INTRODUCTION AND HISTORY

DOME/CIRCULAR KILN (ASCENDANT FLAME / DOWNDRAFT)

This kiln has a circular shape and is a technology widely disseminated across all regions in Brazil, Colombia and Peru. The principle of the operation consists in an ascendant flame that elevates the temperature into the kiln, then the heating moves from the roof to the floor of the kiln aided by a down draft.

The combustion starts at the lateral zones of the kiln (04 or 06 burners located equidistantly), at the beginning of the burning process the gases produced by the combustion move towards the roof of the dome, then the heat goes down through the bricks and finally through the small apertures at the floor.

The flue gases leave the kiln through an underground duct and go to the chimney.

The draft can be natural or forced. The fuels commonly used are logs, branches and pieces of wood.

GEOGRAPHICAL DISTRIBUTION:

FACTSHEET ABOUT BRICK/TILES KILN TECHNOLOGIES IN LATIN AMERICA

TYPE OF KILN

CHARACTERISTICS OF ENTERPRISES USING THIS TECHNOLOGY:

<table>
<thead>
<tr>
<th>Kiln</th>
<th>Level of mechanisation</th>
<th>Nature of Organisation</th>
<th>Type of bricks/tiles produced</th>
<th>Annual production capacity of the enterprise</th>
<th>Operational period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intermittant</td>
<td>Semi-mechanised</td>
<td>Industrial</td>
<td>Hollow/perforated bricks - Tiles</td>
<td>&gt; 5 million bricks (medium scale)</td>
<td>Round the year</td>
</tr>
</tbody>
</table>

ESTIMATED N° OF OPERATIONAL ENTERPRISES AND TOTAL PRODUCTION (USING DOME KILN)

<table>
<thead>
<tr>
<th>Country</th>
<th>N° of enterprises</th>
<th>Total Production (million bricks/tiles/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brazil</td>
<td>~ 1,750</td>
<td>~ 10.300</td>
</tr>
<tr>
<td>Colombia</td>
<td>~ 349</td>
<td>~ 209</td>
</tr>
<tr>
<td>Peru</td>
<td>~10</td>
<td>~10</td>
</tr>
</tbody>
</table>
**DOME/CIRCULAR KILN (ASCENDANT FLAME / DOWNDRAFT)**

**DESCRIPTION & WORKING:**

Dome Kiln dimensions are: 5 - 10 meters of diameter and 2.8 - 3.2 meters of height.

1. The heating produced during the combustion process rise towards the roof of the kiln.

2. Once on the roof the gases change direction and move down through the bricks or tiles.

3. Then the gases leave the kiln through small openings on the floor.

4. Finally the gases (fumes) move toward the chimney through an underground duct; this process can be natural or forced by an exhaust.

The complete production cycle in the kiln is long: 06 - 08 hours for preheating, 36 - 48 hours for firing process and up to 03 days for cooling process; these periods depend on the type of product, raw material, type of burning process and fuel used.

The operation temperature range from 750 to 930°C, the temperature at the roof is slightly higher compared with the rest of the kiln; i.e. the temperature is slightly lower at the zone near the floor where the gases duct is located.
**DOME/CIRCULAR KILN** *(ASCENDANT FLAME / DOWNDRAFT)*

**Air Emissions and Impacts:**
- **Measured Emission Factors**
  - Biomass (e.g., firewood, biomass briquettes, sawdust).
  - Coal (dust).

**Commonly Used Fuels**
- Biomass
- Coal (dust)

**Specific Energy Consumption** *(SEC)*
(measured at firing temperature of 900-1100 °C)
- Average: 3.50 MJ/kg fired bricks or tiles (Range: 2.5 – 3.7 MJ/kg fired brick or tile)

**Emission Standards**
- Emission standards are notified only for PM emissions.
- The values of emission standards for fixed sources depend on the thermal power rating (MW).

**Comments on Emissions**
- This kiln produces low emissions of soot (particulate matter) because the structure acts as a filter; i.e., the particulate matter is retained in the structure of the kiln and the load of bricks.

**Description on Product Quality**
- Non-uniform temperature across the vertical section of the kiln results in under-fired bricks/tiles at the floor zone and hence differences in the product quality.

**Fuel and Energy:**
- **Measured PM Emission** *(mg/Nm³)*
  - Average: 44.6 (with air/fuel injection)
  - 243.7 (without fuel injection)

**Financial Performance:**
- Capital Cost of the Kiln Technology
- (for annual production capacity of 3 – 5 million bricks or tiles) (excluding land and working capital cost)
- **Capital Cost Breakdown**
  - Material Cost: 70%
  - Labour Cost: 28%
  - Equipment Cost: 2%
  - Total: 100%

**Product Quality:**
- **Product quality:**
  - Good - 70%
  - Inferior - 25%
  - Losses and Breakages - 5%

**Occupational Health and Safety (OHS):**
- **Exposure to Respirable Suspended Particulate Matter**
  - Flue gases exhausted from the chimney and unpaved surfaces around cause a very high concentration of soot and dust in the surrounding environment and the workers are exposed to high concentration of suspended particulate matter.
  - This can result in a few cases of respiratory diseases among workers.

- **Exposure to Thermal Stress**
  - Workers responsible of discharging products and fuel supply are exposed directly to heat and some radiation.
  - This can result in dehydration among workers.

- **Risk of Accidents**
  - Danger of burning during the firing or discharging
  - Risk of injuries

- **Compliance with ILO standards and remarks on migratory labour and conditions of labour:**
  - Practices followed at Dome/circular kiln enterprises do not comply with the International Labour Standards on occupational health and safety drawn up by ILO. Workers are usually exposed to thermal stress and emissions.
  - No migratory labour issues have been identified.
CONCLUSION & REFERENCES:

Conclusion:

Parameters | Dome kiln | Comments
---|---|---
AIR EMISSION (G/KG FIRED BRICK) | | 
CO2 | 330 | Incomplete combustion in Dome Kiln results in high value of emissions. The average value of PM emission lie within the notified limit, however, some of the kilns could emit higher PM.
Black Carbon | NA | 
PM | NA | 
CO | NA | 

FUEL & ENERGY | | 
SEC (MJ/kg fired brick) | 3,50 | Incomplete combustion and heat losses result in increase in the fuel consumption in Dome Kiln.

