ANALYSIS OF TECHNOLOGICAL MODELS USED IN SOUTH AFRICA

MISSION OF SOUTH AFRICA
CORPORACIÓN AMBIENTAL EMPRESARIAL CAEM

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1. Introduction

The brick sector is a key player in the South African industrial landscape. The 100 or so industrial brick companies produce some 3.5 billion bricks annually. While most of this production takes place in clamp kilns, there are a number of fixed kilns used, including tunnel kilns, Vertical Shaft Brick Kilns, Hoffman kilns and others.

South Africa has sector-wide data on production levels and total energy use. This helps the entire sector to understand how it is performing versus its peers, but also helps individual companies to understand if they are performing in line with their peers.

South Africa has established a line of comparison of energy indicators with UK. How such information has been hugely beneficial to the sector. The international comparison of energy intensity of the South African brick sector shows that South Africa generally performs in line with other countries. For clamps, the international range of energy required for drying and firing is 1.9MJ/kg to 7.2MJ/kg, with the South African range being 2.2MJ/kg to 5.2MJ/kg. Tunnel kiln energy performance in South Africa is around 2.4MJ/kg, slightly above the international range of 1.8MJ/kg to 2.1MJ/kg.

Given that thermal energy accounts for more than 80% of energy use, it is evident the need for a deeper understanding of thermal energy use in the brick companies and continue to work on the appropriate use of energy and the implementation of energy efficiency projects. However, with rising energy costs for both electricity and fuel, energy efficiency represents a significant opportunity for cost reduction. With rising energy costs of both electricity and fuels, energy efficiency represents a significant opportunity for cost reduction in many industries, not least of all in the manufacture of clay bricks, where energy can represent between 40% and 60% of production costs.

However, one of the major challenges in pursuing energy efficiency projects is understanding where to find finance to help with the funding of projects.

Many clay brick manufacturers are interested in increasing their production. Efficient energy use, or energy efficiency, refers to using less energy for the same or greater levels of output. In the case of bricks, it means producing the same number of bricks, while using less input fuel and electricity.

Energy efficiency should always be tackled by first looking at behaviour, or the way you use energy. Often, simple changes can yield real benefit. Only then should you look down the path of finding ways to optimise your process of energy consumption, including looking at technology replacement by using more efficient versions of existing technology, or through wholesale changes of technology. Energy efficiency offers a powerful and cost-effective tool for achieving a sustainable energy future. Improvements in energy efficiency can reduce the need for investment in energy infrastructure, cut energy bills, improve health, increase competitiveness and improve consumer welfare.
### 2. Characteristics Clay Brick in South Africa

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Formal Sector</th>
<th>Informal Sector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Even distributed rural</td>
<td>Metropolitan townships</td>
</tr>
<tr>
<td>Industry</td>
<td>150 companies</td>
<td>≥1000 entrepreneurs</td>
</tr>
<tr>
<td>Company Size</td>
<td>20m units p/m</td>
<td>5000 - 1000000 units p/m</td>
</tr>
<tr>
<td>Volume</td>
<td>≥ 3 Billion units p/a</td>
<td>100 million units p/a (3%)</td>
</tr>
<tr>
<td>Kiln Firing</td>
<td>70% Clamps (Coal)</td>
<td>100% Clamp (Coal)</td>
</tr>
<tr>
<td></td>
<td>21% Tunnel (Coal, gas, oil)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6% TVA / Hoffman (Coal)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2% VSBK (Coal)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1% Habla Zig - Zag (Coal)</td>
<td></td>
</tr>
<tr>
<td>Job Creation</td>
<td>15000 Jobs</td>
<td>5000 Jobs</td>
</tr>
<tr>
<td>Legal Compliance</td>
<td>Generally fully compliant</td>
<td>Little or no compliance</td>
</tr>
</tbody>
</table>

Some regulations in South Africa is listed below:

#### 2.1. Formal Regulatory

<table>
<thead>
<tr>
<th>Name - number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SABS 227</td>
<td>Quality standards</td>
</tr>
<tr>
<td>SANS 204</td>
<td>Energy Efficiency in Buildings</td>
</tr>
<tr>
<td>SANS 10 - 400XA</td>
<td>Energy Usage</td>
</tr>
<tr>
<td>Air Quality Act (N° 39 of 2004)</td>
<td>Clamp kilns are a Listed Activity with Emission Standards and Reporting</td>
</tr>
<tr>
<td>Carbon Budgeting</td>
<td>Department of Environment</td>
</tr>
<tr>
<td>Energy Management Planning</td>
<td>Department of Energy</td>
</tr>
<tr>
<td>Carbon Tax (2016)</td>
<td>National Treasury</td>
</tr>
<tr>
<td>Many Labour, OHS and Employment Equity Laws</td>
<td>Labor laws</td>
</tr>
<tr>
<td>DMR Mining regulations for quarries</td>
<td>Department of Mines</td>
</tr>
</tbody>
</table>
3. South African Guild

