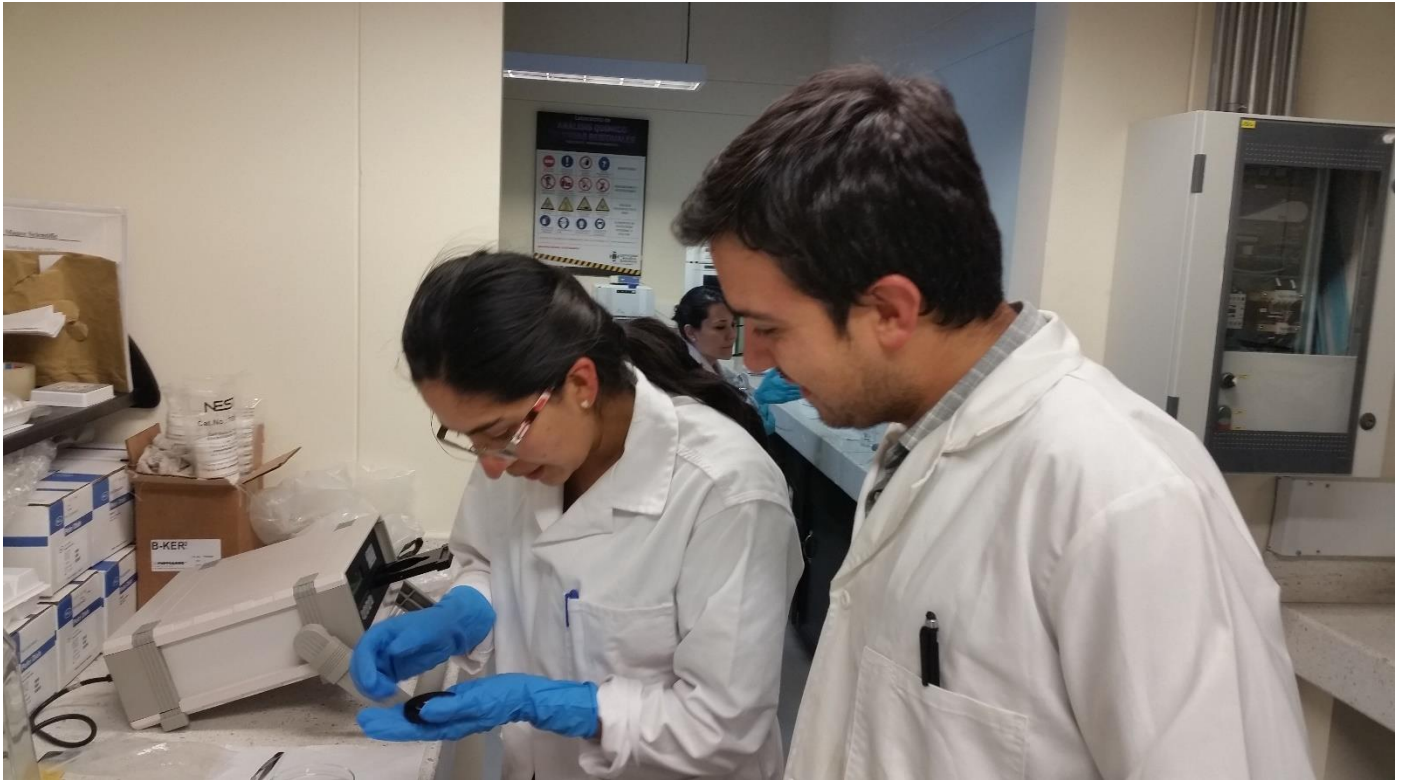


COMPREHENSIVE ANALYSIS OF EIGHT (8) MEASUREMENTS OF EMISSIONS INCLUDING (BC)  
CONDUCTED ACROSS 8 REGIONS IN COLOMBIA ON DIFFERENT TYPES OF BRICK KILNS IN A  
LABORATORY: DTIE-16EN025



Participants: Climate and Clean Air Coalition (CCAC), Entrepreneurial Environmental Corporation (CAEM), Ministry of Environment and Sustainable Development - Republic of Colombia, Bolivarian Pontifical University Bucaramanga city.

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## INTRODUCTION

The present report details a comprehensive analysis in which data and relevant results are collected for (8) measurements of black carbon carried out during 2017, in 8 regions of the country in reference to the implementation plan, in the framework of the small-scale contract (SSFA for its acronym in English) signed between the United Nations Environment Program and the Corporate Environmental Corporation (CAEM).

However, it is important to mention that CAEM, managed to leverage additional measurements with the support of Swisscontact Peru and the project NAMA industry, that is currently being implemented in Colombia; These measures were made with the objective to determine the black carbon emission factors in different types of fuels and technologies, in addition to continuing to consolidate the measurement as an indicator of energy efficiency, which validate the technological implementations carried out by the Colombian brick industry and promote the improvement continues in the productive process, this in order to establish mitigation measures for the sector; and generate strategies at the level of public policies that allow the mobilization of actors that seek to reduce emissions of short-lived climate pollutants that benefit and directly impact on public health issues.

In addition, as annexes to the present report, the data sheets taken in the field are attached, the laboratory analyzes in each of the measurements corresponding to the filters used in the equipment, which are the fuel samples that were taken in each one of them. the brickworks object of measurement, in Figure 1 the laboratory analyzes required for the processing of the information and the obtaining of the emission factors according to the balance of the mass carried out are observed.

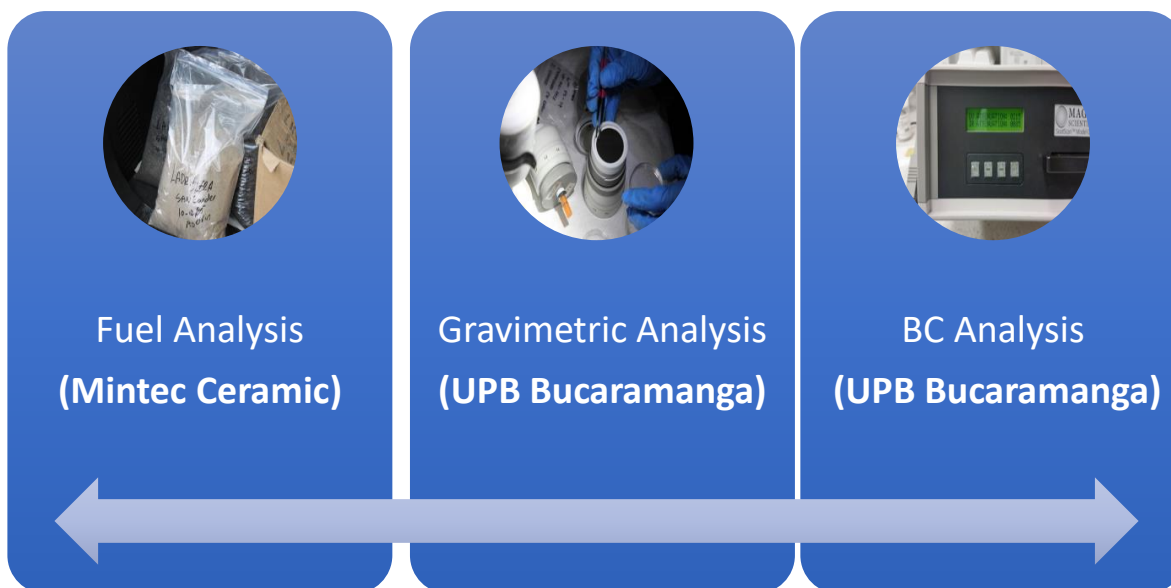


Figure 1. Required lab analysis.

The analyzes of the two filters, both PM2.5 and black carbon, were conducted in the Laboratory of the Environmental Research Group-GIA of the Universidad Pontificia Bolivariana de Bucaramanga, which has an instrument for the quantification of black carbon in filters of air

quality and following its internal procedures; Similarly, the fuel analyzes were performed by a subcontracted laboratory for this purpose.

## GENERALS OF THE SMALL SCALE FUNDING AGREEMENT - Number: DTIE-16EN025

**Ally:** Clean Air and Climate Coalition to reduce short-lived climate pollutants. (CCAC). Initiative by the governments of Bangladesh, Canada, Ghana, Mexico, Sweden, United States, and the United Nations Environment Program (UNEP) to reduce this type of pollutants.

**Subprogram:** Climate Change

**Initiative:** Brick Initiative

**Scope:** Carry out Black Carbon measurements in 8 regions of Colombia, in different technological models that allow us to estimate approximate data on the quantification of the amount of black carbon emitted by the national brick industry.

**Value:** 112,126 USD

**Duration:** 2016 - 2018

### INITIATIVES



#### 1 IMPACT SMALL SCALE FUNDING AGREEMENT (SSFA) DTIE-16EN025

Within the framework of the SMALL SCALE FUNDING AGREEMENT (SSFA) - Reference Name: DTIE-16EN025 signed between THE UNITED NATIONS ENVIRONMENT PROGRAM (UNEP) and the Corporative Environmental Corporation - CAEM, the purpose of this agreement is:

- To Carry out Black Carbon sampling in 8 regions of Colombia, in 8 technological models used by the Colombian brick industry.
- Perform training for the use of the black carbon sampling instrument developed by CLIAMA.

- c) Train local laboratories, brick producers, the academic sectors and those involved in general in the methodology for sampling black carbon and the initiative for the brick industry of the Clean Air and Climate Coalition- CCAC.

## COMPREHENSIVE ANALYSIS OF MEASUREMENTS PERFORMED IN SEVERAL COLOMBIAN REGIONS.

As mentioned in a former report, during year 2017 and after training and capacity strengthening, CAEM performed 17 monitoring activities with the use of a Ratnoze2 equipment in relation to Black Carbon in ten (10) regions of this country, keeping in mind that provinces Cundinamarca, Norte de Santander and Cauca were object of measurement during 2016. Figure 2 shows those regions in green and the other regions are presented in blue.

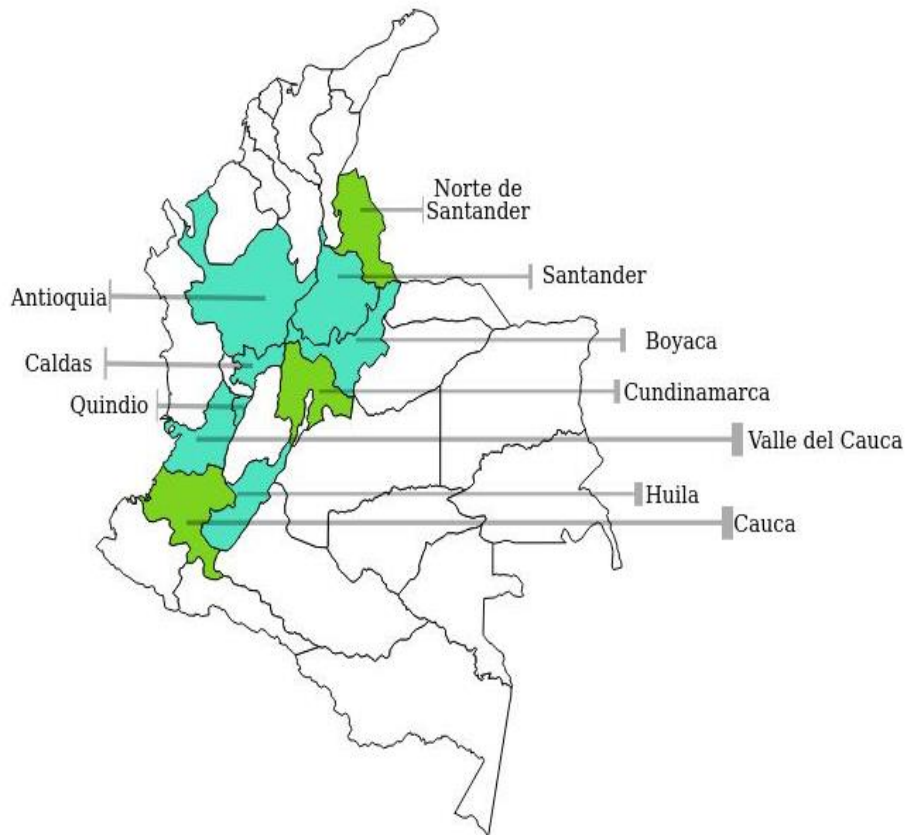


Figure 2. Regions that were measured during years 2016 and 2017.

Table 1. Regions that were measured during year 2017

Year	Measured regions with Ratnoze 2	Monitoring activities		
		2016	2017	Percentage
2016-2017	Cundinamarca	4	5	38%
2017	Antioquia	0	3	13%
2016	Cauca	1	0	4%
2017	Valle del Cauca	0	2	8%
2017	Santander	0	1	4%
2016-2017	Norte de Santander	2	1	13%
2017	Boyacá	0	1	4%
2017	Caldas	0	1	4%
2017	Huila	0	1	4%
2017	Quindío	0	2	8%
<b>Total monitoring activities</b>		<b>7</b>	<b>17</b>	<b>100%</b>

Table 1 shows the percentage distribution of measurements carried out during 2016 and 2017 according to regions. Highest amount of monitoring activities were focused in Cundinamarca (38%). This is due to its closeness to Bogota Capital City, and diversity of brickmaking technological models. Next provinces were Antioquia and Norte de Santander (13%), Valle del Cauca and Quindío (8%), and lastly, there was only one (1) monitoring activity performed in Provinces Cauca, Santander, Boyacá, Caldas and Huila, representing 4%.

Those monitoring activities had the aim not only determining emission factors according to technology applied (artisanal, intermittent or continuous); but moreover, another goal was to validate ways to assess combustion processes in kilns. Variables such as CO, CO<sub>2</sub> and output chimney gas temperatures, which are deemed as indicators allowing to assess a combustion process in this type of kilns. Such results would serve brickmaking entrepreneurs to implement, include activities, corrections and / or modifications to improve their processes.

Table 2 shows dates and activities performed within the frame of the Small Scale Agreement.

Table 2. Schedules and monitoring activities performed during year 2017.

Date	Province or Department	Measurement Place	Filters Used		Monitoring Measurement Days	Filters Total
			BC	Grav		
April 25 <sup>th</sup> to 27 <sup>th</sup> , 2017	Cundinamarca	La Despensa	5	5	3	10
May 3 <sup>rd</sup> to 5 <sup>th</sup> , 2017	Boyaca	El sol	3	3	3	6

Date	Province or Department	Measurement Place	Filters Used		Monitoring	Filters
May 10 <sup>th</sup> to 12 <sup>th</sup> , 2017	Cundinamarca	Santander	4	4	3	8
May 16 <sup>th</sup> to 17 <sup>th</sup> 2017	Quindío	Arcillas La Campana	2	2	2	4
June 06 <sup>th</sup> to 07 <sup>th</sup> 2017	Quindío	Arcillas la campana (2)	1	1	2	2
June 8 <sup>th</sup> to 9 <sup>th</sup> 2017	V. Cauca	Bellavista	2	2	2	4
June 22 <sup>nd</sup> to 24 <sup>th</sup> 2017	Antioquia	San Cristóbal	1	1	1	2
July 17 <sup>th</sup> to 19 <sup>th</sup> 2017	Santander	Ladrillera el Diamante	2	2	2	4
July 24 <sup>th</sup> to 26 <sup>th</sup> 2017	N. de Santander	Ladrillera Tejar de Pescadero	5	5	3	10
August 14 <sup>th</sup> to 16 <sup>th</sup> 2017	Antioquia	Ladrillera el Noral	2	2	2	4
August 17 <sup>th</sup> to 18 <sup>th</sup> 2017	Antioquia	Ladrillera San Cristóbal(Itagüi)	1	1	1	2
August 29 <sup>th</sup> to 31 <sup>st</sup> 2017	Caldas	Ladrillera Tecnigrés	2	2	2	4
September 19 <sup>th</sup> to 21 <sup>st</sup> , 2017	V. Cauca	Ladrillera Mariscal	2	2	3	4
September 26 <sup>th</sup> to 27 <sup>th</sup> , 2017	Cundinamarca	Despensa	1	1	2	2
October 3 <sup>rd</sup> to 4 <sup>th</sup> , 2017	Cundinamarca	Trébol	1	1	2	2
October 11 <sup>th</sup> to 13 <sup>th</sup> , 2017	Huila	Ladrillera Manzanares	2	2	3	4
November 22 <sup>nd</sup> to 24 <sup>th</sup> , 2017	Cundinamarca	Ladrillera la Fe associated to NAMA Project.	3	3	3	6

The chart above shows monitoring dates, brickmaking industry names, location, and number of total filters used per monitoring activity. It would be important to mention that for some measurements, it was possible to cut or reduce sampling times due to the way of kiln work. Moreover, in technical cooperation with the NAMA INDUSTRY Project, experimental measurements were taken, which main purposes were as follows: To Validate the use and quantify Black Carbon emissions in technological continuous brickmaking models which were operated with biomass as a fuel, and establish differences in behaviors of two (2) fuels: mineral coal and biomass under equal operative conditions in the same techno brickmaking model: Continuous Chamber Kiln. This was with the goal to establish a measure in Black Carbon reduction. Additionally, the idea was to continue supplying technical information to support certain legal measures to be taken in the NDC Sector, which are led by the Ministry of Environment and Sustainable Development and the Ministry of Industry and Trade. The final goal

of such legal measures would be the overhauling or reconversion of artisanal brickmaking kilns into continuous chamber ones.

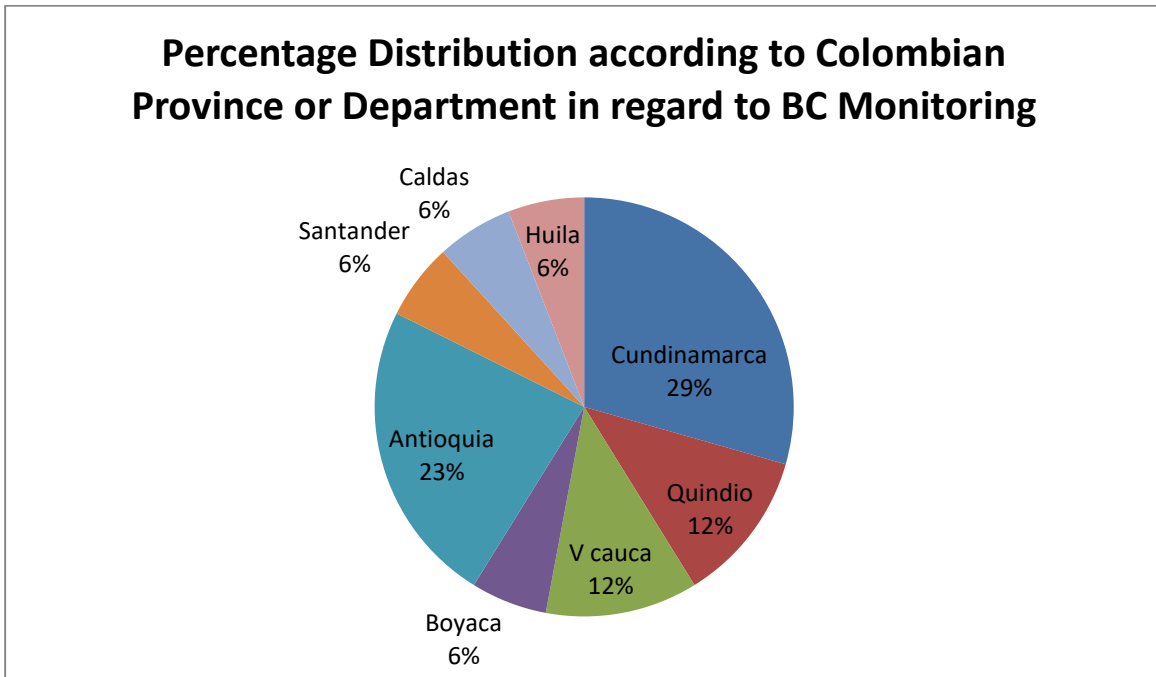


Chart 1. Distribution Percentages of BC Measurements in Provinces.