FINANCIAL PERFORMANCE | | 
Capital Cost (USD) | 30,000 to 50,000 | Low capital investment and high return are one of the main reasons of the popularity of the Dome Kiln.
Production Capacity | 3-8 million bricks/year | 
Simple Payback | 0.6 – 1.7 years | 

PRODUCT QUALITY | | 
Types of product | All types of product | Non-uniform temperature distribution in the cross-section of the kiln results in variation in product quality.
Good Quality Product | 60-80% | 

OHS | | 
Exposure to dust | yes | Dome Kiln operators work under exposition to high heat
Exposure to Thermal stress | yes | 
Risk of accidents | yes | 

FOR MORE INFORMATION:

REFERENCES:

References are provided as ‘Endnotes’

(2) Ibid.
(3) Field observation.
(4) Ibid.
(5) By its initials in Portuguese

ACKNOWLEDGEMENT:

The project team would like to acknowledge the financial support received from the Swiss Agency for Development and Cooperation for the preparation of these fact-sheets.

Note:

In the initial stage of this initiative of developing factsheet on brick kiln technologies, factsheet are developed for South and South-East Asia and Latin America regions. Factsheet on brick kiln technologies of other regions will be developed over time.

Factsheet prepared by:

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Swisscontact, Lima, Peru
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Design & Illustration:

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INTRODUCTION AND HISTORY

This kiln is an alternative version of the traditional Hoffman model and consists in a set of chambers (usually twelve to sixteen chambers) built in pairs to facilitate the flue gases transfer. The heat produced in a chamber is deflected to the dome (roof), then the hot gases move down heating the bricks and leave the chamber through the openings on the floor, move across the openings in the floor and to the next chamber through holes at the bottom zone in the fixed walls which are connected to the next chamber, producing a preheating of this chamber. This kiln produces homogeneous products due to the constant temperature of the heat that moves from one chamber to another, with a low level of losses. The draft can be natural or forced. The fuels commonly used are logs, branches and pieces of wood.

CEDAN KILN (SEMI-CONTINUOUS)

GEOGRAPHICAL DISTRIBUTION:

<table>
<thead>
<tr>
<th>Country</th>
<th>N° of enterprises</th>
<th>Total Production (billion bricks/tiles/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brazil</td>
<td>~150</td>
<td>~1.5</td>
</tr>
</tbody>
</table>

FACTSHEET ABOUT BRICK/TILES KILN TECHNOLOGIES IN LATIN AMERICA
CEDAN KILN (SEMI-CONTINUOUS)

DESCRIPTION & WORKING:

Cedan Kiln is a semi continuous moving fire model in which the heat moves forward in the direction of air flow due to the draught provided by a chimney. This kiln has a rectangular shape and dimensions are: 25 to 30 meters in the front for 12 chambers (06 on each side), sidewall around 08 meters (covering two chambers) and height between 2,8 to 3,0 meters.

The process starts with the burning of the first chamber. The hot gases are conducted through the duct to the stack. The process is repeated from one chamber to the next. The whole cycle takes between 55 to 65 hours, reaching temperatures in the range of 800 to 930°C. The burning takes 16 hours.

- Hot gases produced by the burning process in the chamber moves to the next chambers, where the green products are preheated.
- The hot gases are conducted through the duct to the stack.
- Flue gases to the chimney.
**CEDAN KILN (SEMI-CONTINUOUS)**

**AIR EMISSIONS AND IMPACTS:**

**COMMONLY USED FUELS**
- Biomass (e.g., firewood, biomass briquettes, sawdust).

**SPECIFIC ENERGY CONSUMPTION**
- (SEC) (measured at firing temperature of 900-1100 °C)
  - Average: 1.85 MJ/kg fired bricks or tiles
  - Range: 1.75 – 1.95 MJ/kg fired brick or tile

**EMISSION STANDARDS**
- Emission standards are notified only for PM emissions

**MEASURED PM EMISSION**
- Average: Not available

**COMPARISON WITH OTHER KILN TECHNOLOGIES**
- Cedan Kiln reports a SEC value under the range for traditional kilns (SEC – 2 to 4 MJ/kg fired brick), but the value is slightly above compared to the reported SEC values for continuous kilns (tunnel model).

**DESCRIPTION ON ENERGY CONSUMPTION AND MAIN CAUSES OF HEAT LOSS**
- The fuel consumption is low and there is low PM in the flue gas.

**FUEL AND ENERGY:**

**SPECIFIC ENERGY CONSUMPTION**
- (SEC)
  - 1,85 MJ/kg fired bricks or tiles
  - Range: 1.75 – 1.95 MJ/kg fired brick or tile

**COMMENTS ON EMISSIONS**
- Soot emissions are very low because the internal design of the kiln acts like a filter. Even though the kiln can use a continuous biomass feeding process (sawdust or chopped firewood) reducing or eliminating the soot completely.

