Masterthesis

# Baseline study of the Paraguayan brick production sector

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# Declaration of Authorship

„I declare in lieu of oath that this thesis is entirely my own work except where otherwise indicated. The presence of quoted or paraphrased material has been clearly signaled and all sources have been referred. The thesis has not been submitted for a degree at any other institution and has not been published yet."

# Preface, Dedication, Acknowledgement

I want to thank Univ.-Prof. Dipl.-Ing Dr.mont. Peter Moser for supporting and supervising this thesis and for maintaining a close contact to its students.

I owe a deep sense of gratitude to my tutor Dipl.-Ing Dr.mont. Felix Hruschka for his infectious kindness and enthusiasm and for guiding me through this work with an incomparable professionalism.

My special thanks go to Daniel Taillant, who inspired me with his unique approach to sustainable development and constantly encouraged me to go beyond my comfort zone.

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# Abstract

In 2014, the Climate and Clean Air Coalition (CCAC) of the United Nations' Environmental Program launched the Policy Advocacy Network for Latin America on Clean Brick Production (PAN LAC). Paraguay participates in the PAN LAC, but lacks reliable baseline data about the extent of its brick production sector.

Field investigations of the author in 2017 reveal for the first time the considerable size of the brick industry of Paraguay, but also the invisibility and the high degree of informality prevalent in the sector. In total, the baseline study identified 1,631 artisanal producers that mold solid bricks by hand as well as 332 mechanized producers with at least a basic extruder or electric press incorporated in their production process. These brick manufacturers own 2,190 intermittent kilns with mostly open structures, but also 31 highly productive semi-/continuous kilns that already account for 42 percent of the annual red brick output.

However, most brick producers source their raw material without a license, operate without the required environmental impact assessment, and ignore regulations. Thin clay deposits are extracted inefficiently, without mine planning and reclamation, resulting in high raw material costs and large devastated areas. The widely spread traditional kiln technologies are inefficient and artisanal production processes lead not only to unstandardized and low quality ceramic products but also to significant emissions of greenhouse gases, negatively affecting climate and health. As the number of reforestation projects is limited and no other economic viable substitute, such as mineral coal or natural gas, is available, are most combustibles originating from illegally clear-cut native forests.

While the situation of the brick sector is precarious, there is strong evidence that with systematic governmental, financial and technological assistance, mitigation of the negative effects is possible, while simultaneously improving the sector's social, economic and environmental performance.

Findings, proposed strategies and suggestions were presented at the 3rd PAN LAC Forum in Mexico and validated in discussion with international brick production experts.

# Zusammenfassung

Die „Climate and Clean Air Coalition” (CCAC) des Umweltprogramms der Vereinten Nationen gründete 2014 das „Policy Advocacy Network for Latin America on Clean Brick Production“ (PAN LAC). Paraguay ist Teil dieses Netzwerks, verfügt aber über keine hinreichend verlässlichen Grundlagendaten über seinen Ziegeleisektor.

Die im Jahr 2017 durchgeführten Geländearbeiten des Autors zeigen erstmalig das bedeutende Ausmaß, gleichzeitig aber auch die vorherrschende Informalität und Intransparenz der Ziegelindustrie Paraguays auf. Insgesamt wurden 1.631 handwerkliche Produzenten, die Vollziegel von Hand formen, sowie 332 mechanisierte Betriebe, die zumindest Extruder oder elektrische Pressen einsetzen, erfasst. Diese Produzenten betreiben 2.190 diskontinuierlich arbeitende und meist offene Ziegelöfen, aber auch 31 hochproduktive semi-/kontinuierliche Brennöfen, die bereits 42 Prozent der jährlichen Ziegelproduktion erbringen.

Die meisten Ziegeleien gewinnen ihre Rohstoffe jedoch in nicht genehmigten Abbaubetrieben, ohne Umweltverträglichkeitsprüfung und unter Missachtung von Vorschriften. Geringmächtige Lehm- und Tonvorkommen werden ohne Bergbauplanung und Rekultivierung abgebaut und haben hohe Rohstoffkosten sowie großräumige Umweltschäden zur Folge. Weitverbreitete ineffiziente Brennöfen und rudimentäre Produktionsprozesse führen nicht nur zu minderwertigen keramischen Produkten, sondern auch zu erheblichen, klima- und gesundheitsschädlichen Emissionen von Treibhausgasen. Der meistverwendete Brennstoff ist Holz aus illegalen Rodungen, da es an Aufforstungsprojekten und alternativen Energieträgern wie Kohle oder Erdgas mangelt.

Unter Berücksichtigung der derzeitig prekären Situation des Ziegelsektors zeigen die Untersuchungen Möglichkeiten auf, durch systematische staatliche, finanzielle und technologische Maßnahmen die negativen Auswirkungen zu minimieren und gleichzeitig die soziale, wirtschaftliche und ökologische Nachhaltigkeit zu verbessern.
Die Ergebnisse der Arbeit sowie die vorgeschlagenen Strategien und Empfehlungen wurden beim 3. PAN LAC Forum in Mexiko präsentiert und zur Validierung mit internationalen Experten diskutiert.

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# 1 Introduction

The Climate and Clean Air Coalition (CCAC) of the United Nations' Environmental Program, has been engaged in the reduction of short lived-climate pollutants (SLCPs) such as methane, black carbon, hydrofluorocarbons etc. since 2012. (Taillant, 2015, p. 3) Including the brick industry, the CCAC focuses on 11 sectors that have been identified as major air polluters and significant contributors to global warming through so-called initiatives. Over the last years, the "Brick Initiative" has enabled a significant reduction in the environmental footprint of the sector and catalyzed transformative actions in both the private and public sectors, by constantly bringing together experienced and influential stakeholders. (CCAC, 2018a)

In this context, the Policy Advocacy Network for Latin America on Clean Brick Production (PAN LAC) was launched in 2014. (CHRE, 2018) It acts as a platform for public officials, experts and brick manufacturers to discuss and share current market and policy dynamics throughout the continent and elaborate appropriate regulations and legal actions to improve them. The CHRE works with the CCAC as the coordinator of the PAN LAC and constantly gives organizational, technical and strategic advice, as it did for the compilation of this work. (Taillant 2015, p. 3)

Since the issuance of the law on air quality in July 2014, the department for clean air of the Paraguayan Secretaria del Ambiente (SEAM) has been actively involved in the PAN LAC and leads the transformation of the local brick industry. (CCAC,2018b) However, as the sector is still characterized by its high invisibility and informality, government officials have only little expertise about it and lack basic information such as the number of kilns, their locations, the implemented business models, etc. (Taillant 2015, p. 8)

After having been an active listener at the PAN LAC forums for three years, the SEAM decided to fully engage at the first-ever information gathering of the national brick manufacturing sector and assisted significantly during the planning and execution of the field study done in in April to June 2017.

During the past PAN LAC forums, it was pointed out by experienced authorities and industry experts that data gathering should not only focus on the brickmaking process itself, but on the whole value chain. In order to do so, the field investigation was subdivided into three two-week periods, in which different groups of stakeholders in different locations were met (Figure 1).

| Location | Stakeholders |
| --- | --- |
| Asunción<br>Limpio | • Secretaría del Ambiente (SEAM)<br>• Gesellschaft für Internationale Zusammenarbeit (GIZ)<br>• Red de Inversiones y Exportaciones (REDIEX)<br>• Viceministerio de Minas y Energia<br>• Instituto Nacional de Tecnología, Normalización y Metrología (INTN)<br>• Instituto Forestal Nacional (INFONA)<br>• Cámra Paraguaya de la Industria Ceramica (CPIC)<br>• Industrial brick producers with tunnel kilns |
| Asunción<br>Tobatí<br>Caacupé<br>Itacurubí de la Cordillera<br>Villa del Rosario | • Unique Wood (Unique)<br>• Unión de Ceramistas Industriales de Tobatí (UCIT)<br>• Asociación de Transportistas de Carga de la ciudad de Tobatí<br>• Visión Banco<br>• City hall of Tobatí<br>• Ceramicas, Machanized-/ Olerias<br>• Clay mining sites |
| Asunción<br>Benjamín Aceval<br>Hernandarias<br>Los Cedrales<br>Encarnación<br>Tobatí | • Agencia Financiera de Desarrollo (AFD)<br>• Banco Nacional de Fomento (BNF)<br>• Secretaría Nacional de la Vivienda y el Hábitat (SENAVITAT)<br>• Ceramicas with tunnel, mobile, wagon, dome and albert kiln<br>• Mechanized-/Olerias<br>• Building supply stores |

**Figure 1: Stakeholders and their locations**

## 2 Objective

CHRE emphasized that the field study should elaborate the current state and evolution of the nationwide brick value chain, with the goal to increase its visibility and organization. The focus should be on the processes seen in figure 2 with the primary raw material clay at the beginning and with the sales of the burned ceramic products at the end. Due to their importance for a holistic understanding, the access to authorized combustibles and the availability of sustainable financing should be analyzed, as well.

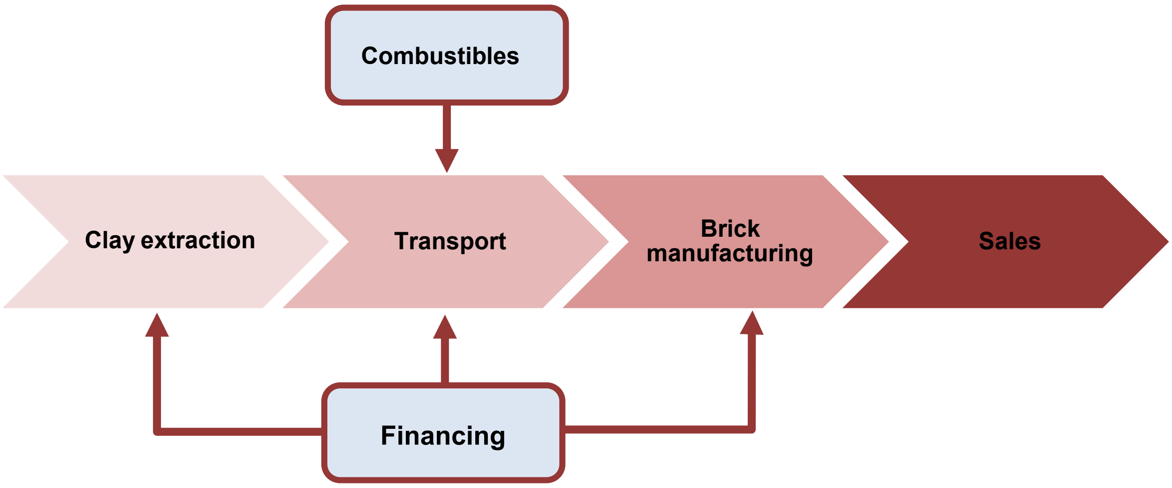


**Figure 2: Brick value chain**

The information gathered should then serve the government and authorities concerned as a basis for further fieldwork, on which sustainable legal, economic and social-related decisions can be made. Additionally, brick producers and other stakeholders should be able to understand the risks and opportunities of their value chain, be offered constructive advice to improve their processes and be sensitized about their impact on the climate and environment. The objective explained above is summarized in the following points:

1. Collecting and presenting information regarding the inventory of Paraguay's existing brick kilns.

2. Collecting and presenting information regarding kiln emissions, their source, the type of fuel utilized, the burning technique utilized, or any other information regarding the burning and related emissions from the sector and particularly from traditional kilns.

3. Collecting and presenting information regarding the social impacts of brick production, particularly in regards to the working conditions of the sector.

4. Collecting and presenting information regarding the economic model in practice, including cost/benefit information.

5. Collecting and presenting information regarding the knowledge of and access to financing for investments in improvements.

6. Collecting and presenting information regarding the government involvement with the brick sector in terms of licensing, regulations, incentives, fines, etc.

7. Developing ideas and presenting a preliminary summary draft of what could be a national brick sector strategy for the country to include economic, environmental and social dimensions of the sector.

# 3 General information

## 3.1 Geography and population

Paraguay is situated in the center of South America and has common borders with Argentina, Brazil and Bolivia. It has a total area of c. 406,750 km$^2$ and is, with Bolivia, the only landlocked state. As seen below, the country consists of 18 departments that are split by the Rio Paraguay running from the north to the south, into a western and an eastern region (Figure 3). (Wikipedia,2017)

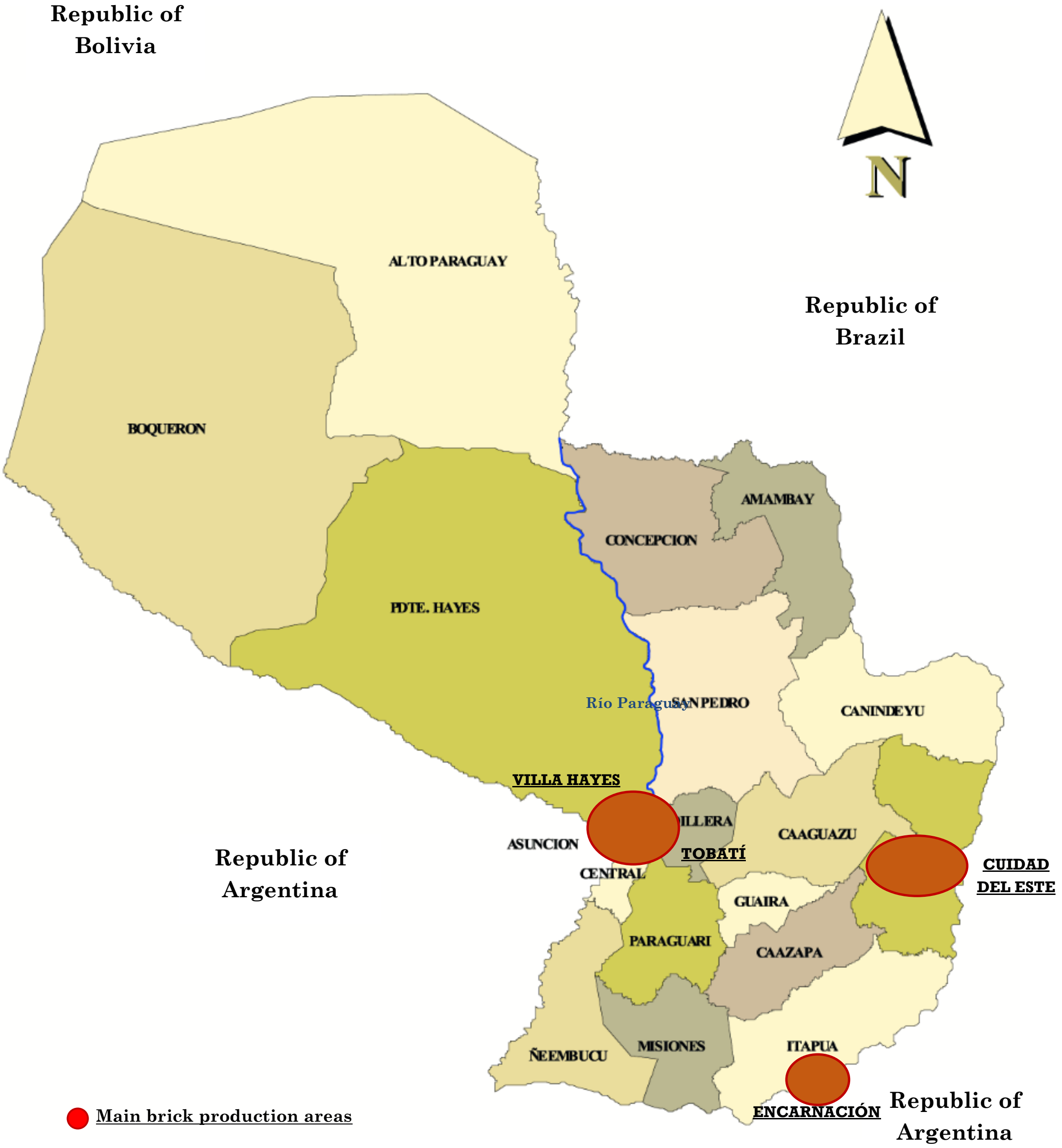


**Figure 3: Map of Paraguay**

Source: (cp. DGEEC, 2017)

The differentiation between the two regions is very important, as only 2 percent of the c. 7 million inhabitants live in West Paraguay, although it accounts for 60 percent of the total area. (Central Intelligence Agency, 2017) The other 98 percent are distributed over the eastern region and are highly concentrated around the three major cities Asuncion, Ciudad Del Este and Encarnación. (Britez Díaz, 2015, p. 31) To fully understand the dynamics of the brick sector, it is crucial to investigate the distribution of the population (Figure 4), as it pictures where the markets and also most of the producers are.

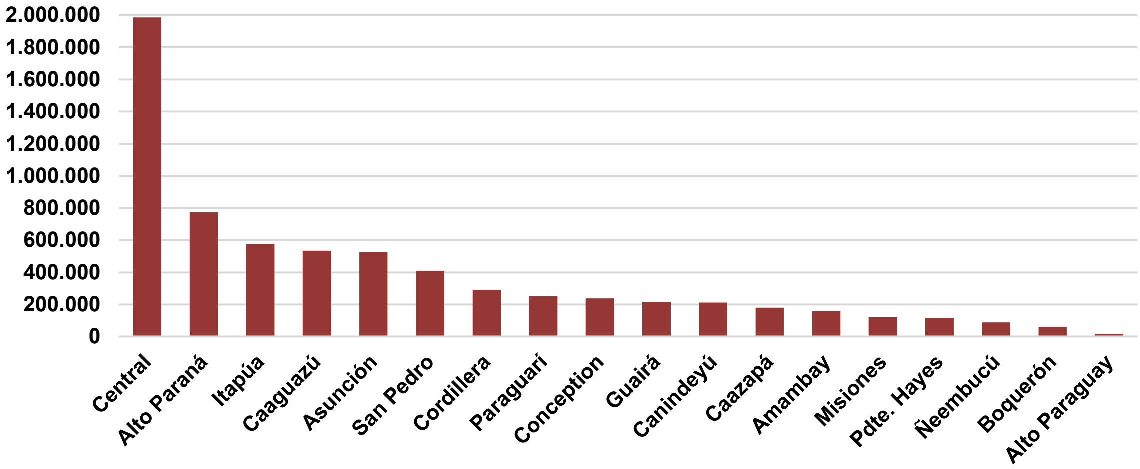


**Figure 4: Inhabitants per department**

(Britez Díaz, 2015, p. 31)

## 3.2 Labor market

Making accurate assumptions about the labor market is difficult, as according to the World Bank, 71 percent of the Paraguayan workforce has informal occupations and is therefore invisible to the authorities and to relevant statistics. (Ruppert Bulmer, 2017, p. iii) This large percentage is alarming, as informal workers are often exposed to significant overtime, inadequate work environments and as well to no labor protection such as guaranteed payments or protection against sudden dismissal. Nevertheless, this situation is steadily improving, as in the last seven years, a strong increase in the quantity of formal jobs could be monitored, which led to a decrease in the informality rate from 79 to 71 percent. This is mainly due to significant workplace creation in urban areas, where informality is, with 61 percent, much lower than in rural areas with 85 percent. The most significant urbanization of aggregate employment was especially toward Greater Asunción, principally in the Central department. (Ruppert Bulmer, 2017, p. 21)

## 3.3 Economy and its dynamics

Despite the unfavorable political and economic situation of its important trade partners Brazil and Argentina in recent years, Paraguay has shown a macroeconomic stability and constantly outperformed its neighbors in terms of GDP growth (Figure 5).

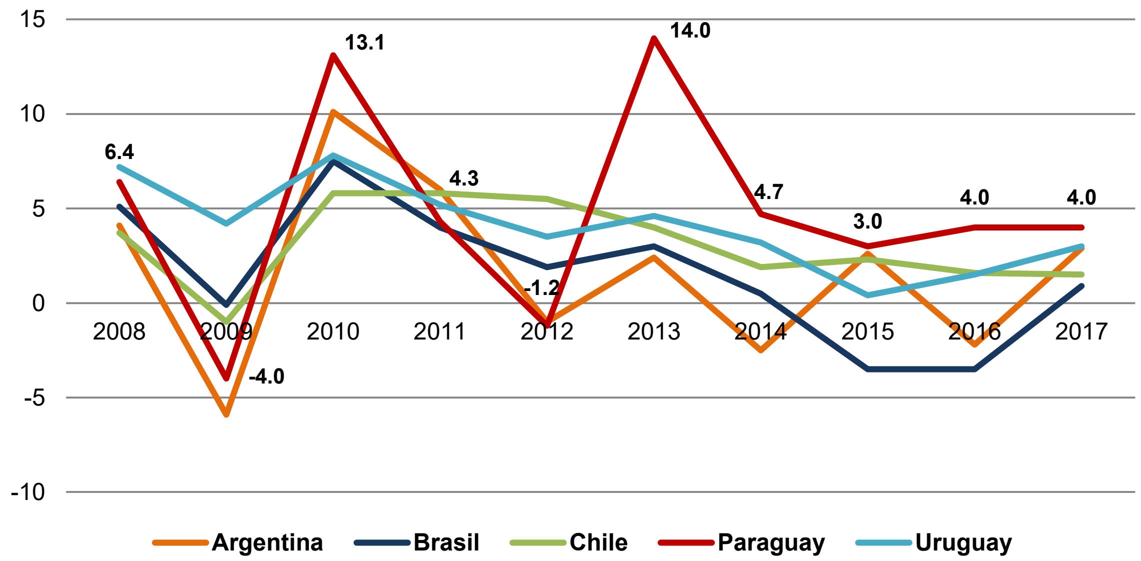


**Figure 5: Annual GDP growth per country**

Source: (CEPAL, 2018, p. 104)

On the other hand the graph above reflects the correlation between soft commodity prices and the GDP growth, as bottoming prices of agricultural products in 2008/2009 and the outbreak of the foot and mouth disease in 2011 significantly slowed the economy. (Index Mundi, 2017) (Loman, 2012, p. 3)

Today, the country ranks among the top ten major exporters of soya and its by-products, stevia, meat and yerba mate and derives 17.9 percent of its GDP from livestock and agriculture. (Roelofs, 2015, p. 2) The remaining GDP consists of 27.7 percent industrial activities and 54.5 percent trade and service activities. (CIA, 2018) Despite its strong performance over the past years, Paraguay has, with c. US$4,000 /capita, in comparison with other South American countries, a low GDP/capita. (Figure 6)

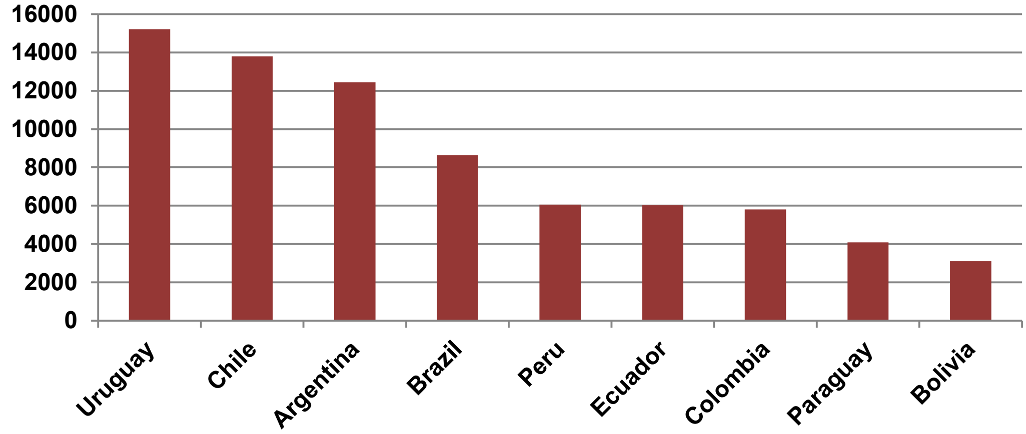


**Figure 6:GDP per country**

Source: (World Bank Group, 2018)