In Chart 1 it is possible to see the percentage distribution according to Province or Department corresponding to 17 monitoring activities that were performed. The biggest amount of monitoring activities was carried out in Cundinamarca (29%), due to the fact that this Province is the biggest brick and clay items producer in Colombia, and also, because it has availability of several techno models that were possible to measure. The next province was Antioquia (23%), since it has continuous brickmaking models using other fuel types, such as natural gas and / or coffee litter. They are special interest with the goal of establishing a comparison between resulting chimney emissions during productive processes operating with mineral coal and biomass.

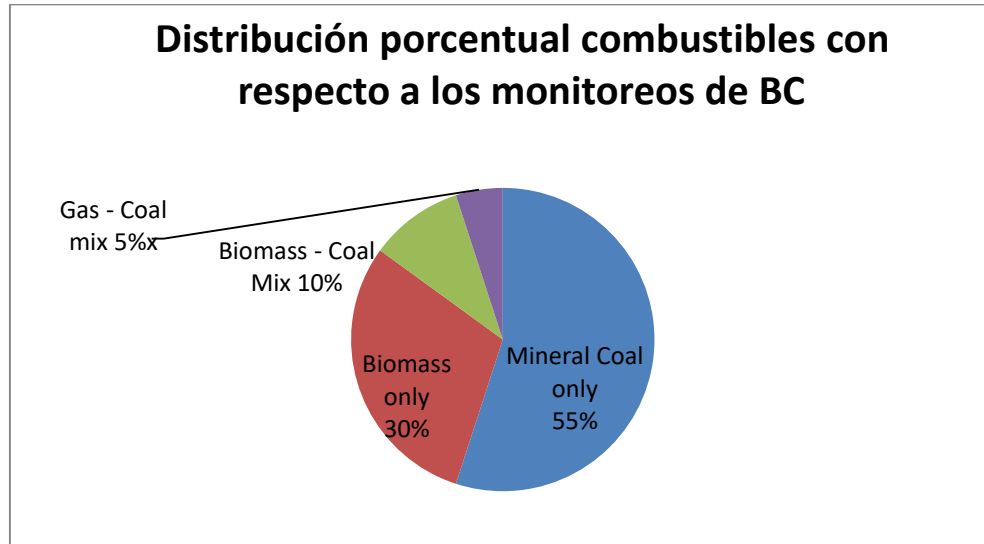


Chart 2. Percentage distribution of fuels used in brickmaking kilns in regard to BC Monitoring

Chart 2 shows percentage distribution corresponding to monitoring activities and focus in regard to fuels used in brickmaking kilns. In 55% of the cases, the most widely used fuel has been mineral coal, followed by 30% biomass, mainly composed by coffee litter, Guadua wood and general wood, and 10% mixtures of biomass and mineral coal and 5% mixtures of natural gas and coal.

Table 3 shows the monitoring technological models and fuels used in the companies that were measured during year 2017.

Table 2. List of Technologies that were Measured.

N°	Technology	Kiln Type	Fuel	Year
1	Art-craft	Sleepy fire	Mineral Coal	2017
2	Art-craft	Sleepy fire	Mineral Coal	2017
3	Intermittent	Pampa	Coffee litter / wood	2017
4	Intermittent	Modified Pampa	Coffee litter/Guadua wood	2017
5	Intermittent	Modified Pampa	Guadua wood	2017
6	Intermittent	Domewith dosage device	Mineral Coal	2017
7	Intermittent	Domewith dosage device	Mineral Coal	2017
8	Intermittent	Wagon	Coffee litter	2017
9	Continuous	Zigzag	Mineral Coal	2017
10	Continuous	Continuous Chambers	Coal/ Coffee litter /mix	2017
11	Continuous	Hoffman	Coal (80%)- Sawdust (20%)	2017
12	Continuous	Hoffman	Coffee litter	2017

13	Continuous	Hoffman	Mineral Coal	2017
14	Continuous	Hoffman	Mineral Coal	2017
15	Continuous	Tunnel	Gas (87%)- Coal (13%)	2017
16	Continuous	Tunnel	Mineral Coal	2017
17	Continuous	Tunnel	Mineral Coal	2017

Based on the Table above, next we have results of monitoring activities in each of those brickmaking companies in relation to fuel analysis, energetic efficiency, pollutant measures, black carbon emission rates, PM2.5, and results of emission factors and rates of pollutant gases CO, CO2 y SO2.

## Result Presentation from Monitored Artisanal Kilns 2017

### 4.1 Artisanal kiln. La Despensa brickmaking company. First monitoring 2017

This section shows results of the first monitoring activity in a sleepy fire brickmaking kiln. It is located in Nemocón town, Vereda La Ruidosa. It uses mineral coal as a fuel and the features are as follows:

KILN INFORMATION			
Kiln Type	Artisanal		
Kiln Capacity	80,000 units	Burning "cooking" time	or 20 days
Fuel Consumption during Burning	14 coal tons.		



Sleepy Fire Kiln

### Fuel Analysis

These analyses were performed by Mintec Ceramic Ltd Company. This is a specialized laboratory in technical advice for the ceramic industries. Two fuel analyses were carried out: Proximal and Ultimate Analyses. Table 4 shows results attained.

Table 3. Proximal Analysis of La Despensa Brickmaking fuel.

Parameter	Coal	Units	Ideal Parameter
Residual moisture	1.14	% mass	< 3%
Ashes	11.44	% mass	< 10%
Volatiles	33.61	% mass	>30%
Fixed Carbon	53.81	% mass	
Total Sulphur	0.75	% mass	< 1%
Heat Power	7.483	Kcal/kg	> 6500 Kcal/kg
Heat Power	13.460	BTU/pound	
Heat Power	31.33	MJ/kg	
Swelling Index	0	FSI	

Table 4. Ultimate Fuel Analysis

Parameter	Coal	Unit
Carbon	55.43	% mass
Hydrogen	4.82	% mass
Oxygen	4.97	% mass
Nitrogen	1.72	% mass

As evidenced from the above Tables, mineral coal used in La Despensa Brickmaking Company has a good quality. However, its ashes are high content, which decreases heat power during kiln combustion. In regard to the rest of criteria or parameters, this fuel has ideal indexes.

### Energetic Efficiency

This parameter is also understood as Specific Energy Consumption (SEC). This was determined through two (2) process variables: fuel consumption with its lab analysis and final bricks produced. The following Table shows process variables, Specific Energy Consumption (SEC) at the moment of data taking with an uncertainty ( $\sigma$ ) estimated through a statistic confidence interval of 68%.

Table 5. Specific Energy Consumption (SEC)

Measurement	Brick Production (kg/hr)		Fuel Consumption (kg/hr)		Energy Consumption (MJ/hr)		SEC (MJ/ brick kg)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
Event 1	354.86	39.68	30.21	3.38	913.20	280.44	2.57	0.84
Event 2	354.86	39.68	30.21	3.38	913.20	280.44	2.57	0.84
Event 3	354.86	39.68	30.21	3.38	913.20	280.44	2.57	0.84
Event 4	354.86	39.68	30.21	3.38	913.20	280.44	2.57	0.84
Event 5	354.86	39.68	30.21	3.38	913.20	280.44	2.57	0.84

It would be worth to mention that for events 1 to 5 results are the same, this is due to the fact that the artisanal kiln working principles consists of keeping a fixed mass of products (bricks), with an alternated fixed fuel load. Therefore, during the cooking or burning process no fuel or more bricks are added. In this way, heat ascends from bottom to top of the kiln. Such a process takes from 15 to 20 days. Thus, it is deemed as highly inefficient.

### Pollutant Analyses

Results of pollutant emission measurements ((CO<sub>2</sub>, CO, SO<sub>2</sub>, PM<sub>2.5</sub> and BC) are presented herein, which are divided into pollutant gases (CO<sub>2</sub>, CO, SO<sub>2</sub>) out of fractions of particulate material (PM<sub>2.5</sub> and BC), since their nature and measurement manner are different. Data presented are: emission rates (pollutant mass flow), and emission ratios according to brick production. In all of the cases an average value of measurement is presented with respective statistical uncertainty ( $\sigma$ ) estimated with a confidence interval of 68%.

The following Tables show results of emission rates (mass flows) of particulate materials PM2.5 and Black Carbon (BC), for each of the measurement activities on an artisanalkiln. By the end of the Table, averages are presented.

Table 6. Emission Rates of PM2.5 and BC in an Artisanal brickmaking Kiln

Measurement	ERPM2.5		ERBC	
	Average	$\sigma$	Average	$\sigma$
Event 1	53.158	22.16	0.5489	0.24
Event 2	73.213	30.46	0.2751	0.11
Event 3	107.567	44.17	0.5466	0.25
Event 4	25.668	10.66	0.1769	0.07
Event 5	135.600	56.41	0.8904	0.39
<b>Average</b>	<b>79.04 g/hr</b>	<b>32.89</b>	<b>0.47</b>	<b>0.22</b>

Next we have attained results in regard to emission factors based on fuel mass consumption, consumed energy and final brick production for PM2.5 and BC according to performed measurements. It is important to note that these data are punctual and extrapolation should be done with caution or deepen in such type of research work.

Table 7. Emission Factors in a brickmaking artisanalkiln

Measurement	EFBCfuel (g/Kg_fuel)		EFBCenergy (g/MJ)		EFBCbrick (g/kg_brick)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
Event 1	0.01817083	0.0029	0.0006	0.0002	0.0015	0.000501
Event 2	0.0090212	0.0014	0.0003	0.0001	0.0008	0.000246
Event 3	0.01809741	0.0036	0.0006	0.0002	0.0015	0.000532
Event 4	0.00585806	0.0008	0.0002	0.0001	0.0005	0.000157
Event 5	0.02947732	0.0046	0.0010	0.0003	0.0025	0.000803
<b>Average</b>	<b>0.01612</b>	<b>0.002680</b>	<b>0.0005</b>	<b>0.0002</b>	<b>0.0014</b>	<b>0.0005</b>

**Pollutant Gas Analyses.**

Next, results are presented on emission rates (mass flows) of pollutant gases CO, CO2 and SO2, For each of the measuring activities performed.

Table 8. Emission Rates in Pollutant Gases

Measurement	ERCO		ERCO <sub>2</sub>		ERSO <sub>2</sub>	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
Event 1	9782.38	4097.72	43774.99	18382.74	237.00	111.83
Event 2	7992.84	3332.10	46586.76	19424.72	141.99	60.21
Event 3	13808.60	5755.26	37448.89	15630	121.23	54.32
Event 4	13344.27	5558.54	38178.46	15915.77	73.34	32.89
Event 5	11141.98	4643.32	41638.76	17363.34	74.88	33.65
Average	11214.02	4677.39	41525.57	17343.34	129.69	58.58

The following Tables show results of emission factors for polluting gases CO<sub>2</sub>, CO and SO<sub>2</sub> BASED on fuel mass consumption, consumed energy and final brick production respectively. For five (5) measurement activities performed during kiln monitoring, likewise for each and all of the results attained, it is important to keep in mind that these data sets are punctual, and extrapolation shall be carried out with caution.

Table 9. Pollutant Gas Emission Factors in an Artisanal kiln

Measurement	EFCOfuel (g/kg_fuel)		EFCO <sub>2</sub> fuel (g/kg_fuel)		EFSO <sub>2</sub> fuel (g/kg_fuel)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
Event 1	323.83	25.43	1449.10	121.65	7.85	1.81
Event 2	264.59	17.74	1542.18	104.07	4.70	0.48
Event 3	457.11	30.36	1239.69	86.77	4.01	0.71
Event 4	441.74	28.67	1263.84	84.66	2.43	0.43
Event 5	368.84	24.39	1378.39	93.37	2.48	0.45
Average	371.22	25.32	1374.64	98.10	4.29	0.78

Based on the table above, it was found that the average emission rates in the artisanalkiln in relation to CO and CO<sub>2</sub> are high. This would validate combustion inefficiency. Additionally, it would be worth to mention that this study is different to the one executed in year 2016 due to the fact that organic carbon was not taken into account, and it was priority during the training period. The reason was that this was important for the Illinois University researchers via a thermal - optic method. In the Colombian case, such organic carbon was analyzed and detected through an optical only method.

The following charts show emission factors obtained by energy units and produced final brick units. It is important that in this technological model (artisanalkiln), clay mass entered and fuel masses were fixed. Therefore, variability could have been present associated to generated gas emissions. Thus, in events 2 and 4 (carried out during the night), there was a reduction in emissions, and this might be due to the general climate temperature drops at those hours in the area where the kiln is located.

Table 10. Emission Factors according to ENERGY consumption in an ArtisanalKiln

Measurement	EFCOenergy (g/MJ)		EFCO2energy (g/MJ)		EFSO2energy (g/MJ)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
Event 1	10.71	3.18	47.94	14.29	0.26	0.0954
Event 2	8.75	2.57	51.01	14.99	0.16	0.0472
Event 3	15.12	4.44	41.01	12.08	0.13	0.0447
Event 4	14.61	4.29	41.81	12.28	0.08	0.0271
Event 5	12.20	3.51	45.60	13.14	0.08	0.0273
Average	12.28	3.60	45.47	13.35	0.14	0.0483

Table 11. Emission Factors according to FINAL BRICK Units Produced in an ArtisanalKiln

Measurement	EFCObrick (g/kg_brick)		EFCO2brick (g/kg_brick)		EFSO2brick (g/kg_brick)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
Event 1	27.57	8.03	123.36	36.10	0.67	0.24
Event 2	22.52	6.49	131.28	37.86	0.40	0.12
Event 3	38.91	11.21	105.53	30.49	0.34	0.11
Event 4	37.60	10.82	107.59	31.01	0.21	0.07
Event 5	31.40	9.04	117.34	33.84	0.21	0.07
Average	31.60	9.12	117.02	33.86	0.37	0.12


Next, the second monitoring activity results are presented, which was carried out on a “sleepy fire” artisanalkiln, BUT in a different burning or “cooking” stage. In this occasion, the emission measurements were performed at the start of burning in the kiln.

#### 4.2 Artisanal Kiln. “La Despensa” Brickmaking company. Second Monitoring activity. Year 2017.

With the aim of obtaining gas emission factors in this technology type, and given long burning periods, three (3) monitoring activities were performed. 1 was executed during year 2016, in which the kiln was finishing burning period. 2<sup>nd</sup> was executed in year 2017, when the kiln was in the middle of burning period; and final 3<sup>rd</sup> monitoring, when the kiln was starting burning stage. In this way, it was possible to attain a kiln burning profile in relation to emission behavior.

#### THIRD MONITORING ACTIVITY INFORMATION.

Kiln Type	Artisanal
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<b>Kiln Capacity</b>	60,000 units	<b>Burning Time</b>	20 days
<b>Fuel Consumption during Burning</b>		12 tons of mineral coal	
			
<b>Sleepy Fire Kiln</b>			

In this third measurement, due to the fact that this kiln was starting burning stage, emissions were very low, so it was deemed necessary to do a 28 hour measurement. Results attained are presented as follows:

### Fuel Analysis

Since the mineral coal had the same origin, same criteria and parameters were assessed in relation to the proximal fuel analysis as above mentioned.

Table 12. Proximal Analysis of Fuel in an Artisanal Kiln

Parameter	Coal	Units	Ideal Parameter
Residual Moisture	1.14	% mass	< 3%
Ashes	11.44	% mass	< 10%
Volatiles	33.61	% mass	>30%
Fixed Carbon	53.81	% mass	
Total Sulphur	0.75	% mass	< 1%
Heat Power	7.483	Kcal/kg	> 6500 Kcal/kg
Heat Power	13.460	BTU/pound	
Heat Power	31.33	MJ/kg	
Swelling index	0	FSI	

The fuel used in this occasion had a higher mass amount compared to the former fuel analyzed. This reflects the fuel quality and a higher heat power.

Table 13. Ultimate Fuel Analysis for an Artisanalkiln

Parameter	Coal	Unit
Carbon	75.44	% mass
Hydrogen	5.70	% mass
Oxygen	5.04	% mass
Nitrogen	1.46	% mass

### Energetic Efficiency

Energetic efficiency parameter named as “Specific Fuel Consumption” (SEC), was determined through two process variables: fuel consumption with respective lab analysis, and final brick units produced. The following Table shows those process variables and Specific Fuel Consumption (SEC) for the moment of data monitoring with an uncertainty ( $\sigma$ ) estimated within the confidence interval of 68%.

Table 14. Specific Energy Consumption (SEC)

Measurement	Bricks Produced (kg/hr)		Fuel Consumption (kg/hr)		Energy Consumption (MJ/hr)		SEC (MJ/kg_brick)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
Event 22	267.50	29.90	25.00	2.80	755.25	227.71	2.82	0.91

This kiln working principle consists of keeping a fixed product mass (bricks), with an alternated fixed fuel mass. During the whole cooking process neither fuel nor bricks are added. In this way, heat ascends from bottom to top of the kiln until reaching the upper position. Such a process takes around 15 to 20 days. It is deemed as highly inefficient. In the monitoring case, a continuous measurement was carried out.

### Pollutant Analysis

Results of gas pollutant analyses (CO<sub>2</sub>, CO, SO<sub>2</sub>, PM<sub>2.5</sub> and BC) are presented in this section. They are divided into pollutant gases (CO<sub>2</sub>, CO, SO<sub>2</sub>) coming out from particulate materials PM<sub>2.5</sub> and BC, since their nature and measurement ways are different. Tables below show emission rates (polluting mass flow), and emission ratios (punctual emission factors), according to consumed fuel amounts, consumed energy and final brick units or kilograms produced. In all cases, measurement averages are presented and their respective uncertainties ( $\sigma$ ), which were estimated within a 68% confidence interval.

## Black Carbon and PM2.5

The following Table shows results on emission rates (mass flows) of particulate materials PM2.5 and Black Carbon (BC), for the monitoring and measurements carried out in the above mentioned kiln. Results attained are presented below.

Table 15. PM2.5 and BC emission rates in an ArtisanalKiln

Measurement	ERPM2.5		ERBC	
	Average	$\sigma$	Average	$\sigma$
Event 22	0.000	0.31	0.1324	0.05

Based on the above, if we compare to the first measurement in the same kiln, there's evidence that during the first cooking stages, particulate material emissions into the atmosphere would be zero, similar to Black Carbon, where emissions, although present, were deemed as negligible.