**FINANCIAL PERFORMANCE:**
- **Capital Cost of the kiln technology**
  - (for annual production capacity of 4-9 million bricks)
  - (excluding land and working capital cost)
  - 200,000 to 260,000 USD (depending of the number of chambers)

**DESCRIPTION ON PRODUCT QUALITY**
- Homogenous and very high quality.

**PRODUCT QUALITY:**
- **Good Brick**
- **Inferior Brick**
  - Under-fired and over-burnt

**OCUPATIONAL HEALTH AND SAFETY (OHS):**
- **Exposure to Respirable Suspended Particulate Matter**
  - Description about the exposure: some dust in the surrounding environment. Workers are exposed to high concentration of suspended particulate matter
  - Impacts: This can result in a few cases of respiratory diseases among workers

- **Exposure to Thermal Stress**
  - Description about the exposure: The workers that are engaged in kiln activities (discharging products and fueling) are exposed directly to heat and some radiation
  - Impacts: This can result in dehydration among workers

- **Risk of accidents**
  - Description about the exposure: danger of falling off during the bricks assembly in the kiln and/or burn
  - Impacts: Risk of injuries

- **Compliance with ILO standards and remarks on migratory labour and conditions of labour:**
  - Practices followed at CEDAN kiln enterprises do not comply with the International Labour Standards on occupational health and safety drawn up by ILO, majority of the workers are usually exposed to thermal stress and significant risk of accidents.
  - No migratory labour issues have been identified.
## Conclusion & References:

### Conclusion:

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Cedan Kiln</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AIR EMISSION (G/KG FIRED BRICK)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO2</td>
<td>175</td>
<td>Cedan Kiln is a good technological option for batch production.</td>
</tr>
<tr>
<td>Black Carbon</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>PM</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>CO</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td><strong>FUEL &amp; ENERGY</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SEC (MJ/kg fired brick)</td>
<td>1,85</td>
<td>Energy performance is good in this kiln.</td>
</tr>
<tr>
<td><strong>FINANCIAL PERFORMANCE</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capital Cost (USD)</td>
<td>200.000-260.000</td>
<td>High capital cost is one of the difficulties.</td>
</tr>
<tr>
<td>Production Capacity</td>
<td>7-8 million bricks or tiles / year</td>
<td></td>
</tr>
<tr>
<td>Simple Payback</td>
<td>2.5 – 3,5 years</td>
<td></td>
</tr>
<tr>
<td><strong>PRODUCT QUALITY</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Types of product</td>
<td>All types of product</td>
<td>Non-uniform temperature distribution across the kiln (cross-section) can result in variation in product quality.</td>
</tr>
<tr>
<td>Good Quality Product</td>
<td>80%</td>
<td></td>
</tr>
<tr>
<td><strong>OHS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exposure to dust</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>Exposure to Thermal stress</td>
<td>yes</td>
<td>Cedan Kiln has some poor OHS conditions, mainly related to work exposition to heat during discharging products.</td>
</tr>
<tr>
<td>Risk of accidents</td>
<td>yes</td>
<td></td>
</tr>
</tbody>
</table>

### References:

2. Ibid.
3. Field observation.
4. Ibid.
5. By its initials in Portuguese
Mobile Kiln is a model in which the entire structure of the kiln can be moved using a rail system and stacked over the green bricks previously loaded for burning. The burners are coupled along the side of the kiln. The structure of this kiln is very light weight, because it only uses ceramic fiber and steel layers. As fuel can be use biomass, gas or oil. Firewood usually employed can be chopped, briquettes and sawdust.

### INTRODUCTION AND HISTORY

Mobile Kiln is a model in which the entire structure of the kiln can be moved using a rail system and stacked over the green bricks previously loaded for burning. The burners are coupled along the side of the kiln. The structure of this kiln is very lightweight, because it only uses ceramic fiber and steel layers. As fuel can be use biomass, gas or oil. Firewood usually employed can be chopped, briquettes and sawdust.

### GEOGRAPHICAL DISTRIBUTION:

**ESTIMATED N° OF OPERATIONAL ENTERPRISES AND TOTAL PRODUCTION (USING MOBILE KILN)**

<table>
<thead>
<tr>
<th>Country</th>
<th>N° of enterprises</th>
<th>Total Production (billion bricks/tiles/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brazil</td>
<td>~ 100</td>
<td>~ 1,0</td>
</tr>
<tr>
<td>Peru</td>
<td>3</td>
<td>NA*</td>
</tr>
<tr>
<td>Bolivia</td>
<td>2</td>
<td>NA*</td>
</tr>
<tr>
<td>Paraguay</td>
<td>5</td>
<td>NA*</td>
</tr>
</tbody>
</table>

*NA*: Not available
**DESCRIPTION & WORKING:**

- The Mobile Kiln has a rectangular shape and its dimensions can be quite variable, with width ranging from 3.4 to 9.4 m and length from 15m to 30m.

- In the Mobile Kiln the brick loading is stacked and the structure of the kiln moves along the rails on the floor with the support of pushers/handles.

- The firing cycle tends to be shorter compared with the traditional kilns, due to its lighter structure that absorbs less heat, and saves time in charging and discharging of materials.

- The structure is made basically of metal and insulated with ceramic fiber.

- The output of the combustion gases occurs in the central duct, at the bottom under the floor, and then continues to the chimney.
MOBILE KILN

AIR EMISSIONS AND IMPACTS:

MEASURED EMISSION FACTORS

<table>
<thead>
<tr>
<th>(in g/kg fired bricks)</th>
<th>CO₂</th>
<th>Black Carbon (BC)</th>
<th>Particulate Matter (PM)</th>
<th>CO</th>
</tr>
</thead>
<tbody>
<tr>
<td>170</td>
<td>Not available</td>
<td>Not available</td>
<td>Not available</td>
<td></td>
</tr>
</tbody>
</table>

COMMONLY USED FUELS

Biomass
Biomass (eg. biomass briquettes, sawdust).

SPECIFIC ENERGY CONSUMPTION

(SEC) (measured at firing temperature of 750-950 °C)
Average: 1.80 MJ/kg fired bricks/tiles (estimated)

EMISSION STANDARDS

Emission standards are notified only for PM emissions

<table>
<thead>
<tr>
<th>Country</th>
<th>PM (mg/Nm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brazil</td>
<td>730 (&lt; 10 MW)</td>
</tr>
</tbody>
</table>

COMMENTS ON EMISSIONS

The values of the emission standards of fixed sources depend on the thermal power rating (MW) of the sources (kilns).