Name: Clay Brick Association of South Africa
Contact information: PO Box 1284 - Halfway House 1685
Tel: +27 (0) 11 805 - 4206
Fax: 086 546-8441

3.1. Characteristics of the Association:

- 80 Brickmakers across Southern Africa
- 48 Associate member companies
- 50,000 people employed in brick manufacture (Formal and informal sector)
- 130,000 people employed in brick-related design and construction
- 55 million South Africans who need safe, energy-efficient, long-lasting homes and social infrastructure and healthy, clean environment.
- Technical management: The technical committee of the CBA, provides strategic direction to members through its investment in research and educational initiatives regarding energy efficiency, reduced emissions, green building and sustainable construction.

3.1.1. Lines of actions and sectoral approach: The sector of the brick industry and the association have participated in projects that facilitate change and the learning within the Clay Brick Sector to trigger industry wide reductions in CO2 emissions and improve energy efficiency. Some of the lines of action of this process are:

- Development of Energy Guidelines
- Development of the energy Thermal Tool
- Energy Management Systems Training
- Energy and Materials: Life Cycle Assessment Methodology: Phase 1: Mining and Manufacture - Phase 2: Gate to completed construction - Phase 3: Operation (50 years to end of building life) - Phase 4: Demolition and Recycling. (Questionnaires completed by ±80 CBA members)
- Emissions, calorific values of fuels, transport energy and operational energy from literature, thermal performance modelling and internationally accepted databases.
3.1.1.1. Life Cycle Assessment Methodology - Non Renewable Energy Consumption

MJ for 1m² (286 Kg fired brick) of 3 types of walling plastered and painted both sides.
Lifespan: for 50 years. Climate Zone 1.

<table>
<thead>
<tr>
<th>Phase</th>
<th>220MM Double Leaf Solid Wall</th>
<th>280 MM Uninsulated Cavity Wall</th>
<th>280MM Insulated Cavity Wall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cradle to gate</td>
<td>715</td>
<td>715</td>
<td>715</td>
</tr>
<tr>
<td>Gate to site</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Materials</td>
<td>318</td>
<td>320</td>
<td>323</td>
</tr>
<tr>
<td>Operational Phase: 50 years</td>
<td>25443</td>
<td>21972</td>
<td>18031</td>
</tr>
<tr>
<td>Demolition and Recycling</td>
<td>59</td>
<td>59</td>
<td>59</td>
</tr>
<tr>
<td>TOTAL</td>
<td>26550</td>
<td>23081</td>
<td>19143</td>
</tr>
</tbody>
</table>

“90% of carbon emissions are generated during the operations phase of a building”

3.1.1.2. Concluding - Clay Brick: Saving energy every day

- A natural insulator, clay brick absorbs heat during the day and releases it at night, making brick buildings more comfortable.
- Cuts the cost of artificial heating in winter and cooling in summer.
- Not “Hotbox” effect-self-regulating.
- Absorbs moisture and releases it back into the environment quickly.
- Minimal build-up of condensation.

There is a whole potential to develop because:

The South Africa government has pledged to build 1.5 million housing units by 2019. We calculate that if 1 million low-cost homes are built from concrete brick rather than clay brick, the additional winter peak power requirement on national grid could cost the country upwards of R45 BILLION in additional power plant capacity and that power is likely to be generated from COAL - FIRED POWER STATIONS.
3.2. Photographic Record

Photographs 1. Meeting with the South African guild

Photographs 2. Presentation of the Colombian guild

Photographs 3. Presentation of the action lines of the South African Guild
4. Energy Efficiency Practices

1) Replace the current Clamp Kiln with a fixed kiln (e.g. Vertical Shaft Brick Kiln (VSBK), Tunnel Kiln)
2) Addition of waste products (e.g. sewerage sludge, paper pulp)
3) Controlled and efficient combustion of fuel
4) Use of recent model mobile plant and movement optimisation
5) Increase perforation size of extruded bricks
6) Reduce thermal mass of kiln car decks using lightweight refractory or fibre
7) Waste heat recovery
8) Variable speed/frequency drives
9) Energy management
10) Optimisation of air compressors

4.1. Replace Current Clamp Kiln with a Fixed Kiln: Clamp kilns are by a large margin the most energy inefficient brick kilns. A significant energy saving can be realised by replacing the current clamp kiln with a fixed kiln of some kind (e.g. Vertical Shaft Brick Kiln (VSBK), Habla Zig-Zag, Transverse Arch (TVA) Kiln, Tunnel Kiln etc.). The choice of the kiln is subjective and dependent on many factors such as projected output, the type of product to be produced (e.g. face bricks or plaster bricks) and the availability of skilled staff. Costs for new kilns can vary significantly, but small kiln types can be R1 million and Tunnel Kilns can be up to R30 million or higher. In this specific example, the choice of kiln was a VSBK kiln.