Next, emission factors for the same artisanalkiln are presented with mass fuel consumption basis, consumed energy and final cooked bricks produced in relation to PM2.5 and Black Carbon. It is important to mention that these data are punctual, and extrapolation should be done with caution or deepen this research study with more data.

Table 16. Emission Factor in an ArtisanalKiln

Measurement	EFBCfuel (g/Kg_fuel)		EFBCenergy (g/MJ)		EFBCbrick (g/kg_brick)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventC22	0.0053	0.0005	0.0016	0.0005	0.0005	0.0001

## Pollutant Gas Analysis

Next, results on emission rates (mass flows) are presented in relation to pollutant gases CO, CO2 and SO2, for each of the carried out measurements.

Table 17. Polluting Gas Emission Rates

Measurement	ERCO(gr/hr)		ERCO <sub>2</sub> (gr/hr)		ERSO <sub>2</sub> (gr/hr)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
Event 22	1804,91	763,78	66275,52	27767,61	0,0000	23,81

The Tables that follow show results on emission factors for polluting gases CO<sub>2</sub>, CO and SO<sub>2</sub> based on fuel mass consumption, energy consumption and final bricks produced respectively. These apply for the monitoring activities carried out in the mentioned kiln. Moreover, it is important to mention that these data are punctual and extrapolation should be performed with caution.

Table 18. Polluting Gas Emission Factors in an Artisanal Kiln

Measurement	EFCOfuel (g/kg_fuel)		EFCO <sub>2</sub> fuel (g/kg_fuel)		EFSO <sub>2</sub> fuel (g/kg_fuel)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
Event 22	72,19	7,13	2651,02	209,37	0,0000	0,95

Table 19. Emission Factors According to Energy Consumption in an Artisanal Kiln

Measurement	EFCOenergy (g/MJ)		EFCO <sub>2</sub> energy (g/MJ)		EFSO <sub>2</sub> energy (g/MJ)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
Event 22	2.39	0.71	87.75	25.53	0.00	0.03

Table 20. Emission Factors according to Final Brick Unit Production


Measurement	EFCObrick (g/kg_brick)		EFCO <sub>2</sub> brick (g/kg_brick)		EFSO <sub>2</sub> brick (g/kg_brick)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
Event 22	6,74	2,00	247,75	72,13	0,0000	0,09

## Presentation on Monitoring Activities in Intermittent Kilns

2017

### 4.3 Pampa Intermittent Kiln. “Manzanares” Brickmaking Company. - Monitoring 2017

This is the information of a pampa type kiln operated with coffee litter as a fuel. It is located in Huila Province, Campoalegre Municipality. For this monitoring, and given short burning time - approximately 22 to 24 hours - the choice was to make a continuous measurement procedure and have the whole kiln burning profile.

KILN INFORMATION			
Fuel Type	Coffee Litter	Coming From	Neiva city, Threshing Co.
Fuel Feeding procedure	Manual	Amount per ton	COP 170,000
Wood used for “caldeo” (start burning or heat up)			170 Kg
Fuel Consumption (Coffee Litter) during this measurement			393.0 Kg
Total fuel used			10 Tons
			
Pampa Type Kiln. (Coffee litter (right) and wood (left) as a burning heat up)			

## Fuel Analysis

Fuel Analyses were carried out by Mintec Ceramic Ltd Co. This is a specialized lab in technical assistance for the ceramic sector. Two analyses were carried out: Proximal and Ultimate. Results are presented in the following Table in relation to coffee litter, given this is the most widely fuel used as it is received in the kiln premises (CSR).

Table 21. Proximal Analysis of Coffee Litter Fuel for a Pampa Type Kiln

Parameter	Coffee Litter	Units	Ideal Parameter
Residual Moisture	8.40	% mass	< 3%
Ashes	5.89	% mass	< 10%
Volatiles	70.08	% mass	>30%
Fixed Carbon	15.63	% mass	
Total Sulphur	0.10	% mass	< 1%
Heat Power	3.720	Kcal/kg	> 6500 Kcal/kg
Heat Power	6.692	BTU/pound	
Heat Power	15.58	MJ/kg	
Swelling Index	0	FSI	

Dry basis analysis for coffee litter showed the following results:

Table 22. Ultimate Fuel Analysis

Parameter	Coffee Litter	Unit
Carbon	46.07	% mass
Hydrogen	3.98	% mass
Oxygen	43.01	% mass
Nitrogen	0.40	% mass

Based on the information above, coffee litter presents a high residual moisture and high volatile percentage with a low heat power, approximately half if compared with mineral coal. Therefore, due to low heat power, this coffee litter must be injected in a higher amount in order to rise and keep the necessary heat and temperature atmosphere necessary to reach the Synterization or “cooking” point for turning clay into bricks.

### Energy Efficiency

This parameter, named as Specific Fuel Consumption (SEC) was determined through two process variables: fuel consumption with a lab analysis and final bricks produced. The following Table shows those variables at the moment of monitoring with an uncertainty ( $\sigma$ ) estimated within a confidence interval of 68%.

Table 23. Specific Energy Consumption (SEC)

Measurement	Brick Production (kg/hr)		Fuel Consumption (kg/hr)		Energy Consumption (MJ/hr)		SEC (MJ/kg_brick)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventC24	3068,18	308,79	454,55	45,75	6654.55	1979.98	2.17	0.68

### Pollutant Analysis

Results on measured pollutant emissions (CO<sub>2</sub>, CO, SO<sub>2</sub>, PM<sub>2.5</sub> and BC) are presented in this section. They are divided into pollutant gases (CO<sub>2</sub>, CO, SO<sub>2</sub>) out of particulate material fractions PM<sub>2.5</sub> and BC, since their nature and measurement ways are different. The Table shows emission rates (pollutant mass flows), and emission ratios (punctual emission factors), according to consumed fuel and energy amounts, and final brick production. In all cases, the average measurement values are presented and their uncertainty ( $\sigma$ ) estimated within a 68% confidence interval.

## Black Carbon and PM2.5

The following Table shows results on emission rates (mass flows) of particulate materials PM2.5 and BC for measurements carried out during monitoring in the above mentioned kiln. Averages are presented accordingly.

Table 24. PM2.5 and BC Emission Rates in a Pampa Type Kiln

Measurement	ERPM2.5		ERBC	
	Average	$\sigma$	Average	$\sigma$
EventC24	62,14 g/hr	25,73	21,06	9,55

Results are now presented in regard to emission factors based on consumed fuel and energy and final brick production in relation to PM2.5 and BC. These data are punctual and extrapolation should be done with caution or deepen in this type of research work.

Table 25. Emission Factors in a Pampa Type Kiln

Measurement	EFBCfuel (g/Kg_fuel)		EFBCenergy (g/MJ)		EFBCbrick (g/kg_brick)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventC24	0,0463	0,0091	0.0032	0.0011	0,00687	0,00235

## Pollutant Gas Analysis

Following there are the results of emission rates (mass flow) of polluting gases CO, CO<sub>2</sub> y SO<sub>2</sub>, in each of the measurements performed:

Table 26. Emission Rates for Polluting Gases in a Pampa Type Kiln

Measurement	ERCO		ERCO <sub>2</sub>		ERSO <sub>2</sub>	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventC24	1465,13	630,12	765066,32	317431,95	0,00	49,11

The following Tables show results of emission factors for polluting gases CO<sub>2</sub>, CO and SO<sub>2</sub> based on fuel mass and energy consumption and final bricks produced respectively. These results belong to the punctual measurements performed in this kiln and extrapolation should be done with caution.

Table 27. Polluting Gas Emission Factors in a Pampa Type Kiln

Measurement	EFCOfuel (g/kg_fuel)		EFCO <sub>2</sub> fuel (g/kg_fuel)		EFSO <sub>2</sub> fuel (g/kg_fuel)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$

<b>EventC24</b>	3,22	0,43	1683,15	121,60	0,00	0,11
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Table 28. Emission Factors according to Energy Consumption in a Pampa Type Kiln

Measurement	EFCOenergy (g/MJ)		EFCO2energy (g/MJ)		EFSO2energy (g/MJ)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventC24	0.2202	0.0684	114.9690	33.2456	0.0000	0.0074

Table 29. Emission Factors according to Final Brick Production in a Pampa Kiln

Measurement	EFCObrick (g/kg_brick)		EFCO2brick (g/kg_brick)		EFSO2brick (g/kg_brick)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
Event 24	0,48	0,15	249,35	72,25	0,00	0,02

#### 4.4 Intermittent Pampa Type Kiln with Peripheral Modifications (Vaulted or Domed). “La Campana” Brickmaking Co. - Monitoring Year 2017

In the subsequent Tables, there is information belonging to a vaulted or domed Pampa Type kiln, which is located in Quindío Province, Municipality La Tebaida. However, it would be important to mention that in this brickmaking company two (2) monitoring activities were performed. One using a mix of coffee litter injected with a dosage device and Guadua wood as fuels; and the second monitoring was performed using Guadua wood only. This with the goal of standardizing results for biomass in two fuels: coffee litter and Guadua wood.

KILN INFORMATION			
Fuel Type	Coffee Litter and Guadua wood	Origin	
Feeding into the Kiln	Coffee litterjet / Manual	COP per Ton	
Fuel Consumption (Coffee Litter) during Burning			12.8 Tons
Fuel Consumption (Guadua wood wood) during burning			2.82 Tons
Total fuel used or consumed			15.62 Tons
Total fuel used (Guadua wood only)			22 M3



The next Table shows number of monitoring activities and further results:

Table 30. Measurements and Hour number per measurement activity

Measurement	Start Date	Hours N°	Shift
Event S4 Pampa type vaulted kiln	May the 16 <sup>th</sup> of 2017	4	Day
Event S5 Pampa type vaulted kiln	May the 17 <sup>th</sup> of 2017	24	Night
Event S6 Pampa type vaulted kiln	June the 6 <sup>th</sup> of 2017	26	Continuous

Events 4 and 5 correspond to one (1) monitoring activity. This was due to the fact that during burning stage, fuel quality was NOT the best and time was extended to 28 hours. In the second monitoring activity, which used Guadua wood only as a fuel, only one (1) continuous monitoring activity was performed. This with the aim of keeping an emission profile during the whole burning stage and moreover, during this measurement, parameters of accumulated mass in filter did not increase as soon as in the case when mineral coal is used as a fuel.

### Fuel Analyses

Fuel analyses were performed by Mintec Ceramic Ltd. Co. This is a specialized lab in technical advice for the ceramic industries. Two analyses were performed on fuels. Proximal and Ultimate Analyses. Results are presented for coffee litter and Guadua wood during the first monitoring activity, and for coffee litter and Guadua wood separately in the second monitoring, which are differentiated by number two (2).

Table 31. Proximal Analysis of Biomass Fuel

Parameter	Coffee litter	Guadua wood	Coffee litter (2)	Guadua wood (2)	Units	Ideal Parameter
Moisture residual	10.79	10.23	8.26	10.66	% mass	< 3%
Ashes	7.37	15.38	5.20	13.61	% mass	< 10%
Volatiles	64.79	57.98	70.42	60.06	% mass	>30%
Fixed carbon	17.05	16.45	16.11	15.67	% mass	
Total sulphur	0.07	0.20	0.05	0.16	% mass	< 1%
Heat power	3.467	3.037	3.792	2.875	Kcal/kg	> 6500 Kcal/kg
Heat power	6.236	5.462	6.821	5.172	BTU/pound	
Heat power	14.51	12.71	15.87	12.03	MJ/kg	
Swelling index	0	0	0	0	FSI	

Dry basis analyses for coffee litter and guadua wood showed the results as follows

Table 32. Ultimate Biomass Fuel Analysis

Parameter	Coffee litter	Guadua wood	Coffee litter (2)	Guadua wood (2)	Unit
Carbon	44.65	37.96	46.96	39.19	% mass
Hydrogen	4.03	3.47	4.00	3.82	% mass
Oxygen	42.54	40.80	42.80	41.10	% mass
Nitrogen	0.44	0.42	0.52	0.47	% mass

Coffee litter used as a fuel shows general good conditions to be used in the brickmaking industry except for the moisture content percentage, which is over the recommended reference values for this type of industrial activity according to the laboratory. Guadua wood is a NON adequate fuel to be used in this brickmaking industries due to its high moisture and ashes and a low heat power.

It would be important to make clear that coffee litter (2) was NOT used in burning during this measurement procedure. This fuel was simply reanalyzed again with a mixture of palm oil with the purpose of validating that mix features and traits and then be able to provide entrepreneurs with information about what would be the most favorable fuel for cooking or burning.

### Energetic Efficiency

This parameter is named as Specific Fuel Consumption (SEC), and it was determined through two process variables: fuel consumption with its respective lab analyses and final brick production. The following Table shows those process variables and Fuel Specific Consumption (SEC) at the moment of data taking with an uncertainty degree ( $\sigma$ ) that was estimated within a confidence interval of 68%.

Table 33. Specific Energy Consumption (SEC)

Measurement	Final Brick Production (kg/hr)		Fuel Consumption (kg/hr)		Energy Consumption (MJ/hr)		SEC (MJ/kg_brick)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
Event S4	2162.7692	218.8214	318.4333	48.7440	4308.4020	1374.8583	1.99219	0.6669
Event S5	2162.7692	218.8214	345.4218	54.4286	4673.5569	1501.5780	2.16099	0.7279
Event S6	2644.1693	269.1234	609.6549	118.4353	6761.0734	2304.1208	2.55704	0.9094
Average	2323.24	235.59	424.50	73.87	5247.67	1726.8524	2.2367	0.7681

### Pollutant Analysis

Pollutant emission results as measured (CO<sub>2</sub>, CO, SO<sub>2</sub>, PM<sub>2.5</sub> and BC) presented in this section, which are divided into pollutant gases (CO<sub>2</sub>, CO, SO<sub>2</sub>) out of particulate material fractions PM<sub>2.5</sub> and BC, since their nature and measurement ways are different. The Tables below show emission rates (pollutant mass flow), and emission ratios (punctual emission factors), according to consumed fuel amounts, consumed energy and final brick production. Average values are presented for all cases and their respective uncertainty degree ( $\sigma$ ) estimated within a confidence interval of 68%.

### Black Carbon and PM<sub>2.5</sub>

Tables below show results on emission rates (mass flows), of the PM<sub>2.5</sub> and Black Carbon particulate material fractions for measurements performed during monitoring in the above mentioned kiln. By the end of these Tables there are the averages of several measurements.

Table 34. Emission Rates for PM<sub>2.5</sub> and BC in a Pampa Type Kiln

Measurement	ERPM <sub>2.5</sub> (gr/hr)		ERBC (gr/hr)	
	Average	$\sigma$	Average	$\sigma$
Event S4	931.07	401.65	190.60	88.09
Event S5	1111.88	604.51	99.73	55.82
Event S6	424.28	189.63	113.46	53.06
Average	822.41	398.60	134.59	65.65

Now, there are results attained in regard to emission factors based on fuel mass and energy consumption and final brick production for PM2.5 and Black Carbon in measurements accordingly. It is important to mention that these data are punctual and extrapolation must be cautious or deepen in this kind of research work.

Table 35. Emission Factors for a Pampa Type Kiln

Measurement	EFBCfuel (g/Kg_fuel)		EFBCenergy (g/MJ)		EFBCbrick (g/kg_brick)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
Event S4	0.60	0.11	0.044	0.015	0.09	0.03
Event S5	0.29	0.10	0.021	0.010	0.05	0.02
Event S6	0.19	0.03	0.017	0.005	0.04	0.01
Average	0.36	0.08	0.003	0.001	0.06	0.02

### Pollutant Gas Analysis

These are the results of emission rates (mass flows) of polluting gases CO, CO<sub>2</sub> and SO<sub>2</sub>, in each of the measurement activities performed:

Table 36. Polluting Gas Emission Rates in a Pampa Type Kiln

Measurement	ERCO		ERCO <sub>2</sub>		ERSO <sub>2</sub>	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
Event S4	32798.67	14255.68	445402.84	193093.16	1458.77	713.56
Event S5	22882.78	12539.75	500175.05	272823.15	392.70	401.57
Event S6	22447.59	10243.44	840253.14	377328.90	1239.59	806.98
Average	26043.02	12346.29	595277.01	281081.74	1030.35	640.70

The following Tables show results of emission factors for the above mentioned polluting gases based on fuel and energy consumption and final brick production for the measurements performed on the Pampa Type Kiln. These results are punctual and extrapolation must be cautious.

Table 37. Polluting Gas Emission Factors in a Pampa Kiln

Measurement	EFCOfuel (g/kg_fuel)		EFCO <sub>2</sub> fuel (g/kg_fuel)		EFSO <sub>2</sub> fuel (g/kg_fuel)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
Event S4	103.00	9.60	1398.73	122.83	4.58	1.11
Event S5	66.25	22.82	1448.01	492.95	1.14	1.06
Event S6	36.82	4.31	1378.24	116.30	2.03	0.97
Average	68.69	12.24	1408.33	244.03	2.58	1.05



Table 38. Emission Factors according to Energy Consumption

Measurement	EFCOenergy (g/MJ)		EFCO2energy (g/MJ)		EFSO2energy (g/MJ)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
Event S4	7.61	2.25	103.38	30.34	0.34	0.13
Event S5	4.90	2.17	107.02	47.17	0.08	0.08
Event S6	3.32	1.01	124.28	36.34	0.18	0.10
Average	5.28	1.81	111.56	37.95	0.20	0.06

Table 39. Emission Factors according to Final Brick Production in a Pampa Type Kiln

Measurement	EFCObrick (g/kg_brick)		EFCO2brick (g/kg_brick)		EFSO2brick (g/kg_brick)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
Event S4	15.17	4.49	205.94	60.67	0.67	0.25
Event S5	10.58	4.70	231.27	102.07	0.18	0.18
Event S6	8.49	2.58	317.78	93.04	0.47	0.26
Average	11.41	3.92	251.66	85.26	0.44	0.23

#### 4.5 Dome Type Intermittent Kiln WITH air / fuel dosage device. The “El Sol” Brickmaking Co. Monitoring performed in 2017

Now we have the analysis results of monitorings performed in a DomeType Kiln that uses a dosage device and it is located in Province Boyacá, Sogamoso municipality.

KILN INFORMATION			
Kiln Type	Dome		
Kiln Capacity	20,800 Units	Burning time	48 hours
Fuel Consumption during burning	7.1 Tons		



Dome Type Kiln

Three (3) measurement activities were performed in this kiln. Two (2) were carried out during daytime, and one was carried out during night time in order to attain a kiln profile and behavior of emissions. Total 39 effective hours of measurement.

### Fuel Analysis

These analyses were performed by Mintec Ceramic Ltd. Co. This is a specialized lab in technical advice for the ceramic sector. Mineral coal was analyzed only in ultimate analysis and results attained are presented herein.

Table 40. Proximal Analysis of mineral coal used in a DomeType Kiln

Parameter	Coal	Unit
Carbon	45.38	% mass
Hydrogen	4.90	% mass
Oxygen	5.11	% mass
Nitrogen	1.68	% mass

Based on the above information, proximal fuel analysis revealed low carbon percentage, which indicates that this specific coal type is NOT the best for this type of proceedings.