This type of kiln usually produces low emissions of soot (particulate matter) due to the continuous fuel feed system and a better adjusting of the relation air/fuel.

EMISSION STANDARDS

Emission standards are notified only for PM emissions

<table>
<thead>
<tr>
<th>Country</th>
<th>PM (mg/Nm³)</th>
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<tr>
<td>Brazil</td>
<td>730 (&lt; 10 MW)</td>
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COMMENTS ON EMISSIONS

The values of the emission standards of fixed sources depend on the thermal power rating (MW) of the sources (kilns).

This type of kiln usually produces low emissions of soot (particulate matter) due to the continuous fuel feed system and a better adjusting of the relation air/fuel.

DESCRIPTION ON ENERGY CONSUMPTION AND MAIN CAUSES OF HEAT LOSS

Heat losses in the flue gas.

FUEL AND ENERGY:

SPECIFIC ENERGY CONSUMPTION

(SEC)
Average: 1,80 MJ/kg fired bricks/tiles (estimated)

COMPARISON WITH OTHER KILN TECHNOLOGIES

Mobile Kiln reports a SEC value under the range for traditional kilns (SEC – 2 to 4 MJ/kg fired brick), mainly because of the firing cycles are shorter and the lightweight and low density properties of the kiln, reducing the needs to heat the kiln itself.

DESCRIPTION ON ENERGY CONSUMPTION AND MAIN CAUSES OF HEAT LOSS

Heat losses in the flue gas.

FINANCIAL PERFORMANCE:

Capital Cost of the kiln technology
(for annual production capacity of 6 – 12 million bricks)
(excluding land and working capital cost)

70,000 to 400,000 USD

Capital Cost Breakdown

<table>
<thead>
<tr>
<th>Material Cost</th>
<th>Labour Cost</th>
<th>Equipment Cost</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>60%</td>
<td>30%</td>
<td>10%</td>
<td>100%</td>
</tr>
</tbody>
</table>

PRODUCT QUALITY:

Good quality product is expected.

OCCUPATIONAL HEALTH AND SAFETY (OHS):

Exposure to Respirable Suspended Particulate Matter
Description about the exposure: low level of dust in the surrounding area.

Exposure to Thermal Stress
Description about the exposure: burner operators are exposed directly to heat and some radiation.

Risk of accidents
Description about the exposure: danger of falling off during the bricks assembly in the kiln.

Compliance with ILO standards and remarks on migratory labour and conditions of labour: Practices followed at mobile kiln enterprises tend to comply with the International Labour Standards on occupational health and safety drawn up by ILO. Because of mechanisation of the processes, the working conditions of workers are relatively better with less exposure to emissions, minimal exposure to thermal stress and reduced risk of accidents. No migratory labour issues have been identified.
## MOBILE KILN

### CONCLUSION & REFERENCES:

#### Conclusion:

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Mobile Kiln</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIR EMISSION (g/Kg fired brick)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO2</td>
<td>170 (estimated)</td>
<td>Low atmospheric emissions.</td>
</tr>
<tr>
<td>Black Carbon</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>PM</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>CO</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>FUEL &amp; ENERGY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SEC (MJ/kg fired brick)</td>
<td>1,80</td>
<td>Low fuel consumption in Mobile Kiln.</td>
</tr>
<tr>
<td>FINANCIAL PERFORMANCE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capital Cost (USD)</td>
<td>70,000 to 400,000</td>
<td>High capital investment and high return of investment.</td>
</tr>
<tr>
<td>Production Capacity</td>
<td>6-24 million bricks/year</td>
<td></td>
</tr>
<tr>
<td>Simple Payback</td>
<td>0.6 – 1.7 years</td>
<td></td>
</tr>
<tr>
<td>PRODUCT QUALITY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Types of product</td>
<td>All types of product</td>
<td>Uniform temperature distribution across the kiln cross-section.</td>
</tr>
<tr>
<td>Good Quality Product</td>
<td>&gt;90%</td>
<td></td>
</tr>
<tr>
<td>OHS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exposure to dust</td>
<td>minimal</td>
<td></td>
</tr>
<tr>
<td>Exposure to Thermal stress</td>
<td>minimal</td>
<td>Mobile Kiln has good OHS conditions, mainly related to work exposition and emissions gases.</td>
</tr>
<tr>
<td>Risk of accidents</td>
<td>minimal</td>
<td></td>
</tr>
</tbody>
</table>

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References are provided as ‘Endnotes.’

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3. Field observation.
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### CONTACT

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  - E-mail: eela@swisscontact.org.pe
  - Web: www.redladrilleras.net
INTRODUCTION AND HISTORY

This model basically consists of pairs of rectangular chambers with walls and dome roof constructed with conventional bricks. The door for loading and unloading material is located in the lateral wall. The internal floor of the chambers is constructed of bricks leaving openings between the pieces which are connected to the chimney through underground ducts.

Paulistinha Kiln has burners (four or six) at the lateral walls, generally constructed in pairs, moving the fire from the floor to the roof and then the heat moves down burning the bricks and the flue gases are conducted to the duct stacked at the floor of the rear wall of the kiln and then moved to the chimney.

The fuels commonly used are logs, branches and pieces of wood.

This kiln presents a slight deficiency related to the heat distribution, that determines hot and cold spots in certain zones and, consequently, different quality products; however, it is a widely disseminated model in all Brazilian regions due to the low construction cost.

GEOGRAPHICAL DISTRIBUTION:

Paulistinha Kiln has burners (four or six) at the lateral walls, generally constructed in pairs, moving the fire from the floor to the roof and then the heat moves down burning the bricks and the flue gases are conducted to the duct stacked at the floor of the rear wall of the kiln and then moved to the chimney.