The total capital expenditure on the project is R18 million, which results in a total energy saving of 70 000 MWh per annum. The project also results in a reduction of carbon emissions to a total of 24 700 tonnes CO2 per annum. For projects with high capital investment values of greater than R30 million, there are more options available in terms of government grants. As the project also results in significant energy and carbon savings, it may also qualify for tax allowances and carbon offset projects.

4.2. Addition of waste products: Description The addition of waste products (e.g. sludge from a sewerage treatment work, paper pulp etc.) can offer a multitude of benefits to clay brick manufacturers. Often, these benefits can be obtained at low rates or, in some cases, brick manufacturers can receive waste streams for nothing, or even be paid to accept them. The potential benefits include:

- Dematerialisation, i.e. lower raw material usage. Waste addition can replace up to 15% of regular raw materials.
• Reduction in requirement for process water (many waste contains significant amounts of water).
• Improvement in workability or extrudability of the column, thus requiring lower energy for the extrusion process and sometimes obviating the need for additional die lubrication.
• Fuelling benefits.
• Production of lighter bricks.

4.3. Controlled and Efficient Combustion of Fuel: Energy savings can be achieved through the optimisation of the temperature profile in the kiln and the effective utilisation of firing fuel. Best practice demands a steady rise in temperature through clean and efficient combustion of fuel, and for this reason, automated fuelling through proprietary burner systems is preferable to manual fuel feeding. Even when basic automation is already installed, more advanced firing control through programmable logic controllers (PLCs) and proportional integral derivative (PID) controllers can still achieve significant gains in efficiency. For this example, it is assumed that the kiln is fired with coal and the cost to deploy the project is R1 million. The total energy savings achieved is 3 333 MWh per annum and the payback period of the project is 7 months (assuming the site is located inland). The project results in carbon savings of 1 433 tonnes CO2e per annum. This example was chosen as most kilns in South Africa are fired with coal.

4.4. Use of Recent Model Mobile Plant: Current generation mobile equipment or plant (more specifically forklifts or frontend loaders and other earth moving machinery) can use as little as 50% of the fuel needed by older generation plants. Additionally, the capacity of new machines means that even with a similar footprint to an old machine they are now capable of doing almost twice the duty. For example, a new 5 ton rough terrain forklift can fulfil the duty of two old generation rough terrain forklifts, each with a lifting capacity of around three tons. Typical costs for equipment:
• 5 ton rough terrain forklift: R920 000. Hire purchase cost is R22 000 per month over 60 months, with additional maintenance costs of R12 612 per month.
• Frontend loader with a standard 2.3m² bucket and 95kN breakout force: R1.68 million.

4.5. Increase Perforation Size of Extruded Bricks: In the clay brick manufacturing process, perforated bricks use less raw material, meaning that the mine life is extended and raw material costs are reduced, and require less fuel to fire.
The potential to use 25% less raw material with commensurate savings in energy is appealing, but nonetheless it is estimated that more than 60% of South Africa’s clay bricks are made without any perforations.

- In order to increase the perforation size of extruded bricks, new extruder machines would need to be purchased.
- This example includes the purchase of two extruders costing R500 000 each. This is expected to result in energy savings of 833 340 kWh per annum and a carbon emission saving of 286 tonnes per year.

4.6. Reduction of the Thermal Mass of Kiln Car Decks using Lightweight Refractory or Fibre: Tunnel kiln energy balances show that a considerable amount of heat is lost through the base of the kiln cars. These losses come about due to conduction of heat through the kiln car structure and are exacerbated by kiln cars of high thermal mass. High thermal mass is problematic as it is difficult to recover all the heat energy from a kiln car of high thermal mass within the kiln. Hot kiln car decks emerging from the kiln normally cool slowly in the factory building, thereby wasting the heat held in the kiln car decks.