### Energetic Efficiency

This parameter is understood as Specific Fuel Consumption (SEC) determined through two process variables: fuel consumption as such with its lab analysis and final brick production. The following Tables show all characteristics in process variables and Specific Fuel Consumption (SEC) with the

data obtained at the moment of measurement. Uncertainty ( $\sigma$ ) was estimated within a 68% confidence interval.

Table 41. Specific Energy Consumption (SEC)

Measurement	Brick Production (kg/hr)		Fuel Consumption (kg/hr)		Energy Consumption (MJ/hr)		SEC (MJ/kg_brick)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventC6	1639.63	40.08	208.33	21.28	6450.00	1922.42	3.93	1.18
EventC7	1639.63	40.08	208.33	21.28	6450.00	1922.42	3.93	1.18
EventC8	1639.63	40.08	208.33	21.28	6450.00	1922.42	3.93	1.18
Average	1639.63	40.08	208.33	21.28	11993.75	3574.74	3.93	1.18

## Pollutant Analysis

Measured pollutants (CO<sub>2</sub>, CO, SO<sub>2</sub>, PM<sub>2.5</sub> and BC) are presented in the following tables. They are divided into polluting gases (CO<sub>2</sub>, CO, SO<sub>2</sub>) out of the particulate material fractions PM<sub>2.5</sub> and BC, since their nature and measurement ways are different. Emission rates are presented as pollutant mass flows and emission ratios (punctual emissions), according to fuel and energy consumed and final brick production. In all cases averages are presented with an uncertainty degree ( $\sigma$ ) estimated within a confidence interval 68%.

## Black Carbon and PM<sub>2.5</sub>

Tables below show results of emission rates of particulate materials (PM<sub>2.5</sub> and BC) for the measurements performed in the above mentioned kiln. Averages are presented at the end of each Table.

Table 42. PM<sub>2.5</sub> and BC emission rates for a Dome Type Kiln

Measurement	ERPM <sub>2.5</sub> (gr/hr)		ERBC (gr/hr)	
	Average	$\sigma$	Average	$\sigma$
EventC6	279.50	115.94	144.64	63.69
EventC7	219.30	91.15	89.40	42.95
EventC8	59.27	24.68	22.79	9.77
Average	186.02	77.26	85.61	38.80

Results are now presented with regard to emission factors based on fuel and energy consumed and final brick production. It is important to note that these results are punctual and extrapolation should be cautious or deepen in this type of research work.

Table 43. Dome Type Kiln Emission Factors

Measurement	EFBCfuel (g/Kg_fuel)		EFBCenergy (g/MJ)		EFBCbrick (g/kg_brick)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventC6	0.69	0.11	0.0224	0.0073	0.09	0.03
EventC7	0.43	0.11	0.0139	0.0052	0.05	0.02
EventC8	0.11	0.01	0.0035	0.0011	0.01	0.00
Average	0.41	0.08	0.0133	0.0136	0.05	0.02

### Pollutant Gas Analysis

Results are presented as emission rates of polluting gases CO, CO<sub>2</sub> and SO<sub>2</sub>, in each of the measurements performed.

Table 44. Polluting Gas Emission Rates in a Dome Type Kiln

Measurement	ERCO		ERCO <sub>2</sub>		ERSO <sub>2</sub>	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventC6	429.22	303.66	345768.46	143944.43	1039.82	456.21
EventC7	6615.93	2870.13	336047.75	140522.93	4010.04	1717.11
EventC8	1414.36	948.93	344220.59	144310.52	1475.83	721.24
Average	2819.83	1374.24	342012.27	142925.96	2175.23	964.85

Tables below show results of emission factors for polluting gases CO<sub>2</sub>, CO and SO<sub>2</sub> with fuel mass and energy consumed and final brick production according to measurements performed on the mentioned kiln. These data are punctual and extrapolation must be careful.

Table 45. Pollutant Gas Emission Factors in a Dome Type Kiln

Measurement	EFCOfuel (g/kg_fuel)		EFCO <sub>2</sub> fuel (g/kg_fuel)		EFSO <sub>2</sub> fuel (g/kg_fuel)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventC6	2.06	1.19	1659.69	129.35	4.99	0.79
EventC7	31.76	4.60	1613.03	140.87	19.25	2.44
EventC8	6.79	3.61	1652.26	152.57	7.08	1.90
Average	13.54	3.13	1641.66	140.93	10.44	1.71

Table 46. Emission Factors according to Consumed Energy

Measurement	EFCOenergy (g/MJ)		EFCO2energy (g/MJ)		EFSO2energy (g/MJ)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventC6	0.07	0.04	53.61	15.58	0.16	0.05
EventC7	1.03	0.32	52.10	15.28	0.62	0.19
EventC8	0.22	0.13	53.37	15.73	0.23	0.09
Average	0.44	0.17	53.03	15.53	0.34	0.11

Table 47. Emission Factors according to Final Bricks produced in a Dome Type Kiln

Measurement	EFCObrick (g/kg_brick)		EFCO2brick (g/kg_brick)		EFSO2brick (g/kg_brick)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventC6	0.26	0.17	210.88	61.30	0.63	0.20
EventC7	4.04	1.27	204.95	60.12	2.45	0.75
EventC8	0.86	0.52	209.94	61.91	0.90	0.35
Average	1.72	0.65	208.59	61.11	1.33	0.43

#### 4.6 Intermittent Dome Type Kiln with an air / fuel dosage device. The “El Tejar de Pescadero” Brickmaking co. - Monitoring year 2017

Now the second Dometype kiln measured information is presented. This productive system has a dosage device. It is important that this brickmaking company had a monitoring performed during training process year 2016; therefore, this would be the second occasion when it was possible to validate and measure the same kiln again. In this monitoring activity, five (5) measurements were executed (3 daytime, and 2 nighttime) for a total of 56 hour measurement, which concurs with the regular Domekiln total average burning times.

KILN INFORMATION			
Kiln type	Dome		
Cooked tons produced	102	Burning time per batch	62 hours
Fuel Consumption during burning	18.4 Tons		



Dome Type Kiln

## Fuel Analysis

Fuel analyses were performed by Mintec Ceramic Ltd. Co. This is a specialized lab in advisory for the ceramic sector. Two analyses were performed on fuel: Proximal and Ultimate. The fuel used in this kiln was mineral coal. Results are presented on dry basis.

Table 48. Coal Fuel Proximal Analysis

Parameter	Coal	Units	Ideal Parameter
Residual Moisture	2.67	% mass	< 3%
Ashes	9.46	% mass	< 10%
Volatiles	38.58	% mass	>30%
Fixed carbon	49.29	% mass	
Total sulphur	0.96	% mass	< 1%
Heat power	7.700	Kcal/kg	> 6500 Kcal/kg
Heat power	13.851	BTU/pound	
Heat power	32.23	MJ/kg	
Swelling index	0	FSI	

Table 49. Coal Fuel Ultimate Analysis

Parameter	Coal	Unit
Carbon	76.13	% mass
Hydrogen	5.64	% mass
Oxygen	5.92	% mass
Nitrogen	1.60	% mass

Based on fuel analyses results, it would be possible to state that although ashes contents is close to the top recommended limits by the above mentioned laboratory, the other criteria are complied with satisfaction according to standards established for cooking bricks, since the coal used has a high heat power.

### Energetic Efficiency

This parameter is named as Specific Fuel Consumption (SEC), and it was determined through two process variables: Lab analysis results and final brick production. The Table below shows those at the moment of measurement with an uncertainty ( $\sigma$ ) estimated within a 68% confidence interval.

Table 50. Specific Energy Consumption (SEC)

Measurement	Final Brick Production (kg/hr)		Fuel Consumption (kg/hr)		Energy Consumption (MJ/hr)		SEC (MJ/kg_brick)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventC11	1821.43	257.59	229.20	2.61	7128.24	1997.56	3.91	1.23
EventC12	1821.43	257.59	229.20	2.61	7128.24	1997.56	3.91	1.23
EventC13	1821.43	257.59	229.20	2.61	7128.24	1997.56	3.91	1.23
EventC14	1821.43	257.59	229.20	2.61	7128.24	1997.56	3.91	1.23
EventC15	1821.43	257.59	229.20	2.61	7128.24	1997.56	3.91	1.23
Average	1821.43	257.59	229.20	2.61	7128.24	1997.56	3.91	1.23

### Pollutant Analysis

Results of measured pollutants (CO<sub>2</sub>, CO, SO<sub>2</sub>, PM<sub>2.5</sub> and BC) are presented below, which are divided into polluting gases (CO<sub>2</sub>, CO, SO<sub>2</sub>) out of particulate materials PM<sub>2.5</sub> and BC given that their nature and measurement ways are different. Emission rates as mass flows and emission ratios are presented according to fuel and energy consumed and final brick production. In all cases averages are presented by the end of Tables and their uncertainties ( $\sigma$ ), which were estimated within a 68% confidence interval.

### Black Carbon y PM<sub>2.5</sub>

The Tables below show results of emission rates of particulate materials PM<sub>2.5</sub> and Black Carbon as obtained from the monitoring activities on this kiln. At the end of each Table, averages are presented

Table 51. Emission Rates for PM2.5 and BC in a DomeType Kiln

Measurement	ERPM2.5(gr/hr)		ERBC (gr/hr)	
	Average	$\sigma$	Average	$\sigma$
EventC11	156.82	63.25	109.46	47.34
EventC12	134.45	54.02	72.46	31.16
EventC13	28.37	11.40	13.46	5.76
EventC14	59.55	23.92	0.76	0.33
EventC15	179.75	72.20	66.13	28.04
Average	111.79	44.96	52.45	22.52

Now, results are presented in regard to emission factors based on fuel mass and energy consumption and final brick production for PM2.5 and BC. These results are punctual and extrapolation need to be done with care or deepen in this type or research studies.

Table 52. DomeType Kiln Emission Factors

Measurement	EFBCfuel (g/Kg_fuel)		EFBCenergy (g/MJ)		EFBCbrick (g/kg_brick)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventC11	0.48	0.08	0.015	0.005	0.06	0.02
EventC12	0.32	0.05	0.010	0.003	0.04	0.01
EventC13	0.06	0.01	0.002	0.001	0.01	0.00
EventC14	0.00	0.00	0.000	0.000	0.00	0.00
EventC15	0.29	0.04	0.009	0.003	0.04	0.01
Average	0.23	0.04	0.007	0.002	0.03	0.01

### Pollutant Gas Analysis

These results are presented as emission rates of polluting gases CO, CO2 and SO2, in each of the measurements executed

Table 53. Polluting Gas Emission Rates in a DomeType Kiln

Measurement	ERCO (gr/hr)		ERCO <sub>2</sub> (gr/hr)		ERSO <sub>2</sub> (gr/hr)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventC11	1038.71	1120.16	637788.01	258800.22	19.86	453.01
EventC12	843.30	376.08	638095.05	257018.94	118.41	78.87
EventC13	836.74	349.69	638105.36	256895.97	185.48	82.92
EventC14	220.60	103.54	639073.45	257256.49	298.81	124.30
EventC15	861.20	367.83	638066.92	256931.93	469.92	198.11
Average	760.11	463.46	638225.76	257380.71	218.50	187.44

Following Tables show results of emission factors for polluting gases CO<sub>2</sub>, CO and SO<sub>2</sub> based on fuel mass and energy consumption and final brick production respectively. It is important to take these results as punctual and any extrapolation should be taken with caution.

Table 54. Polluting Gas Emission Factors in a DomeType Kiln

Measurement	EFCOfuel (g/kg_fuel)		EFCO <sub>2</sub> fuel (g/kg_fuel)		EFSO <sub>2</sub> fuel (g/kg_fuel)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventC11	4.53	4.55	2782.62	244.58	0.09	1.98
EventC12	3.68	0.75	2783.96	202.88	0.52	0.28
EventC13	3.65	0.49	2784.01	199.80	0.81	0.17
EventC14	0.96	0.24	2788.23	199.38	1.30	0.17
EventC15	3.76	0.60	2783.84	201.04	2.05	0.30
<b>Average</b>	<b>3.32</b>	<b>1.33</b>	<b>2784.53</b>	<b>209.54</b>	<b>0.95</b>	<b>0.58</b>

Table 55. Emission Factors According to Energy Consumption

Measurement	EFCOenergy (g/MJ)		EFCO <sub>2</sub> energy (g/MJ)		EFSO <sub>2</sub> energy (g/MJ)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventC11	0.15	0.15	89.47	26.26	0.00	0.06
EventC12	0.12	0.04	89.52	25.90	0.02	0.01
EventC13	0.12	0.04	89.52	25.88	0.03	0.01
EventC14	0.03	0.01	89.65	25.91	0.04	0.01
EventC15	0.12	0.04	89.51	25.88	0.07	0.02
<b>Average</b>	<b>0.11</b>	<b>0.06</b>	<b>89.53</b>	<b>25.97</b>	<b>0.03</b>	<b>0.02</b>

Table 56. Emission Factors according to Final Brick Production


Measurement	EFCObrick (g/kg_brick)		EFCO <sub>2</sub> brick (g/kg_brick)		EFSO <sub>2</sub> brick (g/kg_brick)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventC11	0.57	0.59	350.16	102.78	0.01	0.25
EventC12	0.46	0.16	350.33	101.38	0.07	0.04
EventC13	0.46	0.14	350.33	101.28	0.10	0.04
EventC14	0.12	0.05	350.86	101.42	0.16	0.05
EventC15	0.47	0.15	350.31	101.32	0.26	0.08
<b>Average</b>	<b>0.42</b>	<b>0.22</b>	<b>350.40</b>	<b>101.64</b>	<b>0.12</b>	<b>0.09</b>

# Presentation on Monitoring Activities in Continuous Kilns

2017

## 4.7 Wagon Type Continuous Kiln. “El Noral” Brickmaking Co. - Monitoring 2017

Now results analysis are presented for Wagon Type Brickmaking kiln. This is located in Province Antioquia, Medellin city. It operates with biomass as a fuel, in this case coffee litter. Two (2) measurement activities were performed for a total of 37 effective hours. On the other hand, the function principle of this kiln is intermittent in theory. This specific kiln had four (4) wagons connected to an intermittent channel. They were alternated. When one wagon finished burning, the other entered through the opposite side. This is deemed as continuous operation. Measurements were taken according to the time necessary to process or cook one wagon completely.

KILN INFORMATION			
Kiln Type	Wagon	Burning Start time	2:38 pm
Kiln Capacity	158 Tons / day	Burning Time	20 hours
Measurement dates	Aug 14-15 / 2017	Fuel Consumption	578 ton/month
			
Wagon Type Kiln			

## Fuel Analysis

These analyses were performed by Mintec Ceramic Ltd. Co, a specialized lab in technical advisory for the ceramic sector. Two fuel analyses were performed: Proximal and Ultimate for coffee litter, which is the fuel used in this kiln.

Table 57. Proximal Fuel Analysis

Parameter	Coffee litter	Units	Ideal Parameter
Residual Moisture	10.00	% mass	< 3%
Ashes	4.82	% mass	< 10%
Volatiles	69.13	% mass	>30%
Fixed carbon	16.05	% mass	
Total sulphur	0.16	% mass	< 1%
Heat power	3.747	Kcal/kg	> 6500 Kcal/kg
Heat power	6.740	BTU/pound	
Heat power	15.68	MJ/kg	
Swelling index	0	FSI	

Table 58. Ultimate Fuel Analysis

Parameter	Coffee litter	Unit
Carbon	45.39	% mass
Hydrogen	4.80	% mass
Oxygen	43.80	% mass
Nitrogen	0.47	% mass

Based on fuel analysis, the conclusion is that the residual moisture content in this fuel type is truly high, even when coffee litter fuel is stored in dry areas of the production plant. In regard to other criteria, said fuel complies satisfactorily with the established parameters.

## Energetic Efficiency

This parameter is understood as Specific Fuel Consumption (SEC) and it was determined through two process variables: fuel consumption with a lab analysis and final brick production. The Table below shows those process variables at the moment of measurement performance. Uncertainty (6) was estimated within a 68% confidence interval.

Table 59. Specific Energy Consumption (SEC)

Measurement	Final Brick Production (kg/hr)		Fuel Consumption (kg/hr)		Energy Consumption (MJ/hr)		SEC (MJ/kg_brick)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventC16	4518,60	465,77	802,78	80,29	11704.50	3480.04	2.59	0.82
EventC17	4518,60	465,77	802,78	80,29	11704.50	3480.04	2.59	0.82
<b>Average</b>	4518,60	465,77	802,78	80,29	11704.50	3480.04	2.59	0.82

### Pollutant Analysis

Measured pollutants (CO<sub>2</sub>, CO, SO<sub>2</sub>, PM<sub>2.5</sub> and BC) are presented below and they are divided into pollutant gases (CO<sub>2</sub>, CO, SO<sub>2</sub>) out of the fractions from particulate materials PM<sub>2.5</sub> and BC (mass flows), and emission ratios (punctual emission factors) according to fuel and energy consumed and final brick production. In all cases final averages are presented and their respective uncertainty ( $\sigma$ ) estimated within a 68% confidence interval.

### Black Carbon and PM<sub>2.5</sub>

The Tables below show results of emission rates of particulate materials for measurements exercised during the mentioned kiln monitoring. Averages are presented at the end of those Tables.

Table 60. PM<sub>2.5</sub> and BC emission rates in a Wagon Type Kiln

Measurement	ERPM <sub>2.5</sub> (gr/hr)		ERBC (gr/hr)	
	Average	$\sigma$	Average	$\sigma$
EventC16	57,23	23,68	6,33	2,75
EventC17	82,87	34,31	1,73	0,76
<b>Average</b>	70,05	29,00	4,03	1,75

Tables below show results in regard to emission factors based on fuel mass and energy consumption and brick production related to PM<sub>2.5</sub> and BC. These results are punctual and extrapolation must be taken with caution or deepen in this kind of research studies.

Table 61. Emission Factors in a Wagon Type Kiln

Measurement	EFBCfuel (g/Kg_fuel)		EFBCenergy (g/MJ)		EFBCbrick (g/kg_brick)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventC16	0.0079	0.0012	0.0005	0.0002	0.0014	0.0004
EventC17	0.0022	0.0003	0.0001	0.0000	0.0004	0.0001
Average	0,0050	0,0008	0,0003	0,0001	0,0009	0,0003

### Polluting Gas Analysis

These are the emission rates of polluting gases CO, CO<sub>2</sub> and SO<sub>2</sub>, in each of the executed measurements:

Table 62. Polluting Gas Emission Rates in a Wagon Type Kiln

Measurement	ERCO (gr/hr)		ERCO <sub>2</sub> (gr/hr)		ERSO <sub>2</sub> (gr/hr)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventC16	1595,26	677,56	1332747,48	552576,99	69,46	52,20
EventC17	2968,76	1294,33	1330589,41	552036,06	117,42	141,51
Average	2282,01	985,94	1331668,45	552306,53	93,44	96,85

Tables below show results of emission factors for polluting gases CO<sub>2</sub>, CO and SO<sub>2</sub> based on fuel and energy consumption and brick production. These apply for the measurement activities performed during monitoring of the above said kiln. It is important to mention that these data are punctual and extrapolation need to be managed carefully.