The fuels commonly used are logs, branches and pieces of wood.

This kiln presents a slight deficiency related to the heat distribution, that determines hot and cold spots in certain zones and, consequently, different quality products; however, it is a widely disseminated model in all Brazilian regions due to the low construction cost.

### TYPE OF KILN

- **Nature of Organisation**: Intermittent
- **Level of mechanisation**: Industrial
- **Type of bricks/tiles produced**: Hollow/perforated bricks - Tiles
- **Annual production capacity of the enterprise**: > 1 & < 10 million bricks (medium scale)
- **Operational period**: Round the year

### CHARACTERISTICS OF ENTERPRISES USING THIS TECHNOLOGY:

<table>
<thead>
<tr>
<th>Country</th>
<th>Nº of enterprises</th>
<th>Total Production (billion bricks/tiles/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brazil</td>
<td>~ 1,100</td>
<td>~ 6.2</td>
</tr>
</tbody>
</table>

**ESTIMATED Nº OF OPERATIONAL ENTERPRISES AND TOTAL PRODUCTION (USING PAULISTINHA KILN)**
In Paulistinha Kiln the hot gases from the burning fuel are first deflected to the roof and then are drawn downwards by the chimney draught through the green bricks to fire them.

This kiln has a rectangular shape and dimensions are: 10-15 meters longer length, sidewall around 4-5 meters and height around 2.8 meters.

The fuel combustion is produced in the lateral zone of the kiln.

The hot gases produced by the burning process are used to burn the bricks and tiles loaded.

The gases leave the kiln through the rear wall through - openings near the floor.

Near the floor of the rear wall, flue gases duct moves the gases to the chimney.

The firing cycle is longer; the preheat period delays from 06 to 08 hours, the burning process takes 36 to 48 hours and cooling process can take place within 3 days; the time depends on the type of product, the raw material and the type of fuel used and the burning process. The operating temperature is between 800 to 930°C, although the kiln presents hotter zones close to the roof and cold spots close to the floor and at the intersection of the walls.
**AIR EMISSIONS AND IMPACTS:**

**COMMONLY USED FUELS**

- Biomass (e.g., firewood, biomass briquettes, sawdust).

**SPECIFIC ENERGY CONSUMPTION**

- (SEC) measured at firing temperature of 900-1100 °C.
- Average: 4.0 MJ/kg fired bricks/tiles (Range: 3.8 - 4.7 MJ/kg fired/brick or tile).

**COMPARISON WITH OTHER KILN TECHNOLOGIES**

Paulistinha Kiln presents a slightly higher SEC value compared with other intermittent kilns (SEC = 2 to 4 MJ/kg fired brick) due mainly to its structure.

**MEASURED PM EMISSION**

- Average: Not available.

**EMISSION STANDARDS**

- Emission standards are notified only for PM emission.

**PRODUCT QUALITY:**

- Product quality: (As per the local market perception)
  - Good 50-70%
  - Inferior 25-40%
  - Losses and Breakages 5-8%

**EXPOSURE TO RESPIRATORY SUSPENDED PARTICULATE MATTER**

- Description about the exposure: Flue gases exhausted from the chimney cause a very high concentration of dust in the surrounding environment and the workers are exposed to high concentration of a suspended particulate matter.

**EXPOSURE TO THERMAL STRESS**

- Description about the exposure: The workers that are engaged in kiln activities (discharging products and fueling) are exposed directly to heat and some radiation.

**RISK OF ACCIDENTS**

- Danger of burning during firing or discharging.

**DESCRIPTION ON ENERGY CONSUMPTION AND MAIN CAUSES OF HEAT LOSS**

- Complete combustion of wood, heat losses in the exhaust gases and intermittent cycle (batch cycle).

**CAPITAL COST OF THE KILN TECHNOLOGY**

- For annual production capacity of 3 – 5 million bricks (excluding land and working capital cost).
- 28,000 to 46,000 USD

**CAPITAL COST BREAKDOWN**

- Material Cost: 70%
- Labour Cost: 28%
- Equipment Cost: 2%
- Total: 100%

**DESCRIPTION ON PRODUCT QUALITY**

- Non-uniform temperature across the horizontal-section of the kiln results in under-fired bricks/tiles at the rear zone and hence differences in the product quality.

**TYPES OF PRODUCT THAT CAN BE FIRED IN THE KILN**

- Solid bricks
- Hollow/Perforated bricks
- Roof Tiles
- Others

**EXPOSURE TO RESPIRABLE SUSPENDED PARTICULATE MATTER**

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**DETECTION OF FLUIDS AND MATERIALS**

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CONCLUSION & REFERENCES:

Conclusion:

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Paulistinha Kiln</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIR EMISSION (g/Kg fired brick)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO2</td>
<td>380</td>
<td>Incomplete combustion in kiln results in high value of emissions, mainly after wood feeding.</td>
</tr>
<tr>
<td>Black Carbon</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>PM</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>CO</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>FUEL &amp; ENERGY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SEC (MJ/kg fired brick)</td>
<td>4.0</td>
<td>Incomplete combustion and heat losses result in increase in the fuel consumption in Paulistinha Kiln.</td>
</tr>
<tr>
<td>FINANCIAL PERFORMANCE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capital Cost (USD)</td>
<td>28.000-48.000</td>
<td>Low capital investment and high return is one of the main reasons for popularity of Paulistinha technology.</td>
</tr>
<tr>
<td>Production Capacity</td>
<td>3-8 million bricks/year</td>
<td></td>
</tr>
<tr>
<td>Simple Payback</td>
<td>0.7 – 2.1 years</td>
<td></td>
</tr>
<tr>
<td>PRODUCT QUALITY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Types of product</td>
<td>All types of product</td>
<td>Non-uniform temperature distribution across the kiln cross-section results in variation in product quality.</td>
</tr>
<tr>
<td>Good Quality Product</td>
<td>60 %</td>
<td></td>
</tr>
<tr>
<td>OHS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exposure to dust</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>Exposure to Thermal stress</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>Risk of accidents</td>
<td>yes</td>
<td></td>
</tr>
</tbody>
</table>

Paulistinha Kiln complies partially OHS conditions.