- Redesigned kiln car decks will be significantly cooler on leaving the kiln, translating into additional energy retained in the kiln system and a saving on fuel with a commensurate cost benefit.
- For this project example, it has been assumed that a typical plant has a total fleet of 91 kiln cars. If all the kiln cars are refurbished, it would cost approximately R5.16 million and would result in energy savings of 4 166 MWh per annum and a carbon emission saving of 1 100 tonnes per annum.

4.7. Waste Heat Recovery: All kilns have exhausts and through these, the products of combustion and other emissions are emitted to the atmosphere. These gases are hot and can carry away a large amount of useful heat, in some cases as much as 1MJ/kg. If some of this heat could be cost effectively recovered, it could be used as a virtually free source of heat. Kilns (tunnel kilns in particular) may also have other sources of waste heat that can be recovered, such as vented hot air from under car or roof cooling systems. There are two ways to recover the waste heat from exhausts:

- Use it directly as a source of heat
- Use a heat exchanger to recover heat from exhausts in this specific example, it is assumed that vented hot air is used to preheat combustion air. The project includes a process modification which results in an energy saving of approximately 555 MWh per annum
4.8. Installation of Variable Speed Drives: Variable Speed Drives (VSDs) are used to control the flow or pressure of a fluid to meet demand. In kiln operation they represent one of the most effective energy efficiency investments brick manufacturers can make. Not only do they reduce power consumption by reducing the speed of the motor, the increased control of airflow and kiln pressure can give additional saving in fuel. Where fans are used to control airflow or pressure within a kiln they traditionally use a simple in-line damper to restrict the flow when required.

The control of flow is not very precise and there is only a small reduction in power consumption due to the increase in resistance to flow that the damper has introduced. Replacing the damper with a VSD enables the speed of the motor and fan impeller to be precisely controlled and as no damper is used, the power savings are much larger.

A reduction in fan speed of 10% using a damper might reduce power consumption by 5%; using a VSD will reduce it by 25%.

4.9. Implementation of an Energy Management System: Energy management is an important aspect of manufacturing management. The objective is to deliver the highest value to the business for each unit of heat and power used. In brickmaking, this means manufacturing saleable products with the lowest specific energy consumption (SEC) possible. For organisations that are used to managing resources such as labour, materials, output levels and quality, managing energy consumption is a simple case of incorporating it as a controllable variable cost into the production performance report. The international standard ISO 50001 offers excellent guidance on adopting energy management and at its heart is the continuous improvement concept of understanding use, identifying energy waste or poor performance, planning & implementing improvements and verifying the savings achieved.

The implementation of an Energy Management Plan includes:

- Developing a company energy policy
- Managing energy consumption through measurement and reporting
- Identification and implementation of opportunities to reduce energy consumption
- Undertaking continuous improvement

4.10. Optimisation of Air Compressors: Compressed air is an essential utility in many brickworks, but is very expensive to produce. In fact, nearly 90% of the energy required to compress air is turned into waste heat, and as a result compressed air at the point of use costs around R7 per kWh.
High efficiency screw compressors are available with variable speed drives so that output is continually varied to match demand, delivering more efficient operation when demand is below the design duty.

Compressors can be powered by electricity or by a diesel engine, of which the most common types used are the reciprocating engine and the screw compressor. Screw compressors tend to be more efficient and better at delivering higher volumes but reciprocating engines are capable of achieving higher pressures and are readily available with diesel power when power is not available on site or portability is important.

If the energy savings from this project are high enough it would be possible to qualify for the 12L energy efficiency incentive.

5. Technological Models

5.1. Productive Model: Generally, the raw material clay is mined or won from a clay quarry, pit or mine. In South Africa, a wide range of raw materials is used, including various forms of kaolin, shale and clays of different types. After quarrying, the material is often stockpiled and allowed to weather for a certain period before being ground to a fine consistency, mostly by means of a crushing or grinding facility (generally <2.5mm). In some countries, the grinding step can be very rudimentary, but in South Africa, grinding is generally highly mechanised. The prepared material is then mixed with water to a consistency that allows it to be shaped into a brick. Many countries use mechanisation to achieve this, but others still make use of basic hand-mixing and shaping via a wooden mould box.

In South Africa, the mixing and shaping is generally done via mechanisation, which can produce up to 700,000 bricks a day from a single plant. After shaping, bricks must be dried before they are fired so that they don’t crack during the firing process. Drying can be mechanised or done by simply making use of the sun and wind; this is still commonplace in South Africa. The final step - firing - is the most energy intensive as it involves heating the bricks to temperatures of around 1000°C in order to vitrify them and give them their durability.