Both, the low GDP per capita and the low Global Competitiveness Index (GCI) reflect the significant hurdles that the country still has to overcome, despite its positive trade dynamics. The GCI is defined "[…]as the *set of institutions, policies, and factors that determine the level of productivity of a country.* The level of productivity, in turn, sets the level of prosperity *that can be reached by an economy."* (World Economic Forum, 2018) It is compiled by using statistical data from internationally recognized organizations such as the World Bank, for example, and by surveying business executives. (Baller, 2016, p. 4) In the 2016-2017 Global Competitiveness Report, Paraguay had a GCI rank of 117 (of 138 countries), with the executives surveyed stating corruption, inadequate infrastructure, inadequately educated workforce, government bureaucracy and access to financing, as major obstacles for doing business. (Baller, 2016, p. 292)

## 3.4 Infrastructure

| | Electricity supply | Roads | Ports | Airports |
|---|---|---|---|---|
| **Argentina** | 119 | 103 | 79 | 87 |
| **Bolivia** | 64 | 105 | 126 | 96 |
| **Brasil** | 91 | 111 | 114 | 95 |
| **Chile** | 37 | 30 | 34 | 47 |
| **Colombia** | 70 | 120 | 83 | 76 |
| **Paraguay** | 115 | 136 | 108 | 132 |
| **Peru** | 65 | 110 | 88 | 80 |
| **Uruguay** | 36 | 98 | 39 | 66 |

**Table 1: Competitiveness ranking of infrastructure (of 138 countries)**

Source: (Löwen, 2017, p. 12)

By analysing the competitivness of the infrastructure system (Table 1), it becomes clear that Paraguay is missing significant investments, especially in roads which are perceived to be, after The Democratic Republic of the Congo and Madagascar, the worst in the world. (Baller, 2016, p. 293)

It is estimated that only 12 percent of the road system is asphalted, making transport during strong rainfalls away from the main roads almost impossible. (Löwen, 2017, p. 12) This results in industries being highly vulnerable to weather changes, as they can not reach their production sites or do not have access to the often remotely located raw materials. Some areas in the west can only be accessed by airplane for up to six months per year, as they have no paved roads at all. The difficult landborne transport is one of the reasons why the Paraguayan economy uses river transportation for 70 percent of its external trade and owns the third largest barge fleet in the world, consisting of 2,200 barges and 200 tugs. (Roelofs, 2015, p. 2)

## 3.5 Energy

The energy matrix of Paraguay and its industry, is characterized by its low electricity, but high biomass consumption (Figure 7):

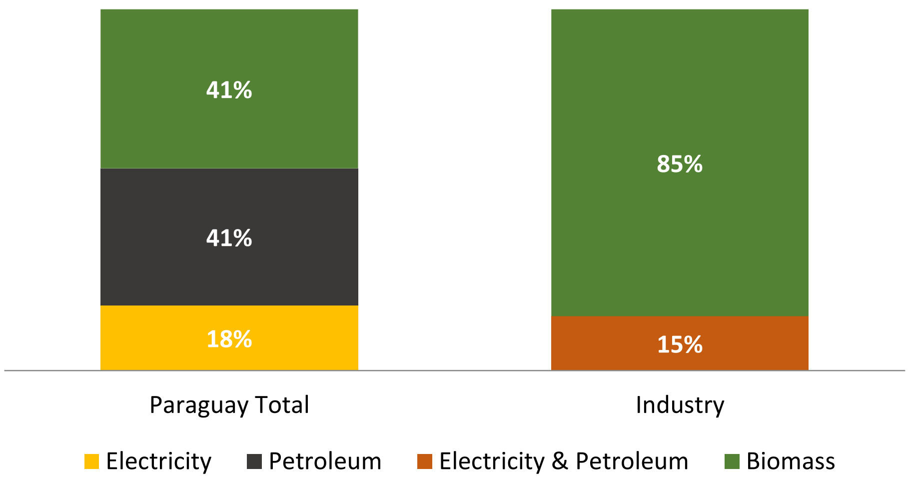


**Figure 7: Energy demand breakdown**

Source: (Lic. Puentes Albá, 2016), (MOPC, 2016)

The biomass consumption is subdivided into 55.5 percent wood, 10.3 percent charcoal and 34.2 percent residuals and biodiesel and is, despite causing significant deforestation (Chapter 9.2.2), still increasing. (Lic. Puentes Albá, 2016,

p. 28) The electricity is produced at the three state of the art hydroelectric power plants Itaipú (shared with Brazil), Yacyretá (shared with Argentina) and Acaray (fully owned) that provide Paraguay with 8.81 GW of power (Löwen, 2017, p. 26)

Nevertheless, the poor transmission and distribution networks across the country have led to severe energy losses and power outages, making it difficult to use the power plants efficiently for the domestic market. In 2016, the energy losses amounted to 25.7 percent of the total electricity supplied within the domestic market. (Lic. Puentes Albá, 2016, p. 20) The missing infrastructure is one of the reasons why most of the electricity is exported and makes the country one of the largest exporters of electric energy per capita worldwide. (Index Mundi,2018)

Energy raw materials like petroleum, mineral coal and natural gas are not economically feasible to use, mainly due to significant transportation distances, as there is no domestic production yet.

To summarize, the ineffective distribution of electricity and the lack of energy raw materials explain why biomass has remained the first choice and why the energy matrix is said to stay the same for the next years, until major investments are made.

# 4 Ceramic products

In this chapter, the different ceramic products are examined as they usually determine the specific business model and production process of each manufacturer. The three main categories of ceramic construction materials are hollow bricks, solid bricks and sophisticated products, as e.g. floor and roof tiles. All of them are still largely produced by informal small to mid-scale operations, which have no standardization and often use basic technology. This frequently results in poor quality ceramics and in bricks being rarely used as structural bricks in houses with more than one or two floors. In multi-story buildings, bricks are therefore only used to raise walls between a pre-built concrete skeleton that takes the weight of the roof structure.

## 4.1 Solid bricks

Although solid bricks have an important market share in Paraguay, they are difficult to categorize, as traditional ways of production and significant informality led to a vast variety of designs and sizes. Nevertheless, in the norm issued in 2015, the Institute for Standardization describes solid bricks as bricks which are not refractories, extruded bricks or structural bricks and have holes amounting to ≤ 20 percent of the total volume or have no perforations at all. Source: (INTN, 2015)

Considering the parameters stated in the norm, three products fall into this category: (Figure 8) the “Ladrillo Prensado” (left), ”Ladrillo Prensado de Tres Agujeros or [3A]”(middle), “Ladrillo Comun”(right)

**Figure 8: Illustration of solid bricks**

Although all three products are categorized as solid bricks, although the production and the firing process varies significantly.

The “Ladrillo Prensado” and the “3A” are mechanically pressed and both are normally thoroughly burned during three to four days. On the contrary, the “Ladrillo comun” is mixed and formed manually and only burned for less than 20 hours, which results in high water absorption and low mechanical resistance.

The standard classifies solid bricks in three categories (Table 2), of which at least category C must be achieved to be approved for public construction:

| Requirements | Category | | |
|---|---|---|---|
| | A | B | C |
| Min. Compressive Strength [MPa] | 9 | 7 | 5 |
| Min. Bending Strength [MPa] | 3 | 2 | 1,5 |
| Max. Water Absorption [%] | 20 | 20 | 25 |

**Table 2: Required properties for massive bricks**

Source: (INTN, 2015)

Detailed information of the Paraguayan Norm for massive bricks (NP 1702777) can be found in the annex 22.

## 4.2 Hollow bricks

Figure 9 illustrates that informality and a lack of standardization also lead to varying designs and qualities regarding hollow bricks. Starting from the left, a hollow brick from Tobati, then from Encarnación and finally two from Ciudad del Este are shown

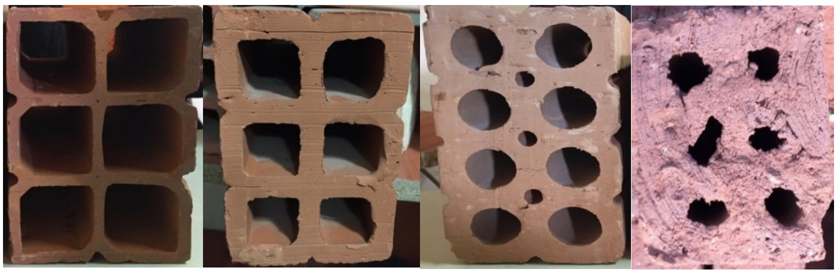

**Figure 9: Illustration of hollow bricks I**

According to the Paraguayan norm no.130, a hollow brick is a brick with parallel perforations that account for a volume of more than 33 percent and consists of a shell, horizontal and vertical dividing walls and grooves (Figure 10). The grooves serve the purpose of improving the connection between plaster and brick and have a design effect in exposed brickworks. Ceramics that are approved for public works need to comply with the resistance and water absorption of the standards that are tested at the Institute for Standardization (INTN) in Asunción. According to

INTN, the grooves result in the brick in a significant reduction in compressive strength and should therefore be avoided if a category A brick is produced. Source: (INTN, 1976)

| Requirements | Category | |
|---|---|---|
| | A | B |
| Min. Compressive Strength | 35 | 20 |
| Max. Water Absorption [%] | 11 | 15 |

**Table 3: Required properties for hollow bricks**

Source: (INTN, 1976)

In figure 10, hollow bricks are shown from the producer called “Ceramica Irene”, which is one of the few producers able to fabricate a class A, allowed to be used as weight bearing bricks in public constructions.

**Figure 10: Illustration of hollow bricks II**

Source: (Ceramica Irene, 2018a)

## 4.3 Sophisticated ceramic products

As for the type of products where no standard was issued, they are classified in this thesis as ceramic products that are thin-walled, difficult both to produce and to handle. Examples are shown in Figure 11, starting with the “convocó” on the left, the colonial roof tile in the centre and the “tejuelón” on the right.

**Figure 11: Illustration of sophisticated ceramic products**

Source: (Ceramica Irene, 2018b)

The convocó is a well-established product and is mainly used to achieve an air and light inflow in structures as e.g. a stable or a staircase. Nevertheless, only the roof tile and the tejuelón are produced on a large scale, as they have traditionally been inevitable for roof structures. The tejuelón is used as the support platform on which the roof tiles are mortared (Figure 12).

In recent years, the sheeted iron roof has been increasingly replacing these traditional structures, as it offers a much cheaper roof construction.


**Figure 12: Roof tile and tejuelón application**

Source: (Ceramica Irene, 2018c) (Ceramica Irene, 2018d)

# 5 Clay

As most Paraguayan brick manufacturer classify their raw material as clay, it is important to emphasize that for brick making often loam is used. Loam is a mixture of clay, silt and sand and has, depending from its origin, different ratios of these constituents. The three components differ in particle size and their exact proportion in the raw material is the first indicator which ceramic product can be fabricated. (Figure 13).

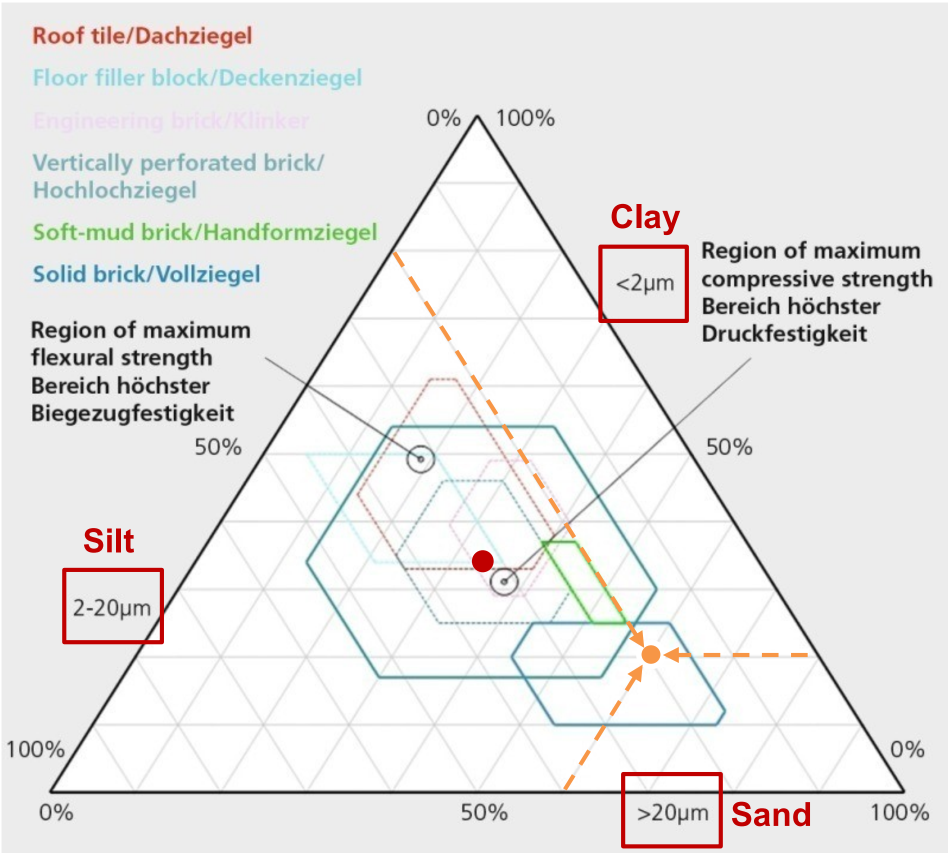


**Figure 13: Winkler Diagram**

Source: (comp. Vogt, 2015)

The so called Winkler diagram (Figure 13) has been compiled through empirical methods and illustrates how different proportions of particle sizes (<2µm,2-20µm,>20µm) enable the production of specific products. For example, only solid bricks can be made, if the loam consists of 60% >20µm, 20% 2-20µm and 20% <2µm particles (orange dot).

It is important to note that the Winkler diagram and a high quality red brick strongly depends on the mineralogy of the raw material, as it determines the swelling, shrinking, resistivity, color etc. of the red brick. E.g. are high contents of illite and kaolinite seen as favorable for brick production, while bentonite is avoided due to its unwanted swelling properties. Furthermore, the red color of bricks is only achievable in the presence of iron minerals, while paler-color result from carbonate minerals, such as calcite and dolomite. These carbonate minerals must be in fine-grained form, as larger lumps can significantly reduce the quality of the red brick due to so-called ‘lime-blowing’. (Bloodworth, 2007, S. 7) In order to achieve optimal product qualities, an exact mineralogical analysis with an x-ray diffraction is suggested.

While the above-mentioned physical (particle size) and chemical (mineralogy) differences lead to a large variety of raw materials, the Paraguayan brick producers only distinguish between “clay” and “flojo”. This missing understanding often leads to poor quality ceramic products and high discard rates.

Clay is used for hollow bricks and if possible for the sophisticated and thin-walled products, such as roof tiles, tejuelón, etc. The flojo, with its high content of organic matter, is only used to produce the artisanal solid brick (ladrillo comun).

**Clay**

As a rule of thumb it can be said that raw material consisting of 1/3 clay, 1/3 silt and 1/3 sand (red dot, Figure 13) and high contents illite or kaolinite, are applicable for most ceramics. Brick manufacturers stated that deposits of this quality only occur near Tobati and Villa Hayes, while they have less favorable ratios in other areas. These statements were confirmed, as most producers in Alto Paraná and Itapuá could only fabricate very thick-walled hollow bricks, as other products disintegrate during the burning process.

**Flojo**

Flojo is a strongly weathered type of clay that is mainly found around Tobati, has a high content of organic matter and is only used for the production of the ladrillo comun. Its constituents and the lack of iron give the raw material its recognizable black color, which turns into a white color after exposure to heat. As only solid bricks are produced with this raw material, impurities such as organic matter are not removed and often even wanted, as they are said to increase the drying speed and facilitate the burning process.

## 5.1 Extraction

### Clay

The extraction is usually done with an excavator that first removes the organic layer and then digs for the clay. The pit created is enlarged until heavy rainfalls cause such a water inflow that further mining activities become impossible. The reason for this issue is that the pit geometry and low permeability of the clay-rich soil do not allow any water outflow. Figure 14 shows a flooded pit (red arrow), which was abandoned as brick manufacturers began to complain about intolerable water contents in the raw material.

**Figure 14: Pit Development**

On the right side of the picture the development of a new excavation site is shown, where trucks are still able to enter through a ramp. However, once the water level rises to a certain limit due to rainfall, trucks are not able to enter the pit anymore and have to drive through the swamp-like field in order to reach the extracting machinery. This results in trucks getting stuck regularly and consequently in significant delay times and inefficiencies.

This kind of unproductive mine development does not only create increased costs across the brick value chain, but also causes substantial environmental damage, as seen in Figure 15.

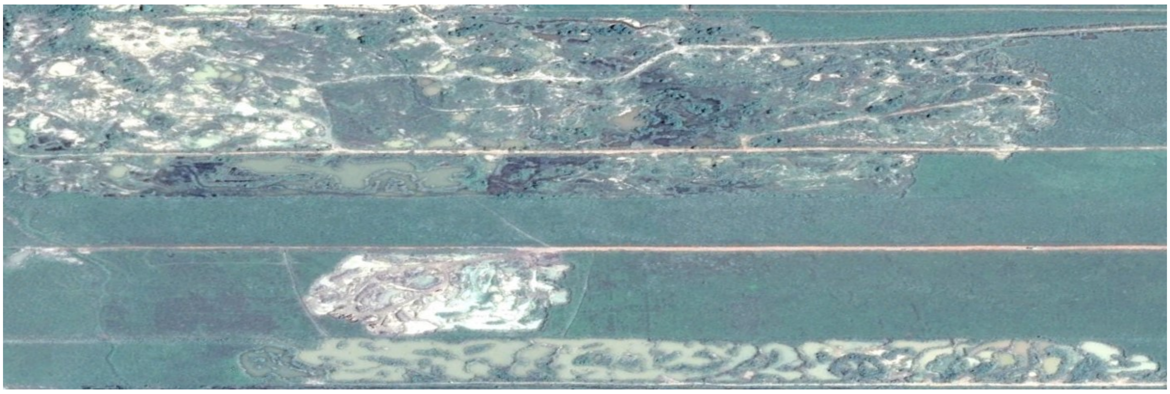

**Figure 15: Environmental impact of clay mining**

Source: (Google Earth, 2017)

## Flojo:

As the raw material occurs on the surface in 0.5-0.8 m-thick deposits, the extraction process in itself is very basic, especially when only the flojo and not also the clay below is mined. Although some small-scale operations only use a shovel as an extraction tool, more concentrated brick making areas are using excavators. As seen below, the combination of heavy machinery and the small width of the deposits in Tobati lead to the manipulation of large areas.


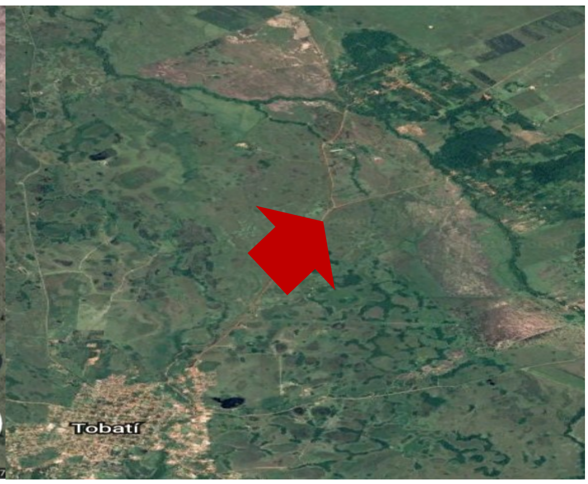


**Figure 17: Ongoing clay extraction** **Figure 16: Extent of mining area**

Source: (Google Earth, 2017)

Figure 17 shows the advancement of a flojo extraction site, together with the machinery highlighted in orange, while Figure 16 illustrates the c. 9 x 2 km large mining area, which is said to have been unusable for decades, as the topsoil was removed and no reclamation efforts made.

# 6 Processing

Brick manufacturers can be subdivided indirectly by end-product quality and end-product variety, by investigating their processing machines. The field investigation revealed that the brick sector has mainly three types of producers, with their specific processing flow sheets: Ceramicas / Industrial producers, Mechanized Olerias and Olerias.

## 6.1 Ceramicas

These are all the industries that process the clay with at least two homogenizing machines and use an extruder that is connected to a vacuum pump. Experience has shown that these machines are necessary to achieve a standardized product that is according to the norm. Depending on the clay quality, the manufactured goods are hollow bricks, roof tiles, tejuelón, floor tiles and various other ceramic products. In this category, the kilns vary greatly in their size, productivity and efficiency.

The processing flow sheet starts with the storage, as some companies store the extracted clay up to two years, to moisturize the raw material and increase its homogeneity. The benefit of a homogenous mass is that it leads to less stress concentrations in the ceramic products and therefore reduces crack developments during drying and burning. If not enough space or infrastructure is available, as is the case e.g. for many producers in Tobati, the storage only has a capacity for some days. From the storage, the clay is transported mostly with a bobcat or similar device to a silo-like structure, with an apron conveyor on the bottom, the so-called “caja alimentadora.” This device is especially convenient as the mass flow can be easily adjusted.

From there, a conveyor belt feeds the “disintegrator,” which is composed of two different-sized cylinders that rotate in opposite directions. The larger cylinder, with its smooth surface, rotates at a relatively low speed and has the function of maintaining a constant feed of material. The smaller cylinder that has so-called “knives,” rotates at a high speed and breaks harder lumps of dry clay. (Bertan, 2017) Furthermore, the disintegrator provides a uniformly sized material which facilitates the work of the following machines. The desired particle size of the out-coming clay can be adjusted by changing the gap width between the cylinders.

From the disintegrator, the raw material falls into a twin shaft paddle mixer, a so-called “mezclador.” At this stage, the required water quantity is added to the clay while it is being mixed. It is crucial that an experienced person constantly analyses the extruded product, to instruct the person at the mixer, to increase or decrease the water quantity. Without the appropriate water content, the wearing of the die at the extruder increases significantly and the quality of the product suffers.

The mixer is connected to a rolling mill, called “laminador,” which consists of two cylinders with a smooth surface, which rotate in opposite directions. (Bertan, 2017) The gap width can be, depending on the clay properties and the general processing facility, as little as one or two millimeters. In other words, this device grinds all particles to less than one to two millimeters and at the same time laminates and de-airs the material.

In the last processing step, the clay is fed into the top section of the extruder, where the final mixing of the clay is done. By compressing the clay with an auger and transporting it through a vacuum chamber it is de-aired, which significantly decreases porosity and therefore improves the end-product quality. After this, the clay is extruded under high pressure as a continuous column. (Bertan, 2017) By changing the size and type of the die at the extruder, different products, like hollow bricks, roof tiles, etc. can be produced. Depending on the producer, the continuous clay column is cut manually or mechanically with a wire cutter. Figure 18 illustrates the complete flow sheet with 1) the caja alimentadora, 2) disintegrator, 3) paddle mixer, 4) rolling mill, 5) extruder and 6) wire cutter.

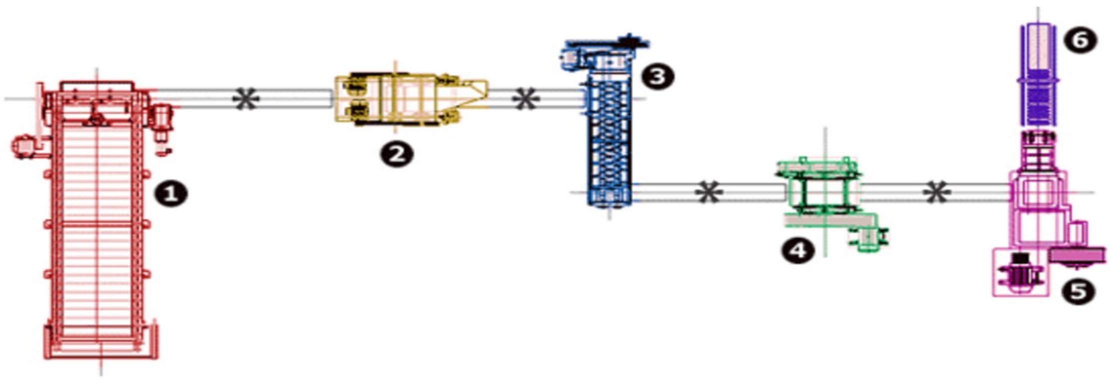


**Figure 18: Flow Sheet Ceramica**

Source: (Bonfanti, 2017)

The resulting, so-called green bricks, are then stacked on the floor, in special drying boxes or in a dryer to initiate the drying process.