Table 63. Polluting Gas Emission Factors in a Wagon Type Kiln.

Measurement	EFCOfuel (g/kg_fuel)		EFCO <sub>2</sub> fuel (g/kg_fuel)		EFSO <sub>2</sub> fuel (g/kg_fuel)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventC16	1,99	0,23	1660,17	118,60	0,09	0,05
EventC17	3,70	0,56	1657,48	120,94	0,15	0,17
Average	2,84	0,40	1658,83	119,77	0,12	0,11

Table 64. Emission Factors according to Energy consumption in a Wagon Type Kiln

Measurement	EFCOenergy (g/MJ)		EFCO2energy (g/MJ)		EFSO2energy (g/MJ)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventC16	0.14	0.04	113.87	32.90	0.01	0.00
EventC17	0.25	0.08	113.68	32.89	0.01	0.01
Average	0,19	0,06	113.77	32.90	0,01	0,01

Table 65. Emission Factors according to Final Brick Production in a Wagon Type Kiln.

Measurement	EFCObrick (g/kg_brick)		EFCO2brick (g/kg_brick)		EFSO2brick (g/kg_brick)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventC16	0,35	0,11	294,95	85,31	0,02	0,01
EventC17	0,66	0,21	294,47	85,28	0,03	0,03
Average	0,51	0,16	294,71	85,30	0,02	0,02

#### 4.8 ZigZag Continuous Kiln. The “El Trébol” Brickmaking Co. - Monitoring 2017

These are the results of a ZigZag Type Kiln located in Province Cundinamarca, Cogua municipality. This was the third measurement activity performed on this type of technology applied for brickmaking in order to obtain a reliable emission factor. During training stage in year 2016, two monitoring activities were performed on these technologies in provinces Cundinamarca and Cauca.

In 2017 only one continuous measurement was performed during 24 hours, given that the kiln conditions and criteria of the accumulated mass in the device’s filter increased rapidly, so therefore, this was deemed as a representative enough measurement.

KILN INFORMATION			
Kiln Type	Zig Zag		
Kiln Capacity	58 tons per chamber	Burning time per line	Depending on material. It takes about 3 to 4 hours
Measurement Dates	Oct 3rd - 2017	Fuel Consumption	525.32 ton/month



Zigzag Type Kiln

## Fuel Analysis

These analyses were carried out by Mintec Ceramic Ltd. Co. This is a specialized laboratory in technical advice for the ceramic sector. Two analyses were performed: proximal and ultimate on mineral coal as a fuel, which is the one used for burning or cooking during the measurements performed.

Table 66. Proximal Mineral Coal Fuel Analysis.

Parameter	Carbon	Units	Ideal Parameter
Residual Moisture	1.69	% mass	< 3%
Ashes	9.26	% mass	< 10%
Volatiles	31.65	% mass	>30%
Fixed carbon	57.40	% mass	
Total sulphur	0.75	% mass	< 1%
Heat power	7.644	Kcal/kg	> 6500 Kcal/kg
Heat power	13.750	BTU/pound	
Heat power	32.00	MJ/kg	
Swelling index	0	FSI	

Table 67. Ultimate Mineral Coal Fuel Analysis

Parameter	Coal	Unit
Carbon	78.15	% mass
Hydrogen	5.30	% mass
Oxygen	4.86	% mass
Nitrogen	1.51	% mass

Based on the above information, the mineral coal used as fuel in this zigzag type kiln has a high ash contents and volatiles are close to the recommended limits. However, it has a high heat power, which makes it ideal for cooking brick products.

### Energetic Efficiency

This parameter named as Specific Fuel Consumption (SEC) was determined through two process variables: Fuel consumption with lab analysis and final brick production. The Table below shows those results at the moment of measurement with an uncertainty ( $\sigma$ ) estimated within a 68% confidence interval.

Table 68. Specific Energy Consumption (SEC)

Measurement	Final Brick Production (kg/hr)		Fuel Consumption (kg/hr)		Energy Consumption (MJ/hr)		SEC (MJ/kg_brick)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventC23	2416,67	261,81	262,66	12,48	8131.95	2309.51	3.36	1.02

### Pollutant Analysis

Results of polluting emissions were measured as CO<sub>2</sub>, CO, SO<sub>2</sub>, PM<sub>2.5</sub> and BC and were divided into polluting gases (CO<sub>2</sub>, CO, SO<sub>2</sub>) out of the particulate material fractions PM<sub>2.5</sub> and BC. Given their nature and measurement ways, they are different. Tables content emission rates (polluting mass flows), and emission ratios (punctual emission factors) according to fuel and energy consumption and final brick production. In all cases, average values are given and their uncertainties ( $\sigma$ ) were estimated within a 68% confidence interval.

### Black Carbon y PM<sub>2.5</sub>

The Tables below show results on emission rates (mass flows) out of particulate materials PM<sub>2.5</sub> and Black Carbon.

Table 69. PM<sub>2.5</sub> and BC in a ZigZag Type Kiln

Measurement	ERPM <sub>2.5</sub>		ERBC	
	Average	$\sigma$	Average	$\sigma$
EventC23	29,28	11,84	4,93	2,12

Based on the above, when compared to the first measurement, this shows that the first cooking stages in this kiln, particulate material emissions into the atmosphere are zero, similar to Black Carbon results, where emissions detected were negligible.

Table 71 shows results attained in regard to emission factors related to fuel and energy consumption and final bricks produced for PM2.5 and Black Carbon. These data are punctual and extrapolation needs to be done with care or deepen in this research matters.

Table 70. Emission Factors related to Fuel and Energy Consumption in a ZigZag Type Kiln

Measurement	EFBCfuel (g/Kg_fuel)		EFBCenergy (g/MJ)		EFBCbrick (g/kg_brick)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventC23	0,02	0,00	0.0006	0.0002	0,0020	0,0007

### Pollutant Gas Analysis

These are the results of emission rates (mass flows) for polluting gases CO, CO2 and SO2, for the measurement performed:

Table 71. Polluting Gas Emission Rates in a ZigZag Type Kiln

Measurement	ERCO(gr/hr)		ERCO <sub>2</sub> (gr/hr)		ERSO <sub>2</sub> (gr/hr)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventC23	1540,61	677,04	749775,81	304070,00	499,33	231,20

The following Tables show results in emission factors for polluting gases CO2, CO and SO2 based on measurement performed during a ZigZag Type Kiln monitoring activity. It is important to bear in mind that these results are punctual and extrapolation needs to be managed with care.

Table 72. Emission factors pollutants zigzag kiln

Measurement	EFCOfuel (g/kg_fuel)		EFCO <sub>2</sub> fuel (g/kg_fuel)		EFSO <sub>2</sub> fuel (g/kg_fuel)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventC23	5,87	1,08	2854,55	209,97	1,90	0,45

Table 73. Energy emission factors Zigzag kiln

Measurement	EFCOenergy (g/MJ)		EFCO2energy (g/MJ)		EFSO2energy (g/MJ)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventC23	0.1895	0.0635	92.2012	26.6923	0.0614	0.0225

Table 75. Emission factor per brick Zigzag kiln

Measurement	EFCObrick (g/kg_brick)		EFCO2brick (g/kg_brick)		EFSO2brick (g/kg_brick)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventC23	0,64	0,21	310,25	89,85	0,21	0,08

#### 4.9 Continuous chamber kilns, brick Kiln La Fe - monitoring 2017.

Below are the results of the biomass validation in a continuous chamber kiln located in the department of Cundinamarca, municipality of Nemocón; It is important to mention that this monitoring was carried out with the support of the NAMA industry project that is currently being implemented in Colombia and that seeks to validate the measures of reduction of black carbon through the use of biomass, in the technological model identified in the reduction sheets of greenhouse gases from the Ministry of Industry and Commerce for the country's NDCs.

The methodology that was implemented was based on the operating principle of the kiln, as its name indicates the carbojet that injects the fuel in the upper part, it moves by burning camera by camera, it was possible to burn 3 adjoining and separated chambers in the following way varying the fuel, for chamber 2 carbon was used, chamber 3 coffee cisco and chamber 4 mixing in a ratio (50 -50) cisco coffee and coal; additional to the carbon black monitoring and with the support of the Mintec Ceramic laboratory, a parametrization of the burning and analysis of the final product entered in each of the chambers was carried out, in order to check the percentage of losses, burns and product quality .

Given that this monitoring was the last carried out in the current year, it was not possible to perform the gravimetric analyzes and therefore process the information to determine the behavior of the emissions and their emission factors; however, it is expected to process the information of this monitoring for next year.

Information of the kiln	
Type of kiln	<i>Continues chambers</i>




As an annex to this report, is the full report of the results of the validation of the use of biomass in this type of technologies in Spanish, however, the following table shows the summary of the energy balance and information about the kiln.

<b>BALANCE DE ENERGIA</b>			
TIPO DE COMBUSTIBLE POR CAMARA	SOLO CARBON	SOLO CISCO	CARBON Y CISCO
N° Cámara	2	3	4
CarboJet - Posición de la Velocidad (Hz)	26,7	60	No hay reporte
Ciclo (horas)	14	24,5	15
Cantidad de Baldes	97	265	110
Peso combustible/balde (Kg/balde)	16,0	6,2	-
Cantidad Total de Combustible (Kg)	1552	1643	1.211
Cantidad de Combustible/hora (Kg/hora)	<b>110,86</b>	<b>67,06</b>	<b>80,75</b>
Cantidad baldes/hora	6,93	10,82	7,33
Cantidad Total de Carbón Utilizado (Kg)	1.440	0	864
Cantidad Total de Cisco de Café (Kg)	0	1.643	347
<b>TOTAL COMBUSTIBLE UTILIZADO (Kg)</b>	<b>1.440</b>	<b>1.643</b>	<b>1.211</b>
<b>CALCULOS</b>			
TIPO DE COMBUSTIBLE POR CAMARA	SOLO CARBON	SOLO CISCO	CARBON Y CISCO
N° Cámara	2	3	4
Temperatura de Inicio (°C)	140	334	334
Temperatura Final (°C)	850	885	885
Poder Calorífico Combustible (Kcal/Kg)	7.659	3.933	6.592
Energía Total Consumida (Kcal/Ciclo)	<b>11.028.960</b>	<b>6.461.919</b>	<b>7.982.914</b>
Energía Suministrada/hora (Kcal/hora)	<b>787.783</b>	<b>263.752</b>	<b>532.194</b>
Consumo de Carbón/Kg Ladrillo Cocido (Kg/Kg Cocido)	<b>0,162</b>	<b>0</b>	<b>0,107</b>
Consumo de Cisco/Kg Ladrillo Cocido (Kg/Kg Cocido)	<b>0</b>	<b>0,200</b>	<b>0,043</b>
Energía Consumida (Kcal/Kg Ladrillo Cocido)	<b>1.239</b>	<b>786</b>	<b>985</b>

**4.10 Hoffman Kiln, ladrillera Santander - monitoring 2017.**

Next, the results of the monitoring carried out in the Hoffman kiln, located in the department of Cundinamarca, in the municipality of Soacha, these kiln operated with a mixture of 20% biomass (sawdust) and 80% coal, three measurements were made and divided in two diurnals and one nocturnal for a total of 22 hours of measurement

Kiln information			
Type of kiln	Hoffman	Turn of work	8 hours
No Chambers and lines	34 chambers y 68 lines	Burning time	30 min by line
Line in which the measurement started			27
Line in which the measurement ended			36
Diameter of the stack	1.21m	Length of the nozzle	.12m
			
Hoffman kiln			

**Fuel analysis**

The fuel analyzes were carried out by Mintec Ceramic Ltda, a laboratory specialized in technical consultancy for the ceramic sector. Two types of fuel analysis were carried out: Proximate and Ultimate analysis, below are the results of these analysis

Table 74. Ultimate analysis .

Parameter	Coal	Saw dust	Mix coal and saw dust	Units	Ideal parameter
H2O	2.08	6.16	2.47	% mass	< 3%
Ash	13.74	5.65	15.09	% mass	< 10%
Volatile matter	37.38	71.04	38.48	% mass	>30%
Fixed carbon	46.80	17.15	43.96	% mass	
Sulfur (S)	0.61	0.17	0.57	% mass	< 1%
Energy Value	7180	3847	6986	Kcal/kg	>6500 Kcal/kg
Energy Value	12915	6920	12351	BTU/lb	
Energy Value	30.06	16.10	29.24	MJ/kg	
Swelling index	1	0	1	FSI	

Tabla 75. Proximate analysis.

Parameter	Coal	Saw dust	Mix coal-sawdust	Units
Coal	72.69	49.17	71.63	% mass
Hydrogen	5.29	3.28	4.60	% mass
Oxygen	5.80	41.00	5.90	% mass
Nitrogen	1.57	0.35	1.02	% mass

As noted in the report, the fuel used has good qualities in general for the use in the brick industry except the percentage of ash which exceeds the reference value recommended by the laboratory.

### Energy efficiency

The parameter of energy efficiency determined as Specific Fuel Consumption (SEC for its acronym in English) was determined through two process variables, fuel consumption, with its respective laboratory analysis) and the production of bricks; the table presents the process variables and the Specific Fuel Consumption (SEC) for the moment of data collection with an uncertainty ( $\sigma$ ) estimated in the confidentiality interval of 68%.

Tabla 76. Specific energy consumption Hoffman Kiln

Brick Production rate (kg/hr)		Fuel rate (kg/hr)		Energy consumption (MJ/hr)		SEC (MJ/kg_brick)	
Promedio	$\sigma$	Promedio	$\sigma$	Promedio	$\sigma$	Promedio	$\sigma$
7352.9086	745.3775	199.1126	13.6629	5539.3122	1596.9036	0.7533	0.2302

If you compare the result of this measurement and this technology (Hoffman Kiln) with the data of the Technical Sheet of Brick Kilns in South and Southeast Asia of the CCAC, which specifies a range of 1.21 - 1.52 MJ / kg ( Greentech Knowledge Solutions Pvt. Ltd., 2013), it can be said that the kiln behaves within the average of that area, according to the standardized base year 2015 developed by the CAEM during the execution of the Energy Efficiency Project in Ladrilleras of

Latin America EELA, similar kilns in the country operate with an average SEC of 1,659 MJ / kg, therefore, compared to Colombian data, the kiln operates with a higher than average efficiency.

### Pollutants results

The emission results of the measured pollutants (CO<sub>2</sub>, CO, SO<sub>2</sub>, PM<sub>2.5</sub> and BC) are presented in this section, the contaminating gases (CO<sub>2</sub>, CO, SO<sub>2</sub>) are divided from the PM<sub>2.5</sub> and BC particulate fractions. since their nature and form of measurement are different. According to the metrics delivered by the Ratnoze2 equipment , the emission rate (mass flow of the pollutant) and the emission ratios (Point Emission Factors) are presented according to the amount of fuel, energy consumed and according to the production of bricks; for all cases, the average value of the measurement and its respective uncertainty ( $\sigma$ ) estimated in the confidentiality interval of 68% are presented.

### Black carbon and PM 2.5

The table presents the results of the emission rate (mass flow) of PM<sub>2.5</sub> particulate fractions and Black Carbon (BC), for each of the measurements made during the Hoffman kiln monitoring of the brick kiln called ladrillera Santander Díaz Muños that operate the kiln with a mixture of fuel Coal (80%) and sawdust (20%); At the end of the table, the average of the different measurements is presented.

Table 77. Emission rate PM 2.5 and BC

Measurement	ERP <sub>PM2.5</sub>		ER <sub>BC</sub>	
	Average	$\sigma$	Average	$\sigma$
EventS1	538.9402	220.0285	151.1002	65.5749
EventS2	281.5698	114.9886	78.5780	34.1415
EventS3	470.4504	192.1625	209.2783	90.6215
<b>Average</b>	<b>430.3201</b>	<b>175.7265</b>	<b>146.3188</b>	<b>63.4460</b>

It can be evidenced that the emissions are of the same order of magnitude, although, they present a variability in the schedule, because during the night the emission was approximately half that during the day, which possibly is due to changes in the way of operation of the kiln for instance when are changing the shift and the operator.

Below are presented the results of the emission factors based on mass of fuel, energy consumed and brick production for PM<sub>2.5</sub> and black carbon (BC for its acronym in English) respectively, for the three measurements made during the monitoring of the kiln, as for all the results obtained, it must be taken into account that these data are specific and their extrapolation must be done with caution.

Table 78. Emission factor PM<sub>2.5</sub>.

Measurement	EF <sub>PM2.5fuel</sub> (g/Kg_fuel)		EF <sub>PM2.5energy</sub> (g/MJ)		EF <sub>PM2.5brick</sub> (g/kg_brick)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventS1	2.7067	0.1946	0.0973	0.0281	0.0733	0.0241

EventS2	1.4141	0.1026	0.0508	0.0147	0.0383	0.0126
EventS3	2.3627	0.1726	0.0849	0.0246	0.0640	0.0210
Average	2.1612	0.1566	0.0777	0.0225	0.0585	0.0192

Table 79. Emission factor BC

Measurement	EFBCfuel (g/Kg_fuel)		EFBCenergy (g/MJ)		EFBCbrick (g/kg_brick)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventS1	0.7589	0.1243	0.027	0.009	0.0205	0.0074
EventS2	0.3946	0.0652	0.014	0.005	0.0107	0.0039
EventS3	1.0511	0.1695	0.038	0.012	0.0285	0.0102
Average	0.7349	0.1197	0.0026	0.009	0.0199	0.0072

## Pollutants results

The emission results of the emission rate (mass flow) of the polluting gases CO, CO<sub>2</sub> and SO<sub>2</sub> are presented for each of the measurements made during the monitoring of the Hoffman Kiln of the brick industry called, Ladrillera Santander Díaz Muños that operate with a mixture of fuel Coal (80%) and Sawdust (20%); At the end of the table, the average of the different measurements is presented.

Table 80 Emission rate pollutants.

Measurement	ERCO		ERCO <sub>2</sub>		ERSO <sub>2</sub>	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventS1	125.1915	12.3934	2428.1390	206.5664	3.6798	1.9274
EventS2	133.3542	13.2904	2415.3135	208.3714	0.4058	1.8855
EventS3	103.4449	10.9476	2462.3078	211.5915	4.7245	2.0477
Average	120.6635	12.2105	2435.2534	208.8431	2.9367	1.9535

The following tables presented the results of the emission factors for CO<sub>2</sub>, CO and SO<sub>2</sub> pollutant gases based on mass of fuel, energy consumed and brick production respectively, for the measurement made during the monitoring of the kiln, as for all the The results obtained should take into account that these data are specific and their extrapolation should be done with caution.