The vast majority (more than two-thirds) of South African brickworks employ clamp kiln firing technology, followed by tunnel kilns (14% of brickworks). Transverse Arch (TVA) Kilns are a derivative of the Hoffman Kiln design. Only a small percentage of the brickworks companies in South Africa have started to employ the Vertical Shaft Brick Kiln (VSBK) technology (2%).
5.2. Kilns for the cooking of bricks

- Tunnel Kiln: Using heavy fuel oil, like principal fuel. It has an external dryer using hot air recovered from the kiln.
Vertical Shaft Brick Kiln (VSBK): The vertical shaft brick kiln is a continuous, moving ware kiln in which bricks are fired in a vertical shaft rectangular cross sections. The height of the shaft is around 6-8 m and nominal cross-section of the 1.90 * 1.40m. The Kiln consists of a banks of multiples shafts. The shafts are enveloped by an outer wall made up of bricks and the gap between the shaft and outer kiln wall is filled with insulating material. The kiln consists of one or more chambers located within a structure of rectangular blocks. The height varies depending on the number of lots to be cooked per cycle. Usually using coal (nuts and duff) as main fuel. The chamber is loaded from the top with a batch of raw bricks. Each batch typically contains four layers of bricks positioned in a predetermined pattern. This batch rests on square support bars, which can be removed or inserted, and supported in turn by a pair of horizontal beams through the arches in the discharge tunnel. During the starting of the kiln, the fire is ignited in the combustion chamber in the bottom (or top) of the kiln. During continuous operation, a batch of raw bricks is layered over the top. The discharge is carried out from the bottom with a discharge carriage, which moves on rails along the length of the tunnel. The next batch of raw bricks is loaded onto the top by loading them onto the loading platform. The exhausts losses are low, which reflects very good use of the heat contained in the exhaust.

**Technical Characteristics**

<table>
<thead>
<tr>
<th>Energy Consumption (MJ/Fired Brick)</th>
<th>0.8 - 1.0 MJ/Kg.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel</td>
<td>Coal</td>
</tr>
<tr>
<td>CO₂ Emissions (1000 Bricks) Country average</td>
<td>250-350 Kg CO₂ 917 Kg CO₂</td>
</tr>
<tr>
<td>Brick Size Perforated</td>
<td>222<em>110</em>73 mm</td>
</tr>
<tr>
<td>Dry</td>
<td>NO</td>
</tr>
<tr>
<td>Air Emissions</td>
<td></td>
</tr>
<tr>
<td>Particulate Matter (PM)</td>
<td>73 mg/Nm³</td>
</tr>
<tr>
<td>Sulphur Dioxide (SO₂)</td>
<td>260 mg/Nm³</td>
</tr>
<tr>
<td>Hydrogen Fluoride (HF)</td>
<td>33 mg/Nm³</td>
</tr>
<tr>
<td>Hydrogen Chloride (HCl)</td>
<td>511 mg/Nm³</td>
</tr>
<tr>
<td>Oxides of Nitrogen</td>
<td>103 mg/Nm³</td>
</tr>
<tr>
<td>Production and quality standards</td>
<td></td>
</tr>
<tr>
<td>Production Capacity Day</td>
<td>Bricks - Shaft 5000 -7000</td>
</tr>
</tbody>
</table>
## Year

<table>
<thead>
<tr>
<th>Year</th>
<th>1.8 - 2.5 million</th>
</tr>
</thead>
</table>

## Good Quality Breakages

<table>
<thead>
<tr>
<th>Breakages</th>
<th>98%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2%</td>
</tr>
</tbody>
</table>

## Number operators (6 Shafts)

<table>
<thead>
<tr>
<th>Number operators (6 Shafts)</th>
<th>3 (75 shafts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operational</td>
<td>2 (30 shafts)</td>
</tr>
</tbody>
</table>

### Combustion Chambers

![Combustion Chambers Image]
Charge - Fuel

Ascent of the load
Clamp kiln: Are by a large margin the most energy-inefficient brick kilns. A significant energy saving can therefore be realised by replacing the current clamp kiln with a fixed kiln of some kind (e.g. VSBK, Zig-zag, TVA, tunnel kiln, etc.).
6. Acknowledgments

In collaboration with:

- Clack Brick Association
- Swiss Agency for Development and Cooperation (SDC) as part of the Energy Efficient Clay Brick (EECB) project implemented in South Africa by Swisscontact.
- Algoa Brick
- Apollo Brick (Gauteng)
- Rowe Design & Consulting (Pty) Ltda.
- HZZK – Habla Zig Zag Kilns
- Rheebok Brick, South Africa