## 6.2 Mechanized Olerias

These are all brick producers that use at least a simple extruder or an electric press to mould the bricks. As the extruder cannot achieve the high pressure and de-airing is needed for sophisticated products (e.g. tejuelón, colonial roof tiles), it is only used to produce thick-walled hollow bricks or massive bricks. The electric press only fabricates solid bricks called ladrillos prensados. (Chapter 4.1) Most of the producers are, because of a lack of knowledge and/or financing, still using open kilns to burn their product, which drastically increases their fuel consumption.

Mechanized operations differ significantly depending on the area, but can be summarized in three main processing flow sheets:

- The first one is the industrial flow sheet, but without a vacuum pump connected to the extruder. In other words, it consists of a disintegrator, a paddle mixer, a roller mill and a standard extruder. The extruded bricks are cut by an automatic or by a manual wire cutter.

- The second one consists of two machines, the “lembu” and an extruder. The lembu resembles a meat mincer and consists of an auger and a perforated disc, through which the clay is pressed. The lembu replaces the paddle mixer and is chosen by small to microscale operations, as it is a much cheaper mixing device.
  The cylindrical clay product that exits the lembu is transported to the extruder. At this technology level, the extruded brick usually has to be cut by hand. (Figure 19) It is important to note that no grinding is done during the processing and therefore pebble rich clay is not suitable for this beneficiation plant. This is the reason why this flow sheet is used near Tobati and not in the south or the east of the country.

**Figure 19: Small-Scale Processing Machinery I**

- The third one consists of just a storage facility, in which the clay is premixed with a shovel and an extruder with an integrated rolling mill (Figure 20). This is only found in Itapúa, where these machines are produced locally and used by the mechanized Olerias, for the production of huecitos in the Caipira kilns.

**Figure 20: Small-Scale Processing Machinery II**

## 6.3 Olerias

These are all the producers that mold their bricks by hand and use the least elaborated open kilns and processing machines. This results in a high emission of black carbon, a low-quality product and a high vulnerability to weather changes.

To produce these types of solid bricks, no elaborated processing tool is needed.(Figure 21) In a first step, the clay in the storage is loosened and premixed with a shovel (top, left), to disperse the organic matter in the raw material.

Afterwards, the clay is placed with additional water into a cylindrical mixer (top, right), which is “powered” by a horse or by an electric motor.

**Figure 21: Mixing of Flojo**

Once the raw material is fully homogenized, it is removed from the bottom of the mixer and put in a mold, which is then removed. The resulting bricks are left on the floor to dry until the water content is low enough that they can be erected. (Figure22)

**Figure 22: Molding and drying of the green artisanal solid bricks**

Once the remaining humidity decreased to a point that an appropriate compressive strength is achieved, are the bricks stacked inside the kiln. Depending on the weather, this process can take from two to four weeks.

# 7 Kilns

Brick manufacturers cannot be subdivided by end-product quality or end-product variety by examining the kiln, as even very traditional types can make bricks that are in accordance with modern standards. Nevertheless, the productivity and efficiency vary significantly, as old-fashioned kilns are intermittent and modern ones are semi-/continuous.

Intermittent kilns can have open or closed structures in which the green bricks are burned and then cooled before they are discharged. This process leads to high fuel consumption, as during every burning cycle, in addition to the bricks, the kiln structure has to be heated up and cooled down. Although the efficiency of the process can be enhanced with heat recuperation and good insulation, it is rarely done due to the high investment costs. Still, intermittent kilns are very adaptable to changing market demands, as the burning process can be paused easily without causing unbearable costs. (Elsharif, 2010, p.41 f.)

Continuous kilns always have a closed structure, burn at all times and have fired bricks removed constantly, while being fed with green bricks. The resulting efficiency and continuous output comes with the disadvantage that the reduction in productivity is not possible without drastically affecting the profitability. Examples for those kilns are e.g. the tunnel and Hoffmann kiln. (Elsharif, 2010, p.41 f.)

## 7.1 Tunnel kiln

The company “Yayou” constructed the first tunnel kiln in 1999 in Itaugua. Since then, at least 14 more have been built, with the largest having capacities of up to two million hollow bricks per month or in other words up to 6,000 tons of red bricks per month. Currently three tunnel kilns are under construction, with the largest having a capacity of 18,000 tons of red bricks per month and being owned by a joint venture between the Spanish producer “Mazarrón” and “Ceramica Paraguaya”. It is located 40 km outside of Asunción, in Benjamin Aceval.

It is the most efficient and productive kiln and consists of a horizontal tunnel, which continuously burns the green bricks as they move from the preheating- into the burning- and finally in the cooling-zone. The low operating costs come with the disadvantage of investment costs exceeding US$ 300,000. (EELA, 2015, p.26 f.)

**Figure 23: Tunnel kiln near Asunción**

## 7.2 Mobile kiln

Mobile kilns are currently used by the companies “Ceramica Rode” and “Ceramica Ita Yvy” and under construction by an unknown Korean company. This kiln technology is seen as highly sophisticated and is currently constructed only by Brazilian companies. It consists of a moveable metallic structure that is pushed over green bricks while still being hot (c. 500°C) from the previous burning and is therefore classified as a semi-continuous kiln.

This feature, combined with the internal lining, ensures a very fuel-efficient technology. The internal lining consists of ceramic fiber that significantly reduces the kiln’s thermal inertia and heat radiation, resulting in a decrease in structural heat loss and an increase in heating and cooling speed.  (EELA, 2015, p.15)

The investment is, with a minimum of US$ 150,000, considerably higher than that for the similar wagon kiln, but is said to cause fewer technical problems.

**Figure 24: : Mobile kiln**

## 7.3 Wagon kiln

This type of kiln is new to Paraguay and was first constructed in 2015 by the company San Andrés in Hernandarias, while another is currently under construction in Arroyos y Esteros. The function is very similar to the mobile kiln, with the main difference being that not the kiln, but the brick batch is moved after every burning cycle using a platform. Once the hot bricks are removed from one side of the kiln by pulling one of the two platforms shown below, the green bricks enter from the other side on the second one. Due to the similarity to the mobile kiln, it is believed that the heat losses and therefore also the fuel consumption are comparable in both kilns.

Especially interesting for the Paraguayan brick sector is that the capacity and burning process of the kiln, is very similar to the widely used "Albert" kiln and therefore guarantees a fast learning process, as well as a high acceptance. The high investment costs of at least US$ 100,000 and the still not perfected technology, which sometimes causes long interruptions in the production process, prevents the technology from spreading.

**Figure 25: Wagon kiln near Cuidad del Este**

## 7.4 Albert/Doble Albert

The Albert is the widest spread intermittent kilns with a closed structure and originates from Brazil, where it is known as the Paulistiña kiln. The difference between an Albert and Doble Albert is simply that a Doble Albert consists of two burning chambers instead of just one.

It is estimated that c. 100 producers are using Albert technology, which is only fueled with firewood or its by-product.

> „The kiln has heat losses due to high thermal inertia (large mass of the masonry structure) and radiation and convection through the side walls, vault and fuel feed holes, so it operates with low thermal efficiency levels." (EELA, 2015, p.8)

Just very few producers have installed ventilators to increase the burning efficiency and even fewer combine them with an automatic chip and/or sawdust feeder and temperature measuring systems. Manufacturers that did implement the full range of the technologies stated above, experienced a decrease in fuel consumption of more than 30 percent and a more controlled burning process.

**Figure 26: Doble Albert fired wood chops**

**Figure 27: Albert kiln fired with sawdust**

## 7.5 The Caipira (Horno Comun)

The Caipira is the widest spread intermittent kiln with an open structure, or in other words with no masonry roof. It is the kiln with the lowest investment costs, but at the same time with the highest fuel costs, due to its low heat insulation.

Furthermore, as water can easily enter into its open structure, it makes production during heavy rain almost impossible. Water inflows during the burning process can even lead to the destruction of a brick batch that had been prepared for weeks, making small brick producers highly vulnerable to weather changes. This kiln is used to fabricate small-sized and thick-walled hollow bricks called huecito, the ladrillo comun and the ladrillo prensado.

The Caipira can be divided into three categories and has a large variety of capacities. It is estimated that up to 2,500 such kilns exist throughout the country, but of which only 60-70 percent are in operation, due to bad market conditions.

### 7.5.1 Basic Caipira kiln

It is the least energy efficient kiln, with sidewalls surrounding only half of the brick batch volume. This feature, combined with a missing roof structure, results in a vulnerability to weather changes and significantly higher fuel consumption. The capacity of the kiln lies at 25,000 bricks and has, depending on the climate, a wood consumption of 9-11 stere (stacked cubic meter). The kiln is especially used during high demand periods as its design has the advantage that the cooling-, loading- and offloading- processes are very fast.

**Products:** Ladrillo Comun

**Figure 28: Basic Caipira from the outside and inside**

### 7.5.2 Sophisticated One Floor Caipira

The kiln has up to 4 m high sidewalls and a corrugated sheet roof, to avoid rain inflow. By putting a layer of red bricks on top of the green bricks, significantly higher heat insulation than in the basic Caipira is achieved.

During a moderately humid climate with this technology, 30-50,000 "ladrillos comun" can be burned using 15 stere of firewood. This leads to the conclusion that its fuel consumption is c. 50 percent lower than that of the basic Caipira. The disadvantage of this type of kiln is that the off-/loading process is more difficult and that the cooling takes almost twice as long. The same type of kiln is also used for the "ladrillo prensado" but is considerably larger as it can burn c. 50-120,000 pieces at once.

**Products:** Ladrillo Comun, Ladrillo prensado

**Figure 29: Sophisticated One floor Caipira kiln from the outside and inside**

### 7.5.3 Two Floor Caipira

This kiln has the same design as the one-floor type, but with the difference that the combustion chamber and the bricks are separated by a perforated floor. This has the advantage that the flames are in less contact with the bricks, reducing the discard rate significantly. In this Caipira kiln only the thick-walled hollow brick huecito is produced, as it brings higher returns than the solid bricks.

**Products:** Huecito

**Figure 30: Two floor Caipira kiln from the outside and inside**

# 8 Assessment of the main brick producing departments

This chapter illustrates the distribution of the national brick sector and lists the quantity of confirmed ceramicas, mechanized olerias and olerias and their monthly output of hollow bricks, solid bricks and sophisticated products. As confirmed, all production sites are classified that had been visited during the field study, are part of the “registro industrial” or are known to governmental authorities or other reliable sources. (Chapter 13.1.2.) Due to data protection the names of the companies are not stated.

## 8.1 Department Central

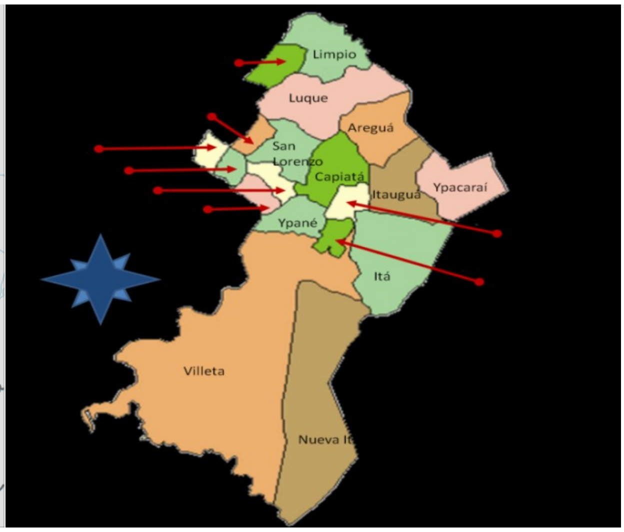


**Figure 31: Department Central** **Figure 32: Districts in Department Central**

Source: (Wikipedia, 2011a), (Pension Kunterbund, 2017)

The Central department has a strong exposure to industrial activities and has good road network. (EcuRed, 2016) It is the most important market for the brick sector, due to the c. 2,000,000 inhabitants (Figure 4) and its close vicinity to Asunción. This area is characterized by its rapid urbanization, which might lead to relocations of kilns as they are often in close proximity to the cities.

**Producing districts:** Limpio, Capiatá, Ñemby, Itauguá, Itá, Ypacaraí, Nueva Italia

**Clay Quality:** The clay quality is seen as good, since every ceramic product can be produced with it, with only small-scale producers having difficulties producing roof tiles.

**Locally produced:** Hollow brick, ladrillo comun, roof tiles, tejuelón

**Kilns:** Tunnel kiln (Limpio, Ypacarai), Hoffmann (Itaugua), Mobile (Nueva Italia), One Floor Caipira (Capiatá, Itá, Ypacaraí), Albert (Nueva Italia, Itaugua)

Currently four brick producers in the region are considered as large-scale producers, as they own a total of three tunnel kilns, two Hoffmann kilns and six mobile kilns. It is important to note that of those kilns, a tunnel kiln with a capacity of 6,000 tons per month is ramping up at present and four mobile kilns with a capacity of 6,100 tons are under construction (included in the table 4). This will lead to a regional production increase of more than 20 percent, which is why in the near future a decreased brick price is forecasted. The small-scale producers are located in the districts Capiatá (c.60), Itá (c.200) and Ypacaraí (c.70).

| Type of Producer | Production of ceramics [t] | | | Quantity of producers |
|---|---|---|---|---|
| | Hollow | Solid | Sophisticated | |
| **Industrial** | 35,800 | | 5,000 | 14 |
| **Mech. Olerias** | 2,700 | | | 29 |
| **Olerias** | | 24,300 | | 312 |
| **Total** | **38,500** | **24,300** | **5,000** | **376** |
| **Total [pieces]** | **11,325,000[1]** | **18,700,000[2]** | **-** | **-** |

**Table 4: Production in Department Central**

1)Huecos with 3.4 kg, 2)ladrillo comun with 1.3 kg or prensado with 2kg

## 8.2 Department Cordillera

**Figure 33:Department Cordillera**


**Figure 34: Districts of Department Cordillera**

Source: (Wikipedia, 2011b), (Wikipedia, 2012)

Cordillera or more precise the city of Tobati, is seen as the heart of the small scale brick production, as nowhere else in the country the concentration of Albert and Caipira kilns is as high.

The department is due to its location and relative little population economically strongly depended on Asunción and the Central department.

**Producing districts:** Tobati, Caacupé, Itacurubí

Although producers can be found in Itacurubí de la Cordillera, Caacupé, Isla Pucú and Esebio Ayala, their production is mostly negligible in comparison to that in Tobati. Therefore, only the ten confirmed Ceramicas in Itacurubí and Caacupé were considered in further calculations.

**Clay Quality:** As explained in Chapter 5, the local clay quality is exceptional, as even with poorly equipped processing plants, high quality products are achieved.

**Locally produced:** Hollow brick, ladrillo comun, roof tiles, tejuelón, ladrillo prensado

**Kilns:** Albert, Caipira, Wagon

The only modern kiln in the department is a wagon kiln in Arroyos y Esteros, which is currently ramping up. This kiln is said to have a monthly capacity of 240,000 hollow bricks, or 800 tons, once fully in production.

**Tobati:**

As the time was not sufficient to count all the producers, their number was elaborated the following way. In a first step the trade licenses of all the ceramicas and olerias were requested from the municipality of Tobati. Together with the president of the local brickmaking chamber and the mayor of Tobati, the producers which had paid for the document in the past, but are not producing anymore, were excluded.

Compiling all the data, a list totaling 70 Ceramicas, 80 mechanized Olerias and 1,200 Olerias could be elaborated. It is important to note that these are only currently active manufacturers and that it is estimated that Tobati has an infrastructure of up to 800 more kilns, which are only activated during favorable market and weather conditions. In those periods, day-laborers are hired from the surrounding cities.

**Summary:**

| Type of Producer | Production of ceramics [t] | | | Quantity of producers |
|---|---|---|---|---|
| | Hollow | Solid | Sophisticated | |
| **Industrial** | 23,000 | | 8.000 | 81 |
| **Mech. Olerias** | 3,100 | 6,500 | | 80 |
| **Olerias** | | 47,000 | | 1,200 |
| **Total** | **26,100** | **53,500** | **8,000** | **1,361** |
| **Total [pieces]** | **7,680,000** | **42,250,000** | **-** | **-** |

**Table 5: Production Department Cordillera**

## 8.3 Department Alto Paraná


**Figure 35: Department Alto Paraná** **Figure 36: Districts of Alto Paraná**
Source: (Wikipedia, 2011c), (Indianer werden, 2018)

Alto Paraná is, with c. 800,000 inhabitants (Figure 4), the second most populated department and incorporates with its capital, Ciudad del Este, also the second largest city. The department draws most of its wealth from agriculture and trading activities with Brazil. What is important for that is the “Puente de la Amistad” bridge in Ciudad del Este is the only bridge on the Rio Paraná that connects Paraguay and Brazil. Additionally, the department is home to the Itaipu and the Acaray hydropower plant and therefore has very good access to electricity. (Wikipedia, 2018)

It is believed that the local production of ceramic products does not cover the local demand by far. Most building supply stores sell hollow bricks from Tobati and Greater Asunción. This undersupply leads to bricks even being transported from the department Presidente Hayes (c. 360 km), and consequently at almost double the prices compared to Tobati.

**Producing districts:** Presidente Franco, Hernandarias, Los Cedrales, Santa Rita, Naranjal, San Alberto, Juan Emilio O'Leary

**Clay quality and products:** The clay quality is considered as weak, as a lack of sand in the raw material results in a disintegration of thin-walled ceramic products during drying and burning. For that reason, only solid and thick-walled hollow bricks are produced locally, while all the other products such as roof tiles, tejuelón, etc. have to be imported from other departments. Nevertheless, neighboring Brazilian companies state that with more processing machines and added sand, the local deposits could be used for the production of very sophisticated ceramics.

**Locally produced:** Hollow brick

**Kilns:** Tunnel kiln (Naranjal), Mobile kiln (San Alberto), Wagon kiln (Hernandarias), Dome Kiln (Los Cedrales), Two Floor Caipira (Hernandarias), One Floor Caipira (Presidente Franco, O'Leary)

The large variety of kilns results from the accessible expertise of Brazilian kiln constructers. Nevertheless, the understanding of the kiln-technology and its optimal handling is very basic and therefore often used in an inefficient way. A good example is the Ceramica San Andrés, which has been struggling for a year to ramp up the newly built wagon kiln, as the air circulation is not as expected. A reason for this situation was the lack of training of the employees to use the new technology properly, making the US$ 100,000 investment almost obsolete. Additionally, the paralysis of the new kiln led to the decision to build Caipira kilns, which have worse efficiency than the replaced Albert kilns (Chapter 7).

**Summary:**

| Type of Producer | Production of ceramics [t] | | | Quantity of producers |
|---|---|---|---|---|
| | Hollow | Solid | Sophisticated | |
| **Industrial** | 3,000 | | | 5 |
| **Mech. Olerias** | 3,400 | | | 47 |
| **Olerias** | | 2,350 | | 30 |
| **Total** | **6,400** | **2,350** | **-** | **82** |
| **Total [pieces]** | **1,880,000** | **1,800,000** | **-** | **-** |

**Table 6: Production Department Alto Paraná**

## 8.4 Department Itapúa

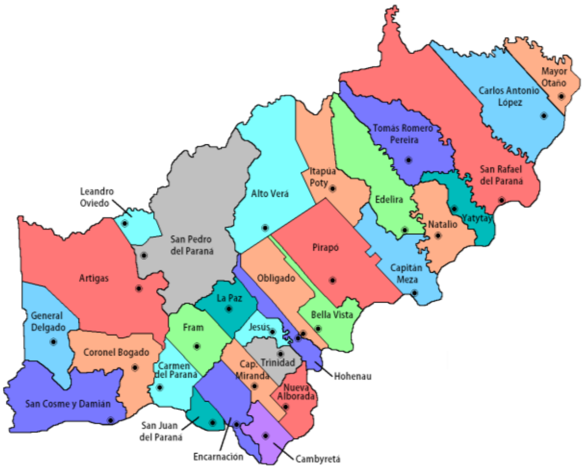


**Figure 37: Department Itapúa** **Figure 38: Districts of Itapúa**

Source: (Wikipedia, 2011d), (Wikipedia, 2011)

Itapúa is, with c. 600,000 inhabitants (Figure 4), the third most populated department and its capital Encarnación, with c. 130,000 inhabitants, after Asunción and Ciudad del Este, is the third largest city in Paraguay. Itapúa's economic performance depends on agriculture, tourism from Argentina and electricity sales from the hydroelectric power plant Yacyretá.. (EcuRed, 2016)

**Producing districts:** Encarnación, Bella Vista

**Clay quality and products:** Although the clay is suitable for manufacturing the complete product range, the ceramic products in this region are smaller and have thicker walls, which is an indication of a lower quality raw material. As the construction of the Yacyretá hydropower plant led to a flooding of the deposits in the close vicinity of Encarnación, the raw material supply near the capital is threatened. Currently, local producers extract the clay from deposits up to 60 km far away, but will soon need to search for new ones as they are already strongly depleted.

The strong demand for small and thick walled hollow bricks called huecitos is special for this region, as well as French/Portuguese style roof tiles instead of colonial roof tiles. The difference between them is that the colonial roof tiles are extruded, while the others are pressed.

**Locally produced:** Hollow brick, ladrillo comun, roof tiles, tejuelón, ladrillo prensado

**Kilns:** Tunnel (Encarnación, Bella Vista), One and two Floor Caipira (Encarnacion)

The variety of kilns is limited with most of the producers operating Caipira kilns. Besides open kilns, three producers with tunnel kilns and one producer using Albert kilns were encountered. Although the owner of the Albert kilns uses a very efficient Albert type that enables an air outflow through the floor instead of the air outlets on the side, he has no access to experienced kiln constructors to replicate them, as a Brazilian company built them 30 years ago. The current lack of professional Paraguayan kiln constructors forces him to build highly inefficient Caipira kilns when expanding production. This case stresses again (Chapter 8.3) the importance of a nationwide knowledge transfer, to facilitate the transition towards less polluting technologies and to prevent producers from reducing their efficiency over time.

**Summary:**

| Type of Producer | Production of ceramics [t] | | | Quantity of producers |
|---|---|---|---|---|
| | Hollow | Solid | Sophisticated | |
| **Industrial** | 5,300 | 300 | 1,000 | 4 |
| **Mech. Olerias** | 1,100 | 200 | | 26 |
| **Olerias** | | 4,700 | | 85 |
| **Total** | **6,400** | **5,200** | **1,000** | **115** |
| **Total [pieces]** | **1,880,000** | **3,850,000** | **-** | **-** |

**Table 7: Production Department Itapúa**

## 8.5 Department Presidente Hayes

Figure 39: Department Presidente Hayes


Figure 40: Districts of Presidente Hayes

Source: (Wikipedia, 2011e), (ABCcolor, 2016)

Presidente Hayes is economically reliant on livestock and agriculture and is the only one of the three western departments that has a mentionable brick production. As the market in West-Paraguay consists of less than 200,000 people (Figure 4), most of the production is sold in Asunción and the Central Department. The "Puente Internacional San Ignacio de Loyola" is important for the region and for some brick exporters, being the only bridge that connects Argentina to the west of Paraguay over the river Pilcomayo.

**Clay quality and products:** During a meeting with the industrial brick association, manufacturers stated that the clay has a very favorable composition for brick making and that its deposits are several meters thick. Combining the quality of the raw material with advanced processing and burning technology enables the local companies to produce very sophisticated products that can hardly or not be replicated in the rest of the country.

**Locally produced:** Hollow brick, roof tiles, tejuelón, special bricks (Figure 41)

**Figure 41: Special bricks**

(Ceramica Irene, 2018)

**Producing districts:** Villa Hayes, Benjamin Aceval

**Kilns:** Tunnel and Doble Albert

Every producer is in this region has at least one tunnel kiln and sometimes additionally several Doble Albert kilns (Figure 42). The Alberts are mostly used to produce roof tiles and other sophisticated products, as the burning curve can be easily adapted to reach optimal qualities.