Table 81. Emission factor by fuel Hoffman kiln

Measurement	EFCOfuel (g/kg_fuel)		EFCO2fuel (g/kg_fuel)		EFSO2fuel (g/kg_fuel)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventS1	125.1915	12.3934	2428.1390	206.5664	3.6798	1.9274
EventS2	133.3542	13.2904	2415.3135	208.3714	0.4058	1.8855
EventS3	103.4449	10.9476	2462.3078	211.5915	4.7245	2.0477
Average	120.6635	12.2105	2435.2534	208.8431	2.9367	1.9535

Table 82. Emission factors by energy Hoffman Kiln

Measurement	EFCOenergy (g/MJ)		EFCO2energy (g/MJ)		EFSO2energy (g/MJ)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventS1	4.50	1.34	87.28	25.54	0.13	0.08
EventS2	4.79	1.42	86.82	25.44	0.01	0.07
EventS3	3.72	1.11	88.51	25.92	0.17	0.09
Average	4.34	1.29	87.54	25.63	0.11	0.08

Table 83. Emission factors per brick produced Hoffman kiln.

Measurement	EFCObrick (g/kg_brick)		EFCO2brick (g/kg_brick)		EFSO2brick (g/kg_brick)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventS1	3.3901	1.1370	65.7526	21.8004	0.0996	0.0612
EventS2	3.6112	1.2119	65.4053	21.7055	0.0110	0.0512
EventS3	2.8012	0.9453	66.6779	22.1220	0.1279	0.0690
Average	3.2675	1.0981	65.9453	21.8760	0.0795	0.0604

#### 4.11 Hoffman Kiln, brick kiln ladrillera Bellavista - 2017.

The table presented the results of the monitoring of the Hoffman kiln located in the department of Valle del Cauca in the municipality of Cartago, this kiln was selected because its operation is completely in biomass, using coffeedust as a fuel and injected by medium of ciscojets; for this monitoring a measurement was made with a duration of 14 hours; additionally and given the climatic and speed conditions of the stack approx (17 m / sg), night measurements could not be made.

Kiln information			
Type of kiln	Hoffman		
Capacity	138.000 units reference No 4 (30 length-20 height -10 width)	Burning time per line	4 hours

<b>Measurement date:</b>	06 of August 2017	<b>Fuel consumption</b>	588.5 ton
			
Hoffman kiln			

### Fuel Analysis

The fuel analyzes were carried out by Mintec Ceramic Ltda, a laboratory specialized in technical consultancy for the ceramic sector. Two types of fuel analysis were carried out: Proximate and Ultimate analysis, below are the results of these analyses

Table 84. Proximate analysis.

Parameter	Coffe dust	Units
H2O	7.13	% mass
Ash	7.21	% mass
Volatile matter	70.38	% mass
Fixed carbon	15.28	% mass
Sulfur (S)	0.06	% mass
Energy Value	3653	Kcal/kg
Energy Value	6571	BTU/lb
Energy Value	15.29	MJ/kg
Swelling index	0	FSI

Table 85. Ultimate analysis.

Parameter	Coffe dust	Units
Coal	44.67	% mass
Hydrogen	3.99	% mass
Oxygen	43.01	% mass
Nitrogen	0.50	% mass

As noted in the report, the coffee dust presents a low heat capacity compared to coal, the other properties such as ash content, humidity and volatile content are appropriate for the production in brick kilns.

### Energy efficiency

The parameter of energy efficiency determined as Specific Fuel Consumption (SEC for its acronym in English) was determined through two process variables, fuel consumption, with its respective laboratory analysis) and the production of bricks; the table presents the process variables and the Specific Fuel Consumption (SEC) for the moment of data collection with an uncertainty ( $\sigma$ ) estimated in the confidentiality interval of 68%.

Table 86. Specific energy consumption

Measurement	Brick Production rate (kg/hr)		Fuel rate (kg/hr)		Energy consumption (MJ/hr)		SEC (MJ/kg_brick)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventS7	2980.7445	303.5501	174.8020	13.7828	2511.9045	730.6879	0.8427	0.2597

### Pollutants results

The emission results of the measured pollutants (CO<sub>2</sub>, CO, SO<sub>2</sub>, PM<sub>2.5</sub> and BC) are presented in this section, the contaminating gases (CO<sub>2</sub>, CO, SO<sub>2</sub>) are divided from the PM<sub>2.5</sub> and BC particulate fractions. since their nature and form of measurement are different. According to the metrics delivered by the Ratnoze2 equipment, the emission rate (mass flow of the pollutant) and the emission ratios (Point Emission Factors) are presented according to the amount of fuel, energy consumed and according to the production of bricks; for all cases, the average value of the measurement and its respective uncertainty ( $\sigma$ ) estimated in the confidentiality interval of 68% are presented.

### Black carbon and PM 2.5

The following table presents the results of the emission rate (mass flow) of PM<sub>2.5</sub> particulate fractions and Black Carbon (BC) for the measurement made to the Hoffman kiln which operates with coffee dust as fuel.

Tabla 87. Emission rate PM<sub>2.5</sub> and BC

Measurement	ERPM <sub>2.5</sub>		ERBC	
	Average	$\sigma$	Average	$\sigma$
EventS6	567.9675	232.5740	40.6042	17.6403

Below are presented the results of emission factors based on mass of fuel, energy consumed and brick production for PM<sub>2.5</sub> and black carbon (BC for its acronym in English) respectively for the

monitoring performed, as for all results obtained is it important to take into account that these data are specific and their extrapolation must be done with caution.

Table 88. Emission factor PM 2.5

Measurement	EFPM2.5fuel (g/Kg_fuel)		EFPM2.5energy (g/MJ)		EFPM2.5brick (g/kg_brick)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventS7	3.2492	0.2218	567.97	232.57	0.1905	0.0594

Tabla 89. Emission factor BC

Measurement	EFBCfuel (g/Kg_fuel)		EFBCenergy (g/MJ)		EFBCbrick (g/kg_brick)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventS7	0.2323	0.0373	0.016	0.005	0.0136	0.0047

### Pollutants results

The emission results of the emission rate (mass flow) of the polluting gases CO, CO<sub>2</sub> and SO<sub>2</sub>, for the measurement made to the Hoffman kiln of the brick kiln called Ladrillera Bellavista, which operates with coffee dust as fuel.

Table 90. Emission rate pollutants

Measurement	ERCO		ERCO <sub>2</sub>		ERSO <sub>2</sub>	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventS6	12477.20 70	5124.754 3	266530.293 7	109312.687 3	471.9835	202.345 6

The following tables presented the results of the emission factors for CO<sub>2</sub>, CO and SO<sub>2</sub> pollutant gases based on mass of fuel, energy consumed and brick production respectively, for the measurement made during the monitoring of the kiln, as for all the The results obtained should take into account that these data are specific and their extrapolation should be done with caution.

Table 91. Emission factor by fuel Hoffman kiln.

Measurement	EFCOfuel (g/kg_fuel)		EFCO <sub>2</sub> fuel (g/kg_fuel)		EFSO <sub>2</sub> fuel (g/kg_fuel)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventS7	71.3791	5.3803	1524.7556	109.8620	2.7001	0.3892

Table 92. Emission factors by energy Hoffman Kiln

Measurement	EFCOenergy (g/MJ)		EFCO <sub>2</sub> energy (g/MJ)		EFSO <sub>2</sub> energy (g/MJ)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventS7	4.97	1.44	106.11	30.68	0.19	0.06


Table 93. Emission factors per brick produced Hoffman kiln

Measurement	EFCObrick (g/kg_brick)		EFCO2brick (g/kg_brick)		EFSO2brick (g/kg_brick)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventS6	4.1859	1.3111	89.4174	27.9369	0.1583	0.0533

At comparing the results of this Hoffman kiln , with the kiln that operate with coal and sawdust in an 80:20 ratio, two things are evident: 1) That this kiln has a specific energy consumption of approximately 20% and 2) that the emissions of this kiln are much lower; which allows us to infer that although the operation of the Hoffman kiln with coal makes the kiln operate efficiently, the emission rate of pollutants and the lower emission factors could compensate, from the point of view of pollution, this loss of efficiency; However, since this corresponds to a single measurement, this conclusion must be taken care of with caution and more studies are required to arrive at conclusive data.

#### 4.12 Hoffman Kiln, Brick kiln Ladrillera el Diamante - 2017.

The following results are related to the monitoring of the Hoffman kiln located in the department of Santander, in the municipality of Girón, this kiln operates with coal 100%; for this monitoring two measurements were made with a total duration of 20 hours.

Kiln information			
Type of kiln	Hoffman	Production during the measurement	250.000Kg
Capacity	400.000 Units	Fuel consumption during the measurement	0.3529 ton
Measurement start line			16 and 13
Measurement end line			28 and 25
			
Hoffman kiln			

## Fuel Analysis

The fuel analyzes were carried out by Mintec Ceramic Ltda, a laboratory specialized in technical consultancy for the ceramic sector. Two types of fuel analysis were carried out: proximate and ultimate analysis, below are the results of these analyses

Table 94. Proximate analysis

Parameter	coal	Units	Ideal parameter
H2O	1.71	% mass	< 3%
Ash	11.18	% mass	< 10%
Volatile matter	40.42	% mass	>30%
Fixed carbon	46.69	% mass	
Sulfur (S)	1.01	% mass	< 1%
Energy Value	7.316	Kcal/kg	> 6500 Kcal/kg
Energy Value	13.160	BTU/lb	
Energy Value	30.63	MJ/kg	
Swelling index	0	FSI	

Tabla 95. Ultimate analysis.

Parameter	Coal	Units
Coal	74.58	% mass
Hydrogen	5.54	% mass
Oxygen	5.92	% mass
Nitrogen	1.56	% mass

As noted in the report, the fuel used in general present good conditions for the use in the Brick industry, except for the percentage of ashes which exceeds the reference value recommended by the laboratory.

## Energy efficiency

The parameter of energy efficiency determined as Specific Fuel Consumption (SEC for its acronym in English) was determined through two process variables, fuel consumption, with its respective laboratory analysis) and the production of bricks; the table presents the process variables and the Specific Fuel Consumption (SEC) for the moment of data collection with an uncertainty ( $\sigma$ ) estimated in the confidentiality interval of 68%.

Table 96. Specific energy consumption (SEC)

Measurement	Brick Production	Fuel rate	Energy	SEC
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	rate (kg/hr)		(kg/hr)		consumption (MJ/hr)		(MJ/kg_brick)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventC9	1666,67	175,68	67,16	3,27	1983.23	563.62	1.19	0.36
EventC10	1666,67	175,68	67,16	3,27	1983.23	563.62	1.19	0.36
<b>Average</b>	1666,67	175,68	67,16	3,27	1983.23	563.62	1.19	0.36

## Pollutants results

The emission results of the measured pollutants (CO<sub>2</sub>, CO, SO<sub>2</sub>, PM<sub>2.5</sub> and BC) are presented in this section, the contaminating gases (CO<sub>2</sub>, CO, SO<sub>2</sub>) are divided from the PM<sub>2.5</sub> and BC particulate fractions. since their nature and form of measurement are different. According to the metrics delivered by the Ratnoze2 equipment , the emission rate (mass flow of the pollutant) and the emission ratios (Point Emission Factors) are presented according to the amount of fuel, energy consumed and according to the production of bricks; for all cases, the average value of the measurement and its respective uncertainty ( $\sigma$ ) estimated in the confidentiality interval of 68% are presented.

## Black carbon and PM<sub>2.5</sub>

The following tables present the results of the emission rate (mass flow) of PM<sub>2.5</sub> particulate material and Black Carbon (BC) fractions, for measurements made during the measurements made to the Hoffman kiln.

Table 97. Emission rate PM<sub>2.5</sub> and BC.

Measurement	ERPM <sub>2.5</sub> (gr/hr)		ERBC (gr/hr)	
	Average	$\sigma$	Average	$\sigma$
EventC9	4,76	1,93	0,45	0,19
EventC10	9,67	3,91	0,67	0,73
<b>Average</b>	7,21	2,92	0,56	0,46

Below are presented the results of emission factors based on mass of fuel, energy consumed and brick production for PM<sub>2.5</sub> and black carbon (BC for its acronym in English) respectively for the monitoring performed, as for all results obtained is it important to take into account that these data are specific and their extrapolation must be done with caution.

Table 98. Emission factor BC by fuel .

Measurement	EFBCfuel (g/Kg_fuel)		EFBCenergy (g/MJ)		EFBCbrick (g/kg_brick)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventC9	0,0068	0,0011	0.0002	0.0001	0,00084	0,00027
EventC10	0,0099	0,0101	0.0003	0.0004	0,00171	0,00040
<b>Average</b>	0,01	0,01	0,0003	0,0002	0,00128	0,00034

## Pollutants results.

The emission results of the emission rate (mass flow) of the polluting gases CO, CO<sub>2</sub> and SO<sub>2</sub>, for the measurement made to the Hoffman kiln

Table 99. Emission rate pollutants

Measurement	ERCO (gr/hr)		ERCO <sub>2</sub> (gr/hr)		ERSO <sub>2</sub> (gr/hr)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventC9	83,66	52,38	183413,07	74386,04	2,72	16,62
EventC10	122,55	70,11	183351,97	74376,42	148,39	65,70
<b>Average</b>	<b>103,10</b>	<b>61,24</b>	<b>183382,52</b>	<b>74381,23</b>	<b>75,56</b>	<b>41,16</b>

The following tables presented the results of the emission factors for CO<sub>2</sub>, CO and SO<sub>2</sub> pollutant gases based on mass of fuel, energy consumed and brick production respectively, for the measurement made during the monitoring of the kiln, as for all the The results obtained should take into account that these data are specific and their extrapolation should be done with caution.

Table 100. Emission factor by fuel Hoffman kiln.

Measurement	EFCOfuel (g/kg_fuel)		EFCO <sub>2</sub> fuel (g/kg_fuel)		EFSO <sub>2</sub> fuel (g/kg_fuel)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventC9	1,25	0,60	2730,99	199,16	0,04	0,25
EventC10	1,82	0,75	2730,08	200,34	2,21	0,42
<b>Average</b>	<b>1,54</b>	<b>0,67</b>	<b>2730,53</b>	<b>199,75</b>	<b>1,13</b>	<b>0,34</b>

Table 101. Emission factor by energy Hoffman kiln


Measurement	EFCOenergy (g/MJ)		EFCO <sub>2</sub> energy (g/MJ)		EFSO <sub>2</sub> energy (g/MJ)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventC9	0.0422	0.0235	92.4818	26.7587	0.0014	0.0084
EventC10	0.0618	0.0307	92.4510	26.7605	0.0748	0.0254
<b>Average</b>	<b>0,0520</b>	<b>0,0271</b>	<b>92.4664</b>	<b>26.7596</b>	<b>0.0381</b>	<b>0,0169</b>

Table 102. Emission factors by brick Hoffman kiln

Measurement	EFCObrick (g/kg_brick)		EFCO <sub>2</sub> brick (g/kg_brick)		EFSO <sub>2</sub> brick (g/kg_brick)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventC9	0,05	0,03	110,05	32,55	0,00	0,01
EventC10	0,07	0,04	110,01	32,55	0,09	0,03
<b>Average</b>	<b>0,06</b>	<b>0,03</b>	<b>110,03</b>	<b>32,55</b>	<b>0,05</b>	<b>0,02</b>

#### 4.13 Hoffman kiln , Brick kiln ladrillera Mariscal Sucre - 2017.

The following results are related to the monitoring of the Hoffman kiln located in the department of Valle del Cauca, in the municipality of Cartago, this kiln operates with coal 100%; for this monitoring two measurements were made with a total duration of 9 hours, this is because it corresponds to the time of change of chamber of the carbojet.

Kiln information			
Type of kiln	Hoffman	Change chamber of	In 24 hours, they advance 28 lines
Capacity	Entre 2900 y 2800 toneladas/Mes	Burning time per line	51 min/line
Measurement start line			33
Total brick kiln lines			72
Diameter of the stack			70cm
			
Hoffman kiln			

### Fuel Analysis

The fuel analyzes were carried out by Mintec Ceramic Ltda, a laboratory specialized in technical consultancy for the ceramic sector. Two types of fuel analysis were carried out: proximate and ultimate analysis, below are the results of these analyses

Table 103. Proximate analysis.

Parameter	coal	Units	Ideal parameter
H2O	8.86	% mass	< 3%
Ash	10.22	% mass	< 10%

Parameter	coal	Units	Ideal parameter
Volatile matter	37.99	% mass	>30%
Fixed carbon	42.93	% mass	
Sulfur (S)	0.60	% mass	< 1%
Energy Value	6.929	Kcal/kg	> 6500 Kcal/kg
Energy Value	12.464	BTU/lb	
Energy Value	29.01	MJ/kg	
Swelling index	0	FSI	

Table 104. Ultimate analysis

Parameter	Coal	Units
Coal	74.90	% mass
Hydrogen	5.01	% mass
Oxygen	6.80	% mass
Nitrogen	1.42	% mass

As noted in the report, the fuel used in general present good conditions for the use in the Brick industry, except for the high percentage of H<sub>2</sub>O ( it correspond to the humidity of the coal) which exceeds the reference value recommended by the laboratory

### Energy efficiency

The parameter of energy efficiency determined as Specific Fuel Consumption (SEC for its acronym in English) was determined through two process variables, fuel consumption, with its respective laboratory analysis) and the production of bricks; the table presents the process variables and the Specific Fuel Consumption (SEC) for the moment of data collection with an uncertainty ( $\sigma$ ) estimated in the confidentiality interval of 68%.

Table 105. Specific energy consumption (SEC)

Measurement	Brick Production rate (kg/hr)		Fuel rate (kg/hr)		Energy consumption (MJ/hr)		SEC (MJ/kg_brick)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventC20	4132,17	447,65	219,58	23,79	6126.38	1839.30	1.48	0.47
EventC21	4132,17	447,65	219,58	23,79	6126.38	1839.30	1.48	0.47
<b>Average</b>	4132,17	447,65	219,58	23,79	6126.38	1839.30	1.48	0.47

### Pollutants results

The emission results of the measured pollutants (CO<sub>2</sub>, CO, SO<sub>2</sub>, PM<sub>2.5</sub> and BC) are presented in this section; the contaminating gases (CO<sub>2</sub>, CO, SO<sub>2</sub>) are divided from the PM<sub>2.5</sub> and BC

particulate fractions. since their nature and form of measurement are different. According to the metrics delivered by the Ratnoze2 equipment , the emission rate (mass flow of the pollutant) and the emission ratios (Point Emission Factors) are presented according to the amount of fuel, energy consumed and according to the production of bricks; for all cases, the average value of the measurement and its respective uncertainty ( $\sigma$ ) estimated in the confidentiality interval of 68% are presented.

### Black carbon and PM2.5

The following tables present the results of the emission rate (mass flow) of PM2.5 particulate material and Black Carbon (BC) fractions, for measurements made during the measurements made to the Hoffman kiln.

Table 106. Emission rate PM2.5 and BC.

Measurement	ERPM2.5(gr/hr)		ERBC (gr/hr)	
	Average	$\sigma$	Average	$\sigma$
EventC20	204,86	85,23	31,32	13,98
EventC21	69,11	28,74	7,80	3,44
<b>Promedio</b>	<b>136,98</b>	<b>56,98</b>	<b>19,56</b>	<b>8,71</b>

Below are presented the results of emission factors based on mass of fuel, energy consumed and brick production for PM2.5 and black carbon (BC for its acronym in English) respectively for the monitoring performed, as for all results obtained is it important to take into account that these data are specific and their extrapolation must be done with caution.

