil is not suitable for the production of good pasture. As a result, not even one cattle can be raised per hectare (Leticia Municipality, 2015). Fedegan informs of about 661 heads in 2014 (FEDEGAN, 2015). It is also important to note that, in addition to the commercialization of fish for consumption, there is also an important market for ornamental fish, which are is exported to the United States, Asia and Europe (Leticia Municipality, 2015).

Wood

Forestry is important for the local economy. However, available statistics do not provide reliable information on this issue. For example, about 533 m^3 were extracted in 1997. By 1998, this figure grew to 7,610 m^3. According to the results of consultations on the matter, a fraction of this wood was extracted in Peru and legalized in Leticia through imports by companies engaged in the manufacture of wood-made products (Leticia Municipality, 2015).

Public services

Leticia has aqueduct coverage in the urban area of 69.63%. Coverage of the sewerage system is about 46.7%. As a result, a significant fraction of residual water is discharged into the Amazon River (Leticia Municipality, 2015). Regarding electricity, coverage and quality of the service is limited. Table 179 shows electricity coverage and demand in the municipality.

Table 179: Electricity coverage and demand in Leticia, Amazonas

Municipality	Electricity coverage (%)	Electricity demand per capita, 2014 (kWh/person/year)
Leticia	70.22	1,008

Source: (DANE, 2011; SIEL, 2012)

Environment

The ecosystem is very sensitive and vulnerable to climate change. The rise two to three degrees Celsius in the temperature and the reduced rainfall imply high risk of droughts in large parts of the countries that are part of the Amazon basin. These two factors can convert 30 to 60% of the Amazon rainforest in savannah (Leticia Municipality, 2015).