**Figure 42: Tunnel and Albert kiln filled with roof tiles**

**Summary:**

| Type of Producer | Production of ceramics [t] | | | Quantity of producers |
|---|---|---|---|---|
| | Hollow | Solid | Sophisticated | |
| **Industrial** | 35,800 | 500 | 6,000 | 6 |
| **Mech. Olerias** | | | | 0 |
| **Olerias** | | | | 0 |
| **Total** | **35,800** | **500** | **6,000** | **6** |
| **Total [pieces]** | **10,530,000** | **250,000** | **-** | **-** |

**Table 8: Production Department Presidente Hayes**

## 8.6 Other production in Paraguay

Known are ten Ceramicas of which three use tunnel kilns, one uses a Hoffmann kiln, while the others use Albert kilns and are mostly located in Pedro Juan Caballero, Asunción and Guirá. Of these kilns is currently one tunnel kiln (Chaco) with a total capacity of 1,500 tons per month ramping up.

| Type of Producer | Production of ceramics [t] | | | Quantity of producers |
|---|---|---|---|---|
| | Hollow | Solid | Sophisticated | |
| **Industrial** | 17,500 | | 1,800 | 10 |
| **Mech. Olerias** | 700 | | | 3 |
| **Olerias** | | | | 0 |
| **Total** | **18,200** | **-** | **1,800** | **13** |
| **Total [pieces]** | **5,350,000** | **-** | **-** | **-** |

**Table 9: Production Rest of Paraguay**

## 8.7 Total monthly production

By compiling the data stated above, it results that the most frequently used (by tonnage) ceramic product is the hollow brick and that Paraguayan brick sector consists of at least 1,963 producers of which most are artisanal operations.

| Type of Producer | Production of ceramics [t] | | | Quantity of producers |
|---|---|---|---|---|
| | Hollow | Solid | Sophisticated | |
| **Industrial** | 120,400 | 800 | 13,808 | **130** |
| **Mech. Olerias** | 11,000 | 6,700 | 0 | **202** |
| **Olerias** | 0 | 78,350 | 0 | **1,631** |
| **Total** | **131,400** | **85,850** | **21,800** | **1,963** |
| **Total [pieces]** | **27,320,000** | **64,800,000** | **0** | **-** |

**Table 10: Total monthly production**

# 9 Emissions and nationwide wood consumption

The large quantity of open kilns used by the c.1.850 mechanized olerias and olerias,(chapter 8.7, Table11) is a strong evidence that the brick sector emits significant amounts of fine particles and gases, such as black carbon, CO and $CO_2$, which affect the climate and the health of the Paraguayan people. (Figure 43)

**Figure 43: Smoke emitted by artisanal kilns**

However, as the emissions of the brick sector had not been investigated until today, they can only be estimated by using the nationwide yearly fuel consumption. In order to do so, the national kilns were divided into seven large categories [Tunnel, Mobile/Wagon/Hoffmann, Albert, Dome, Caipira for ladrillo comun, Caipira for red bricks] and their specific wood consumption was elaborated by field investigations, interviewing experts or using international sources (Table 11). To effectively compare the combustible consumption of manufacturers using different types of wood (chops, chips, sawdust, native/eucalyptus) and with specific products (hollow, solid, sophisticated), the tons of wood per ton of red bricks were assessed.

$$fuel\ consumption = \frac{ton\ wood}{ton\ ceramic\ product}$$

By multiplying the nationwide yearly production of a kiln category (e.g. of all the tunnel kilns) with the respective fuel consumption, the total quantity of wood burned per year and per category resulted.

It is clear that the results should only be used as guiding values, as not enough brick producers have been examined to get statistically relevant data and as every producer has unique production parameters, which might lead to inaccurate assumptions. The various parameters, which the type and amount of emissions depend on, are e.g. the kiln size, clay composition, exact combustible (e.g. wood species), air inflow, etc.

In order to elaborate the real emissions, it is therefore recommended to undertake accurate measurements of the exhaust fumes at all – or at least at a statistically significant number of – kilns in the country. The data gathered would support Paraguayan authorities to define specific emission targets for the brick industry and monitor the effect of implemented actions, such as new kilns. In the case of Colombia, additional regulations were issued that demanded every kiln have a chimney, to enable authorities to quantify the emissions even more accurately. (Taillant 2016, p.29) After this were emission thresholds of particular matter, $SO_2$ and $NO_x$ implemented, while distinguishing between existing and new production sites. (SwissContact,2014, p.10, Annex 24) This regulation lead together with the active support of the NGO SwissContact to a significant improvement of the brickmaking infrastructure and consequently to a reduction of greenhouse gas discharges equaling 198,407 tons of $CO_2$. (Bickel, 2017,p. 30)

## 9.1 Burning techniques

Wood is the only combustible used by the brick sector and is mainly sourced from illegally clear-cut native forests (Chapter 9.3). Small-scale operations generally burn with one meter long and up to 50 centimeters-wide chopped wood, while industrial producers increasingly switch to woodchips and sawdust (Figure 44) to achieve greater combustion efficiency. It is notable that the large-scale tunnel kilns also operate with wood chips/sawdust, as there is currently no other economically viable substitute.

**Figure 44: Burning with chopped wood or woodchips/sawdust**

There are several reasons why owners of less developed kilns have not implemented the more elaborate burning system (ventilator + saw dust), which has the potential to reduce the fuel consumption by 30-40 percent (Taillant 2016, p.26)

Firstly, the investments are significant, as dozers, ventilators and ideally also thermometers are needed to feed the kiln in an efficient and stable manner. Secondly, there is no nationwide supply of wood chips available and expenses for chipping machineries are high. Thirdly, the technology is still not very established in the brick sector, making producers fear significant ramp up times and therefore additional losses.

## 9.2 Specific fuel consumptions of kilns

**Caipira:**

When estimating the fuel efficiency of a Caipira kiln, it is important to investigate the whole burning process and not to focus only on the kiln, as e.g. varying burning times and temperatures are main factors that affect the wood consumption.

For example, Caipiras have low fuel inputs when being used for burning of the artisanal solid brick (ladrillo comun), due to short burning cycles of 12-15 hours.On the other hand, Caipiras that are used by mechanized producers for the production of red bricks have much longer burning cycles of up to 3.5 days and therefore also a higher combustible consumption per brick.

**Albert**

When analyzing the Albert kiln, the differences are even more significant as the size of the kiln, air inflow, combustibles, burning temperatures, etc. vary strongly. For example, a producer that feeds the kiln with dried bricks, burns with woodchips, uses ventilators and stops burning at 800 °C has a much lower wood consumption than producers that feed the kiln with moist bricks, burn large trunks of wood, have poor air inflow and go up to 1000°C. Therefore, a rather high range of specific combustible use per ton of finished goods results.

**Semi-/Continuous Kilns**

As explained in Chapter 7, semi-/continuous kilns like the tunnel, mobile, wagon and Hoffman kilns achieve high efficiencies. Although brick producers stated that mobile and Hoffmann kilns are less efficient than tunnel kilns, their specific fuel consumption was not known to them and therefore taken from international sources. More calculations behind the specific emissions can be found in the Annex 28.

## 9.3 Total wood consumption and emissions

| Kiln type | Tunnel | M/W/H[1] | Albert | Caipira[2] | Caipira[3] |
|---|---|---|---|---|---|
| **Quantity of kilns** | 18 | 10 | 337 | 1,631 | 220 |
| **Monthly production [t/m]** | 79,200 | 22,600 | 40,935 | 78,200 | 17,600 |
| **Fuel consumption [kg/t]** | 0.2-0.22 | 0.22-0.24 | 0.35-0.39 | 0.16-0.18 | 0.42-0.49 |
| **Min. wood consumption [t]** | 15,800 | 5,000 | 14,300 | 12,500 | 7,400 |
| **Max. wood consumption [t]** | 17,400 | 5,400 | 16,000 | 14,100 | 8,600 |

[1]Mobile/Wagon/Hoffmann kiln, [2]Short burning times (ladrillo comun); [3]Long burning times;

**Table 11: Kilns and their specific wood consumption**

Source: EELA, 2015, p.34, self-elaboration

Adding up the monthly combustible consumption and multiplying it by 12, leads to the conclusion that annually 660,000 – 740,000 tons of wood are burned by the brick sector.

To convert these amounts of biomass into greenhouse gas emissions, they have to be multiplied by the specific emission of the combustible (tons of gas or particles per ton of wood burned). As these emissions are not known for the different Paraguayan wood species', Mexican analyses were taken as a reference.

| Emission type | BC PM 2.5[2)] | $CO_2$ | $CH_4$ | $N_2O$ |
|---|---|---|---|---|
| **Specific emission [t/t][1)]** | $0.061*10^{-3}$ | 1.542 | $4.35*10^{-3}$ | $0.06*10^{-3}$ |
| **Min. emissions [t]** | 40.26 | 1,017,858.60 | 2,871 | 39.60 |
| **Max. emissions [t]** | 45.02 | 1,138,150.98 | 3,210.30 | 44.28 |

[1)] Tons of emission per ton of wood [2)]Black carbon smaller than 2.5 micron

Source: Hidalgo Guerra, 2014, p.31

# 10 Wood demand and supply

Stakeholders across the brick value chain suffer under the increasingly decreasing offer of biomass, resulting from heavy clear cutting, few reforestation projects and missing provision of economical viable substitutes. In this chapter, the availability of wood and its yearly consumption are investigated and underpinned with concrete numbers. Table 11 shows conversion factors used in the following calculations:

| | |
|---|---|
| **0.7 $m^3$ wood** | **1 stere /stacked cubic meter** |
| **1 $m^3$ wood** | **2,5 $m^3$ chip** |
| **1 $m^3$ woodchip** | **0,400 $m^3$ wood** |
| **1 $m^3$ native species** | **0.800 tons[1)], 30% humidity** |
| **1 $m^3$ Eucalyptus** | **0.700 tons, 30% humidity** |
| **1 hectare of native forest** | **190 tons of wood[2)]** |
| **Yearly growth rate eucalyptus reforestation** | **25-30 $m^3$/hectare** |

**Table 11: Conversion factors**

Source: cp. (Borsy, 2013, p. 48), [1)] (Borsy, 2013, p. 29), [2)] (Rafael Ortiz, 2017)

## 10.1 West Paraguay

The western part of Paraguay (Figure 45) is mainly used by the livestock industry, which demands large pasture areas, as the cattle is fed with natural grass. This led to a significant expansion of pasture area (yellow) from 2000 to 2015, or in other words, the decrease in native forest (green).

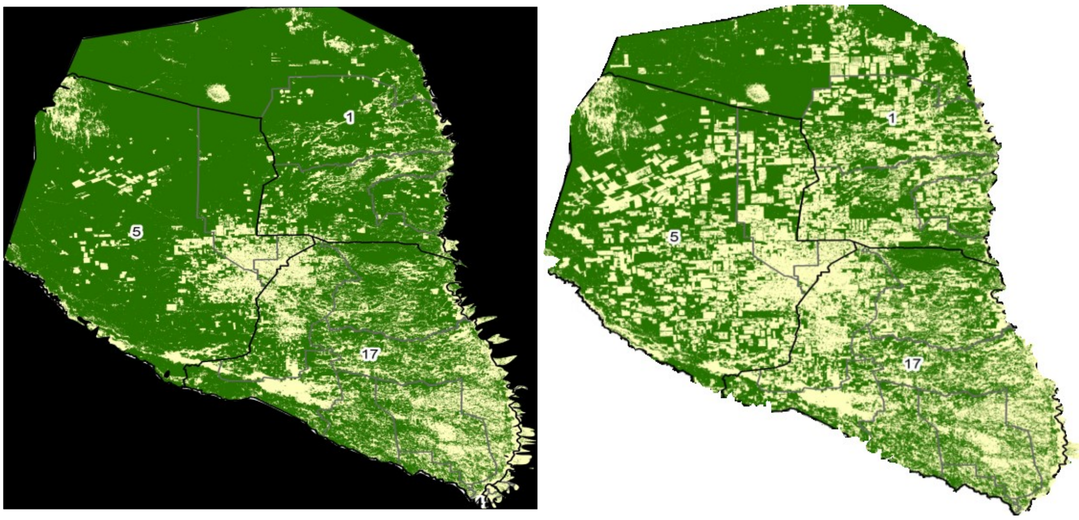


**Figure 45: Forestall area in West-Paraguay in 2000 (left) and 2015 (right)**

Source: (INFONA, 2015a) (INFONA, 2015c)

In these 15 years c. 4,500,000 ha were cleared, which reduced the total forestall surface from 18,702,505 to 14,159,176 hectares. (INFONA, 2015a) (INFONA, 2015c)

Despite this massive deforestation, only a negligible part of the accruing biomass is utilized, as poorly maintained and long transportation routes make relocations unfeasible. As a result, it is common practice to burn the wood locally on the field, after two parallel driving caterpillars root out the trees with an interconnected massive metal chain. Only brick and other manufacturers from cities such as Benjamin Aceval and Villa Hayes are said to occasionally use wood from the west, as they have a logistically favorable location.

## 10.2 East Paraguay

As described before, 98 percent of the population (Chapter 3.1) and the major industry (except livestock) are located in East Paraguay, resulting in a high demand for wood and consequently in significant deforestation.

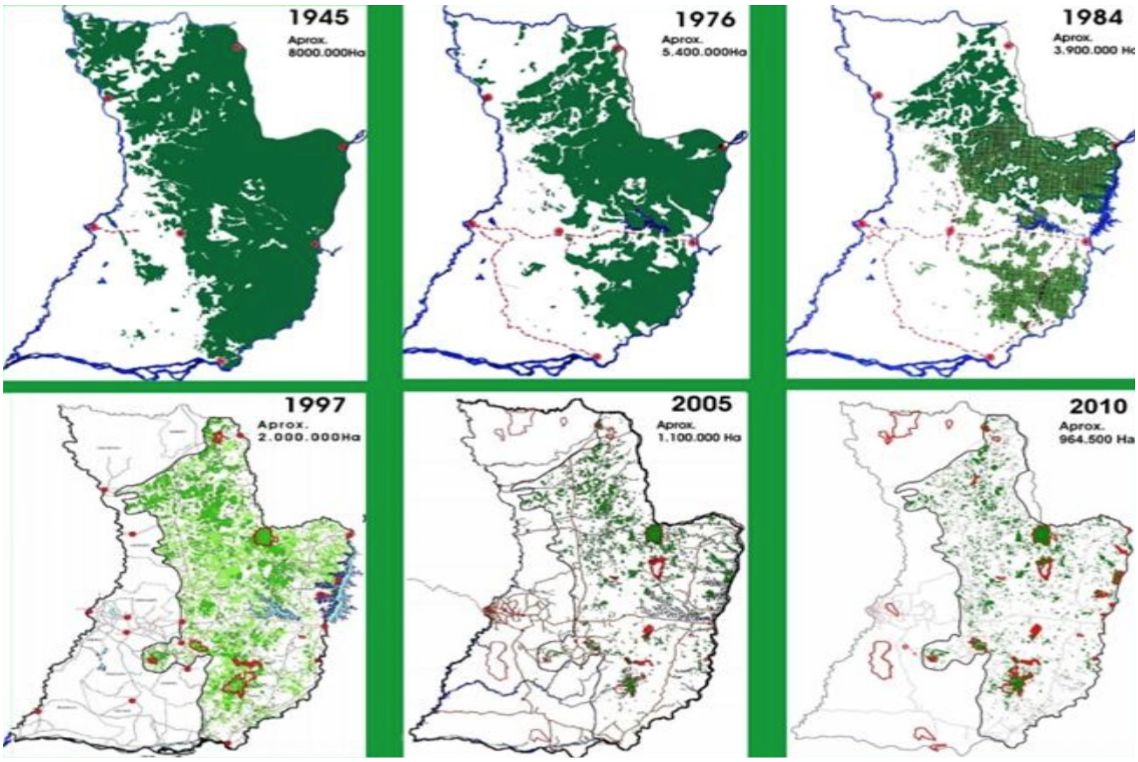


**Figure 46: Deforestation of the Alto Paraná Atlantic Forest**

(Borsy, 2013)

The analysis of remote sensing images since the year 1945 (Figure 46) shows the immense reduction of the Alto Paraná Atlantic Forest (green), in the east of Paraguay. The major drivers for this process is the residential and industrial use of firewood (chapter 9.3.1), but also the increasing demand for agricultural areas for e.g. soya plantations, which amounted in 2016 to c. 3.324.000 ha. (Pekholtz, 2016)

### 10.2.1 Deforestation since 2011

To get a clearer picture of the location and the magnitude of deforestation, the table below was requested from the INFONA, showing all the eastern departments with their forest area in 2011 and 2015.

| Department | Forest area 2011 | Forest area 2015 | Difference [ha] | Difference [%] |
|---|---|---|---|---|
| **Alto Paraná** | 270,510 | 245,680 | 24,830 | 9% |
| **Amambay** | 306,810 | 267,751 | 39,059 | 13% |
| **Asunción** | 189 | 183 | 6 | 3% |
| **Caaguazú** | 208,544 | 187,523 | 21,021 | 10% |
| **Caazapá** | 218,024 | 193,073 | 24,951 | 11% |
| **Canindeyú** | 415,268 | 366,692 | 48,576 | 12% |
| **Central** | 13,409 | 12,152 | 1,257 | 9% |
| **Conception** | 523,327 | 486,754 | 36,573 | 7% |
| **Cordillera** | 45,845 | 42,724 | 3,121 | 7% |
| **Guaira** | 63,470 | 60,061 | 3,409 | 5% |
| **Itapúa** | 289,598 | 262,571 | 27,027 | 9% |
| **Misiones** | 25,119 | 24,365 | 754 | 3% |
| **Neembucú** | 50,127 | 43,970 | 6,157 | 12% |
| **Paraguari** | 81,911 | 79,175 | 2,736 | 3% |
| **San Pedro** | 384,782 | 322,664 | 62,118 | 16% |
| **TOTAL** | **2,896,933** | **2,595,338** | **301,595** | **10%** |

**Table 12: Deforestation per department**

Source: (INFONA, 2015a) (INFONA, 2015c)

Analyzing the data given reveals that during the illustrated period, 10 percent of Paraguay’s forests had been cut. This equals a clearance of 75,500 ha per year that equal 14,345,000 tons of biomass. If this pace of deforestation were to keep up, it would result in the complete clearance of the native forest within 40 years. It is notable that this hazardous situation is in place despite the issuance of a “zero deforestation” law, which states that no clear cutting is allowed in East Paraguay and that forests can only be thinned in a sustainable way (Chapter 12.1.4). These informal dynamics are believed to occur, as no economic substitute for native wood was offered after the issuance of the law, forcing the population to keep buying it from deforesting operations to cover their demand.

### 10.2.2 Reforestation since 2011

According to the INFONA biomass from reforestations is the only substitute that could potentially meet the demand for native wood. The table below shows the increase of plantation areas by both, the timber and firewood industry:

| Department | Reforestation 2011 | Reforestation 2015 | Difference [ha] |
|---|---|---|---|
| **Alto Paraguay** | 0 | 456 | 456 |
| **Alto Paraná** | 10,361 | 15,363 | 5,001 |
| **Amambay** | 339 | 2,328 | 1,988 |
| **Asunción** | - | - | - |
| **Boquerón** | 0 | 99 | 99 |
| **Caaguazú** | 3,923 | 10,029 | 6,107 |
| **Caazapá** | 10,285 | 31,010 | 20,725 |
| **Canindeyú** | 3,019 | 3,928 | 909 |
| **Central** | 143 | 871 | 728 |
| **Conception** | 1,465 | 6,265 | 4,801 |
| **Cordillera** | 616 | 1,866 | 1,251 |
| **Guaira** | 641 | 7,439 | 6,798 |
| **Itapúa** | 5,163 | 10,605 | 5,442 |
| **Misiones** | 521 | 1,588 | 1,067 |
| **Neembucú** | 4,974 | 12,366 | 7,392 |
| **Paraguari** | 734 | 3,160 | 2,427 |
| **Presidente Hayes** | 321 | 1,237 | 916 |
| **San Pedro** | 10,325 | 13,841 | 3,517 |
| TOTAL | **52,829** | **122,451** | **69,623** |

**Table 13: Reforestation per department**

Source: (INFONA, 2015d)

As seen above, between 2011 and 2015 the total surface of plantations increased by c. 70,000 ha (c. 17,500 ha yearly), of which almost 50 percent are located in the three departments Caazapá, Neembucú and Guaira.These 17,500 ha add yearly 306,000 to 367,500 tons of wood, while the share of firewood accounts for 65 – 70 percent. (Borsy, 2013, p. 31)

Figure 47 indicates the distribution of the reforestations and shows the strong concentration in the south-east of the country, leading to high transportation costs for customers from Greater Asunción.

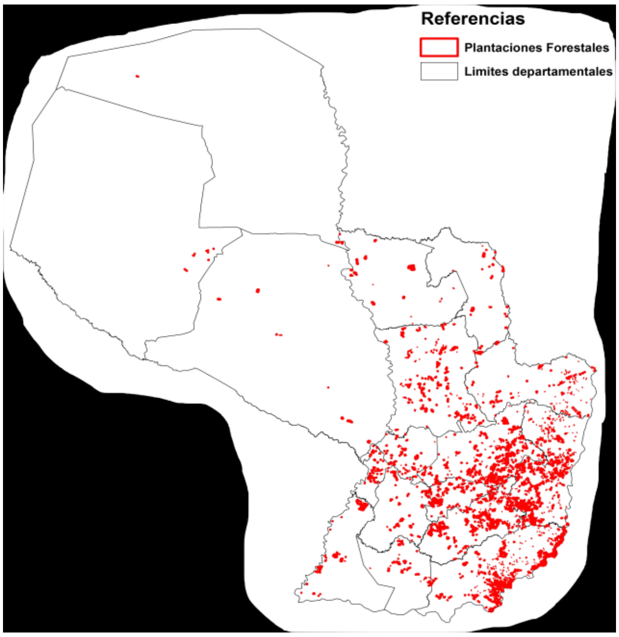


**Figure 47: Visualization of nationwide reforestations**

Source: (INFONAd, 2015)

## 10.3 Demand by sector

Although the total demand is expected to be the sum of the total supply of reforestation and deforestation, it is calculated differently by investigating the sector-specific consumption of wood. According to a government report (Table 13), the demand is mainly driven by residential consumption, as well as the grain, lumber and charcoal industries. (Borsy, 2013, p. 26) Residential use is considerable, as the rural population mainly uses firewood-fueled stoves for cooking and heating purposes. (Borsy, 2013, p. 13)

From the official data, the wood demand of the brick sector was modified to 660,000 - 740,000 tons (Chapter 9.3), as the authors of the report only analyzed 78 brick producers and estimated that they account for 80 percent of the total brick production (Borsy, 2013, p.19). By adapting these values, it is revealed that the brick sector is the fifth largest wood-consuming industry in Paraguay.

| Demand per sector [t] | Minimum | Maximum |
|---|---|---|
| **Residential consume** | 4,300,000 | 5,700,000 |
| **Grain** | 1,600,000 | 2,900,000 |
| **Lumber** | 1,800,000 | 1,800,000 |
| **Wood for charcoal** | 1,480,000 | 1,480,000 |
| **Ceramics** | 660,000 | 740,000 |
| **Other industries** | 468,000 | 468,000 |
| **Oil (vegetable)** | 350,000 | 400,000 |
| **Alcohol, sugar, honey** | 132,000 | 253,000 |
| **Chiperia** | 65,000 | 90,000 |
| **Cooling units, dairy** | 56,000 | 64,000 |
| **Tobacco** | 37,000 | 37,000 |
| **Starch from Manioc** | 32,000 | 35,000 |
| **Total** | **10,980,000** | **13,965,000** |

**Table 14: Wood demand per sector**

Source: (cp.Borsy, 2013, 26)

## 10.4 Sustainable supply from native forests and reforestations

**Native forests:**

According to Unique, East-Paraguay had a total forestall area of 2,400,000 ha in 2013, only 700,000 ha or 29 percent of which were seen as productive. While productive is defined as forests having the potential to be thinned each year, by the amount they increase their wood volume, which is said to be 2–3 $m^3$ o 1.6–2.4 tons per year. (Borsy, 2013, p.29)

Multiplying this value by the total productive forest area, a sustainably usable increase of 1,120,000 to 1,680,000 tons per year results. Although these numbers look promising, it is believed that only 10 percent of the total potential volume enters the market, as there has been no evidence that sustainable thinning is done on a larger scale.