REFERENCES:

References are provided as 'Endnotes'.

(2) Ibid.
(3) Field observation.
(4) Ibid.
(5) By its initials in Portuguese

ACKNOWLEDGEMENT:
The project team would like to acknowledge the financial support received from the Swiss Agency for Development and Cooperation for the preparation of these fact-sheets.

Note:
In the initial stage of this initiative of developing factsheet on brick kiln technologies, factsheet are developed for South and South-East Asia and Latin America regions. Factsheet on brick kiln technologies of other regions will be developed over time.

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National Institute of Technology – INT®, Rio de Janeiro, Brazil
(Dr Mauricio Henriques Jr.)
Swisscontact, Lima, Peru
(EELA Program staff members)

Design & Illustration:
Luis Enrique Caycho Gutierrez

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E-mail: eela@swisscontact.org.pe
Web: www.redladrilleras.net
INTRODUCTION AND HISTORY

This model was adapted to the local context with good results. The operationally principle is very similar to the Hoffman kiln, the only difference is the fuel consumption that is slightly higher due to the large mass of the kiln. One of the advantages is the possibility to produce different products (in each chamber) with a superior and uniform quality since the product is not direct contact with the flame. In Colombia the kiln usually is operated with coal.

GEOGRAPHICAL DISTRIBUTION:

<table>
<thead>
<tr>
<th>Country</th>
<th>N° of enterprises</th>
<th>Total Production (million bricks or tiles year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colombia</td>
<td>12</td>
<td>~ 26,07</td>
</tr>
</tbody>
</table>

TYPE OF KILN

<table>
<thead>
<tr>
<th>Kiln</th>
<th>Nature of Organisation</th>
<th>Level of mechanisation</th>
<th>Type of bricks/ tiles produced</th>
<th>Annual production capacity of the enterprise</th>
<th>Operational period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous</td>
<td>Industrial</td>
<td>Semi-mechanised</td>
<td>Solid bricks Hollow/perforated bricks</td>
<td>&gt; 1 &amp; &lt; 10 million bricks (medium scale)</td>
<td>Round the year</td>
</tr>
</tbody>
</table>

FACTSHEET ABOUT BRICK/TILES KILN TECHNOLOGIES IN LATIN AMERICA

Front view of the kiln
Multi Chambers Kiln brings the possibility to use the heating energy in the interconnected chambers; this kiln also permits to recover the heat from the chamber to dry the green bricks, reducing the drying period. The recovery of the heat is made with a specially designed duct and a forced draught that drives the air through the chambers containing the bricks burned, the process takes place during the cooling stage.

- Cooling. This process can take between 6 to 12 hours per chamber supported with cooling fans until it reaches a temperature close to room temperature.
- The complete production cycle of the kiln is long and depends on the number of chambers, type of product, raw material and quality of fuel used.

1. Ignition and preheat. Begins at the first chamber, passing the residual heat of the combustion gases go to the adjacent chamber to preheat and complete the drying of the green bricks.

2. Fuel dosage. Each chamber has a sluice for the combustion, during this process the fuel supply is made on the top of the kiln using dosing equipment with supply hoses.

3. Firing of the bricks. When the first chamber reaches a temperature of 950 - 1050°C, the second chamber will be at 300 - 450°C, temperature to start the combustion on this chamber.

4. The third chamber will use the residual heat of the second chamber, and so on until complete the series of chambers.
**MEASUREMENT FACTORS²**

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>CO₂ (g/kg fired bricks)</th>
<th>Black Carbon (BC)</th>
<th>Particulate Matter (PM)</th>
<th>CO (g/kg fired bricks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomass</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mineral coal</td>
<td>257 (212 – 302)</td>
<td>Not available</td>
<td>Not available</td>
<td>Not available</td>
</tr>
</tbody>
</table>

**SPECIFIC ENERGY CONSUMPTION⁴ (SEC)**

<table>
<thead>
<tr>
<th>Country</th>
<th>SEC (MJ/kg fired bricks) (measured at firing temperature of 900-1100 °C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colombia</td>
<td>2,37 - 3,85</td>
</tr>
</tbody>
</table>

**COMMENTS ON EMISSIONS**

Air infiltration on the lateral areas could increase the percentage of oxygen; in this case the emissions will not meet the national standards. It is recommended to use refractory material on the domes of the chamber in order to improve the conditions of the heat flux into the combustion zone. This kiln produces low emissions of soot (particulate matter).

**DESCRIPTION ON ENERGY CONSUMPTION AND MAIN CAUSES OF HEAT LOSS**

Thermal losses could occur in the cracks on the doors and lateral walls of the kiln.

**CAPITAL COST BREAKDOWN**

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material Cost</td>
<td>50%</td>
<td></td>
</tr>
<tr>
<td>Labour Cost</td>
<td>40%</td>
<td></td>
</tr>
<tr>
<td>Equipment Cost</td>
<td>10%</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
<td></td>
</tr>
</tbody>
</table>

**PRODUCTION CAPACITY**

120,000 bricks/tiles per month
Main brick size: 300 x 200 x 100 mm

**PAYBACK PERIOD**

- Simple Payback: 0.5 – 2.0 years
- Discounted Payback (at 6.5%): 1 – 3 years

**PRODUCT QUALITY**

<table>
<thead>
<tr>
<th>Type of Product that can be fired in the kiln</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid bricks</td>
<td>✔</td>
</tr>
<tr>
<td>Hollow/Perforated bricks</td>
<td>✔</td>
</tr>
<tr>
<td>Roof Tiles</td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td></td>
</tr>
</tbody>
</table>

**EXPOSURE TO RESPIRABLE SUSPENDED PARTICULATE MATTER⁵**

Flue gases exhausted from the chimney or cracks on the walls unpaved surfaces around cause concentration of soot and dust in the surrounding environment and the workers are exposed to concentration of suspended particulate matter. This can result in a few cases of respiratory diseases among workers.