Table 107. Emission factor BC by fuel

Measurement	EFBCfuel (g/Kg_fuel)		EFBCenergy (g/MJ)		EFBCbrick (g/kg_brick)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventC20	0,14	0,02	0.0051	0.0017	0,0076	0,0025
EventC21	0,04	0,01	0.0013	0.0004	0,0019	0,0006
<b>Average</b>	<b>0,09</b>	<b>0,02</b>	<b>0,0032</b>	<b>0,0011</b>	<b>0,0047</b>	<b>0,0016</b>

### Pollutants results.

The emission results of the emission rate (mass flow) of the polluting gases CO, CO2 and SO2, for the measurement made to the Hoffman kiln

Table 108. Emission rate pollutants

Measurement	ERCO (gr/hr)		ERCO <sub>2</sub> (gr/hr)		ERSO <sub>2</sub> (gr/hr)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventC20	4530,34	1913,66	595565,66	248365,93	271,70	141,68
EventC21	1903,01	796,00	599693,79	249852,07	191,56	81,83
<b>Average</b>	<b>3216,68</b>	<b>1354,83</b>	<b>597629,72</b>	<b>249109,00</b>	<b>231,63</b>	<b>111,76</b>

The following tables presented the results of the emission factors for CO<sub>2</sub>, CO and SO<sub>2</sub> pollutant gases based on mass of fuel, energy consumed and brick production respectively, for the measurement made during the monitoring of the kiln, as for all the The results obtained should take into account that these data are specific and their extrapolation should be done with caution.

Table 109. Emission factors pollutants Hoffman kiln

Measurement	EFCOfuel (g/kg_fuel)		EFCO <sub>2</sub> fuel (g/kg_fuel)		EFSO <sub>2</sub> fuel (g/kg_fuel)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventC20	20,63	2,05	2712,25	198,83	1,24	0,40
EventC21	8,67	0,69	2731,05	194,02	0,87	0,10
<b>Promedio</b>	14,65	1,37	2721,65	196,42	1,05	0,25

Table 110. Emission factors by energy Hoffman kiln

Measurement	EFCOenergy (g/MJ)		EFCO <sub>2</sub> energy (g/MJ)		EFSO <sub>2</sub> energy (g/MJ)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventC20	0.74	0.22	97.21	28.14	0.04	0.02
EventC21	0.31	0.09	97.89	28.28	0.03	0.01
<b>Average</b>	0,53	0,16	97.55	28.21	0,04	0,01


Table 111. Emission factors by brick Hoffman kiln

Measurement	EFCObrick (g/kg_brick)		EFCO <sub>2</sub> brick (g/kg_brick)		EFSO <sub>2</sub> brick (g/kg_brick)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventC20	1,10	0,33	144,13	42,14	0,07	0,03
EventC21	0,46	0,14	145,13	42,35	0,05	0,01
<b>Average</b>	0,78	0,23	144,63	42,25	0,06	0,02

#### 4.14 Tunnel Kiln, Brick kiln ladrillera San Cristóbal (kiln operated with a mixed gas-coal) - 2017.

The following results are related to the monitoring of the Tunnel kiln located in the department of Antioquia, in the municipality of Medellin, one of the characteristics of this brick kiln is that they have a high level of technification, and also because the kiln operate with a mixed of 87% gas and 13% coal, this measurement allow us to validate the most efficient fuel in order to avoid the emissions of GHG and BC.

Kiln information			
Type of kiln	Tunnel		
Capacity	280 ton/day	Time of burning	27 to 32 min
Wagons per day			53

Fuel information used			
Type of fuel	Gas	Source	Industrial service
	Coal	Source	Amaga
Way of feeding	Gas burners and Carbojets		
Fuel consumption during measurement			Gas-8150 cubic meters Coal-1100 kg
Percentage % of Coal used			13 %
Percentage % of Gas used			87%
			
Fuel (Gas and coal )			

## Fuel Analysis

The fuel analyzes were carried out by Mintec Ceramic Ltda, a laboratory specialized in technical consultancy for the ceramic sector. Two types of fuel analysis were carried out: proximate and ultimate analysis, below are the results of these analyses

Table 112. Proximate analysis

Parameter	coal	Units	Ideal parameter
H2O	11.79	% mass	< 3%

Parameter	coal	Units	Ideal parameter
Ash	8.84	% mass	< 10%
Volatile matter	36.81	% mass	>30%
Fixed carbon	42.56	% mass	
Sulfur (S)	0.84	% mass	< 1%
Energy Value	5.837	Kcal/kg	> 6500 Kcal/kg
Energy Value	10.500	BTU/lb	
Energy Value	24.43	MJ/kg	
Swelling index	0	FSI	

Table 113. Ultimate analysis

Parameter	coal	Units
Coal	77.59	% mass
Hydrogen	5.01	% mass
Oxygen	4.78	% mass
Nitrogen	1.65	% mass

As noted in the report, the fuel used shows a low quality because it has a high residual humidity and a low calorific power, given that its injection has a minimum percentage with respect to gas, it is not evidenced so drastically in emissions, and however, having better quality combustion would further increase the thermal efficiency of this kiln.

In the present analysis of fuel is not found the gas because the brick industry for reasons of confidentiality did not provide the information.

### Energy efficiency

The parameter of energy efficiency determined as Specific Fuel Consumption (SEC for its acronym in English) was determined through two process variables, fuel consumption, with its respective laboratory analysis) and the production of bricks; the table presents the process variables and the Specific Fuel Consumption (SEC) for the moment of data collection with an uncertainty ( $\sigma$ ) estimated in the confidentiality interval of 68%.

Table 114. Specific energy consumption (SEC)

Measurement	Brick Production rate (kg/hr)		Fuel rate (kg/hr)		Energy consumption (MJ/hr)		SEC (MJ/kg_brick)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventS7	11666.66	1191.71	340.53	34.23	7931.11	2359.54	0.68	0.21

If you compare the result of this measurement for this technology (Tunnel Kiln) with the data of the Technical Sheet of Brick Kilns in South and Southeast Asia of the CCAC, which specifies a range of 1.34 - 1.47 MJ / kg ( Greentech Knowledge Solutions Pvt. Ltd., 2013) value specified for

coal-fired kilns, it can be said that this kiln behaves much more efficiently than the average, according to the standardized base year 2015 developed by the CAEM during the implementation of the EELA project, tunnel kilns in the country, with coal as fuel, operate with an average SEC of 1,514 MJ / kg, therefore, compared to Colombian data, this kiln operates with a higher than average efficiency.

## Pollutants results

The emission results of the measured pollutants (CO<sub>2</sub>, CO, SO<sub>2</sub>, PM<sub>2.5</sub> and BC) are presented in this section; the contaminating gases (CO<sub>2</sub>, CO, SO<sub>2</sub>) are divided from the PM<sub>2.5</sub> and BC particulate fractions. since their nature and form of measurement are different. According to the metrics delivered by the Ratnoze2 equipment, the emission rate (mass flow of the pollutant) and the emission ratios (Point Emission Factors) are presented according to the amount of fuel, energy consumed and according to the production of bricks; for all cases, the average value of the measurement and its respective uncertainty ( $\sigma$ ) estimated in the confidentiality interval of 68% are presented.

## Black carbon and PM 2.5

The following tables present the results of the emission rate (mass flow) of PM<sub>2.5</sub> particulate material and Black Carbon (BC) fractions, for measurements made during the measurements made to the Tunnel kiln.

Table 115. Emission rate PM<sub>2.5</sub> and BC

Measurement	ERPM <sub>2.5</sub>		ERBC	
	Average	$\sigma$	Average	$\sigma$
EventS8	167.7995	93.9526	1.9121	1.1869

Below are presented the results of emission factors based on mass of fuel, energy consumed and brick production for PM<sub>2.5</sub> and black carbon (BC for its acronym in English) respectively for the monitoring performed, as for all results obtained is it important to take into account that these data are specific and their extrapolation must be done with caution.

Table 116. Emission factor BC by fuel

Measurement	EFBC <sub>fuel</sub> (g/Kg <sub>fuel</sub> )		EFBC <sub>energy</sub> (g/MJ)		EFBC <sub>brick</sub> (g/kg <sub>brick</sub> )	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventS8	0.0056	0.0017	0.00024	0.00010	0.0002	0.0001

Table 117. Emission factor PM<sub>2.5</sub>

Measurement	EFPM <sub>2.5fuel</sub> (g/Kg <sub>fuel</sub> )		EFPM <sub>2.5energy</sub> (g/MJ)		EFPM <sub>2.5brick</sub> (g/kg <sub>brick</sub> )	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventS8	0.4927	0.0595	0.0212	0.0065	0.0144	0.0080

The emission results of the emission rate (mass flow) of the polluting gases CO, CO<sub>2</sub> and SO<sub>2</sub>, for the measurement made to the Hoffman kiln

Table 118. Emission rate pollutants

Measurement	ERCO		ERCO <sub>2</sub>		ERSO <sub>2</sub>	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventS8	6021.5281	3400.2174	885878.3744	496597.2712	203.2726	156.6538

The following tables presented the results of the emission factors for CO<sub>2</sub>, CO and SO<sub>2</sub> pollutant gases based on mass of fuel, energy consumed and brick production respectively, for the measurement made during the monitoring of the kiln, as for all the The results obtained should take into account that these data are specific and their extrapolation should be done with caution.

Table 119. Emission factor pollutants Tunnel kiln

Measurement	EFCOfuel (g/kg_fuel)		EFCO <sub>2</sub> fuel (g/kg_fuel)		EFSO <sub>2</sub> fuel (g/kg_fuel)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventS8	17.6824	2.4976	2601.4134	322.1004	0.5969	0.3242

Table 120. Emission factors by energy Tunnel kiln

Measurement	EFCOenergy (g/MJ)		EFCO <sub>2</sub> energy (g/MJ)		EFSO <sub>2</sub> energy (g/MJ)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventS8	0.7592	0.2381	111.6966	34.1964	0.0256	0.0157


Table 121. Emission factors by brick Tunnel kiln

Measurement	EFCObrick (g/kg_brick)		EFCO <sub>2</sub> brick (g/kg_brick)		EFSO <sub>2</sub> brick (g/kg_brick)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventS8	0.5161	0.2890	75.9324	42.2097	0.0174	0.0134

If we compared the black carbon emission factors obtained according to the fuel in the different monitoring carried out to the kilns without taking into account their technology, the kiln that operates mainly with gas (87%) presents emissions that are between 98% and 99% lower than fuels such as biomass and coal.

#### 4.15 Horno continuo Túnel, ladrillera Casagres (planta Tecnigres) - 2017

The following results of the tunnel kiln, located in the department of Caldas, in the city of Manizales, operated with coal; for this monitoring, two measurements were made for a total of 18 hours of measurement, day and night.

Kiln information			
Type of kiln	Tunnel		
Capacity	3.58 Kg per wagon	Time of burning per wagon	64 minutes
Measurement dates	30 -31/08/2017	Nozzle diameter	2.381
No of wagons	26	Wagons per day	11
Time of wagons inside the kiln	Every 2 hours comes in and out a wagon		
			
Tunnel Kiln			

#### Fuel Analysis

The fuel analyzes were carried out by Mintec Ceramic Ltda, a laboratory specialized in technical consultancy for the ceramic sector. Two types of fuel analysis were carried out: proximate and ultimate analysis, below are the results of these analyses

Table 122. Proximate analysis

Parameter	coal	Units	Ideal parameter
H2O	4.16	% mass	< 3%
Ash	7.75	% mass	< 10%
Volatile matter	40.48	% mass	>30%
Fixed carbon	47.61	% mass	
Sulfur (S)	0.67	% mass	< 1%

Parameter	coal	Units	Ideal parameter
Energy Value	5.811	Kcal/kg	> 6500 Kcal/kg
Energy Value	10.453	BTU/lb	
Energy Value	24.32	MJ/kg	
Swelling index	1	FSI	

Table 123. Ultimate analysis

Parameter	coal	Units
Coal	78.55	% mass
Hydrogen	4.21	% mass
Oxygen	7.88	% mass
Nitrogen	1.28	% mass

As noted in the report, the fuel used in general present good conditions for the use in the brick industry, only it has a little bit residual humidity and a low calorific power, below the 6500Kcal/kg, due to in its process, they use recirculation of heat, it is not evidence so drastically in the emissions, however, having a better quality of coal will help the improve the energy efficiency of the kiln.

### Energy efficiency

The parameter of energy efficiency determined as Specific Fuel Consumption (SEC for its acronym in English) was determined through two process variables, fuel consumption, with its respective laboratory analysis) and the production of bricks; the table presents the process variables and the Specific Fuel Consumption (SEC) for the moment of data collection with an uncertainty ( $\sigma$ ) estimated in the confidentiality interval of 68%.

Table 124. Specific energy consumption (SEC)

Measurement	Brick Production rate (kg/hr)		Fuel rate (kg/hr)		Energy consumption (MJ/hr)		SEC (MJ/kg_brick)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventC18	3391,67	441,50	274,83	35,78	6442.09	1989.18	1.90	0.64
EventC19	3391,67	441,50	274,83	35,78	6442.09	1989.18	1.90	0.64
<b>Average</b>	3391,67	441,50	274,83	35,78	6442.09	1989.18	1.90	0.64

### Pollutants results

The emission results of the measured pollutants (CO<sub>2</sub>, CO, SO<sub>2</sub>, PM<sub>2.5</sub> and BC) are presented in this section; the contaminating gases (CO<sub>2</sub>, CO, SO<sub>2</sub>) are divided from the PM<sub>2.5</sub> and BC particulate fractions. since their nature and form of measurement are different. According to the

metrics delivered by the Ratnoze2 equipment , the emission rate (mass flow of the pollutant) and the emission ratios (Point Emission Factors) are presented according to the amount of fuel, energy consumed and according to the production of bricks; for all cases, the average value of the measurement and its respective uncertainty ( $\sigma$ ) estimated in the confidentiality interval of 68% are presented.

## Black carbon and PM2.5

The following tables present the results of the emission rate (mass flow) of PM2.5 particulate material and Black Carbon (BC) fractions, for measurements made during the measurements made to the Tunnel kiln.

Table 125. Emission rate PM2.5 and BC

Measurement	ERPM2.5(gr/hr)		ERBC (gr/hr)	
	Average	$\sigma$	Average	$\sigma$
EventC18	34,71	14,66	3,70	1,68
EventC19	28,51	12,03	4,76	2,10
<b>Average</b>	31,61	13,35	4,23	1,89

Below are presented the results of emission factors based on mass of fuel, energy consumed and brick production for PM2.5 and black carbon (BC for its acronym in English) respectively for the monitoring performed, as for all results obtained is it important to take into account that these data are specific and their extrapolation must be done with caution.

Table 126. Emission factor BC by fuel

Measurement	EFBCfuel (g/Kg_fuel)		EFBCenergy (g/MJ)		EFBCbrick (g/kg_brick)	
	Promedio	$\sigma$	Promedio	$\sigma$	Promedio	$\sigma$
EventC18	0,0135	0,0024	0.0006	0.0002	0,00109	0,00036
EventC19	0,0173	0,0024	0.0007	0.0002	0,00140	0,00044
<b>Promedio</b>	0,0154	0,0024	0,0007	0,0002	0,00125	0,00040

## Pollutants Analysis Results

The emission results of the emission rate (mass flow) of the polluting gases CO, CO2 and SO2, for the measurement made to the tunnel kiln:

Table 127. Emission rate pollutants

Measurement	ERCO		ERCO <sub>2</sub>		ERSO <sub>2</sub>	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventC18	408,07	217,10	790445,30	334402,43	268,18	130,06
EventC19	474,52	227,83	790340,89	334308,15	1153,20	493,94
<b>Promedio</b>	441,30	222,46	790393,09	334355,29	710,69	312,00

The following tables presented the results of the emission factors for CO<sub>2</sub>, CO and SO<sub>2</sub> pollutant gases based on mass of fuel, energy consumed and brick production respectively, for the measurement made during the monitoring of the kiln, as for all the The results obtained should take into account that these data are specific and their extrapolation should be done with caution.

Table 128. Emission factor pollutants Tunnel kiln

Measurement	EFCOfuel (g/kg_fuel)		EFCO <sub>2</sub> fuel (g/kg_fuel)		EFSO <sub>2</sub> fuel (g/kg_fuel)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventC18	1,48	0,49	2876,09	208,03	0,98	0,24
EventC19	1,73	0,41	2875,71	206,93	4,20	0,41
<b>Average</b>	<b>1,61</b>	<b>0,45</b>	<b>2875,90</b>	<b>207,48</b>	<b>2,59</b>	<b>0,33</b>

Table 129. Emission factors by energy Tunnel kiln

Medición	EFCOenergy (g/MJ)		EFCO <sub>2</sub> energy (g/MJ)		EFSO <sub>2</sub> energy (g/MJ)	
	Promedio	$\sigma$	Promedio	$\sigma$	Promedio	$\sigma$
EventC18	0.063	0.027	122.700	35.484	0.042	0.016
EventC19	0.074	0.027	122.684	35.468	0.179	0.053
<b>Promedio</b>	<b>0,069</b>	<b>0,027</b>	<b>122.69</b>	<b>35.47</b>	<b>0,110</b>	<b>0,034</b>

Table 130. Emission factors by brick Tunnel kiln

Measurement	EFCObrick (g/kg_brick)		EFCO <sub>2</sub> brick (g/kg_brick)		EFSO <sub>2</sub> brick (g/kg_brick)	
	Average	$\sigma$	Average	$\sigma$	Average	$\sigma$
EventC18	0,12	0,05	233,06	67,68	0,08	0,03
EventC19	0,14	0,05	233,02	67,65	0,34	0,10
<b>Average</b>	<b>0,13</b>	<b>0,05</b>	<b>233,04</b>	<b>67,67</b>	<b>0,21</b>	<b>0,07</b>

#### 4.16 Tunnel kiln, Brick kiln ladrillera San Cristóbal (located in Itagüí) - 2017

The last kiln object of measurement, was the tunnel kiln, located in the department of Antioquia in the city of Medellín, this kiln is operated with coal and is located in Itagüí; although it was monitored within the framework of the field days of monitoring in the region, it was not possible

to carry it out satisfactorily, this because at the time of measurement, there was a clog in the nozzle so the flows sampled and samples taken did not enter the equipment in the determined flows, therefore the information taken is not valid and representative for the operation of this technology. Therefore, it was the only measurement that was not analyzed, through the datacruncher software.

However, the fuel samples were taken and analyzed.