**Reforestations:**

As stated in Chapter 9.2.4, the total reforested area increased from 2011 to 2015 by 70,000 ha to totaling 122,500 ha. From this follows that with a biomass increase of 17.5-21 tons/ha/year, 2,145,000-2,575,000 tons of wood grow on current plantations annually. However, it is important to note that the increase does not immediately equal the supply, as it takes at least seven years until the trees can be cut economically and sold. In other words, the 70,000 ha planted since 2011 will enter the market starting from 2018. Therefore, it is believed that currently only c. 50 percent of the yearly growing wood volume on the plantations is available for the market.

| Supply [t] | Minimum | Maximum |
|---|---|---|
| **Sustainable native forests:** | 112,000 | 168,000 |
| **Reforestations:** | 1,073,000 | 1,286,000 |
| **Total:** | **1,185,000** | **1,454,000** |

**Table 15: Total yearly supply**

## 10.5 Difference between demand and supply

| Difference [t] | Minimum | Maximum |
|---|---|---|
| **Total Demand:** | **10,980,000** | **13,965,000** |
| **Total Supply:** | **1,185,000** | **1,454,000** |
| **Difference:** | **9,795,000** | **12,511,000** |

**Table 16: Difference between wood demand and supply**

By subtracting the demand from the supply, a yearly difference of up to 12,522,000 tons of native wood results, which corresponds to a clearance of 65,850 ha of native forest. It is believed that the estimated deficit deviates from the actually cut 75,500 ha of native forests (Chapter 9.2.3), as the demand of illegal wood was not sufficiently considered in the official data. Other reasons for deviations could be that areas were cleared without using the incurring biomass or that the supply from reforestations and thinned native forests is less than expected.

To summarize, with the current reforestation areas, yearly more than 12,522,000 tons of native wood are cut. As the current yearly increase in eucalyptus plantations amounts to 367,500 tons of wood (Chapter 10.1.3), it will take more than 35 years until Paraguay is able to source its firewood fully from sustainable sources. During those years, further massive deforestation will be inevitable, unless large-scale plantation and fuel efficiency projects are prioritized by the government.

# 11 Economic situation

## 11.1 Cost structure: mid-scale producers with Albert kiln:

Due to their informality, most mid-scale producers hesitate to share accurate data and/or do not keep a professional record of their spending. Only two brick manufacturers were encountered that were willing and able to show their exact cost structures (due to data privacy, their names are not published):

Ceramica A (left, Figure 48) is a brick producer from Tobati owning two Doble Alberts, while ceramica B (right, Figure 48) is a rural manufacturer with only one Doble Albert. They can be compared well as they have the same production processes and similar cost positions in their books. It is mentionable that the fixed costs consist of expenditures for electricity, water, social security, administration (e.g. bookkeeping) and internet and that the variable costs originate from petrol and the maintenance of the machines and infrastructure.

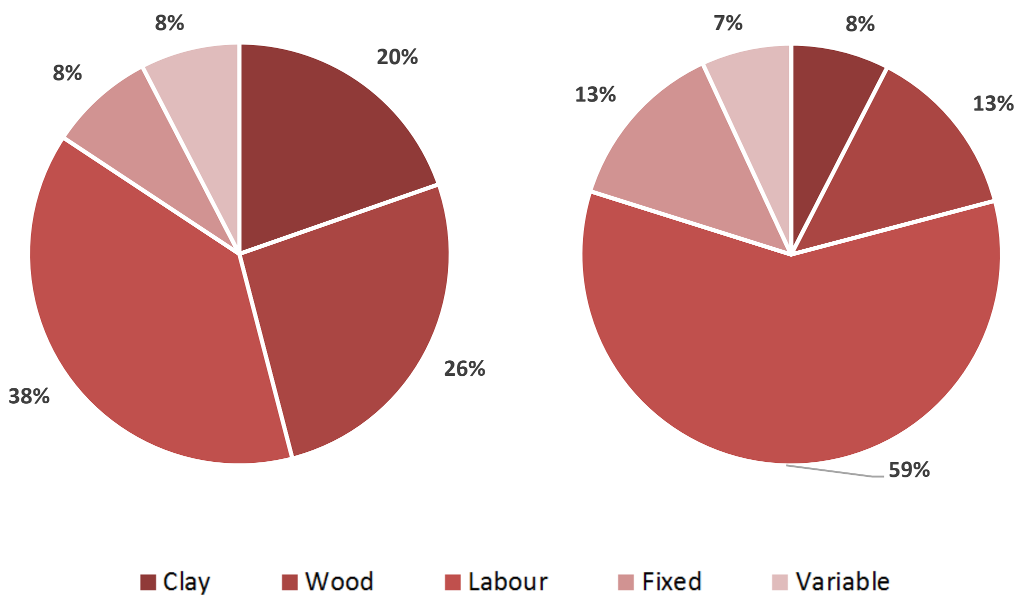


**Figure 48: Cost structure of ceramicas**

The two diagrams in Figure 48 lead to the conclusion that the size of an operation and its location lead to significantly different cost structures and therefore to varying cost reduction opportunities.

Economies of scale in ceramica A lower the relative labor costs, as with the same number of permanent employees (with social security), twice the output is achieved. Although this makes the share of raw material, cost naturally increasing relative to ceramica B, especially fundamental supply dynamics make them account for 46 percent in contrast to 21 percent. In Tobati the market price for clay is exceptionally high, as both the clay pit operator and the transportation businesses place a margin on the raw material before selling it to the brick manufacturer. This is not the case for rural producers, as they often own the clay pit and pay less for leased extraction and transporting units. Furthermore, due to the high demand and low supply in the surrounding area of Tobati, the price for firewood is c. 30 percent higher than in rural areas.

This highlights the fact that every producer has to be investigated individually with its respective environment before implementing any changes in its production process/technology. A reduction in fuel consumption (by implementing ventilators) does not affect small rural manufacturers as much as larger Tobati producers, as the cost for wood amounts to only 15 percent versus 25 percent of the total costs. On the other hand, an additional kiln enables small-scale operations to significantly reduce their labor costs and therefore their profitability.

It is important to note that most producers need financing to implement technological changes, but only the Visión Banco, which mainly operates in Itá and Tobatí, has been known to give loans to brick manufacturing businesses. (Chapter 13.1) In other parts of the country, brick producers can only take out private loans, making them reluctant to implement unknown technologies, as they have to offer their private wealth, as e.g. their house or car, as collateral.

## 11.2 Small scale olerias in Tobati

As no oleria could be encountered that was fully aware of its cost structure, it was estimated by analyzing each cost input of the production process.

To fabricate the ladrillo comun the so-called flojo is used as raw material,(chapter 5) of which a 12-m3 truck costs 700,000 Guarani or 127 US$ for larger scale customers and 800,000 Guarani / 145 US$ for small-scale operations, as they have less bargaining power. (Conversion 5500 Guarani/US$)

Average olerias have kilns that burn batches of 30.000 bricks and require per burning cycle c. 24 $m^3$ of clay, c. 10 stere of native wood and additionally two day laborers which mix, mold, burn and off-/load the bricks (if the brickmaking is not done by family members). The costs sum up to 6,600,000 Guarani / US$1,200 if external workers are paid and to 2,600,000 Guarani/ US$470 in cases of family businesses. Considering that the prices per ladrillo comun are depending on the market situation between 280 and 400 Guarani, the profits can be very limited especially if the business depends on expensive external financing.

Olerias mainly take a loan with up to 38 percent interest at the local Visión Banco, which is used to purchase the raw materials like firewood and clay. As the loan is paid back with the profit made from selling the bricks, can heavy rainfalls lead to serious liquidity problems, if production gets delayed or the green bricks are destroyed. Another possibility is that olerias have a so-called “patron” who pays for the raw materials and which requests in return a significant share (30-50 percent) of the revenue.

## 11.3 Clay extraction

The most common business model outside of Tobati is that the deposit is owned and operated by the brick manufacturer itself. Variations are that small-scale producers mine with basic tools such as a shovel, close to the production site, while mid to large-scale manufacturers use modern excavators, at locations often far away from the kiln. Small-scale producers are very reliant on the deposits on their own property as they cannot afford to buy additional land. Once the clay has been depleted, they are left with the options to buy expensive clay from the market or to mine illegally in other areas. An example is the town of Capiatá, where brick producers need to pay double the price for clay, as they have depleted their local deposits and now procure the raw material from Tobati.

Another common business model is that the owner of the deposit is not linked to the manufacturing process and only does extraction activities. In this case, private truck drivers are intermediaries in the value chain and buy the raw material, to sell it independently to end consumers.

## 11.4 Case study: Clay in Tobati

When considering the number of producers in a relatively small area, Tobati's clay extraction industry is unique. To cover the high demand for clay, c. 30 extraction sites operate in a radius of 10 km, which are sometimes not distinguishable from each other. Figure 49 illustrates the immense area of the pit system that has developed over the years, to supply the up to 1,360 producers in the region.


**Figure 49: Pit system Tobati**

Source:Google Earth,2017

### 11.4.1 Business models

The extracting activities rely mainly on two business models:

- The clay pit operator owns or rents the extraction machines (excavator or tractor) from local people or from companies that specialize in leasing. The clay is then sold to a truck driver that resells it to the brick factories. The c. 200 truck drivers have a business of their own and transport clay, if market and especially weather conditions are favorable, up to 5 times a day to their customers. Nevertheless, these transporters suffer from the lack of mine management, as during times of heavy rainfalls, the extraction and therefore also transportation, stops. Furthermore, queuing times at the pits are up to seven hours once the production has restarted, enabling them to do maximum two deliveries a day.
- The clay pit owner does not do any operative work and allows brick producers to mine and transport the clay with their own machinery.

### 11.4.2 Cost structure

One truckload of clay ex-works costs 150,000 Guaraní / US$ 27 for an 8m$^3$ four-wheeler truck and 220,000 Guarani / US$40 for a 12m$^3$ six-wheeler. The cargo is usually bought by the truck driver, who sells it for twice as much to the brick manufacturers, resulting in a final price of 300,000 or 450,000 Guarani.

These prices are twice as high as for tunnel kiln operators encountered near Asunción that only pay 270,000 Guarani / US$50 for a 12m$^3$ delivery, as industrial producers reduce the excavation costs with efficient mine planning, combined with large-scale storage. If the miners from Tobati were to adapt to these working practices and extract clay in layers, implement a drainage system, proper access roads and storage facilities, the main cost drivers listed below could be avoided.

- The mine operator needing to halt its mining activities during rain due to water inflow and difficult accessibility
- Digging of new pits as old once are flooded
- Truck drivers charging brick manufacturers for the days they cannot follow their activities, due to closed mine sites

The price for flojo is more expensive due to high demand and the longer transport distances of up to 15km between the deposits and the brick kilns. $12m^3$ of this raw material costs 700,000 Guarani / US$128 delivered on site, while very small operations even have to pay 15 percent more, due to lacking bargaining power.

## 11.5 Native and reforested wood

To understand the reason why native wood is still the first choice, the cost structure of both native and reforested wood was investigated.

**Reforested wood**

The first three years, the planting of the trees, removal of weeds, disbranching, etc. costs US$2,200 /hectare. Considering a good productivity of 17.5-21 t per year, the trees are usually left by themselves for four more years, until they are cut and loaded onto trucks for US$10 / t.

As a hectare of plantation achieves 123-147 tons in seven years, the cost per ton (including planting, cutting, loading, etc.) totals to c. US$25-28. This leads, with a certain margin, to an ex-works price for eucalyptus wood of c. US$32 or 175,000 Guarani per ton. The exact price depends on the actual productivity of the reforestation and on the humidity of the wood, as e.g. freshly cut wood has up to 40 percent water content and wood stored for three months only 20-30 percent.

As additional transportation costs to the plantation and back have to be considered, it is assumed that reforestations are within 100 km. The variable fuel consumption per drive to the plantation is considered to be 200,000 Guarani or US$36, with current diesel prices of US$0.9 /liter and consumption of 40 liters per 100 kilometers. The back transport is due to additional weight being costlier and amounts to 900,000 Guarani or US$ 160 per 100 km for the usual 16-ton cargo.

This leads to the conclusion that a 16 t delivery of legal fire wood from a plantation 100 km away costs around 3,900,000 Guarani. Compared to the illegal wood that is delivered in Tobati, it is around 30 percent more expensive.

**Native wood**

To get a better understanding of the cost structure, a wood transporter from Tobati was interviewed. He stated that the fixed costs per transport of a 16 t or 33 stere cargo are 1,200,000 Guarani or US$220 for the cut wood, 200,000 Guarani or US$36 for loading the truck and 400,000 Guarani or US$73 for payment to the controlling authorities. The fines paid to the officials are because the wood is mostly sourced from illegally deforested areas. (12.1.4) Furthermore, the variable fuel consumption per transport, with the current transport distances of c. 300 km ( 150 km one way), costs c. 700,000 Guarani or US$128. The market price of 3,000,000 Guarani or US$545 for 33 steres of native wood in Tobati results if the total costs from above and a margin of 500,000 Guarani or US$90 are added together.

Although native wood is still cheaper, its future price stability is in danger, as both the volumes of fines and the transportation costs are steadily rising. The reasons for that are newly build police control stations on the main transportation routes and that trucks are forced to drive longer distances and to use poorly maintained mud roads, which strongly wear their trucks, as most trees located next to the asphalted roads have been cut.

## 11.6 General market dynamics

As illustrated by the graphs below, the output of the Paraguayan construction sector is in the short-term highly volatile, but in the long term steadily growing.

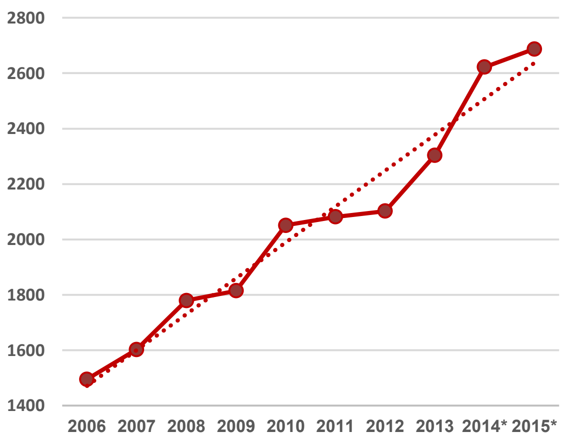


**Figure 50: Production in billion Guarani**

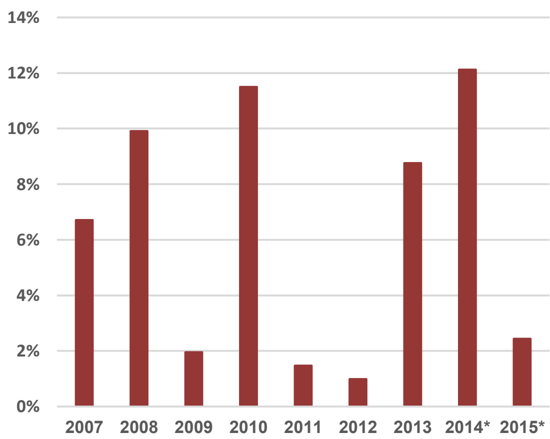


**Figure 51: Yearly production value growth**

Source: cp. (Banco Central, 2015, p. 4355)

Figure 50 (in billion Guarani) shows the steady rise of six percent between 2006 and 2015, while Figure 51 shows the year-to-year increase in production value of construction material varying between one and twelve percent.

The weaker growth periods often lead to an oversupply of ceramic products, as a consequence of too much increased production capacities in the previous positive market conditions. Especially tunnel kilns face difficulties in these lower than expected demand periods, as they cannot reduce their productivity without dramatically affecting their efficiency. This can lead to the production of millions of bricks which are stored until the market recovers.

On the contrary, intermittent kiln owners can adapt to changing demand (Chapter 7), as they can reduce the production and hire fewer day laborers, significantly reducing variable costs. Nevertheless, the fixed costs remain the same, so especially leveraged producers can go into bankruptcy as the high interest cannot be paid with the reduced cash flows

## 11.7 Exports

As Brazil and Argentina have suffered economically in recent years, the Paraguayan export market of ceramic products did not perform well, either. Figure 52 shows the export of ceramic products in tons with an expected export of c. 52,000 tons in 2017. According to REDIEX, this market is only accessible for industrial producers and is relatively small when comparing it to a monthly production of 238.140 tons. Figure 53 illustrates the three importing countries Argentina, Brazil and Uruguay and their share of the 2016 exports.

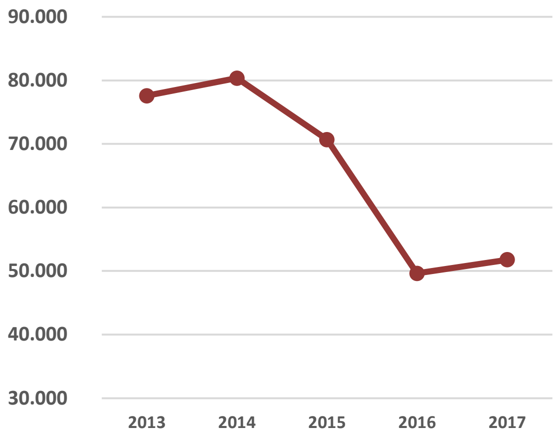


**Figure 52: Export of ceramic products in tons**

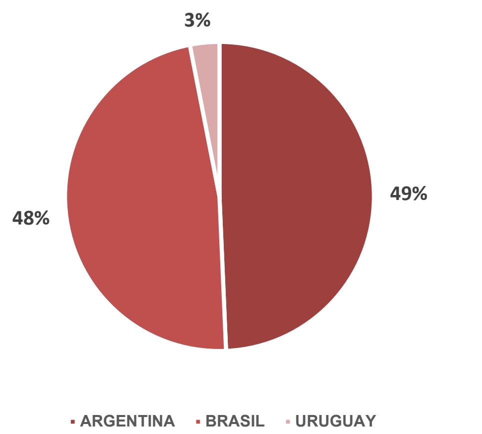


**Figure 53: Main export destinations**

Source: (REDIEX, 2016)

## 12 Social impact: Working conditions and job creation

As seen in Chapter 3.2, most of the Paraguayans have informal occupations, with the workers in the brick sector being no exception. While large-scale producers normally comply with the labor regulations, it is mostly not the case for the small to medium-scale producers, as they are invisible and less likely to be controlled by governmental authorities. The SME sector has to be differentiated between family businesses, in which the workforce consists mainly of family members, and businesses that work as companies and have day laborers or employees. The majority of the family businesses are very basic producers, which means that they mold the brick by hand, use animals for the mixing of the raw materials and own one-floor Caipira kilns. Manufacturing bricks at this technology level is highly hazardous to the health, as the producers are constantly exposed to the emissions of the kilns, conduct physically exhausting tasks, have to work during harsh climates in winter and summer, etc.

This harmful environment is especially problematic when connected to child labor, which is still frequent in family-owned Olerias. In Encarnación, production sites were visited in which children were frequently helping in the family business, to reduce the production costs on the one hand, and on the other hand, to acquire the necessary knowledge to take over the production from their fathers. Children are said to be especially suited for the loading of the kiln, as the green bricks can support their weight. It has to be highlighted that it was also observed that some producers that could afford it supported their children in finding another profession, as they realize the unsustainability of their business model. (12.2.1) In contrast to other countries in Latin America and due to cultural reasons, women generally do not work in the brick industry at all and stay at home cooking and caring for their children.

The enterprise-like producers normally have only very few or no family members working in the production. Although this can vary strongly, the owner of the kiln has few full-time employees responsible for processes that require experience, like e.g. the person in charge of the burning process. Normally, these people have social security, get regular payments and have a right to compensation in cases of causeless dismissal. In many cases, however, the employees would still rather not have social security, as according to the law, they have to pay for part of it (Chapter 12.1.3). This is mostly the result of a lack of understanding of the benefits that could result for them and their families.

The remaining major part of the workforce consists of day laborers, who have no labor protection, as guaranteed payments or protection against sudden dismissal, have no social security and earn the minimum wage of c. 2,040,000 Guarani, or US$360 per month. (Tusalario.org, 2017) The working conditions are not changing for these workers, as they can be easily substituted and are afraid to lose their job when demanding more rights and employment security. When investigating the most significant health risks, they are quite distinct in manual and mechanized production sites.

**Manual production:**

- uses kilns without a chimney, which is why the exposure to toxic fumes is considerable
- the molding process is very tiring and includes frequent backbreaking movements
- work is normally not done under a roof, which is especially tiring in summer

**Mechanized production:**

- the molding process is more dangerous, as the machines are often not secured by e.g. a cage, making workers lose their limbs if they get sucked in by rotating parts
- as the ceramic products are normally very heavy, every dislocation of them (stacking for drying, loading and offloading of kilns and trucks, etc.) is physically exhausting
- as the cooling phase of the kiln takes up to four days, the producers try to reduce it by forcing workers to offload the kiln while the bricks and the kiln structure are still hot. This work is especially exhausting in summer, but also dangerous in winter, when the workers have to constantly switch between the hot and cold environment and therefore often get seriously sick.

- the reasons for not improving the working environment in mid-scale enterprises are that owners are not aware of these health threats or do not have / do not want to spend the capital to reduce them. Furthermore, as there are no labor unions that could enforce improvements, most of the workers keep a low profile to not put their job at risk.

Despite these facts stated above, the brick sector and especially the informal small- to mid-scale operations are creating significant amounts of jobs. The exact number of workers per production site depends largely on the size and the production practices of the company and had to be estimated in order to compile the following data. The large number of workers in the Mobile/Wagon/Hoffmann kiln (M/W/H) category results especially from the labor intensive Hoffman kilns.

| Kiln type | Tunnel | M/W/H[1] | Albert | Caipira[2] | Caipira[3] |
|---|---|---|---|---|---|
| **Producers** | 15 | 6 | 109 | 202 | 1,631 |
| **Workers per site min.** | 70 | 50 | 12 | 5 | 3 |
| **Workers per site max.** | 90 | 70 | 15 | 8 | 3 |
| **Total workers min.** | 1,050 | 300 | 1,308 | 808 | 4,893 |
| **Total workers max.** | 1,350 | 420 | 1,635 | 1,414 | 6,524 |

[1]Mobile/Wagon/Hoffmann kiln, [2]Short burning times (ladrillo comun); [3]Long burning times;

**Table 17: Workplace generation per kiln type**

Table 17 shows that between c. 8,350 and 11,350 are believed to work directly in the brick production, while these numbers do not take into account the numerous clay miners, wood and lay transporters, kiln constructors, etc. that are indirectly linked to the industry.

In summary, it can be said that the brick industry has significant room for improvement in its working conditions, as many suffer from them. At the same time, the social importance of the brick sector is becoming visible, especially when taking the smallest brick producers into account, as they belong to the poorest of the population and have only their business as a source of income.

# 13 Access to financing

## 13.1 Visión Banco

The major banks in Paraguay are the Banco de Fomento, Banco Continental, Banco BBVA, Banco Itaú, Banco Central de Paraguay and Visión Banco. These financial institutions grant loans to private persons and to businesses which are creditworthy and whose operations comply with the law.

The creditworthiness of a private person is assessed by investigating the cash flows and by valuing the owned assets, e.g. a house or a car, which can be sold by the bank if the client cannot pay back its obligations. The credit risks of businesses are more difficult to assess, as credit institutions need extensive expertise in the respective sector in order to value the assets such as an Albert kiln, for example, and the business model implemented. As a consequence, the invisible and not well understood brick industry has difficulties being classified as creditworthy.

During the seven weeks of investigation, only the Visión Banco, which specializes in micro-financing and has a strong presence in Tobati and Itá, was found to give loans to brick manufacturers in a frequent manner. With its more than 1,000 clients that are directly related to brick making, it has great expertise regarding the financing of brick-related operations. In order to manage the risk behind the significant informality of the sector, only businesses that submit at least their trade license (patente commercial) and the proprietorship of the land are considered to be creditworthy. If the municipality or the state owns the land, the client has to prove with his trade license that he has been in the business for at least two or three years. Additionally, experts thoroughly investigate the production sites and evaluate the infrastructure as well as the production processes. If both the documents and the site visits meet the bank's requirements, a loan is offered. The close relationship between the bank and the client during the application process and the credit period that follows, results in a low loan default rate of three percent.