**EXPOSURE TO THERMAL STRESS⁶**

Workers responsible of discharging products and fuel supply are exposed directly to heat and some radiation. This can result in dehydration among workers.

**RISK OF ACCIDENTS**

Danger of fall down during fuel supply on the top of the kiln. Electric shock by operating the equipment.

**RISK OF INJURIES**

Practices followed at Multichambers Kiln enterprises do not comply with the International Labour Standards on occupational health and safety drawn up by ILO, majority of the workers are usually exposed to thermal stress and emissions from the chimney. Significant risk of accidents during fuel supply on the roof of the kiln. No migratory labour issues have been identified.
## Multi Chambers Kiln

### Conclusion & References:

### Conclusion:

<table>
<thead>
<tr>
<th>Parameters</th>
<th>FCBTK</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Air Emission (g/kg Fired Brick)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO2</td>
<td>257</td>
<td></td>
</tr>
<tr>
<td>Black Carbon</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>PM</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>CO</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td><strong>Fuel &amp; Energy</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SEC (MJ/kg fired brick)</td>
<td>2.37</td>
<td></td>
</tr>
<tr>
<td><strong>Financial Performance</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capital Cost (USD)</td>
<td>170,000</td>
<td></td>
</tr>
<tr>
<td>Production Capacity</td>
<td>600 ton bricks/month</td>
<td></td>
</tr>
<tr>
<td>Simple Payback</td>
<td>0.5 – 2 years</td>
<td></td>
</tr>
<tr>
<td><strong>Product Quality</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Types of product</td>
<td>Solids, hollow and perforate bricks and tiles.</td>
<td></td>
</tr>
<tr>
<td>Good Quality Product</td>
<td>80%</td>
<td></td>
</tr>
<tr>
<td><strong>OHS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exposure to dust</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>Exposure to Thermal stress</td>
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### Factsheet prepared by:

- Business Environmental Corporation – CAEM, Bogota, Colombia (CAEM Colombia staff members for EELA Project)
- Swisscontact, Lima, Peru (EELA Program staff members)

### Design & Illustration:

- Luis Enrique Caycho Gutiérrez

### Contact:

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  - Bogota, Colombia
  - Telephone: +57 1 3830300
  - Web: [www.corporacionambientalempresarial.org.co/](http://www.corporacionambientalempresarial.org.co/)
- Swisscontact
  - Lima, Peru
  - Telephone: +51 1 2641707
  - E-mail: eela@swisscontact.org.pe
  - Web: [www.redladrilleras.net](http://www.redladrilleras.net)

### For More Information:

### References:

1. CAEM 2011, Technical report of appropriate technologies for the reconversion of the artisan brick sector.
4. Ibid.
5. Field observation.
6. Ibid.
7. By its initials in Spanish.
INTRODUCTION AND HISTORY

One of the most recognized alternative model of the Hoffman Kiln is the zigzag model or Bührer Kiln, a semi continuous and moving fire kiln consisting on 10 to 30 chambers; one of the more relevant characteristics of the Zigzag Kiln is the segmented displacement of the fire from one chamber to the next, chambers are parallel and the length of the two side walls is larger than the central walls cut and separated in the space where the duct of gases and heating recovery zone are located. At small and medium scale requires less space than the traditional Hoffman model and the fire movement through the chamber is horizontal. One of the main characteristic of the Zigzag Kiln is the fuel injection, at the beginning of the firing process, the supply process is manual and carried out through the burners located over the front part, then the supply process is made at the roof of the kiln using pneumatic equipment (carbojet), injecting the fuel using hoses and air pressure. The fuel commonly used is coal. In some cases, mixing with biomass (specifically coffee husk) has been reported.

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</tr>
</thead>
<tbody>
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<td>5</td>
<td>~ 10,0</td>
</tr>
</tbody>
</table>

FACTSHEET ABOUT BRICK/TILES KILN TECHNOLOGIES IN LATIN AMERICA
ZIGZAG KILN

**DESCRIPTION & WORKING:**

- Zigzag Kiln consists on parallel chambers with tunnel shape and a dome roof; the ducts are located over the roof of the kiln. The fire moves between the chambers through the openings used to supply the fuel. The firing process is produced due to the horizontal displacement of the heating along the kiln (forced draught).
- Then the processes described in items 03 to 05 are repeated in the second chamber. The whole process is repeated from one chamber to the next.
- Once the heating is transferred to the next chamber and the optimal firing temperature is reached, the cooling process in the chamber with the fired bricks is started. Usually this process is supported by industrial fans to accelerate the cooling and to reduce operation time.
- During the firing process in a chamber, the operators can start the cooling process and downloading products in the previous chamber, as well as the loading of the pieces for preheating in the next chamber (semi continuous process).

1. At the first stage, the kiln is manually ignited using the frontal burners; the process can take 06 to 08 hours until reach a temperature between 200 and 300°C. During this period the gases duct is completely sealed.

2. Once the elevation of the temperature starts, the fuel is supplied mechanically with the carbojet (coal feeder); during this stage the temperature can reach a range between 900 to 1,000°C in the firing zone.

3. Once the temperature threshold is reached, the coal feeder keeps the temperature so the heating is distributed along the chamber using the carbojet device; during this process, gases duct is opened a 20%.