### Fuel Analysis.

The fuel analyzes were carried out by Mintec Ceramic Ltda, a laboratory specialized in technical consultancy for the ceramic sector. Two types of fuel analysis were carried out: proximate and ultimate analysis, below are the results of these analyses

Table 131. Proximate analysis

Parameter	coal	Units	Ideal parameter
H2O	9.72	% mass	< 3%
Ash	7.97	% mass	< 10%
Volatile matter	38.91	% mass	>30%
Fixed carbon	43.40	% mass	
Sulfur (S)	0.46	% mass	< 1%
Energy Value	5.658	Kcal/kg	> 6500 Kcal/kg
Energy Value	10.178	BTU/lb	
Energy Value	23.68	MJ/kg	
Swelling index	0	FSI	

Table 132. Ultimate analysis

Parameter	coal	Units
Coal	76.6	% mass
Hydrogen	4.70	% mass
Oxygen	8.01	% mass
Nitrogen	1.35	% mass

According to the information, a low quality of the fuel is evidenced, due to the fact that it has a high residual humidity and a lower energy value than 6500 Kcal / Kg, since it was not possible to carry out the emission analysis, it was not possible to validate the combustion efficiency.

It is expected next year, to be able to perform the measurement again in this type of technology in order to be able to validate the monitoring information and obtain an emission factor for it.

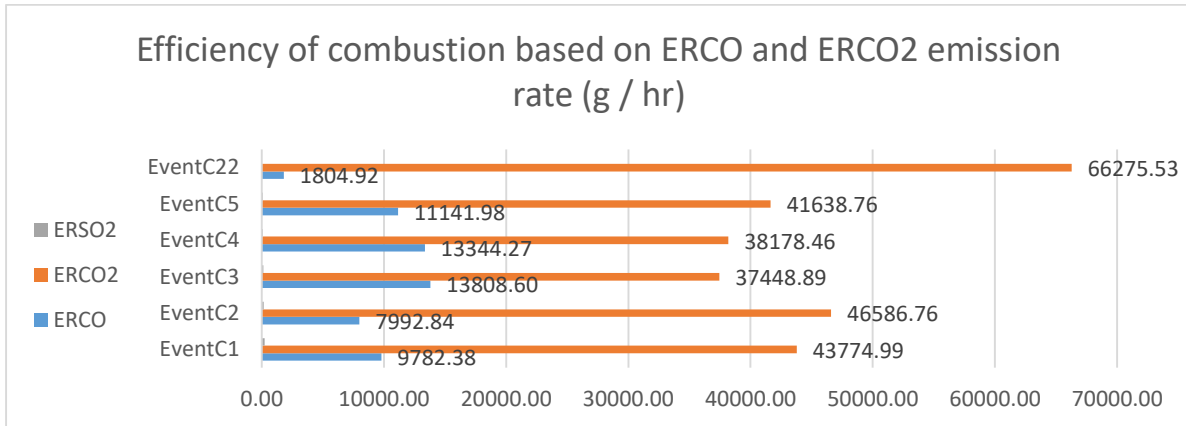
## Conclusions

### Artisanal Kilns

According to the monitoring carried out in the artisanal kilns mentioned above and taking into account that in the framework of this report the results were not analyzed so deeply, since these

are analyzed in the "Technical Analysis report". The present conclusions are based on the efficiency of the combustion by type of technologies dividing them into artisanal, intermittent and in the frame of the continuous technologies separating the technological models wagon, zigzag, hoffman and tunnel.

Graphic 2. Emission rates consolidation of the artisanal kiln .



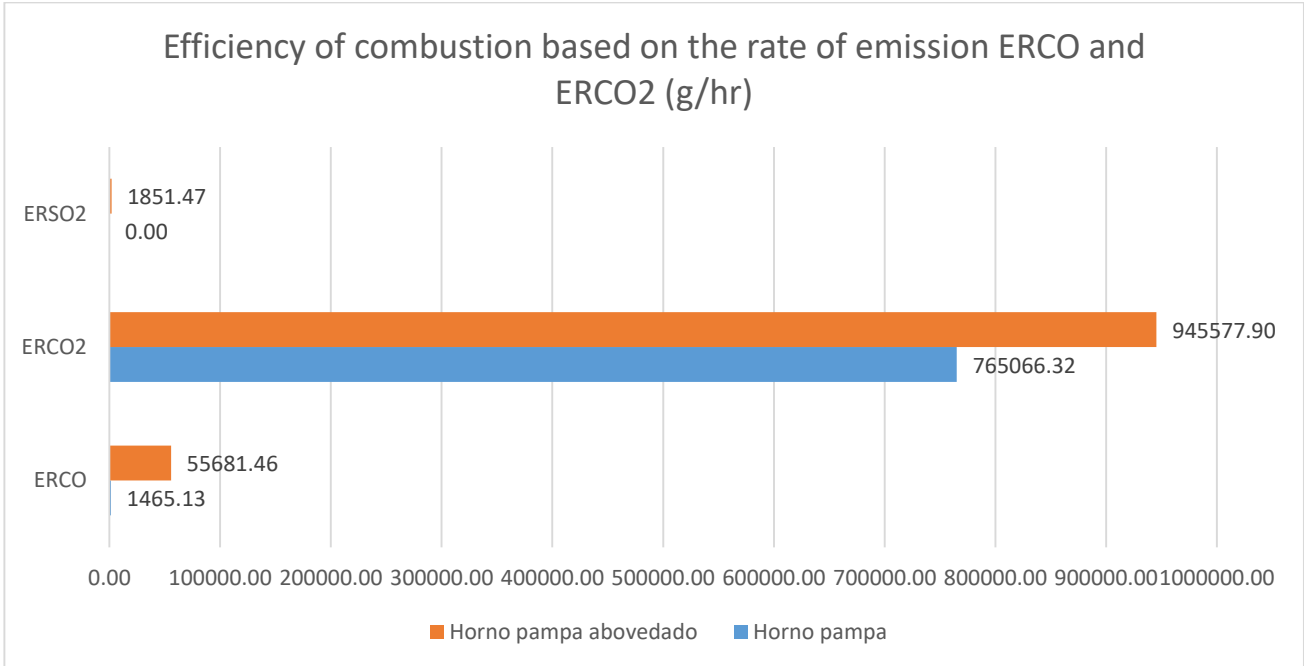
At comparing the two monitoring carried out during 2017 to the artisanal kiln that were made in different times for example, the first one was at the half of the burning (eventC1 to eventC5) and the last one was at the beginning of the burning (eventC22), it is evidenced that the highest CO2 generation value occurs at the beginning of the burn; In the opposite case when the kiln is gaining temperature, the generation of CO2 emissions does not have such a marked and marked variation; However, the high presence of CO2, due to the long period of time of this type of technology, not only validates the inefficiency of combustion, but also the opportunity of a high potential to reduce Greenhouse Gases for this artisanal sector.

Hence the importance of the validation and linkage of the Ministry of Industry and Commerce who, within the framework of the NDC's goals set out by Colombia government, has formulated, with the support of CAEM, a measure for the contribution of this goal which has been prioritized. And consists in the substitution of artisanal kilns by continuous-chamber this type of kiln has a greater energy efficiency.

**Intermittent kilns -type pampa fuel biomass.**

Based on the results obtained for this type of kilns and specifically for the use of this type of fuel (coffee dust) in two different regions of the country, we obtained the following:

Graphic 3. Emission rate consolidation of the pampa type kilns artisanal vs. modified.

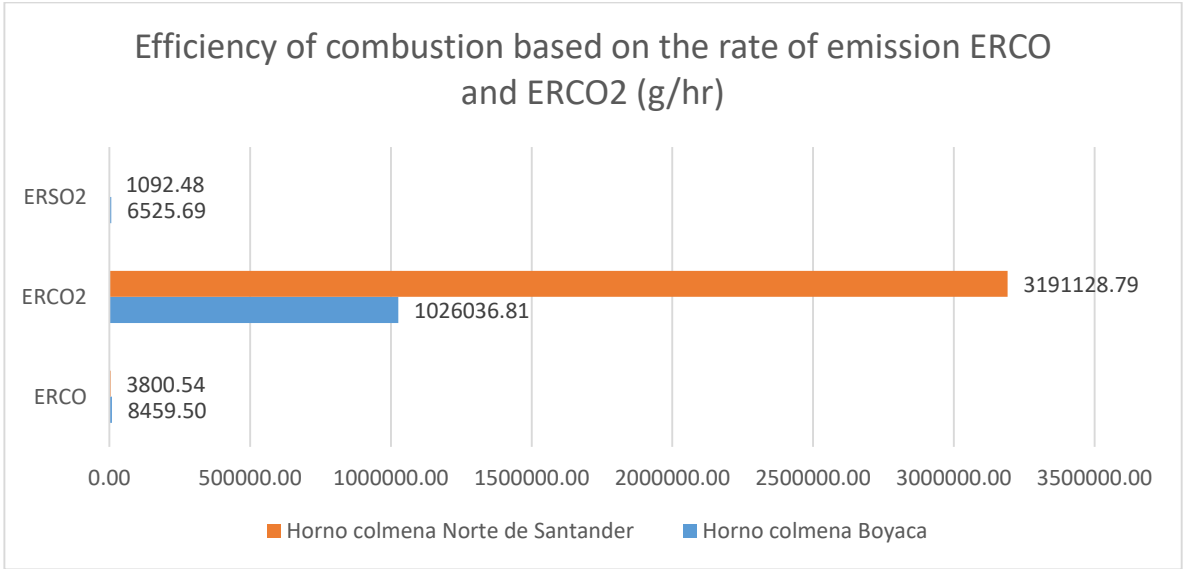


At comparing the results and adding the two measurements made in the domed pampa kiln in Quindio (eventS4 and eventS5) for which coffee cisco was used and the monitoring in the pampa kiln in Huila (eventC24), it was obtained that for the case study of the total emissions generated from both CO<sub>2</sub> kilns and taking into account that even the quality of coffee cisco is better in Huila, 55% correspond to the domed pampa kiln while 45% correspond to the pampa kiln, which is an indicator that combustion is more efficient in the domed kiln and likewise allows to promote the implementation of peripheral measures such as domes and chimneys for this type of technology.

**Intermittent kiln -type dome kiln with air/fuel injection.**

Based on the results obtained for this type of kiln and in two different regions of the country, we obtained that:

Graphic 4. Emission rate consolidation of the dome kiln with air/fuel injection.

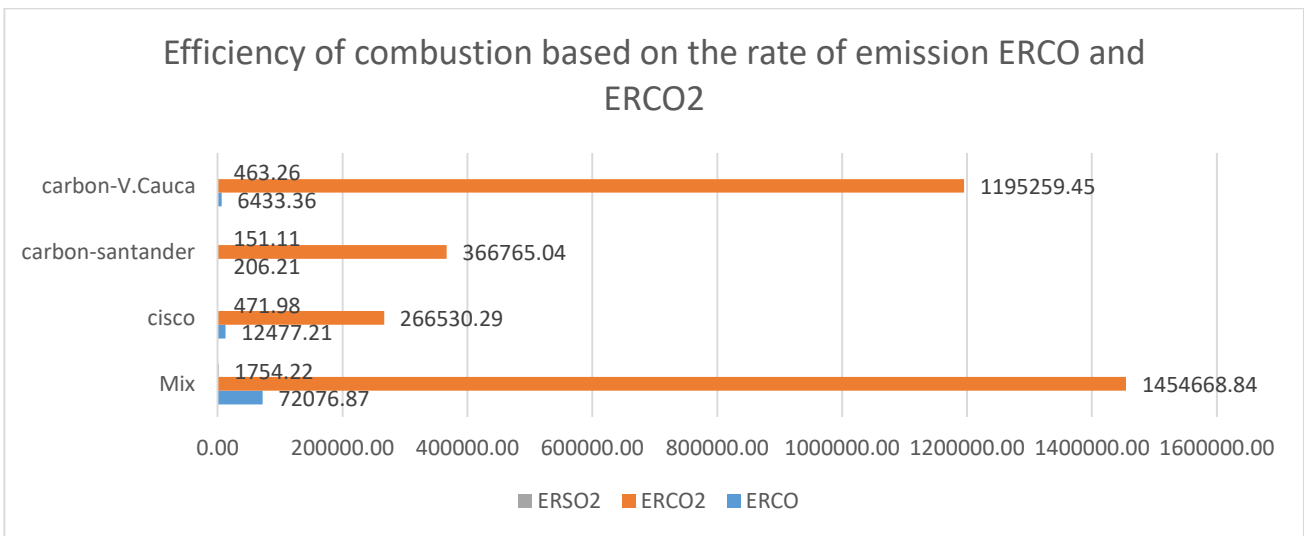


Based on the previous graph it is observed that the dome kiln of Norte de Santander due to the process of reducing atmosphere that it carries out to give a specific tonality to its bricks or tablets generates a greater quantity of CO<sub>2</sub>, which is an indicator that the combustion is better with respect to the Boyacá kiln, however both kilns have a SEC, similar in the fundamental parameter of the combustion that is the CO the dome kiln of Boyacá is less efficient, in its combustion this possibly to an inadequate handling of the damper

**Continuous Kilns.**

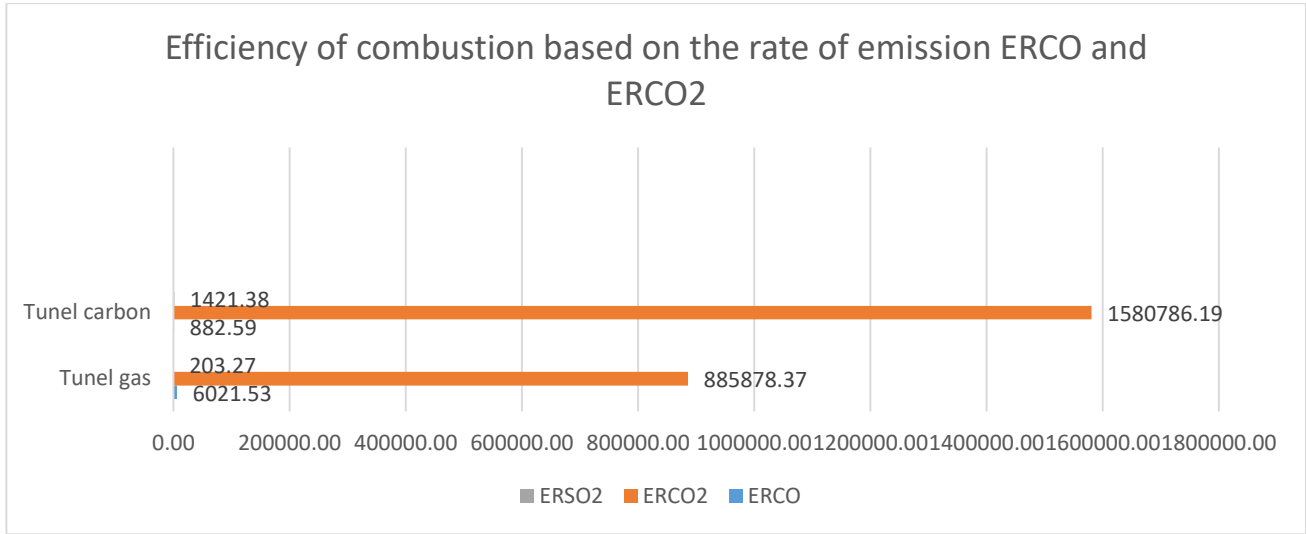
Based on the results of the measurements for these types of kilns that were carried out in different regions of the country it were obtained for the Hoffman kilns the following results:

Graphic 5. Emission rate consolidation Hoffman kiln (g/hr).



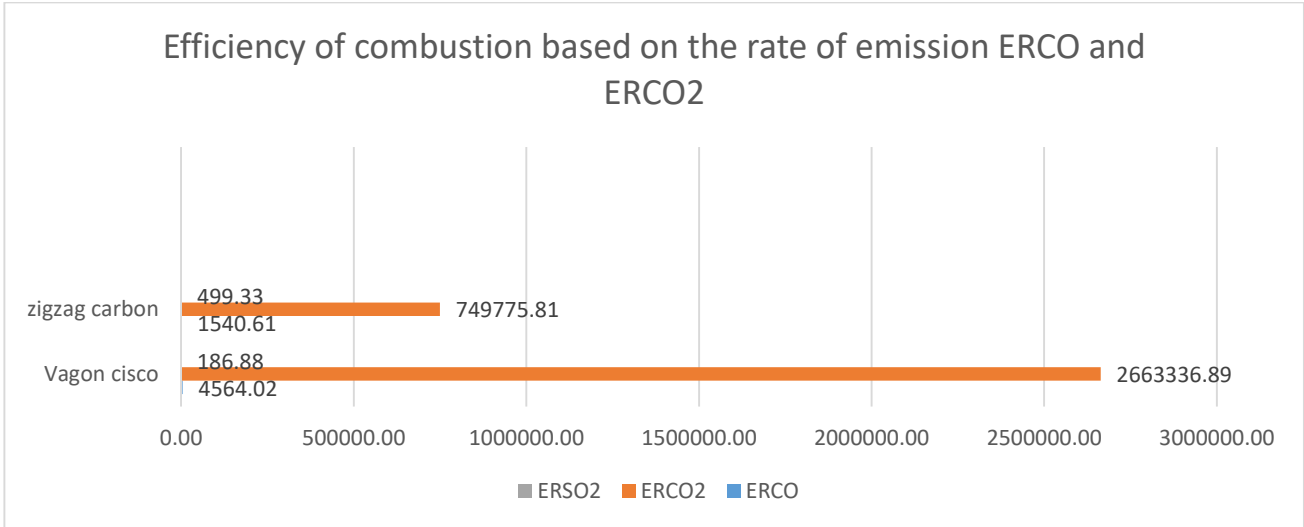
As seen in the previous graph, the CO<sub>2</sub> emission rate is higher in the hoffman kiln that uses the mixture of coal and sawdust, followed by the coal-operated kiln in the Cauca valley, the good combustion process of the hoffman kiln operated with the mix can be attributed to the quality of the fuel and its calorific value, additionally validates the SEC index of the hoffman kiln in terms of the combustion process; by the other side the kiln located in Valle del Cauca and operated 100% with coal also has a SEC of 1.5 MJ / kg which is in the ranges similar to Tunnel kilns operated in Asia (Greentech Knowledge Solutions Pvt. Ltd., 2013).

Graphic 6. Emission rate consolidation Tunnel kiln (g/hr).



In the previous graph, is identified that the emission rate of the tunnel kiln operated completely with coal versus the tunnel kiln that operates with the gas and coal mixture, varies considerably therefore, the use of gas as a fuel is an appropriate measure of GHG reduction, taking into account that for reasons of confidentiality it was not possible to obtain the complete information of the fuel with the highest proportion in the combustion process that was the gas.

Graphic 7. Emission rate consolidation Zig Zag and Wagon Kiln (g/hr).



Finally, the emission rate of the wagon and zigzag kiln is represented graphically, because their operation and fuel is totally different; it is not possible to relate them directly, however they are shown by way of simplification and comparison, it is important to mention that for the wagon kiln operated with cisco, a high temperature in the exit of the flue gases was evidenced, which is an indicator that there could be energy losses associated with combustion and therefore a higher fuel consumption, beyond that the kiln has a good SEC of 2.6 Mj / kg and a good combustion process with respect to a continuous technology such as the zig zag kiln.

## ANNEXES.

- Annex 1 - Results report analysis of gravimetric filters and BC UPB laboratory.
- Annex 2- Results report fuel analysis. Mintec Ceramic.
- Annex 3- Biomass fuel validation results report, kiln called “la fe”.