The amount of credit and the interest rates that are given by the bank depend on the risk the bank takes. A small-scale Oleria that applies for a loan for the first time has, according to Visión Banco, a high risk of loan default, which is why only up to

5-10 million Guarani / US$ 900-1800 are lent, with interest rates of c. 38 percent. On the other hand, a well-organized industrial producer with a positive track record of past loan repayments receives up to 500 million Guarani / US$ 91,000 with interest rates of 18 percent. Industrial associations are able to draw loans of up to 1.5 billion Guarani / US$ 273,000 with interest rates of less than 18 percent.

90 percent of the clients in Tobati are Ceramicas or Olerias and use a total annual credit volume of around 15,000,000,000 Guarani / US$ 2,730,000 with an average interest rate of 28 percent. The loans are mostly used to finance operating capital, for buying raw materials to enable production, financing transport or financing investments in machines or infrastructure, to name a few. Depending on the purpose, the loan period changes. For operating capital, the loan period is 24 months and for investments five years, with a hypothec and four without.

## 13.2 Agencia Financiera De Desarollo

The Agencia Financiera De Desarollo (AFD) is a second-tier bank, which does not directly grant loans, but indirectly through accredited banks, financial institiutions or cooperatives. In other words, an accredited bank such as Visión Banco takes a loan at the AFD and provides it, with an additional margin, to its clients. The goal of the AFD is to channel financial resources for investment projects and loans to the population, by supporting the financing of housing, infrastructure, reforestation,etc. For the brick sector, especially the PROPYMES and the PROFORESTAL programmes could significantly reduce the costs of borrowing. It is important to note that the interest rates are not the interest rates for the client, as the accredited bank will increase them by four to five percent. (AFD, 2016a), (AFD, 2016b)

| Programe | Purpose | Interests | Life of credit | Grace period |
|---|---|---|---|---|
| **PROPYMES** | machines, infrastructure, trucks,etc. for SME's | 6,5 % | 12 | 2 |
| **PROFORESTAL** | reforstation | 5,75 % | 12 | 12 |

**Table 18: AFD credit programs**

Source: (AFD, 2016a), (AFD, 2016b)

# 14 Governmental engagement and legal documents

## 14.1 Business license (Patente commercial)

“The business license is one of the requirements for the commencement of commercial activities and its issue is the responsibility of the municipality where the trade premises are located.” (Hubbard, 2007, p.13 f.) To calculate the price of the yearly renewed document, authorities investigate, list and value the assets of company once a year. It is an essential license as it proves the existence of a business and therefore enables them to take out a loan. In the municipality of Tobati, the costs, depending on the size of the brick related operations, are between 270.000-1.092.000 Guarani / US$. 50-200 (Annex 31.3).

## 14.2 Industrial registry (Registro industrial)

The decree 6258/2011 states in article 3 that the inscription and update of data in the Industrial Registry (RIEL) is mandatory for all natural persons and legal entities that carry out any type of industrial activity in the territory of the Republic of Paraguay. (MIC, 2016, p. 2) Although this clearly includes the Paraguayan brick sector, an excerpt of the RIEL shows that only 72 brick manufacturers are possessing this document. The costs for the up to three years valid registration are depending on the business 471.030 or 1.099.070 Guarani / US$ 86 or US$ 200. (MIC, 2016, p. 5)

## 14.3 Environmental Impact Assessment

The law No. 294/93 of the environmental impact assessment states in article 7, points c), d) and s), that an assessment is mandatory for all extracting, industrial and any other activities that effect the environment.(SEAM, 1993) The EIA is valid for two years and consists of a comprehensive description of the operation and of planned measures to avoid, mitigate and monitor its influence (emissions, residuals, manipulation of the soil, etc.) on the environment. (SEAM, 2015) (SEAM, 2018) Although they fall under the law, only very few brick manufacturers and clay pit operators holding an EIA were encountered. There are two main reasons for that:

- Industries become visible through the process and therefore fear unfavorable legal consequences for themselves, as the value chain itself stays illegal. In other words, although they have a legal status from an environmental point of view, they still source from illegal clay and wood producers and sell products without an invoice. This leads to the conclusion that only when the brick manufacturing value chain as a whole works towards legality can it be assured that more kiln owners apply for EIAs, as they don't have to fear legal prosecution when becoming visible.

- While the exact costs depend on the size of the operation and the advisor amounts an EIA for mid-scale operations to c. 12,000,000 Guarani / US$. 2,200 and small scale operations to c. 9,000,000 Guarani / US$. 1,650 The advisor is crucial for the application as the producers have not enough support, information or literacy to do it by themselves.
  To increase the transparency of the application process the in average needed working hours and costs of an EIA expert were published by ministry (Annex 31.1.

Additional information can be found under:

http://www.seam.gov.py/servicios/servicios-ambientales/c%C3%B3mo-obtener-licencia-ambiental

## 14.4 Social security

> "Contributions to the Social Security Institute (Instituto de Previsión Social) (IPS), which is an independent government body that administers the social security system, are mandatory and must be made by both the employer and the employee. The IPS provides benefits (including coverage for sickness or injury, maternity, work accidents, pensions for disability, old age and death) for the worker and the worker's family." (BDO Auditore Consultores, 2015)

The social insurance is calculated by multiplying 18 or 30 days of minimum wages by 25.5 percent, depending if someone is a day laborer or is contracted. The exact calculation for different employment categories can be seen in the Annex 31.2.

The minimum daily wage is currently 78,505 Guarani, or c. US$14. (Instituto de Previsión Social , 2017)

According to the law of the 25.5 percent, 9 percent have to be paid by the employee and the remaining 16.5 percent by the employer. (Hubbard, 2007, p.24) In reality, as the workers would rather have no social security than reduce their income, brick manufacturers have to pay the total social security payments of 360,338 Guarani, or US$ 65 per month. A mid-scale operation with an average of 10 day laborers bears, therefore, extra annual costs of 43,240,560 Guarani, or US$ 7.800, if they provide social security for all of them.

## 14.5 Legal firewood

In the east of Paraguay, since the issuance of the “zero deforestation” law in 2004, any kind of deforestation is strictly forbidden, while in the west up to 75 percent of an assigned area can be clear-cut.(Juridiccion Paraguaya, 1973, art. 42) (INFONA, 2004). In order to cut and sell wood legally in the east, a so-called “guia” has to be granted by the forestry ministry. This document assures that the forest, from which the wood is sourced, is used in a sustainable way and that no clear cutting is done. Before its issuance, authorities of the SEAM and INFONA inspect the forest area, to identify amongst others its annual growth rate that equals the allowed cutting rate. Once the legal process is completed, a landowner is able classify his source of wood as sustainable and sell the raw material together with the guia. In other words, the guia has to be handed over with the cargo to e.g. the transporter of the goods, which in return has to pass the document to his client who is in most cases the end-consumer of the wood. This should achieve the result that at any point in the value chain, the legal status of the products can be proven.

In practice neither the producer of wood (e.g. peasant, land owner), nor the purchaser of firewood or coal (ceramics, olerias, factories, etc.) is interested in obtaining guias, as they are only checked on the transportation routes. As a consequence, only the truck drivers are fined and criminalized for transporting illegal wood, making the law having no effect on the stakeholders causing the deforestation. These dynamics prevent the law from changing the hazardous situation of uncontrolled clear cutting, which made 10 percent of the forest area disappear between 2011 and 2015. (Chapter 10.1.2) According to a brick manufacturer sourcing from legal sources, the high costs of the guia are an additional reason why it is avoided. For the first issuance of the guia for 300 ha of native forest, he had to pay US$ 2,000 to the SEAM and US$3,000 to the INFONA and has to renew the document every four years.

## 14.6 Mining license

As all actions of extraction are under the jurisdiction of the "Vice-Ministry of Mines and Energy", also clay mining is affected. Currently most brick related extraction activities are informal and invisible leading to sometimes highly inefficient and polluting operations. According to the official documents, every industry that extracts stones, terrestrial and calcareous minerals has to apply for a license and show the documents listed below. (Viceministerio de Minas y Energia, 2016)

- **Authenticated Copy of the title of property**
- **Original or certified copy of the environmental impact assessment**
- **Geological report certified by a geologist including**:
  - Description of the extraction area
  - Microscopic description and average specific weight of the material to be exploited
  - Methodology for exploitation
  - Calculations of estimated monthly extraction volume, and total quantity of reserves (tons)
  - Use and destination of material

(Viceministerio de Minas y Energia, 2018)

## 14.7 Relocation programs

Until today, the only large-scale relocation program was carried out in Encarnación, from which valuable lessons about the importance of implementing advanced technology and emphasize capacitation can been learned.

Due to the newly build hydropower plant "Yacyreta", the water level of the Rio Paraná has risen between1976-78 to the point, that 92 oleria owners and their families had to be relocated. As their homes, kilns and clay pits were flooded, the government provided every family with a new house in Encarnación in the settlement ”Etapa 1”, 1,500 $m^2$ of land at ten minutes walking distance from it and free clay until five years after the relocation. Nevertheless, as the authorities did not promote a change of profession or the use of more efficient and less polluting technologies, every single brick producer constructed inefficient Caipira kilns on their piece of land and restarted production. This polluting area is nowadays called the “parque industrial”. Additionally, to the unproductive production processes, local brick producers are struggling under high transportation cost, as the risen water level flooded all the local clay deposits. Nowadays the extraction sites are over 60 kilometers far away from the kilns, while the resulting increased production costs cannot be charged to the customers without losing market share.

Furthermore, the living conditions are constantly worsening, as more and more families live in the industrial park itself, as the relocated population grew over the housing capacity of Etapa 1 and are due to the factors mentioned above too poor to afford a different housing. These people are now constantly exposed to the toxic fume emissions of the kilns, which is especially harmful for the children. While the exact number of people residing there is not known, the “parque industrial” consists of 95 Olerias that are molding the bricks by hand and 20 mechanized Olerias that are producing hollow bricks. Figure 54 shows the local infrastructure and illustrates in the right corner an example of a house built directly next to the kiln.

Figure 54: Parque industrial Encarnación

# 15 Conclusion

## 15.1 Brick producers

The baseline study conducted leads to the conclusion that the Paraguayan brick industry consists of 1,963 producers using 2,221 kilns, which are mainly located in Greater Asunción and in the departments Itapuá and Alto Paraná (Figure55). The largest concentration of small scale operations, which own 70 percent of the national brick kilns while only accounting for 35 percent of the total brick output, can be found near Tobatí.

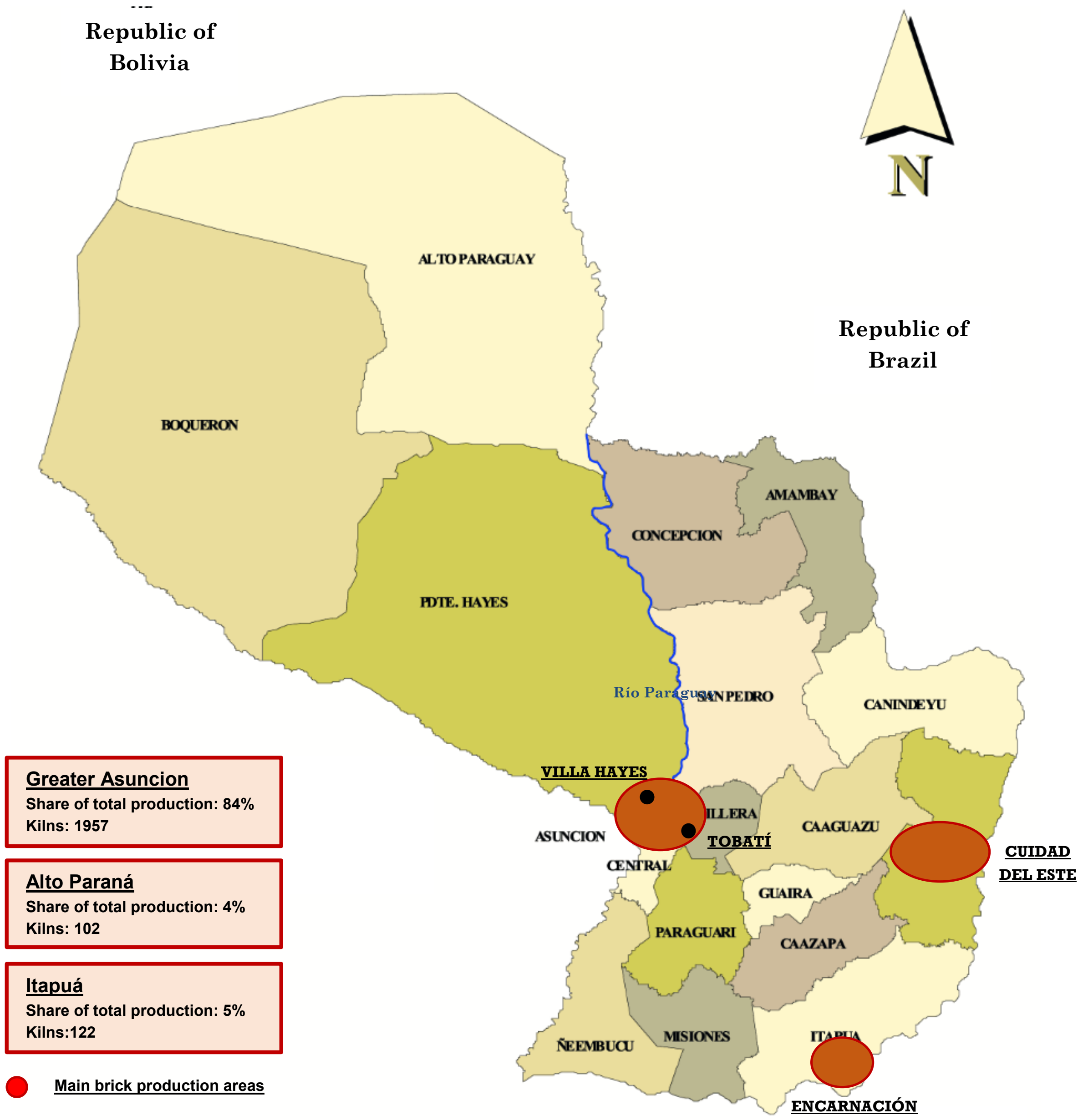


**Figure 55: Three major production centres**

Source: (cp.DGEEC, 2017)

The sector is characterized by its significant invisibility and informality, which results in a large variety of production processes, ceramic products, business models, etc. and makes a categorization of brick producers necessary. In order to do so, the different manufacturers are subdivided in a first step according to the specific processing flow sheet and in a second step according to the kiln types. Depending on the beneficiation system implemented, which indicates the achievable red brick quality and variety, producers are classified as oleria, mechanized oleria or ceramica.

### 15.1.1 Processing system

Olerias are small-scale operations that use the most basic production technologies and mold solid bricks called ladrillos comunes by hand. Despite often having – due to short burning cycles – a low compressive strength and high water absorption, these bricks are in high demand as they have a low price and a distinct white color.

Mechanized olerias are small to midscale producers that work with a simple extruder or an electric press to mold the bricks. Their main products are solid bricks such as the ladrillo prensado and "3A" as well as thick hollow bricks called huecitos. These green bricks are burned for up to four days and show a large variety of chemical and mechanical resistivity, depending on the producer.

Ceramicas are mid- to large-scale industries that fabricate bricks using at least two homogenizing machines and an extruder that is connected to a vacuum pump. These operations are able to produce any ceramic product (hollow and solid bricks, roof tiles, floor tiles, etc.) with a reasonable quality, while restrictions may arise due to poor raw materials.

### 15.1.2 Kiln types

The six different kiln types that are well established or increasingly used by the sector, can be divided into intermittent and continuous kilns (Tables 19, 20). These two groups of kilns differ strongly in terms of productivity and efficiency, but cannot be subdivided according to their achievable red brick quality, as also very traditional types realize products that meet modern standards.

Intermittent kilns have open or closed structures in which the green bricks are burned and then cooled, before they are discharged. This process leads to high fuel consumptions, as during every burning cycle in addition to the bricks also the kiln structure has to be heated. Moreover, open kilns lose, due to the low heat insulation, considerable amounts of energy and have high emissions of black carbon and CO due to poor air inflows. This causes damage to the environment, as well as to the health of people living in the vicinity of the kilns.

The three widely used intermittent kilns (Table 19) have a large range of production capacities and investment costs. It is important to note that in order to change from Caipira to Albert the costs for changing processing machines have to be included. Experience showed that the products from mechanized-/olerias are not suitable for the Albert kiln.

| Type | Caipira | Caipira Grande[2] | Doble-/Albert |
|---|---|---|---|
| **Used by** | **Olerias** | **Mechanized-/Olerias** | **Ceramicas[1]** |
| **Quantity** | **300** | **1551** | **337** |
| **Capacity** | **25,000 sb/month** | **30–120,000 sb/month** | **30–150,000 hb/month** |
| **Costs** | **US$ 1–3,000** | **US$ 8–10,000** | **US$ 20–50,000** |

sb…solid bricks; hb…hollow bricks; [1)]rarely used by mechanized olerias [2)]1-2 floor Caipira

**Table 19:Intermittent kilns**

Continuous kilns have always a closed structure, burn at all times and have fired bricks removed constantly, while being fed with green bricks. Semi-continous kilns are hybrids and therefore more efficient than intermittent kilns, but less than e.g. the tunnel kiln. Table 20 shows that investment for each type of kiln are significant, although expenses for the construction of a dryer and for additional processing and handling machinery are not yet included. However once a continous kiln is in production, the environmental footprint and profitability of the operation are significantly improved, as the fuel consumption and labor costs are reduced, while the output is increased.

| Type | Wagon | Mobile | Tunnel |
|---|---|---|---|
| Used by | Ceramicas | Ceramicas | Ceramicas |
| Quantity | 2 | 8 | 18 |
| Capacity* | 120–320,000 hb/month | 240–640,000 hb/month | > 500,000 hb/month |
| Costs | US$ 100–120,000 | US$ 150–180,000 | > US$ 300,000 |

hb…hollow bricks

**Table 20:Semi-/ continuous kilns**

### 15.1.3 Products

Due to the informality of most brick manufacturers ceramic products are generally not standardized, which results in bricks with the same appellation, but with significantly different sizes, designs, compressive strength, water absorption etc. This makes many customers actively search for more standardized substitutes, leading to a significant market penetration of prefabricated concrete, plasterboards, corrugated sheet iron, etc. and threatens the profitability of the brick sector. (Chapter 4) The lack of standardization is also problematic in terms of safety, as in rural areas houses and other buildings such as schools, are still built with the not thoroughly burned artisanal brick (ladrillo comun) and without any reinforcement. As the ongoing climate change has already led to increased precipitation in Paraguay (Annex 30), it is more and more dangerous to use low quality ceramics, as a moist environment reduces their compressive strength.

## 15.2 Related value chain

Despite the fact that brick production is the pivotal element of the brick sector, it is important to analyze the entire value chain, in order to holistically understand and sustainably change the sector dynamics. (Figure 56)

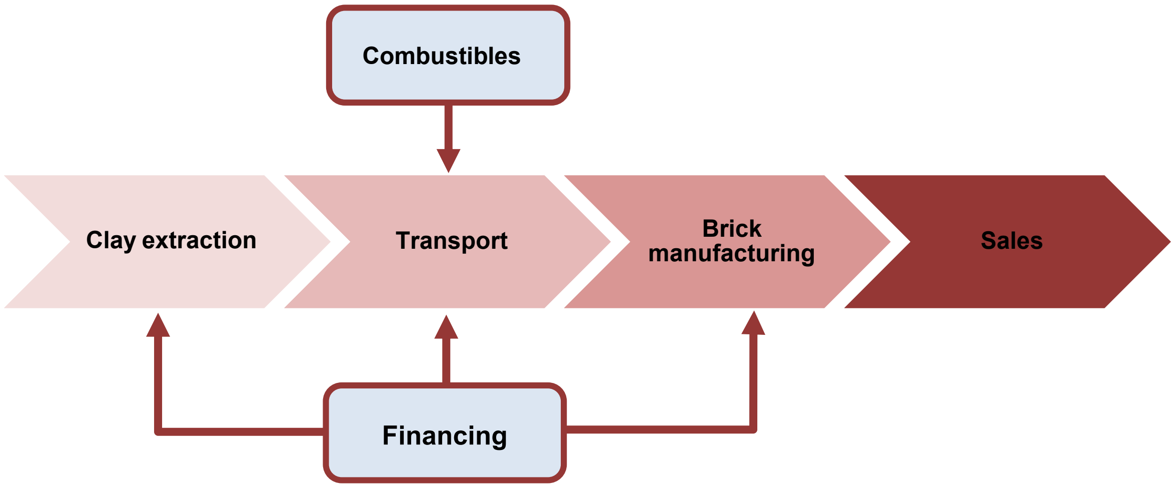


**Figure 56: Brick value chain**

Clay, which is the primary raw material of the sector, occurs in a large variety of qualities and can be used for different ceramic products, depending on its physical and chemical composition. As each raw material has specific properties, it is crucial to adapt the processing and burning practices to it. However, the general unawareness of the distinct clay types and the lack of understanding of their effect on the end product results in ineffective production processes and red bricks with a low chemical and mechanical resistance. (Chapter 8.3)

As pointed out in Chapter 14.6, clay extraction falls under the jurisdiction of the Viceministerio de Minas y Energias, which has issued several regulations, but does not have effective enforcement mechanisms in case of non-compliance. The consequence is a mining process that is characterized by high informality, little governmental supervision, destructive exploitation and missing reclamation. These dynamics are especially harmful in regions of high demand as Tobatí, as large areas are degraded and becoming unusable for other purposes like agriculture due to intensive topsoil removal.

Despite the use of modern excavation machinery, missing mine planning results in unproductive mining operations and in increased raw material costs across the value chain. In Tobatí, for example, this missing expertise leads to clay prices being double those in other areas. This reduces the profitability of the miners and brick manufacturers. Nevertheless, there is significant evidence that more structured and standardized extraction methods could unlock significant economies of scale, while reducing the environmental impact.

In Paraguay, biomass is the most intensively used energy source and especially important for industrial purposes. Most of it originates from illegally clear-cut native forests, as reforestation projects are scarce and no other economically viable substitutes, such as natural gas or mineral coal, are available. As a consequence, only in the east of Paraguay are 75,500 ha or 2.5 percent of its wooded area deforested on a yearly basis (Chapter 10.2.19). If no countermeasures are taken, the surface of the native forest will halve in the next 20 years, while having substantial environmental, but also economic implications for the country.

As explained in Chapter 14.5, the SEAM and INFONA tried to end the hazardous deforestation by emphasizing the issuance of the zero deforestation law, which strictly forbids any clear cutting in the east of Paraguay. However, its effects were not as expected, and a nationwide black market emerged, as no economical substitute was offered after the prohibition of native wood. These informal dynamics will remain as long as only the intermediaries (wood transporters) and not the suppliers (wood cutter) or the demanders (industries) are fined for handling illegal wood.

For the brick sector, the ongoing deforestation may lead to significant price increases of the main combustible, as resources become scarce, transportation distances increase, fines are increased and environmental regulations might be enforced more strictly.

In order to improve the environmental footprint and assure their economical sustainability, brick manufacturers therefore need to invest in fuel-efficient and output increasing technologies, for which a reliable financial institution is essential. In Paraguay, only the Visión Banco frequently grants loans to brick manufacturers at present. The bank lends more than 15,000,000,000 Guarani / US$ 2,730,000 to more than 1,000 brick-related clients near Tobatí and Itá and is therefore one of the stakeholders with the strongest expertise in the sector. The loan conditions offered depend on the formality and size of the operations and range from 10 million Guarani / US$ 1800 with 38 percent interest for Olerias, to 500 million Guarani / US$ 91,000 and 18 percent interest for Ceramicas to 1.5 billion Guarani / US$ 273,000 and less than 18 percent interest for industrial associations. (Chapter 13.1) Producers in other regions of the country are only able to take out private loans and have to use assets such as their house or car as collateral that can be sold by the bank, if the obligations are not paid back. Many brick manufacturers therefore shy away from implementing new technologies, as they might lose their livelihood if the investment goes wrong.