4. When 70% of the firing process has been completed in the first chamber, the gases duct is closed, and both duct for firing and duct of gases on the second chamber are opened.

5. Once the firing process is concluded in the first chamber, part of the injection hoses of the coal feeder are placed over the power line of the second chamber, increasing the supplying frequency to transfer the heating to this chamber. When the temperature threshold is reached, the rest of the hoses are placed over the fuel supply openings in the second chamber.
ZIGZAG KILN

**Air Emissions and Impacts:**

**Measured Emission Factors**

<table>
<thead>
<tr>
<th>Emission Factor</th>
<th>Biomass</th>
<th>Mineral Coal</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂ (g/kg fb)</td>
<td>Not available</td>
<td>Not available</td>
</tr>
<tr>
<td>Black Carbon (BC)</td>
<td>Not available</td>
<td>Not available</td>
</tr>
<tr>
<td>Particulate Matter (PM)</td>
<td>Not available</td>
<td>Not available</td>
</tr>
<tr>
<td>CO (g/kg fb)</td>
<td>Not available</td>
<td>Not available</td>
</tr>
</tbody>
</table>

**Specific Energy Consumption**

- Measured at firing temperature of 900-1100 °C
- Average: 2.04 MJ/kg fired bricks (Range: 2.0 – 2.05 MJ/kg fired brick)

**Comparison with Other Kiln Technologies**

Zigzag Kiln efficiency depends on the number of chambers, compared with intermittent kilns (for example, Dome Kilns) this model is more efficient in approximately 40% (1 - 2 MJ/Ton); but compared with other continuous kilns (Hoffman, Chambers or Tunnel) is less efficient in 40% (1 - 1.1 MJ/Ton)

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**Fuel and Energy:**

**Measured PM Emission**

Average: Not available

**Emission Standards**

Emission standards are notified only for PM emissions

- **Country** | **PM (mg/Nm³)**
- Colombia | 250 mg/Nm³

**Comments on Emissions**

Physical chemical conditions of coal, fuel storage and supplying process have a direct incidence in the combustion process, if these aspects are not adequately controlled higher emission levels could be produced as well as lower energy efficiency.

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**Financial Performance:**

**Capital Cost of the Kiln Technology**

For annual production capacity of ~2 million bricks (excluding land and working capital cost)

- 165,000 USD

**Capital Cost Breakdown**

- Material Cost: 62%
- Labour Cost: 28%
- Equipment Cost: 10%
- Total: 100%

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**Product Quality:**

**Product Quality**

(As per the local market perception)

- **Good**: 91%
- **Inferior**: 8%
- **Losses and Breakages**: 1%

**Description on Product Quality**

Assuming optimal conditions and proper fuel feeding, products are homogeneous and have a good quality; however, some products placed on the heating zone could be affected. It is not recommended to fired tiles due to the thermal behavior in the interior of the kiln that is optimal when pieces are placed leaving a space between the bricks.

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**Occupational Health and Safety (OHS):**

**Exposure to Respirable Suspended Particulate Matter**

Flue gases exhausted from the chimney and unpaved surfaces around cause concentration of soot and dust in the surrounding environment and the workers are exposed to concentration of suspended particulate matter.

- This can result in a few cases of respiratory diseases among workers.

**Exposure to Thermal Stress**

Workers responsible of discharging products and fuel feeding are exposed directly to heat and some radiation.

- This can result in dehydration among workers.

**Risk of Accidents**

Danger of fall down during fuel supply on the roof of the kiln.

Electric shock during the operation of the feeding equipment.

- Risk of injuries.

Practices followed at Zig-zag kiln enterprises do not comply with the International Labour Standards on occupational health and safety drawn up by ILO, majority of the workers are usually exposed to thermal stress and emissions from the chimney. Significant risk of accidents during fuel supply on the roof of the kiln. No migratory labour issues have been identified.
## Conclusion & References:

### Conclusion:

<table>
<thead>
<tr>
<th>Parameters</th>
<th>FCBTK</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AIR EMISSION (g/Kg fired brick)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO$_2$</td>
<td>Not available</td>
<td>The average value of PM emissions is within the notified limit (Colombian Norms)</td>
</tr>
<tr>
<td>Black Carbon</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>PM</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>CO</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td><strong>FUEL &amp; ENERGY</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SEC (MJ/kg fired brick)</td>
<td>2.04</td>
<td>Energy consumption could be reduced in approximately 40 % when the kiln operates continuously.</td>
</tr>
<tr>
<td>Capital Cost (USD)</td>
<td>165,000</td>
<td>The production capacity can be increased in 10 to 15% with an income increase around 50,000.00 USD per year due to less use of fuel.</td>
</tr>
<tr>
<td>Production Capacity</td>
<td>2.1 million bricks/year</td>
<td></td>
</tr>
<tr>
<td>Simple Payback</td>
<td>0.5 - 2.0 years</td>
<td></td>
</tr>
<tr>
<td><strong>PRODUCT QUALITY</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Types of product</td>
<td>solid and hollow bricks</td>
<td>The bricks produced meet the requirements established in the Colombian Technical Norm for construction products.</td>
</tr>
<tr>
<td>Good Quality Product</td>
<td>91%</td>
<td></td>
</tr>
<tr>
<td><strong>OHS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exposure to dust</td>
<td>yes</td>
<td>This model of kiln improves labor conditions compared with other intermittent technologies; the risk of accidents is reduced in 50% due to its ease of operation.</td>
</tr>
<tr>
<td>Exposure to Thermal stress</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>Risk of accidents</td>
<td>yes</td>
<td></td>
</tr>
</tbody>
</table>

### FOR MORE INFORMATION:

**REFERENCES:**

References are provided as ‘Endnotes’

3. Ibid.
4. Field observation.
5. Ibid.
6. By its initials in Spanish

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3. Ibid.
4. Field observation.
5. Ibid.
6. By its initials in Spanish