## 15.3 Main brick production areas

Experience showed that the specific market dynamics as well as the needs of brick producers in terms of financial, governmental and educational support depend greatly on their location (Figure 55). In Itapuá a lack of capacitation is a major issue, as the brick industry has access to state of the art kiln types, but lacks expertise on how to operate them. In this case, the access to brick production experts that give valuable technical advice and support manufacturers in ramping up the production, would be of significant help. (Chapter 8.3)

On the other hand, producers near Encarnación are trying to reduce their clay consumption or even change their business model, because the flooding of most clay pits led to unbearable raw material prices. In this case, especially the access to financing is missing, in order to switch from the production of solid bricks to hollow bricks or from clay bricks to concrete bricks. (Chapter 8.4)

The region of Greater Asunción is the only area where even closed intermittent kiln users are increasingly becoming unprofitable, due to significant competition. (Chapter 8.1, 8.5) These producers need substantial financial and technical support in order to shift to more efficient technologies, such as semi-/continuous kilns.

These findings lead to the conclusion that in order to sustainably transform the sector every producer needs to be analyzed in the context of its specific environment and production processes.

# 16 Suggestions

## 16.1 Micro-level

On the company level, it is important to investigate the different production practices and technologies used in respect to the three pillars of environmental, social and economic sustainability.

| Kiln types | Efficiency / Emissions | Work conditions | Workplace generation | Long-term profitability | Sustainability |
|---|---|---|---|---|---|
| Semi-/ Continuous | + | + | -/~ | + | + |
| Closed intermittent | ~ | ~ | + | -/~/+ | ~ |
| Open intermittent | - | - | + | - | - |

**Table 21: Sustainability of brick kilns in Paraguay**

As seen in table 21 each kiln type has its advantages and disadvantages, but with increasing governmental regulations and industrialization, in a long term only the semi-/continuous kilns will be sustainable. It is therefore suggested that producers increasingly change from open (Caipira) to closed kiln structures (e.g.Albert) and from closed intermittent kilns, to semi-/continuous kilns.

Nevertheless, it has to be kept in mind, that changing Caipira kilns to closed Albert kilns, might not be enough to guarantee an economic sustainability in all cases, as e.g. in Greater Asunción. On the other hand, a too rapid adoption of continuous kilns as the tunnel kiln, may create social problems as this technology requires 6-12 workers less than would be needed for the same output in an Albert kiln. In other words, one tunnel kiln with 18,000 tons of production per month and 50-100 employees, could replace up to 50 traditional manufacturers with up to 600 workers. If this transition to continuous technologies is not accompanied by a transfer of workplaces, it might have a considerable social and economic impact in cities as Tobati (31,956 inhabitants), where according to the Visión Banco up to 80 percent of the economy depends directly or indirectly on the brick industry.

To summarize, the issues related with brick production must not be reduced to the kiln technology alone. The local market dynamics and its social impact need to be thoroughly investigated before changing the production process.

Furthermore, a different kiln structure is not the only way to increase the economic and environmental sustainability of an operation, as the following examples are showing: Process improvements as the use of ventilators, thermometers, dryers, additives, etc. can reduce the wood consumption and therefore the emissions by 30-40 percent, in a win-win scenario benefitting from reduced operating costs. Training on the correct extraction and processing of clay, can lead to higher quality products, reduced burning temperatures, less drying time, etc. resulting in lower operating costs and in higher achievable prices for the red bricks. The implementation of an extruder can significantly reduce the clay costs as it enables a switch from solid bricks to less raw material intensive hollow bricks. In comparison to the implementation of new kilns, these improvements require less investment and allow quick profits for the producers.

Despite technical changes, it is important that manufacturers work increasingly together, in order to reduce their production costs, increase their bargaining power and become capable of accepting large-scale orders. Currently almost every producer has its own processing machines, kilns, handling machinery as e.g. a bobcat, etc. that are by far not operating at full capacity and require large investments. Buying and sharing infrastructure and machinery as an industrial cooperation, would significantly decrease fixed costs, increase the output of uniform bricks requested by large scale construction sites and facilitate the implementation of large scale projects, as a continuous kiln.

Associations of clay miners could significantly improve their extraction operations. Clay pits often operate at lower capacity or even suspend operations entirely due to rainfalls. This leads to high raw material prices along the value chain. (Chapter 1.4) In order to do so they should organize the extraction process more professionally, do simple geological surveying and implement a mine design that avoids these delays. (Annex 31) Especially Tobatí has great potential of consolidating the c. 30 unproductive pits, by using pit geometries that allow a more continuous mining process.

Additionally to cost savings and better organizational structures, producer groups have collectively a lower default risk than single businesses. This enables banks to offer credit volumes with lower interest rates. (Chapter 13.1) In order to create an industrial association, producers would need to create a legal entity, transfer the production assets into it and choose a board that takes relevant decisions. The board members would then be able to ask for cheaper credits in the name of the association and distribute the capital under its members.

## 16.2 Meso-level

In order to ensure a nationwide access to financing the lack of information and expertise about the sector has to be addressed, as it is a major reason for financial institutions being reluctant to lend money. Consequently both, the brick producers as well as governmental authorities should increase the transparency of the industry by working towards formality and explain to banks the fundamental dynamics and exact business models of brickmaking. The Visión Banco could be of great help in this stage, as it is with its more than 1,000 brick producing clients and credit defaults rates of less than three percent, an exceptional dialog partner for other financial institutions. (Chapter 13.1)

To ensure that future emission and sustainability targets can be met, it is crucial that every stakeholder in the brick value chain also has state of the art technology, in addition access to capacitation. As examples in Cuidad del Este and Encarnación showed, even highly efficient equipment is useless without proper training and knowledge transfer to the local community (Chapter 8.3 and 8.4). In order to facilitate the transition to modern production processes, an information-sharing platform that connects technical experts from ministries and other institutions with the brick producers, could be of great importance. Especially as currently neither a governmental nor a nongovernmental organization is overlooking the national brick value chain and available if support is needed.

The website redladrilleras.net, which was implemented by the CCAC and the NGO Swisscontact, is ideal for that purpose, as it tracks the state of the brick industry in different countries, publishes state of the art working processes and technologies and offers various contact details of industry experts that can give valuable advice. (CCAC, 2018c) Although a platform might help to make the brick sector more visible and organized, it will solely not result in transformation towards sustainability. For this, more governmental engagement is needed together with experienced authorities or an NGO understanding the brick value chain and developing specific strategies.

## 16.3 Macro-level

Based on this work, governmental authorities are encouraged to refine the so far gathered data with further investigation and to organize workshops, in which they exchange their experiences and visions with local producers, intermediaries (clay miners, wood transporters, etc.) as well as international experts. However, as these actions neither enable a frequent communication between governmental authorities and the stakeholders, nor a constant monitoring of the developments in the brick sector, in addition either a governmental or nongovernmental organization should be assigned to overlook the brick industry and to function as a drop-in center for any inquiries.

Furthermore, responsible parties are advised to revise outdated or not applicable regulations and balance incentives for compliance, with effective enforcement mechanisms in case of non-compliance. In this process three areas should be under special scrutiny:

- Emissions and polluting production processes
- Quality control
- Wood sourcing

**Emissions and polluting production processes**

To reduce the pollution caused by brick production, in a first step its actual emissions should be assessed on a national basis by using professional emission measuring devices. Subsequently, authorities could introduce national and kiln-specific emission thresholds, to accelerate a change towards better production processes and new kiln technologies. One such example is that Colombian authorities achieved that the most basic technologies were abandoned, by prohibiting open kilns and introducing emission thresholds. This incentivized the sector to improve its production processes. Although this approach might also be viable for Paraguay, it is strongly suggested that these regulations not be implemented all at once, but to allow a certain transition time in which the brick sector is accompanied by financial institutions, production experts, NGOs, etc. Furthermore, it has to be considered that a transition to modern production standards always goes along with a consolidation of producers and in the case of Paraguay, might threaten the livelihood of up to 8,000 people working in artisanal productions (Chapter 12). In order to guarantee a positive social impact, the government should thus offer instruments of financial support to manufacturers that want to improve their operations and focus simultaneously on the creation of workplaces in other suitable areas such as e.g. reforestation and on offering education/training that enables workers to leave physically exhausting jobs behind.

**Quality control:**

The public construction sector is a major consumer of ceramic products and has the potential to incentivize better production processes by emphasizing special quality standards. Currently it is very difficult for small scale operations to participate in public tendering as they would need to transport their bricks over long distances (up to 400 km) to prove their compliance with the norm. This is because the Asuncion-based INTN is the only institution that provides a valid certificate of ceramic products. In order to enable small scale producers to offer certified quality products, it is suggested that additional testing laboratories are provided in production areas as Tobatí, Cuidad del Este and Itapúa

**Wood sourcing**

Change towards a sustainable wood value chain is currently slow, due to the lack of investment into substitution of native wood and due to the missing prosecution of the clear cutting landowners. To address the first point, it is seen as viable that the governmental authorities work together with the INFONA and implement so-called “reforestation toll stations”. In this concept, tolls (instead of fines) would be paid by every passing native wood transporting truck and would be used to invest in large scale eucalyptus plantations. This would have the twofold effect of making illegal firewood more expensive and at the same time subsidizing the urgently needed reforestation projects. The response to this idea, proposed during field work, was very positive, with the “Asociación de Transportistas de Carga de la ciudad de Tobatí“ expressing their sincere interest in the project. Fining the deforesting landowners has never been simpler than today as the INFONA is now able to monitor the full forest surface and its changes using satellites. (Chapter 10) It is therefore suggested that the governmental authorities increasingly analyze aerial pictures (e.g. every two years) in order to tackle the informal wood value chain at the beginning.

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# 20 List of Abbreviations

| | |
|---|---|
| 3A | Ladrillo Prensado de Tres Agujeros |
| AFD | Agencia Financiera De Desarollo |
| CCAC | Climate and Clean Air Coalition |
| e.g. | For example |
| GIZ | Gesellschaft für Internationale Zusammenarbeit |
| INFONA | Instituto Forestal Nacional |
| INTN | Instituto Nacional de Tecnología, Normalización y Metrología |
| PAN LAC | Policy Advocacy Network for Latin America on Clean Brick Production |
| REDIEX | Red de Inversiones y Exportaciones |
| SEAM | Secretaría del Ambiente |
| SENAVITAT | Secretaría Nacional de la Vivienda y el Hábitat |

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# Annex

# 21 Subdivision of the working population

The total potential workforce in Paraguay is estimated to be around 5 million persons of which around 3.4 million are actively working. More than 1.8 million workers in Paraguay are either formal or informal wage employees (figure 58). Including the mostly informal farmers, unpaid family workers, and other self-employed workers, which account for another 1.3 million jobs. This leads to the conclusion, that in 2015 nearly 2.4 million workers were employed informally.


**Figure 57: Snapshot of the working-age population in Paraguay**
Source: (Ruppert Bulmer, 2017, p. 27)

# 22 Norm solid bricks

According to the norm this product massive bricks should have the following characteristics:

| Dimensions | Minimum measures [cm] |
|---|---|
| **Length** | 22 |
| **Width** | 11 |
| **Height** | 4,5 |

**Table 22: Requested dimensions of a solid brick**

Source:(INTN, 2015)

Brick category A:

- Should be burned uniformly
- needs uniform color, without stains and without being burned (black)
- should not contain soluble salt and/or efflorescent
- should not have any apparent defects

Brick category B:

- Should not have apparent defects that prevent its use for exterior sight-constructions
- Should not have cracks, splits, stains, burning that affect more than 15% of the sight area
- should not contain soluble salt and/or efflorescent

Brick without category:

- Are not according to A or B

Source:(INTN, 2015)

# 23 Norm hollow brick

<table>
<tr><th>Length</th><th>Height</th><th>Tolerance</th><th>Width</th><th>Tolerance</th></tr>
<tr><td rowspan="5">Max. 400<br>Min. 190</td><td>120</td><td rowspan="5">± 0,5</td><td>50</td><td rowspan="5">± 0,5</td></tr>
<tr><td>180</td><td>80</td></tr>
<tr><td>180</td><td>130</td></tr>
<tr><td>180</td><td>180</td></tr>
<tr><td>250</td><td>180</td></tr>
</table>

**Table 23: Requested dimensions of a hollow brick**

Source:(INTN, 1976)

Further prerequisites:

- shell with a width of ≥7mm
- horizontal and vertical dividing walls with a width of ≥4mm
- grooves between 1 and 4 mm deep

# 24 Emission thresholds Colombia

| Estándares de emisión admisibles de contaminantes al aire para las industrias existentes de fabricación de productos de cerámica refractaria, no refractaria y de arcilla | | | |
|---|---|---|---|
| Combustible | Estándares de emisión admisibles (mg/m³) | | |
| | MP | SO2 | NOx |
| Sólido | 250 | 550 | 550 |
| Líquido | 250 | 550 | 550 |
| Gaseoso | No aplica | No aplica | 550 |
| Estándares de emisión admisibles de contaminantes al aire para las industrias nuevas de fabricación de productos de cerámica refractaria, no refractaria y de arcilla | | | |
| Combustible | Estándares de emisión admisibles (mg/m³) | | |
| | MP | SO2 | NOx |
| Sólido | 50 | 500 | 500 |
| Líquido | 50 | 500 | 500 |
| Gaseoso | No aplica | No aplica | 500 |
| Estándares de emisión admisibles de contaminantes peligrosos al aire para las industrias de fabricación de productos de cerámica refractaria, no refractaria y de arcilla | | | |
| Combustible | Estándares de emisión admisibles (mg/m³) | | |
| | HCl | HF | |
| Todos | 40 | 8 | |

Source: (SwissContact,2014, p.10)

# 25 Additional information on Albert kilns

## 25.1 Stacking

The kiln is first loaded with the hollow bricks, which are stapled over each other, with the holes looking upwards. It is important that a space with a width of one and a height of two hollow bricks, is left between the fuel feeding opening and the vents on the other side, to facilitate the stack-effect (red arrows). Depending on the producer, the by the huecos the kiln volume can vary strongly. In SANSI SL the huecos account for around 70 percent of the total volume, on the contrary 20 percent in Santa Maria. Once the hollow bricks are stapled, the tejualon are put on top and then the other products as roof tiles and the convocó.

As seen in figure 59, in a last step a wall of only hueco bricks is erected in order to protect the thinner walled products (e.g. tejualon, tiles), from flames. Important is to leave, despite the wall, around 50 cm of space, between the fuel feeding openings and the ceramic products, to avoid a black colouring of the bricks. The red arrows show the spaces that facilitate the stack-effect.

**Figure 58: Detailed stacking process**

Figure 60, shows the airflow once the kiln is in operation.

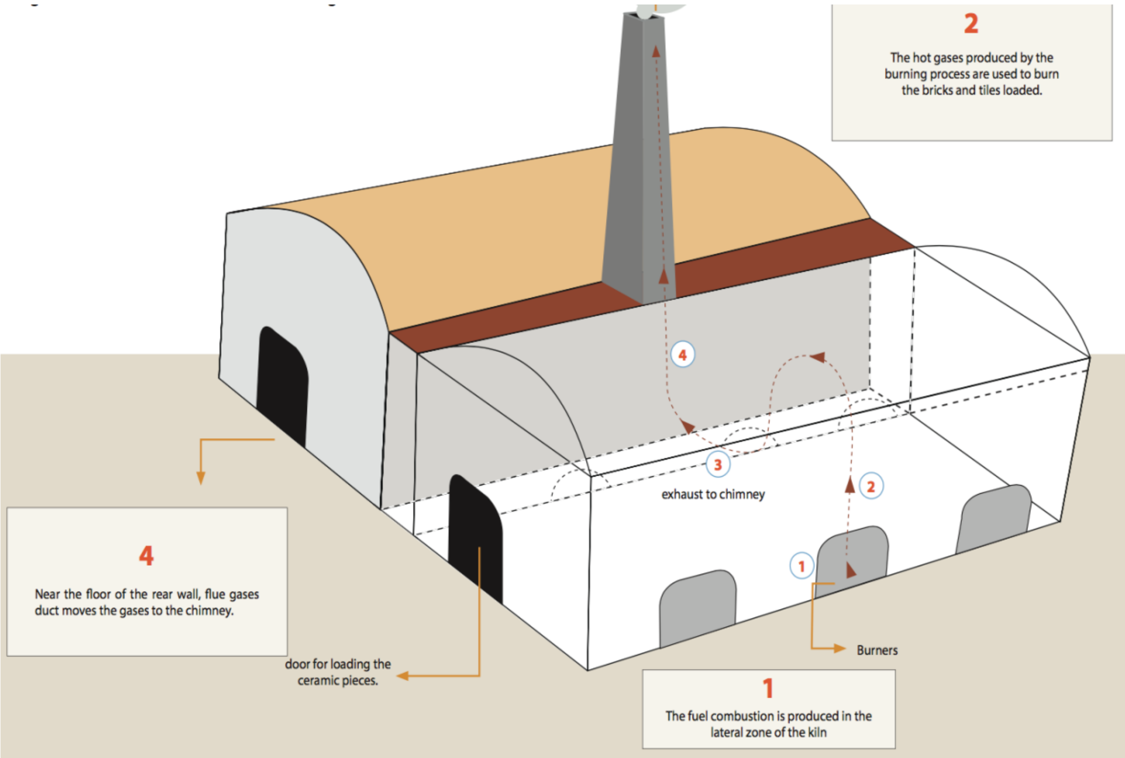


**Figure 59: Schematic air flow in a Doble Albert**

Source: (SwissContact, 2013)

## 25.2 Burning cycle

The burning process strongly depends on the ratio between sand, silt and clay, on the moisture content and on the processing technology available. Those parameters strongly influence the stress distributions and concentrations inside the ceramic product and therefore should be well understood to reduce crack formations. To further increase the quality of the final product many producers installed thermometer inside the kiln, to firstly assess the optimal heating curve (temperatures at certain times) with the given raw material and secondly operate the kiln according to it.

In other words, a thermometer allows standardizing the heating process, with the result of a significantly more predictable quality and of in many cases reduced fuel costs. Without it temperatures and heating curves are just assumed by the foreman at the kiln, the so called “quemador”. If ventilators are installed, they are able, by regulating the airflow into the kiln, to adjust the actual temperatures automatically towards the programed optimal heating curve. This again drastically improves the energy efficiency, if the technology is well used. Important is that not much wood is fed into the kiln, as otherwise the system shuts of the ventilators almost all the time, to avoid a too high temperature. This can even reduce the energy efficiency, as too little air inflow can lead to low burning temperatures and therefore to an incomplete combustion.

**Pre-heating (drying):**

First thinner wood pieces are put into the fuel feeding opening and lighted, until enough ember is created to fire with large trunks. In this period, the temperature is increased very slowly, as a too fast drying process can easily lead to crack formations. It is advices to maintain the pre-heating processes until the bricks are thoroughly dry, which can be assessed when the smoke, which is leaving the chimney, loses its white colour and becomes transparent.

Important to note is that just a very short preheating period is needed, when the ceramic products are first placed in a separate dryer. The dryer is a tunnel like structure, which is normally connected to a separate burner, that constantly increases the temperature during 24 hours to 100°C, to achieve a humidity content of the bricks of c. 2 percent. The big advantages of the dryer are, that shrinking fractures can be better controlled, the temperature in the kiln can be increased faster as

**Burning:**

Is the brick dry and therefore not shrinking as much anymore, more fuel can be fed into the kiln, to achieve a steeper heating curve. If ventilators are available, they should be turned on from that moment on. This process should be maintained until a temperature of c. 950 °C is realized in the top part of the kiln, to guarantee a well burned ceramic product. But to cut costs and because of little knowledge, many producers only burn to temperatures which can be as low as 700°C, leading to products with low chemical and mechanical resistance. Experience showed that during the burning process, the temperature at the top of the kiln is around 200°C higher than at the bottom, wherefore the ceramic products at the floor are still not burned thoroughly.

**Retention:**

As the kiln structure itself is said to not support temperatures much above 1000°C the "retention" is done, in order to burn the lower lying products. In this process, the fuel and air inflows are decreased to that stage, that the temperature at the top remains, while it is slowly increasing at the bottom up to 800°C**.** This should guarantee thoroughly burned and less stressed ceramic products. Many manufacturers stated that a reduction of the maximum temperature, but a longer duration of the “retention” significantly increased the quality of the product.

**Without thermometer:**

If no heat measuring device is installed, the success of the burning process strongly relies on an experienced foreman (quemador). He assumes by examining the fuel, the steam coming out of the chimney and the ceramic products on a regular basis, the needed heating curve.

In best practices, when the upper ceramic products are glowing, the retention is started and lasts until the lower brick are glowing. Although this practice is less energy efficient, it assures a well burned product, also with changing raw material qualities, as the glowing is a sign for the wanted particle change.

**Cooling:**

Once the retention is considered as finished, the ventilators are shut off (if there are any) and no more fuel is fed. To insure a faster cooling process, the doors are opened at both sides a little, when the kiln is cooled down a bit or immediately, depending strongly on the raw material. It is important to insure that the air inflow is not to strong, to avoid a thermic shock and cracks in the products.

The moment the doors are opened the ember, which fell inside the kiln should be removed, as they drastically hinder the cooling process. An issue is that kiln can be up to 15 m long, which means that the embers are from both ends up to 7,5 m away. Because entering is impossible, due to the >500°C inside the kin, first just the closest ember is removed with a shovel. Then as the kiln cools more and more off, the workers are able to extract more and more embers, by entering the hot structure.

**Ember:**

Some producers have built themselves a c. 5-meter-long rake to extract the amber. To remove the ashes from the openings were the wood is put, is because of geometrical reasons, not working well. To put water on the amber to cool it faster was not considered yet, but the producers fear that it might create a pressure in the kiln which may result in a collapse of the stacked ceramic products. This fear is not seen as justified as the 2 opened doors and the up to 5 opened fuel feeders on the side of the kiln give enough opportunity to release any building up pressure.

Furthermore, negative effects can be avoided by sprinkling very small amount of water on the amber.

As the cooling process of up to 4 days accounts for almost 50 % of the whole burning cycle, the potential of cooling the kiln in a faster way is seen as significant. The total hours that are needed to cool the structure strongly vary with the maximum temperature in the kiln, the use of ventilators and the square meters of openings (e.g. doors) where the hot air is released. Once the ashes are removed, ventilators are put into the doors until the bricks can be off-loaded by hand. This is typically a temperature between 0°C and 70°C. Important to note is that producers, that use a sawdust and chips mixture as fuel, have due to a very complete combustion, a negligible amount of ember, which significantly increases the cooling speed.

# 26 Stacking in a one floor Caipira kiln

As the ladrillo comun burned in a one floor Caipira the fire is lighted on the sides of the kiln, wherefore the bricks have to be stapled in a way that the heat circulates through the whole kiln. Figure 61 shows on the right the stacked bricks that build the combustion chamber at the bottom of the kiln, which is connected to each wood feeding hole on the side of the kiln. The left picture shows the top part of a kiln, which is almost completely filled with green bricks. Important to note is that in the upper part of the kiln the bricks are not stacked with space in between them to increase the heat insulation of the kiln.

**Figure 60: stacking of ladrillo comunes in Capira kiln**

# 27 Processing improvements

## 27.1 Storage

Instead of having storages just with a daily capacity and therefore only little time between extraction and the processing, it is suggested to let the raw material stored for several month. This process is known as souring or ageing, in which the clay will improve its workability by achieving a homogenous humidity and the disintegration of dry lumps. The improved plasticity and more homogenous mas results in less stress concentrations in the extruded brick and to less crack formation.

## 27.2 Drying process

While brick producers only count the number of disintegrated bricks after the burning process, are losses also significant during drying. In order to achieve a minimum amount of cracks and deformation the rate at which moisture evaporates from the surface should not be greater than the rate at which it diffuses through the fine pores of green brick. The three parameters that influence drying or in other words the transport of water from the inside to the outside, are the air velocity, the relative moisture and the air temperature. A higher air temperature and velocity increases, while higher relative moisture of the air decreases the release of water from the ceramic product to the surrounding air. Considering these facts it is important to adapt outdoor drying facilities to the specific weather conditions. E.g. is the air very dry it should be avoided that the wind blows through the green bricks, as it will rapidly dry up the surface and cause cracks. (Karoglou, 2005)

# 28 Specific wood consumption

As the time was not sufficient to conduct exact measurements of the combustibles burned per ton of red bricks, it was mainly relied on statements of brick producers and on the data given in table 22, which was compiled by the NGO SwissContact. The conversion factors are 1,240–2,500 kg of ceramic product per thousand bricks and a calorific value of 2,400 kcal per kg of wood.

| KILNS | | Caipira | Paulistinha | Abovedado | Hoffmann | Cedan | Mobile | Tunnel |
|---|---|---|---|---|---|---|---|---|
| **Specific firewood consumption** (st/thousand) | | 1,2 to 1,5 | 1,25 to 1,7 | 1,15 to 1,6 | 0,9 to 1,2 | 0,6 to 0,7 | 0,7 to 0,8 | 0,6 to 0,65 |
| **Specific Energy Consumption** (Kcal/kg) | *Lower* | 795 | 583 | 536 | 418 | 409 | 397 | 341 |
| | *Greater* | 1104 | 914 | 860 | 637 | 545 | 519 | 422 |
| **Average capacity per firing** | *thousands* | 23 to 40 | 30 to 60 | 60 to 110 | 35/chamber | 28/chamber | 50 to 120 | 100 to 130 ton/day |
| **First quality pieces** | *%* | 20 to 40 | 50 to 70 | 60 to 80 | 90 | 90 | 90 | 95 |
| **Thermal Efficiency** | *average (%)* | 27 | 35 | 38 | 50 | 54 | 56 | 66 |
| **Production losses** | *average (%)* | 10 to 20 | 5 to 8 | 2 to 5 | <2 | <2 | <1 | <1 |
| **Products** | | Te/La | Te/La/Ba/LH | Te/La/Ba | Te/La/Ba/LH | Te/La/Ba/LH | Te/La/Ba/LH | Te/La/Ba/LH |
| **Heat Recovery** *yes/no* | | No | Yes | Yes | Yes | Yes | Yes | Yes |
| **Particulate emissions** | | Considerable | Little | Little | Very little | Very little | Very little | Very little |
| **Cost** | *US$ thousands* | 8,3 to 10 | 33 to 50 | 33 to 50 | 250 to 283 | 133 to 166 | 150 to 183 | 366 to 433 |

Te: roof tiles; La: Brick; Ba: floor tiles; LH: hollow brick.

**Table 24: Factsheet of different kiln types**

(EELA,2015,p.34)

## 28.1 Caipira kiln

According to Table 24 are the specific combustible consumption of Caipira kilns between 0.33 and 0.46 tons per ton of red bricks [t/t]. In Paraguay the Caipira kilns have to be subdivided in kilns used for ladrillos comunes and in kilns used for red bricks as, the ladrillo prensado and hollow brick. As ladrillo comunes are only heated for less than 20 hours they require less wood and resulting in low fuel usages of between 0.16-0.18 [t/t]. The Caipiras (one floor and two floor) that are used to burn red bricks have significantly higher consumptions of 0.42-0.49 [t/t].. These values are higher than suggested from table 22, as the Paraguayan brick sector is not mixing internal fuel as e.g. sawdust into the raw material, which increases the fuel consumption between 10 and 15 percent. (SwissContact,2016, p. 22)

## 28.2 Albert kiln

Although many producers stated a roughly estimated fuel consumption, were only two able to show the specific amount of firewood bought and the quantity of finished goods produced over a year.

The first company bought in 2015 154 truckloads each containing 30 sters of firewood, which equals a yearly amount of 4.600 sters.

According to Unique a ster equals 0,7 $m^3$ of massive wood and the density of the common wood species equals 0,75 $t/m^3$. Considering this data, the yearly consumption of 4.600 sters equals 2.425 tons. By having multiplied the quantity of the different products produced in 2015 (e.g. hollow brick, roof tile, etc.) with the specific weight of each piece, the total yearly tonnage of 6.912 tons of finished ceramic products resulted. Dividing the tons of fuel consumed, by the produced tons of ceramics mentioned above, a specific wood consumption of 0,35 was calculated.

The same proceeding was used to calculate the specific wood consumption of the second company and resulted in a value of 0,39.

The similar Paulistinha kilns from Brazil, have according to table 24 wood consumptions of c. 0.24-0.38 tons of fresh wood per ton of bricks.

Still it has to be pointed out that the statistical relevance is not given with the amount of data gathered and that the assumptions made can significantly deviate from reality.

## 28.3 Tunnel kiln

At a meeting of the brick association the producers agreed to have a consumption of around 0,8 $m^3$ or in other words of 220 kg of loose saw dust and wood chip mixture per ton of finished ceramic products, which are considerably higher than shown in the documents of SwissContact, wherefore the range of 200 to 220 kg was used.

# 29 Interview: “Intermediary in an illegal value chain”

In order get additional insight in the illegal dynamics of the Paraguayan wood industry, was Lidio Zayas, the president of the “Asociación de Transportistas de Carga de la ciudad de Tobatí“ interviewed:

“There is a great concern about the “Zero Deforestation” Law issued by the INFONA in 2004, as various institutions and officials use it as a weapon of blackmail and for personal benefits, by doing arbitrary inspections on the major transportation routes.

The association has been created to participate actively in the process of change, but got never involved in it by the authorities, although the wood transporters are heavily affected.

The issue we have with the law is that it should regulate the hazardous situation of deforestation, but in reality is applied in another way: The legal text and the general logic says that the one who produces firewood and its by-products (e.g. charcoal) , is the one who should carry out the procedures to obtain the „guias” and hand it over to the trucker. In other words the producer should hand in his products of logs or charcoal with the „guia“ and therefore ensure a „smooth“ transfer. The trucker should in return, when offloading the cargo, transfer the guia to his client.

But this is a legal fiction and in reality works in this way, that neither the producer of wood or coal (e.g. peasant, land owner), neither the purchaser of firewood or coal (ceramics, olerias, factories,etc. ) are interested in obtaining „guias“ and leave the transporter in a legal dilemma.

There are two main reasons:

Firstly, that peasants or landowners often do not have the property certificate, which is one of the documents that requests the INFONA for the emission of „guias“, as the acquisition was not done in a legally proper way .
Secondly all institutions (INFONA, SEAM, NATIONAL POLICE, FOREST POLICE, etc.) only carry out their "control” of the guias or as we call it "fishing" on the transportation routes. That makes payments for guias an economic nonsense for the wood providers and consumers, as they never have to show them to authorities.

This makes the truckers the victims, of this, from the beginning illegal value chain, as only they need to pay the fines or in other words the blackmailing.

To "collaborate" with the "control authorities" (the representatives of these institutions) is crucial, if you don't want to be prosecuted for environmental crimes. Prosecution involves being detained and referred as the worst criminal, followed by a vehicle retention, seizure of the cargo and at last a fine and maybe a criminal record.

We really ask ourselves: Why don't they investigate the properties where the wood is cut? Why don't they visit each business and require them to display the documents of the products they are using?

I want to precise: Each trucker has to pay for each load of firewood or coal that comes to the cities of Tobatí, Itagua and Asunción, between two hundred and three hundred thousand Guaraníes of "black money ".There arises a forced question: how much are these "so-called authorities“ collecting per day?

Route No. 3,Gral. Elizardo Aquino, is "no man's land", where the authorities have their own law. Truckers have to get out of their vehicle dirty, sweaty and tired, at every police station to "collaborate ". If you do not stop at the police stations, you can not even advance for a thousand meters without being chased by the police to rebuke why you did not halt to pay your "collaboration" and that if you would continue "mess around" they will refer you to the prosecution. Furthermore there is a police station which makes detained people sit naked on top of an ant's nest and does other inhuman practices. Another example is to make truckers kneel down with his ear near the exhaust of a motorcycle and start to accelerate thoroughly, leaving them practically deaf for a moment.

In the city of Guajaybi, whoever tries to get a "permit" to drive through it, needs to pass through the police station to "collaborate" 200 000 Guarani . If not, one is in danger to lower once ears.As truckers, we are tired, and we ask ourselves as association: what does the National Police have to do with asking the display of administrative documents as the "guia" ? They are saying that it is the document of the load. But we answer again that that is what the control stations of the INFONA in the whole national territory are for. They should request the documents of the load and the "guias" for the transfer of firewood or Coal.If the INFONA would inspect the main transportation routes during the night, they would observe, that the streets are full of hidden police patrols, which get every coal or firewood transporter of the road, to receive their reward.

Since the issue of the "Zero deforestation law" virtually all the peasants and all workers handling forest by-products passed to the category of delinquents, due to the impossibility of complying with the law, without causing an economic disaster. Our authorities are experts in adopting to international requirements, but without taking into account the Paraguayan reality and especially if those requirements bring an economic benefit to the executioner of the law.As an association we ask the following questions:

How to enforce zero deforestation, if 85% (according to INFONA sources) of our industry depends on firewood and coal ? What do you do with the workforce, that lives of the production of firewood and charcoal? What do you do with the peasant families, which source of income is based on the sale of firewood and charcoal? What do we do with ACEPAR, the major steel producer and the other industries? These questions show that "the law of zero deforestation" is a fiction since there is no one that is able to comply with this law in a proper way.In our opinion, as the state does not even have a reforestation plan at the national level, this legal rule is difficult if not impossible to comply to.

As truck drivers, being aware of the lack of interest of the wood producers in managing the issuance of guias and that the truck drivers carry the full weight of the law, we tried to introduce several projects jointly with the Association of Ceramists of the city of Tobatí. One reforestation project was even presented to Itaipu, but could not be implemented because they demanded a percentage of the budget or in other words blackmailing, as a condition for approval of the project.

Nevertheless, it is the state through INFONA, that is in charge of ensuring a reforestation plan and not truck drivers and is the state that has the power to force the landowners to reforest the empty properties from which nobody benefits. There are thousands of hectares that are not useful for the owners, so why not enact a law that obliges landlords to cede obsolete portions so that trees can be planted? Furthemore, doing a good reforestation needs technical knowledge. So we ask ourselves, why are the engineers of INFONA clinging to their seats in their offices and are not going to carry out data collection, reforestation plans by zones and execute them?

We as association must underline that we come from the city of Tobatí, which is also known as the “City of Ceramics” and depends 100% economically of the ceramic industry. That means, the production of building materials (bricks, tiles, etc.) is the mainstay of the city's economy and really everything depends absolutely on this production. Even children depend on this to be able to go to schools. Tobatí is the "city that shelters the country", is the largest supplier of building materials nationwide. We dare say that 20% of the social housing built by the state are covered by Tobati-production. We know perfectly well, that the field of construction in the country is fundamental as a source of work and therefore it must be understood that the firing of the materials is made with firewood. The point we want to make is that Tobati-production has so much relevance in the national and local economy, but no state institution has come up with a program or reforestation plan and much less our departmental and local institutions, to insure that it can go on. Consequently, because of the laziness of the authorities, the people of Tobati must work like delinquents. The substitution of energies from the economic point of view is totally counterproductive because it "cuts the productive chain" and therefore source of work. That is to say, in the production of firewood or charcoal, the peasant, the tractor driver, the lumberjack, the wood carrier, the tire changing specialists, the places of sale and edible, ceramist or Oleros, etc. A whole chain of production and source of work is supported by this product. However, if we change by electric power; We eliminate the source of work of all these people we quote. So we firmly believe that the authorities must sit down and agree on a reforestation plan at the national level where all these agents of production are actively involved.

To sum it up, we are the first defendants in judicial proceedings, despite just being simple intermediaries in this value chain and therefore it is very urgent for us to find a mechanism in which we can participate actively in the reforestation of our country. As the law is applied currently, the massive deforestation is practically not reduced and the control agents are enriched (through the blackmailing), while we continue to prey for change. Taking into account all that we have discussed with regard to the problem of transporting forestal by-products, we believe that it is a valid alternative to move the creation of "forest tolls" throughout the national territory, since in this way we are going to "whiten" what we contribute by blackmailing.
The transporter contributes more than the needed, eg, the cost of a guia is approximately 1,000 guaraníes. However, today we are contributing two hundred to three hundred thousand guaraníes for "the dogs”, which change their car every year. We are sure that if we build these forest tolls we would facilitate a reforestation plan at the national level, that will be financed with the tolls we pay. We would not need external funding, but the reforestation must be done by the hundreds of engineers

which understand the matter. We also believe that it should be accompanied by a special law that obliges landowners who have unused land to be used for reforestation. All of this suggestions have been send to the INFONA and other authorities, but were never commented." (Lidio Zayas,2017)

## 30 Effects of climate change

Climate change is can be clearly felt as quantity of rainy days increases from year to year, making the clay extraction and brick manufacturing process increasingly challenging and demands better quality bricks that are not damaged by long term moist exposure. Important to note is that an increased precipitation leads to higher levels of the national rivers and to more frequent flooding's, making it even more important to control the maximal water absorption and chemical resistivity of ceramic products. The diagram below is showing the maximal (blue) and minimal (brown) water level of the Rio Paraguay.

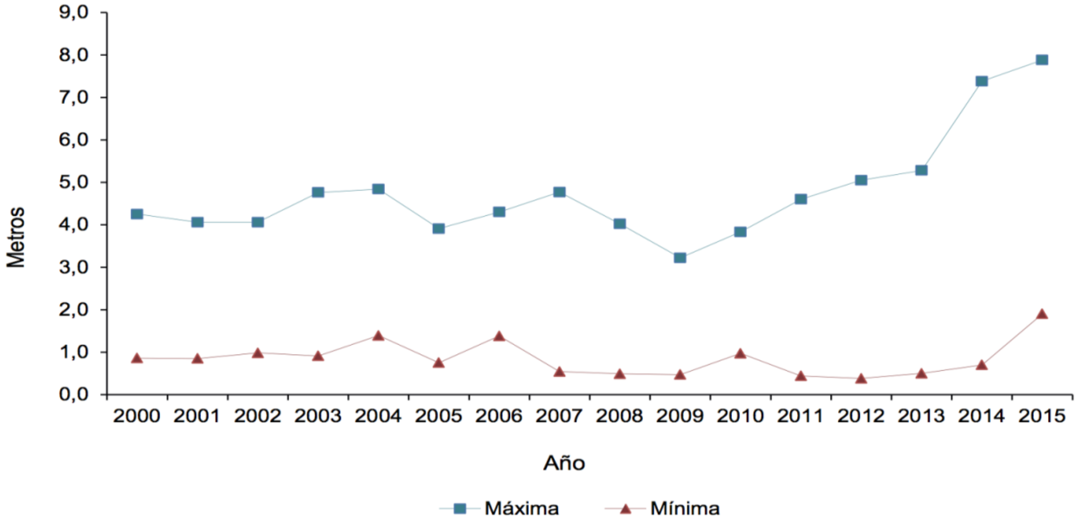


**Figure 61: Levels of the Rio Paraguay between 2000 and 2015**

Source: ( DGEEC, 2017, p.32)

# 31 Cost breakdown for different legal documents

## 31.1 Environmental impact assessment: Costs of consultation

| EXP. SEAM Nº | EMPRESA / PROPONENTE | JORNALES | MONTO Gs. | TOTAL |
|---|---|---|---|---|
| Presentación y Evaluación de EIAp | | 20 Jornales | 1.275.560 | |
| Presentación y Evaluación de EDEp | | 20 Jornales | 1.275.560 | |
| Términos de Referencia | | 5 Jornales | 318.890 | |
| Requiere de información (observaciones) | | 5 Jornales | 318.890 | |
| Orden de Publicación | | 5 Jornales | 318.890 | |
| Orden de Audiencia Publica | | 5 Jornales | 318.890 | |
| Aprobación de DIA (EDE y EIA) | | 5 Jornales | 318.890 | |
| Presentación de Informe de Avances | | 5 Jornales | 318.890 | |
| Presentación de Ampliación y Modificación del proyecto. | | 5 Jornales | 318.890 | |
| Aprobación de Ampliación y Modificación del proyecto. | | 5 Jornales | 318.890 | |
| Expedición de Certificados de Registro de Consultores (Persona Física y Jurídica) | | 20 Jornales | 1.275.560 | |
| Presentación de Auditoría Ambiental | | 5 Jornales | 318.890 | |
| Presentación de Informe de Avances | | 5 jornales | 318.890 | |
| Documentos Varios | | 1,5 Jornales | 95.667 | |
| Multas | | 1 Jornal | 63.778 | |
| TOTAL | | | | |

**Table 25: Working hours needed for the compilation of an EIA**

Source:(SEAM, 2013)

## 31.2 Social security payments

| SALARIOS A PARTIR DEL 1 DE JULIO 2017 | | | | | | |
|---|---|---|---|---|---|---|
| TIPO SEGURO EN SISTEMA SAOP | SALARIO MINIMO JUNIO-2017 | DIVIDIDO DIAS | APORTE | | | MONTO APORTE TOTAL |
| | | | TRABAJADORES 9% | PATRONES 16,5% | TOTAL 25,5% | |
| APRENDICES | 1.224.674 | 30 | 110.221 | 202.071 | 25,5 | **312.292** |
| ASCENDIENTES CONTRIBUTIVOS | 4.082.247 | 30 | - | - | 10,5 | **428.636** |
| CHOFER COBRADOR | 2.680.004 | 30 | 241.200 | 442.201 | 25,5 | **683.401** |
| COTIZANTE GENERAL | 2.041.123 | 30 | 183.701 | 336.785 | 25,5 | **520.486** |
| CHOFER DE OMNIBUS | 2.061.541 | 30 | 185.539 | 340.154 | 25,5 | **525.693** |
| CHOFER A. INCONSTITUCIONAL | 2.680.004 | 30 | 241.200 | 442.201 | 25,5 | **683.401** |
| JORNALERO O A DESTAJO | 1.413.090 | 18 | 127.178 | 233.160 | 25,5 | **360.338** |
| COTIZANTE ZAFRERO | 1.413.090 | 18 | 127.178 | 233.160 | 25,5 | **360.338** |
| ESTIBADOR MARITIMO | 785.050 | 10 | 70.655 | 129.533 | 25,5 | **200.188** |
| FISCALIA | 2.041.123 | 30 | - | - | 9,5 | **193.907** |
| FISCALIA JORNALERO | 1.413.090 | 18 | - | - | 9,5 | **134.244** |
| GANADERO TIPO A | 870.381 | 30 | 78.334 | 143.613 | 25,5 | **221.947** |
| GANADERO TIPO B | 1.196.608 | 30 | 107.695 | 197.440 | 25,5 | **305.135** |
| COBRADOR Y/O GUARDA | 2.041.123 | 30 | 183.701 | 336.785 | 25,5 | **520.486** |
| MENORES Y APRENDICES | 1.224.674 | 30 | 110.221 | 202.071 | 25,5 | **312.292** |
| SEGURO DOMESTICO | 1.224.674 | 30 | 110.221 | 202.071 | 25,5 | **312.292** |
| TRABAJADORES INDEPENTIENTES | 2.041.123 | 30 | - | - | 13 | **265.346** |
| OBSERVACIÓN: El cálculo del jornal se realiza en base al sistema SAOP | | | | | | |

**Table 26: Calculation of the mandatory social security payments**

Source:IPS,2017

## 31.3 Patente commercial payments in Tobatí

| Value of the assets in the balance sheet [G] | | Fixed payment [G] | Variable payment [%] |
|---|---|---|---|
| Minimum | Maximum | | |
| **0** | **1.000.000** | 13.800 | 0 |
| **1.000.000** | **3.000.000** | 13.800 | 0,85 |
| **3.000.000** | **6.000.000** | 34.200 | 0,8 |
| **6.000.000** | **30.000.000** | 58.200 | 0,55 |
| **30.000.000** | **60.000.000** | 190.200 | 0,4 |
| **60.000.000** | **300.000.000** | 310.200 | 0,28 |
| **300.000.000** | **600.000.000** | 982.200 | 0,22 |
| **600.000.000** | **1.800.000.000** | 1.642.200 | 0,2 |
| **1.800.000.000** | **3.000.000.000** | 4.042.200 | 0,18 |
| **3.000.000.000** | **6.000.000.000** | 6.202.200 | 0,15 |
| **6.000.000.000** | **9.000.000.000** | 10.702.200 | 0,13 |
| **9.000.000.000** | **12.000.000.000** | 14.602.200 | 0,1 |
| **12.000.000.000** | **15.000.000.000** | 17.602.200 | 0,08 |
| **15.000.000.000** | **>15.000.000.000** | 20.002.200 | 0,05 |

**Table 27: Payments for trade license in Tobati**
Source: Municipalidad de Tobatí, 2017

An example: If the kilns, the processing machines, the roof structure, and other brick making related facilities have a total worth of 50.000.000 Guarani or ~9.000 US$, the payments are:

982.000+50.000.000*0,0022= 1.092.000 or 200 US$

| Types of activities | Reduction factors: |
|---|---|
| **General industries** | 20% reduction of the resulting tribute has to be payed |
| **New industries** | for 5 years: a 40% reduction of the resulting tribute has to be payed |
| **New industrial activity** | for 5 years: a 40% reduction of the increased tribute has to be payed |

**Table 28: Reduced payment conditions**
Source: Municipality of Tobatí, 2017

# 32 Example of a productive clay mine

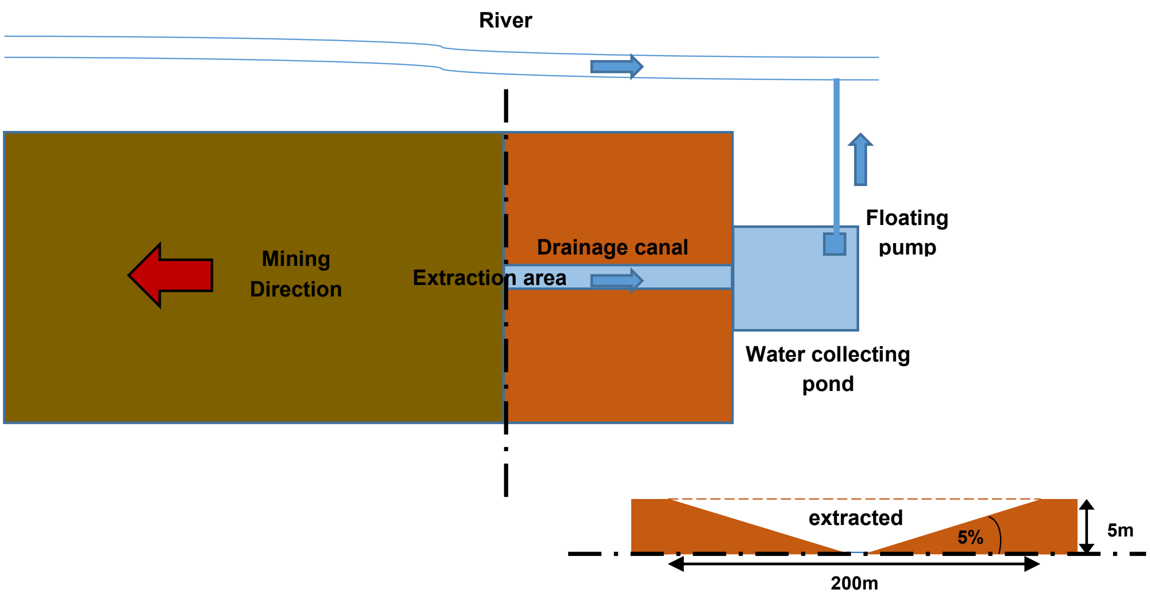


**Figure 62: Example of planned extraction**

To enable a good accessibility of the mining site and at the same time an adequate water removal, an inclination of 5 percent is suggested for the two access ramps (orange). This leads in case of a e.g. 5 meter thick deposits to a 200 meters long extraction face, assuring that multiple machines can dig and load simultaneously. The accruing water runs off in a drainage canal towards a collecting pond, in which the clay particles can sediment before a floating pump transports the cleaned water to the river. If the natural dip of the surface is not sufficient (normally into the flow direction of the river), the canal has also to be dug with an inclination of 5 percent.